Republic of Malawi

Ministry of Natural Resources, Energy and Environment

The Second National Communication of the Republic of Malawi to the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC)

Ministry of Natural Resources, Energy and Environment, Lilongwe, Malawi

October, 2011

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Table of Contents

List of Tables

List of Figures

Appendices

Foreword

The successful implementation of the Malawi Growth and Development Strategy (MGDS) hinges on the pursuance of key priority areas of agriculture and food security, irrigation and water development, transport infrastructure development, energy generation and supply, integrated rural development, and the prevention and management of nutritional disorders and HIV and AIDS. The achievements that our country will register in the six critical areas mentioned above will not only contribute towards the realization of the goals set out in the MGDS, but will also enable Malawi to meet the United Nations Millennium Development Goals (MDGs). However, it is important to note that such success is highly dependent on the sustainable management and utilization of our natural resources.

The realization of the Government's vision of transforming the economy from that of an importing to an exporting nation depends on the country's resilience to external shocks, such as those emanating from climate change and climate variability. The increasing intensity and frequency of floods and severe droughts that our country has experienced in the past ten years bear testimony to our vulnerability to the adverse impacts of climate change and the vagaries of climate variability. It is, therefore, our responsibility as a nation to join hands with the rest of the world to combat global warming, a phenomenon that causes climate change.

The Second National Communication (SNC) of Malawi to the Conference of the Parties (COP) of the United Nation's Framework Convention on Climate Change (UNFCCC) is a clear manifestation of our unwavering commitment to contribute towards the global efforts to reverse the adverse effects and impacts of climate change. As such, the implementation of the research and extension recommendations highlighted in the SNC captured from the various themes of national circumstances, mitigation of greenhouse gases, and vulnerability and adaptation assessments will not only fulfill our obligations to the UNFCCC, but also create a conducive environment for the realization of the Millennium Development Goals (MDGs) and the Malawi Growth and Development Strategy (MGDS). It is the expectation of my Government that the cooperation that exists between Malawi and our neighbours and that of international community under the UNFCCC shall result in the sustainable utilization and management of our natural resources.

It is the prerogative of my Ministry to ensure the full implementation of the strategies and measures for curbing the adverse impacts of climate change and variability on all the sectors of economic growth to promote sustainable economic growth and development. However, this requires collective efforts among all stakeholders in the public and private sector organizations, including Non-Governmental Organizations (NGOs), civil society, the donor community, and local communities themselves. The Government will provide all the necessary support required for the successful implementation of the strategies measures spelt out in the Second National Communication of Malawi document.

Dr. Goodall E. Gondwe, M.P.
Minister of Natural Resources, Energy and Environment

Preface

Malawi derives the bulk of her revenues from the agriculture sector, whose viability depends on the availability of adequate and reliable rainfall. As such, the country's economy, prosperity and the well being of its people are highly vulnerable to climate change and climate variability. In the light of the above, it is imperative that appropriate measures and strategies are taken into account to ensure accurate predictions of weather and climate-related changes and their associated adverse impacts on sectors of economic growth and vulnerable communities. We are fully aware that establishing the required management and response strategies is a daunting task because local weather changes and variability are embedded in global climate systems that transcend national boundaries. However, we take consolation in the realization that opportunities for managing and mitigating the adverse impacts of climate change are global endeavors, whose goals are ensuring a future that preserves the health and prosperity of the local and global communities, and that many countries in the world to day strongly support efforts to combat global warming. It is in this regard that the Government and the people of Malawi wish to reaffirm their commitment to environmental protection in general, and climate change in particular, by preparing the Second National Communication (SNC) of Malawi document.

In June 1992, Malawi signed the United Nations Framework Convention on Climate Change (UNFCCC). The Convention entered into force on 21st April 1994, and Malawi ratified the Convention in April 1994, and became a party to it on 21st July 1994. In 1999, Malawi received funding from Global Environmental Facility (GEF) to prepare its Initial National Communication (INC) under the "Climate Change Enabling Activities Project". The preparation and production of the INC in 2003, and that of the National Adaptation Programmes of Action (NAPA) in 2006, marked important and significant milestones in Malawi's quest to address the adverse impacts of climate change on sectors of economic growth and vulnerable communities. The preparation of these documents facilitated institutional capacity building in the country, and also enabled local experts to acquire the requisite skills for modeling climate change capabilities. This led to the building of strong technical teams of local Malawians who prepared various thematic technical reports that appear in both the Initial National Communication (INC) and the National Adaptation Programmes of Action (NAPA).

This document takes stock of the efforts Government and its developmental partners have made in order to address issues of climate change highlighted in the Initial National Communication. It fills gaps that were identified in the Initial National Communication, and highlights opportunities which our country needs to embrace in order to protect the environment and vulnerable communities against the adverse impacts of climate change. The Second National Communication of Malawi gives information on: (i) national circumstances, (ii) greenhouse gases inventory for the period 1995-2000, (iii) programmes containing measures to facilitate adaptation to climate change ((V&A assessments), (iv) programmes containing measures to mitigate climate change, (v) other information considered relevant to the achievement of the objective of the Convention, (vii) constraints and gaps, and related financial, technical and capacity needs, and (viii) proposed climate change projects.

I wish to express my heartfelt gratitude, and that of the Government and people of Malawi, to all those who have generously contributed in various ways in the production of this Second National Communication. Let me also extend my special thanks to the Global environment Facility (GEF) and the United Nations Development Programme (UNDP) for financial and technical support.

Ben Botolo
Secretary for Natural Resources, Energy and Environment

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Acronyms and Abbreviations

ADD	:	Agricultural Development Division
ADMARC	:	Agricultural Development and Marketing Corporation
ADP	:	Malawi Agricultural Development Programme
AGDP	:	Agricultural Gross Domestic Product
AIDS	:	Acquired Immune Deficiency Syndrome
ALDSAP	:	Agriculture and Livestock Development Strategy and Action Plan
A msl	:	Above mean sea level
APF	:	Adaptation Policy Framework
APINA	:	Air Pollution Information Network for Africa
APR	:	Annual Project Report
APRU	:	Agricultural Policy Research Unit
ARET	:	Agricultural Research Extension Trust
ASAP	:	Agricultural Sector Assistance Programme
ASP	:	Adaptation Strategy Paper
AU	:	African Union
AvGas	:	Aviation Gas
AWS	:	Automatic Weather Station
BARREM	:	Barrier Removal to Renewable Energy Project
BCA	:	Bunda College of Agriculture
B_{frac}	:	Fraction of waste open burned
BNF	:	Biological Nitrogen Fixation
BOC	:	British Oxygen Company
BOD_5	:	Biochemical Oxygen Demand
CAB	:	Congo Air Boundary
CBD	:	Convention on Biological Diversity
CBNRM	:	Community Based Natural Resources Management
CCAF	:	Climate Change Adaptation Fund
CCC	:	Climate Change Committee
CCCMI–TR	:	Canadian Climate Centre for Modeling and Analysis 1– Transient
CCPO	:	Climate Change Project Office
CCPSC	:	Climate Change Project Steering Committee
CCU	:	Climate Change Unit
CDM	:	Clean Development Mechanism
CGE	:	Consultative Group of Experts
CGM	:	General Circulation Model
CHAM	:	Christian Hospital Association of Malawi
COF	:	Certificate of Fitness
COMAP	:	Comprehensive Mitigation Analysis Process
COP	:	Conference of Parties
CPL	:	Coal Products Limited
CRSP	:	Collaborative Research Support Project
CSIRO-TR	:	Commonwealth Scientific and Industrial Research Organisation-Transient
CSR	:	Centre for Social Research
CURE	:	Coordination Union for the Rehabilitation of the Environment
DAHI	:	Department of Animal Health and Industry

DAHLD	**:**	**Department of Animal Health and Livestock Development**
DANIDA	**:**	**Danish International Development Agency**
DARS	**:**	**Department of Agricultural Research Services**
DEA	**:**	**Department of Environmental Affairs**
DEAP	**:**	**District Environmental Action Plan**
DFID	**:**	**Department for International Development**
DoLRC	**:**	**Department of Land Resources Conservation**
DoMS	**:**	**Department of Meteorological Services**
DOC	**:**	**Degradable Organic Carbon**
DoEA	**:**	**Department of Energy Affairs**
DoI	**:**	**Department of Irrigation**
DoM	**:**	**Department of Mines**
EAD	**:**	**Environmental Affairs Department**
ECHAM 4	**:**	**European Centre/Hamburg Model 4 Transient (Germany1996)**
EIA	**:**	**Environmental Impact Assessment**
ENSO	**:**	**El Nino/Southern Oscillation**
ESCOM	**:**	**Electricity Supply Corporation of Malawi**
ETHCO	**:**	**Ethanol Company of Malawi**
EU	**:**	**European Union**
FAO	**:**	**Food and Agriculture Organization of the United Nations**
FEWS	**:**	**Famine Early Warning System**
FINNESE	**:**	**Financing Energy Services for Small Scale Energy Users**
FOD	**:**	**First Order Decay**
FRIM	**:**	**Forestry Research Institute of Malawi**
GAP	**:**	**Guide to Agricultural and Natural Resources Management in Malawi**
GAW	**:**	**Global Atmospheric Watch**
GCOS	**:**	**Global Climate Observatory System**
GCOS	**:**	**Global Climate Observing System**
GCOS-N	**:**	**Global Climate Observing System-Network**
GDP	**:**	**Gross Domestic Product**
GEF	**:**	**Global Environment Facility**
GHG	:	Greenhouse Gas
GIS	**:**	**Geographical Information System**
GNP	**:**	**Gross National Product**
GoM	**:**	**Government of Malawi**
GSN	**:**	**Global Surface Network**
GTS	**:**	**Global Telecommunication System**
GTZ	**:**	**Deutsche Gescllschaft fur Technische Zusammenarbeit**
GUAN	**:**	**Global Upper Air Network**
GWH	**:**	**Giga Watt Hour**
GWP	**:**	**Global Warming Potential**
Had CM2	**:**	**Hadley Centre Unified Model 2 Transient Ensemble Mod(1996) UK**
HDR	**:**	**Human Development Report**
HEP	**:**	**Hydro-electric Power**
HH	**:**	**Household**
HIPIC	**:**	**Highly Indebted Poor Countries**
HIV	**:**	**Human Immuno-deficiency**
HSI	**:**	**Habitat Suitability Index**
IBSNAT	**:**	**International Benchmark Sites Network for Agro technology**
IC	**:**	**Inception Report**
IE	**:**	**International Expert**
IGCC	**:**	**Integrated Gas Combined Coal**

IHS2	**:**	**Second Integrated Household Survey**
ILO	**:**	**International Labour Organization**
INC	**:**	**Initial National Communication**
IPCC	:	Inter-governmental Panel on Climate Change
IR	**:**	**Inception Report**
ITCZ	**:**	**Inter-Tropical Convergence Zone**
IW	**:**	**Inception Workshop**
JICA	**:**	**Japanese International Co-operation Agency**
LANDGEM	**:**	**Landfill Gas Emissions Model**
LDC	**:**	**Least Developed Country**
LEAD	**:**	**Leaders for Environment and Development**
LEAP	**:**	**Long-range Energy Alternative Planning**
LPG	**:**	**Liquefied Petroleum Gas**
LUCF	**:**	**Land-Use Change and Forestry**
M&E	**:**	**Monitoring and Evaluation**
MACRO	**:**	**Malawi Aids Counseling and Resource Organization**
MAGICC	**:**	**Model for the Assessment of Greenhouse Gas Induced Climate Change**
MARKAL	**:**	**Market Allocation**
MASAF	**:**	**Malawi Social Action Fund**
MB	**:**	**Mechanical-biological Treatment**
MCF	**:**	**Methane Correction Factor**
MD	**:**	**Meteorological Department**
MDGs	**:**	**Millennium Development Goals**
MDHS	**:**	**Malawi Demographic and Health Survey**
MEET	**:**	**Malawi Environment Endowment Trust**
MEGS	**:**	**Malawi Economic Growth Strategy**
MEMNR	**:**	**Ministry of Energy, Mines and Natural Resources**
MEP	**:**	**Malawi Energy Policy**
METEOSAT	**:**	**Meteorological Observing Satellite**
MGDS	**:**	**Malawi Growth and Development Strategy**
MIRTDC	**:**	**Malawi Industrial Research and Technology Development Centre**
MK	**:**	**Malawi Kwacha**
MMCT	**:**	**Mount Mulanje Conservation Trust**
MNLDMP	:	Malawi National Livestock Development Master Plan
MNSSD	**:**	**Malawi National Strategy on Sustainable Development**
MOAFS	**:**	**Ministry of Agriculture and Food Security**
MoAI	**:**	**Ministry of Agriculture and Irrigation**
MoH	**:**	**Ministry of Health**
MoIWD	**:**	**Ministry of Irrigation and Water Development**
MoNREA	**:**	**Ministry of Natural Resources and Environmental Affairs**
MoTPW	**:**	**Ministry of Transport and Public Works**
MPRS	**:**	**Malawi Poverty Reduction Strategy**
MPRSP	**:**	**Malawi Poverty Reduction Strategy Paper**
MSW	**:**	**Municipal Solid Waste**
MtwDC	**:**	**Mtwara Development Corridor**
MWP	**:**	**Malawi Water Partnership**
MZUNI	**:**	**Mzuzu University**
NAPA	**:**	**National Adaptation Programmes of Action**
NAREC	**:**	**National Resources and Environment Centre**
NC	**:**	**National Communication**
NCCC	**:**	**National Council on Climate Change**
NCE	**:**	**National Committee on the Environment**

NCNSA	:	National Capacity Needs Self-Assessment
NCSA	:	National Capacity Self Assessment
NCSP	:	National Communication Support Programme
NCST	:	National Commission for Science and Technology
NDC	:	Nacala Development Corridor
NEAP	:	National Environmental Action Plan
NEP	:	National Environmental Policy
NEPAD	:	New Partnership for Africa's Development
NERICA	:	New Rice for Africa
NES	:	National Energy Strategy
NEs	:	National Experts
NEX	:	National Execution
NGCC	:	Natural Gas Combined Coal
NHBG	:	National Herbarium and Botanic Gardens of Malawi
NPD	:	National Project Director
NPM	:	National Project Manager
NRA	:	National Roads Authority
NSO	:	National Statistical Office
NSREP	:	National Sustainable Renewable Energy Programme
NSSD	:	National Strategy for Sustainable Development
NTL	:	National Team Leader
ODS	:	Official Development Assistance
OECD	:	Organisation for Economic Cooperation and Development
OILCOM	:	Oil Company of Malawi
OPD	:	Out Patient Department
PA	:	Project Assistant
PC	:	Project Coordinator
PCC	:	Petroleum Control Commission
P_{frac}	:	Fraction of population burning waste
PMT	:	Project Management Team
POP	:	Persistent Organic Pollutant
PQPR	:	Project Quarterly Progress Report
ProBEC:	:	Programme for Biomass Energy Conservation
PRSP	:	Poverty Reduction Strategy Paper
PSC	:	Project Steering Committee
PT	:	Project Team
PTR	:	Project Technical Report
PV	:	Photo voltaic
R&D	:	Research and Development
RDL	:	Red Data Lists
REIAMA	:	Renewable Energy Industry Association of Malawi
RET	:	Renewable Energy Technology
RS	:	Remote Sensing
RSDI	:	Regional Spatial Development Initiative
RTH	:	Regional Telecommunication Hub
S&T	:	Science and Technology
SADC	:	Southern African Development Community
SB	:	Subsidiary Bodies
SBAA	:	Standard Basic Assistance Agreement
SCENGEN	:	Scenario Generator
SDNP	:	Sustainable Development Network Programme
SEMU	:	Soil Erosion Management Unit

SIDIs	:	Small Island Developing States
SL	:	Sustainable Livelihood
SLEMSA	:	Soil Loss Estimated Model for Southern Africa
SNC	:	Second National Communication of Malawi
SPGRC	:	SADC Plant Genetic Resources Centre
SWD	:	Solid Waste Disposal
SWDS	:	Solid Waste Disposal Site
SWOT	:	Strength, Weakness, Opportunity and Threats
TA	:	Traditional Authority
TCCC	:	Technical Committee for Climate Change
TCE	:	Technical Committee on the Environment
TEG	:	Technical Expert Group
TFR	:	Total Fertility Rate
TNA	:	Technology Needs Assessment
ToR	:	Terms of Reference
TR	:	Technical Report
TRF	:	Tea Research Foundation
TRIM	:	Tobacco Research Institute of Malawi
UDF	:	United Democratic Front
UN	:	United Nations
UNCED	:	United Nations Conference on Environment and Development
UNDAF	:	United Nations Development Assistance Framework
UNDP	:	United Nations Development Programme
UNEP	:	United Nations Environmental Programme
UNFCCC	:	United Nations Framework Convention on Climate Change
UNICEF	:	United Nations Children's Fund
UNIMA	:	University of Malawi
USAID	:	United State Agency for International Development
USCSP	:	United States Country Studies Programme
V&A	:	Vulnerability and Adaptation Assessments
WASHTED	:	Water, Sanitation and Health Research Centre
Watbal	:	Water Balance Model
WB	:	World Bank
WCRP	:	World Climate Research Programme
WEHAB	:	Water, energy, health, agriculture and biodiversity
WICO`	:	Wood Industries Corporation of Malawi
WMO	:	World Meteorological Organisation
WMS	:	Waste Management Sector
WSSD	:	World Summit on Sustainable Development
WWM	:	Waste Water Management
ZMM-GT	:	Zambia- Malawi-Mozambique Growth Triangle

Chemicals

C	:	carbon
$C_{12}H_{22}O_{11}$	:	mollasses
$C_6H_{12}O_6$	:	glucosa
Ca	:	calcium
$CaCO_3$	:	calcium carbonate (limestone)
CaO	:	calcium oxide (lime)
CFCs	:	chlorofluocarbons
CH_3CH_2OH	:	Ethanol
CH_4	:	methane
CO	:	carbob monoxide
CO_2	:	carbon dioxide
H_2O	:	water
HFCs	:	hydrofluorocarbons
K	:	potassium
Mg	:	magnesium
N	:	nitrogen
N_2O	:	nitrous oxide
NH_3	:	ammonia
NMVOC	:	non-methane volatile organic compounds
NO_x	:	nitrogen oxides
O_3	:	Ozone
P	:	phosphorus
PFC	:	perflourocarbon
PFCs	:	perfluorinated carbons
SF_6	::	Sulphur hexafluoride
SO_2	:	sulphur dioxide
SO_x	:	sulphur oxides

Units of Measure

atm	:	atmosphere
Cal	:	calories
cap	:	capita
Cm	:	centimeter
D	:	day
Dm	:	dry matter
G	:	gram
Gg		giga gram
H	:	hour
Ha	:	hectare
J	:	Joule
kJ	:	kilojoules
Km	:	kilometre
kPa	:	kilopascal
M	:	metre
mbar	:	millibar
MJ	:	megajoule
mm	:	millimeter
Mo	:	months
MW	:	Mega Watt
^oC	:	degree Celcius

^oK	:	degree Kelvin
Pa	;	Pascal
ppm	:	parts per million
T	:	tonne
W	:	Watts
Yr	:	year

Currency

1 US Dollar	**=**	**MK 139.2094 (Reserve Bank of Malawi, February 2009)**

Executive Summary

Background

Introduction

Malawi Government ratified the United Nation Convention on Climate Change (UNFCCC) in 1994, and as a Party to the Convention is obliged to periodically report on its levels of greenhouse gas emissions and sink capacity, as well as implementation of various climate change related activities.

Climate sensitive rain-fed agriculture is the backbone of Malawi's economy. It is a major contributor to the national gross domestic and foreign exchange earnings. It also supports the livelihoods of over 80% of Malawians who are involved in primary and secondary agricultural activities. Furthermore it is the principal producer of raw material for agro-based industries. As such, Malawi as a nation is very vulnerable to the impacts of climate change.

The Government of Malawi has included climate change, natural resources and environment within priority of priority of the government business as stipulated by the Malawi Growth and Development Strategy. There is however need to mainstream climate change in its sectoral policies and strategies, as well as strengthening of institutional capacity.

The Second National Communication (SNC) has been developed under the scenario of worsening climate change related impacts. The SNC is a comprehensive documentation of measures and strategies, developed through a consultative process, to address threats and challenges posed by negative impacts of climate change and climate variability.

National Circumstances

Malawi is a land-lock country in Southern Africa part of the Great East African Rift Valley bordering Tanzania to the north, Zambia to the east and Mozambique to south and east. Currently the Government is developing an inland port at Nsanje that would eventually open direct access to the sea through the Shire-Zambezi waterway.

According to the National Statistical Office census of 2008, Malawi's population is about 13 million and growing at the rate of 2.8% per annum, up from 2% growth rate in 1998 census. This dense and growing population, whose livelihood depend on the availability and health of natural resources (NRs), is putting undue stress on NRs through unsustainable exploitation and utilization practices.

Lake Malawi, which stretches across all the three regions of the country, has a major influence on the climate. Other factors affecting Malawi's Climate are its latitude and altitude. The mean annual rainfall ranges from 725mm to 2500mm and temperature from 12°C to 32°C. The general trend indicates increase in frequency and intensity of climate related extreme events such as floods, hailstorm and strong winds.

Infrastructure plays a critical role in the achievement of sustainable development through improved transport, energy services, information and communication technology, water and sanitation and provision of improved shelter. In recent years, Malawi has experienced damage of buildings, roads and even hydro-power station from climate-related events. As such, infrastructure designs and codes of practice must take cognizance of the threats and challenges of climate related extreme events.

Malawi's health indicators in terms of infant and maternal mortality, malaria, diarrhoeal diseases, HIV/AIDS and malnutrition are generally poor even under favourable climate scenario. Therefore, under adverse climate scenario the indicators are likely to worsen unless urgent and drastic measures are undertaken to reverse trend.

Women and girls are providers of a number of household essentials such as collection of water, firewood for energy and food. Women and girls are likely to be burdened further in search of water, food and firewood as these resources become scarce under worsened climate scenario.

Malawi's economy has been growing steadily in recent years. The main stabilizing factors of the economic performance were tobacco earnings and been food self sufficiency both of which depend on favourable climate in addition to supportive government policies and strategies. In its National Adaptation Programmes of Action (NAPA), the Government has clearly spelt out the threats the economic sectors face under adverse climate change scenario, and hence the inclusion of climate change in the Malawi Growth and Development Strategy.

Technology is one of the critical factors necessary to enhance the adaptive capacity of a vulnerable country, sector or community. Malawi undertook its climate change technology transfer needs assessment in 2006 to prioritise technologies that would contribute towards its adaptation and mitigation efforts. Some progress has been made through implementation of projects such as Barrier Removal to Renewable Energy in Malawi (BARREM). An action plan is necessary to ensure that efforts to implementation planned programmes are adhered to.

Greenhouse Gas Inventory

Africa's contribution to the global greenhouse gas emissions (GHGs) is low and was projected to rise to 3.8% by 2010, but yet it's considered to be the most vulnerable to the impacts of climate change. Malawi is already experiencing an increasing trend of climate related disasters.

The Government of Malawi has undertaken three inventories to assess the level of emissions and capacity of sinks for greenhouse gases. The inventories were undertaken for base years 1990 and 1994, and time series 1995 to 2000. The most recent inventory covered four broad sectors, namely, Energy, Agriculture Forestry and other land use (AFOLU), Industrial Processes and other Product Use (IPPU) and Waste. The GHG emissions inventorized were carbon dioxide, methane and di-nitrogen oxide. The 2006 Intergovernmental Panel on Climate Change (IPCC) methodology was used to undertake the inventories.

The table below shows the summary of the emissions from the four sectors expressed in gigagrammes (Gg) of carbon dioxide equivalents.

	Total emissions in Gigagrams per year						
SECTORS	1995	1996	1997	1998	1999	2000	Annual mean
Energy	743.5	753.0	808.7	844.2	782.4	726.8	776.4
IPPU	59.6	46.8	38.7	48.4	57.7	59.7	51.8
AFOLU	21007.0	21226.3	21555.7	21623.4	21869.6	22334.3	21602.7
Wastes	248.6	259.4	270.5	281.6	293.5	308.8	277.1
Annual totals	**24053.6**	**24281.4**	**24670.5**	**24795.5**	**25002.2**	**25429.5**	**22708.0**

The results seem to reflect a clear picture of Malawi's socio-economic circumstances: an economy dependent on natural resources, a low but growing energy sector and industrial sector that is still in its infancy. Thus the most significant sector is Agriculture Forestry and Other Land Use (AFOLU) which accounts for 95% of the total emissions. AFOLU encompasses emissions from agricultural livestock, chemical fertilisers, burning of agricultural residues, use of biomass fuels as well as the sink from within the Forest sector. The Energy sector is second at 3.4%, and mostly accounts for combustion of and fugitive emissions from fossil based solid, liquid and gaseous fuels. The results indicate that on average Malawi emits around 22708 Gigagrammes (Gg) of carbon dioxide equivalent. Malawi is a net emitter of GHGs.

Vulnerability and Adaptation Assessments

The vulnerability and adaptation assessments (V&As) provide a means of identifying and developing appropriate adaptation responses to the impacts of climate change. As alluded to in the earlier sections, majority of Malawians are vulnerable to the impacts of climate change. The V&A assessment used the MAGICC/SCENGEN model to develop climate scenarios for Malawi. In general, the results of the model showed that Malawi will receive below mean rainfall and experience above mean temperatures.

The outputs of MAGICC/SCENGEN were used as part of inputs into various sector specific models to assess the impacts of changes in temperature and precipitation.

Sector	Model used	Remarks
Agriculture	Century Model Version 4.0 for maize	Assesses the impact temperature and rainfall on plant productivity
	SPUR-2 for livestock	Could not be used due to lack of activity data- hence expert judgment was used
Forestry	Holdridge	Assesses forest productivity in general
	Gap models	Assesses productivity of species specific
Energy	LEAP model	Assesses consumption, production and resource extraction
Wildlife	Habitat Suitability Index	Assesses capacity of a habitat to support a given species of wildlife
Fisheries	ECOPATH-II model	Assesses fish productivity through production, predation, normal catches and non-predation processes
Human health	Non	Expert judgment was used

Based expert opinion and research results, climate change would affect the performance of most of the Malawi's livelihood systems and key socio-economic sectors. The following are the probable trends:

Crop yields and livestock production

Moderate increase in temperature tends to increase growth rate but temperatures above 35^{o} C would result reduction in biomass productivity and hence crop yields. Maize yields tend to be more sensitive to moderate changes in temperatures than moderate changes in rainfall.

Animal productivity in terms of milk and beef production would be affected by climatic factors which may have direct impact on the animal such as heat and water stresses affecting milk production and animal growth; or indirectly through increase incidences of diseases, vectors and reduction of pasture quality and availability.

Efforts should be channeled towards enhancing farmers' adaptive capacity through promotion and support of such technologies as irrigation, drought resistant crops and fodder, improved crop and animal husbandry practices, pests and diseases control, soil conservation and farm infrastructure.

Forestry and Other Land Use

The Holdridge model indicate that moderate changes in temperature would not affect high altitude forest areas such as Nyika and Viphya Plateaux, while plains and rift valley areas of Vwaza, Kasungu, and Chikhwawa would significantly be affected and may result in changes in tree species by 2020. The Gap model, under hot and dry scenario, tends to result in decline in biomass productivity and increase in the incidents of forest fires.

Energy Sector

The LEAP model was used to assess the biomass energy demand and availability assuming that the current energy mix persists. In general the demand for biomass energy exceeds supply. Under the baseline scenario, the supply can only meet 66% of the projected demand for Lilongwe City as a result of decline in Dzalanyama Forest Reserve productivity.

Adaptation in the energy sector could be achieved through dissemination and promotion of alternative energy sources such as renewable energy technologies (solar, wind, biogas, biomass briquettes), affordable energy efficient biomass stoves, afforestation, regional electricity inter-connectivity, industrial and household level energy efficiency and conservation technologies.

Water Resources Sector

Hydrological assessment of rivers systems of South Rukuru, Dwangwa, Lilongwe and Mwanza indicate a mixed picture depending on climate scenario, i.e. whether there would above normal or below normal rainfall. Under below normal rainfall, most rivers would seize to flow and drought conditions of more than four years around Lake Malawi basin would result in no outflow from Lake Malawi. The below normal scenario would also result in negative impact on our rain-fed agriculture and hydro electric power generation.

Malawi needs to invest in water infrastructure, catchment protection, small dams, water harvesting technologies and water conservation.

Wildlife

Climate change is a threat to wildlife habitat in terms of availability of both water and suitable plants for the wild animals. In response to climate change threats, Malawi must adopt ecosystem approach to conservation, improve on habitat management which should include water holes and forest fire threats, provide safe corridors for large mammals such as elephants and have strategies for translocation of animals if a need arises.

Fisheries

Climate change directly affects fish productivity as a result of temperature changes and droughts which would affect water availability. Furthermore, climate change may indirectly affect the fisheries sector as people move to fishing as an alternative livelihood system following failure in other sectors such as farming and livestock production.

The government should enhance efforts to promote co-management of fisheries resources, protected areas management, and promotion of aquaculture and cage aquaculture technologies.

Human health

During the NAPA studies, it was shown that climate change would result in increased epidemics of diseases such as malaria, cholera and dysentery. As a result of partial or total crop failures, incidents and severity of malnutrition, especially in children below the age of five, would increase.

The government should enhance the capacity to prevent and control malaria through dissemination of insecticide treated nets to vulnerable groups and provide effect treatment for malaria. Diarrhoeal diseases such as cholera and dysentery could be prevented through improved personal and household hygiene and treatment of infected water before use through boiling or chlorination. Communities should be capacitated to diversify crop production so that food security is enhanced at household level.

Forestry

Droughts which are expected to increase in frequency and intensity as a result of climate change affect the forestry sector through reduction in biomass productivity and increased incidents of forest fires.

Forestry sector is very critical in climate change mitigation through carbon sequestration. Therefore, every effort should be put in place to ensure that Malawi sustains and even expands its forestry resources, noting that Malawi is currently a net emitter. The forestry sector is a major source of livelihood for many household. Therefore, efforts should be channeled towards co-management of forestry resources through effective policing of protected areas as well as tree planting and management of community owned forests.

Mitigation and abatement analysis

Mitigation and abatement analysis aims at finding innovative ways how sectors could reduce their emissions through policy and technological interventions. The following sectors were analyzed: agriculture, forestry, energy, waste management, industrial processes.

The summary of the mitigation options are presented in the following table:

SECTOR	MODEL USED	MITIGATION OPTIONS
1. Agriculture	Century 4.0 model	• Manure management • Efficient utilization of nitrogen-based chemical fertilizers • Use nitrogen fixing plants • Tree crops for carbon sequestration • Zero tillage
2. Forestry	Comprehensive Mitigation Analysis Process (COMAP)	• Forest protection • Reforestation programmes • Use sustainable wood fuel in place of fossil fuel such as coal
3. Energy	LEAP	• Efficient technologies for cooking • Fuel switch for lighting in households • Increase ethanol-petrol ratio for motor vehicles
4. Waste	LANDGEM	• Reduce waste generation • Use landfill and harvest biogas (methane) • Controlled incineration • Composting for organic manure
5.Industrial processes	Excel spreadsheet (No specific model)	• Solvay process in lime making • Use rice husk-cement blend in building • Promote industries that use carbon dioxide as raw material • Carbon capture and storage

Other relevant information

Malawi undertook various climate related studies which included the Initial National Communication, Research and Systematic Observation, Technology Transfer and Needs Assessment, National Adaptation Programmes of Action and National Capacity Self Assessment. These studies revealed the need to:

- Integrate climate change in government policies, strategies and programmes;
- Enhance institutional capacity in climate change research;
- Enhance climate change data collection, modeling and analysis as bases for developing effective adaptation and mitigation strategies and programmes; and
- Develop, package and share climate change information.

Constraints and gaps

Despite the improvement in the compilation of the Second National Communication, Malawi is still unable to undertake detailed GHG inventories and modeling so as to inform the development of effective policies, strategies and programmes. Critical gaps that need to be addressed include, amongst others, the following areas:

- Limited human resources capacity in terms of numbers and skill range and depth;
- Limited climate change systematic data observation, collection and storage;
- Lack of capacity to use and apply analytical tools and models for enhancing effective and efficient decision making;
- Unclear sectoral policies that impact or are impacted by climate change;
- Limited institutional capacity ;
- Limited sustainable funding for climate change research and programmes; and
- Limited coordination of climate change research and interventions.

Proposed Climate change projects

Ten project concepts were developed to address issues on gaps analysis, policy issues, climate change adaptation and mitigation highlighted in this report, INC and NAPA. These are:

i. Renovation and extension of Matandani mini hydro power station;
ii. Establishment of energy data management system and preparation of energy balances for Malawi;
iii. Emergency floods and drought mitigation works programme;
iv. Development of water resources conservation and management programme;
v. Water demand side management programme;
vi. Siltation reduction along the Shire River hydro power enhancement and GHG reduction programme;

vii. Global climate observation system surface station at Mount Mulanje;
viii. Establishment of centre of excellence for climate change studies;
ix. Develop appropriate agriculture technologies to mitigate climate change and

Concluding remarks

Malawi has in recent years seen an increase in the frequency and intensity of climate related extreme events and disasters. Therefore, Malawi needs to make deliberate efforts to respond to the challenges imposed on its socio-economic sectors and peoples guided by an integrated climate change policy which government has started developing.

Malawi is a net emitter of GHG. Efforts must be put in place to develop appropriate mitigation measures to reduce our levels of GHG emissions and enhance our sink capacity. As we develop, Malawi should target to become a carbon neutral country.

Malawi needs to build local capacity to apply and/or develop various analytical models and tools
in order to reap maximum benefits from a wide range of climate change mitigation options. This could best be taken up by research institution and universities.

Majority of Malawians live in the rural areas and are dependent on climate sensitive sectors as sources of their livelihood. Climate change poses an additional challenge to poor and vulnerable communities who are already exposed to other multiple challenges. Programmes should be developed to enhance resilience of its people to the negative impacts of climate change.

Malawi Government should continue to strengthen the link with other multilateral and bilateral institutions to facilitate capacity building and technology transfer in the various areas of climate change policies, science and technologies.

Chapter 1:
Background Information

1.1 Introduction

Malawi faces many social, economical and environmental degradation problems, which are threatening the sustainable livelihoods of the majority of family households. The cause of these problems are many and varied, and include: (i) increasing human population pressures on a limited land resource base, (ii) accelerating deforestation resulting from increasing demands for fuel-wood, forest products and agricultural expansion, (iii) overgrazing, and (iv) the cultivation of marginal and fragile agro-ecosystems, such as steep hillsides and wetlands. All these impact directly on human health, agriculture, food security, water security, infrastructure, and educational support systems.

Over time, these problems have resulted into an engendered cyclic pattern of accelerating land and environmental degradation and depletion of the natural resource base. These have further resulted in increased poverty, food shortages and greater vulnerability of communities to natural hazards and calamities. Since the early 1970s, these problems have been exacerbated by the adverse impacts of climate change and climate variability, as manifested in various forms, especially intense rainfall, floods, droughts, cyclones, heat waves, mudslides and landslides. These climate-related hazards and calamities adversely impact on all sectors of economic growth (Agriculture, Water Resources, Fisheries, Forestry and Other Land-Use, Wildlife, Energy, Industrial Processes and Product Use, Waste Management and Human Health); and the sustainable livelihoods of both rural and urban communities.

The need to address climate change issues to ensure food and water security, alleviate poverty, arrest environmental degradation and ensure sustainable rural livelihoods are more urgent now. It is against this background, apart from meeting her obligation as a Party to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) that Malawi took a bold step to conduct several studies in different sectors of economic growth, and among communities and fragile agro-ecosystems that has resulted in the preparation of the Second National Communication (SNC) of Malawi for submission to the COP of the UNFCCC, and the Government of Malawi (GoM).

1.2 Climate Change

Climate change is defined as the change in climate that is attributed directly or indirectly to human activity that alters the composition of the global climate, whereas natural climatic fluctuations from year to year is termed climate variability (IPCC; 1995; 2007). The definitions of other terms related to climate change and climate variability are given in Appendix 1. Climate change is attributed to an increase in the greenhouse gas (GHG) concentrations in the atmosphere resulting from human-induced activities. The main greenhouse gases of concern are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the chlorofluorocarbons. These gases trap outgoing long wave radiation in the lower levels of the atmosphere, thereby resulting in global warming.

In addition, deforestation contributes to climate change in that it lays the soil surface bare resulting in radiation imbalance. Climate change is manifested through many climatic hazards or calamities, such as: (i) intense rainfall, (ii) floods, (iii) seasonal droughts, (iv) multi-year droughts, (v) dry spells, (vi) cold spells, (vi) strong winds, (vii) thunderstorms, (viii) heat waves, (ix) landslides, (x) hailstorms, (xi) mudslides, (xii) volcanoes, (xiii) earthquakes, and (xiv) epidemics. All these have serious effects on all sectors of economic growth, especially the agriculture sector, which is the engine of growth of the Malawi's economy.

1.2.1 Global climate change and its impacts

There is presently strong scientific evidence that global climate is already changing in response to human influences. The Inter-governmental Panel on Climate Change (IPCC) in 2007 concluded that climate and ecosystems are already changing as a result of human activities.

Presently, most climate change models predict that global temperatures will rise by about 1-3 ^{0}C by the year 2100 in response to a rise in CO_2 concentration levels. This projected change is larger than any other climate change over the last 10,000 years, and is likely to have a significant impact on the global environment, especially: (i) sea level rises, (ii) flooding, and (iii) droughts; with negative impacts on food security and sustainable livelihoods, and undesirable consequences on physical infrastructures, economic growth and development, human settlements and human health. These changes are likely to have a significant impact on resource-poor small-scale farming communities and other vulnerable groups, especially women, children, the elderly, the physically challenged and those infected and affected by the HIV and AIDS.

Over the last four decades, the number and the impact of both natural and man-made disasters have significantly increased, mostly affecting Least Developed Countries (LDCs). In 2003 alone, 254 million people were affected by natural disasters. Disaster situations impact intensely on poor people as they have the least capacity to cope and recover from the effects of such disasters, and do not have adequate security and protection in order to defend their rights to a dignified life. Access to basic needs, such as food, water, shelter and health services is often denied and livelihoods are destroyed. However, different groups of people are affected differently. Some are more vulnerable than others, especially when stratified by gender, ethnicity or disability. For example, women and girls are affected differently than men, and have different recovery patterns. It is women, girls and children who are in many cases denied opportunities and basic rights, often having less access to any available assistance.

1.2.2 Climate change and climate variability in Malawi

Over the last few decades, Malawi has experienced extreme weather events, ranging from droughts (1991/92) to floods (1996/97) and flush floods (2000/01). During the 1996/97 crop season, when there were floods in the southern region, some parts of the northern region along the Karonga Lakeshore plain experienced drought conditions. These extreme weather events clearly show that there are large temporal and spatial variabilities in the occurrence of climate-related disasters and calamities. In the affected areas, these events have had irreversible and damaging effects on crop and livestock production, especially the droughts that occurred during the 1978/79, 1981/82, 1991/92 and 1993/94 crop growing seasons.

Although temperature variations on the Medium Altitude Plateau are not large enough to significantly reduce crop growth and development, relatively higher temperatures (coupled with low and erratic rainfall) in the Shire Valley, and some areas along the Lakeshore plain result into low crop yields of grain and biomass. Vulnerability and adaptation (V&A) assessment studies conducted in Malawi (EAD 2005; 2008) have predicted that temperatures are likely to increase by 1.0, 2.0 and 4.0 ^{o}C for the years 2020, 2075 and 2100, respectively, and that rainfall will increase by between 2.0 and 8.0% by the year 2100. This clearly shows that climate change and climate variability will be a common feature of the climate system in the future. Hence, measures and strategies are required to be put in place to prepare for such eventualities.

1.3 Institutional and Legal Frameworks

1.3.1 Background

Malawi was formerly known as Nyasaland. It became a British Protectorate in May 1891, and as part of the Federation of Rhodesia and Nyasaland (comprising Southern Rhodesia (now Zimbabwe), Northern Rhodesia (now Zambia) and Nyasaland (now Malawi)) in 1953, which lasted for 10 years (1953-1963). Malawi attained her independence on July 6, 1964 and the Republican status two years later on July 6, 1966. From 1964 to 1994, Malawi was constitutionally under one party state rule. In 1993, a Referendum was held, which led to the adoption of a multi-party system of government. The first multi-party elected president was ushered into office in May 1994, signalling a new era of plural politics in the country. In the same year, a new constitution was adopted in response to the many challenges that had taken place, including the decentralization which aims at devolving power to local levels of decision making.

1.3.2 Administration

Administratively, Malawi is divided into three regions (north, centre and south), and twenty-eight districts, including the newly created districts of Likoma in the north, and Balaka, Phalombe, and Neno in the south. The north has six districts, the centre has nine districts, and the remaining thirteen districts are in the south. There is presently an increasing tendency to divide the Southern Region into two: eastern and southern regions.

1.3.3 Government Structure

The Government comprises three branches: (i) Executive, (ii) Legislature, and (iii) Judiciary. The Executive Branch comprises the cabinet and bureaucracy, which have authority to make and implement policies. There are several ministries, departments and sections within the Executive Branch that perform different duties and tasks to achieve the Government's policies and strategic objectives. The Legislature consists of the Members of Parliament (MPs). Parliament is the forum where natural and social problems are highlighted and policies to address them are debated and passed for implementation. The legislators approve bills and enact policies and scrutinize Government budgets that fund implementation of activities. The Legislature has committees on different themes including the Parliamentary Committee on Agriculture and Environment where climate change issues are presented, highlighted and debated.

The Judiciary deals with legal aspects in the country. Different types of legal issues, including environmental law, are assessed for their conformity with international standards and the Constitution of the Republic of Malawi, which is the Law of the Land. Among other issues, the Judiciary deals with constitutional standards, specialized statutes on environmental management that are directly related to legislation and the prevention of environmental degradation, conservation of biological diversity, and the provision of a healthy living and working environment for all citizens of Malawi (Weiss, 1996; WCED, 1987). Such statutes and standards guide the enforcement and compliance of legal requirements on environmental management principles, including climate change, and mitigation and adaptation measures and strategies. The evolving national standards in environmental law have been greatly influenced by standards in international law.

1.3.4 International Conventions and Protocols

The Government of the Republic of Malawi has over the last four decades been deeply concerned about the adverse impacts of climate change on the environment, fragile agro-ecosystems, different sectors of economic growth, and the sustainable livelihoods of vulnerable communities and rural family households. It is against this backdrop that Government has put in place a series of legislative frameworks to promote and consolidate the environment, climate change and other socio-economic developmental issues in line with international conventions and protocols that deal with sustainable economic growth and development, starting with the United Nations Conference on the Environment and Development (UNCED) in 1992.

The UNCED, which is also known as the "Earth Summit", was held in Rio de Janeiro, Brazil in June 1992, where a set of agreements and conventions were agreed by world leaders. These agreements included: (i) the United Nations Framework Convention on Climate Change **(UNFCCC),** (ii) the Convention on Biological Diversity (CBD), (iii) the United Nations Convention to Combat Desertification (UNCCD), (iv) the Statement of Forest Principles **(SFP)**, and (iv) Agenda 21 (which is a 40-chapter programme of action for sustainable development). It is Agenda 21, which contains the Rio Declaration on Environment and Development that is a set of twenty seven basic principles for achieving sustainable development based on the need to manage the economy, the environment, and social issues in a coherent and coordinated manner. It is designed to prepare the world to meet the challenges of poverty, hunger, disease, illiteracy and environmental degradation as a set of inter-related issues. However, what is of special focus for the Second National Communication (SNC) of Malawi is the UNFCCC.

United Nations Framework Convention on Climate Change. Malawi signed the UNFCCC in Rio de Janeiro, Brazil in June 1992, and ratified it in April 1994. As a Party to the Convention, Malawi is obliged under Article 4.1(a) of the Convention to develop, periodically update, publish and make available to the Conference of Parties (COP), in accordance with Article 12, national inventories of anthropogenic emissions by sources, and removals by sinks, of all greenhouse gases that are not controlled by the Montreal Protocol using comparable methodologies agreed upon by the COP. The results from these studies are reported to the COP of the UNFCCC in the form of a national communication. Malawi prepared and reported its Initial National Communication (INC) in 2003, and proposes to submit the Second National Communication (SNC) in 2009.

1.3.5 National Policies and Strategies

The Government has put in place a series of legislative frameworks to promote and consolidate environment, climate change and other socio-economic developmental activities in the country. The main policies, strategies and programmes for Malawi's development agenda are given in several policy and strategy documents at national and sectoral levels. Some of these are briefly described below.

Vision 2020. In the late 1990s, the Government of Malawi(GoM) developed Vision 2020. which was launched in 2000. Vision 2020 sets out a long-term development perspective for Malawi and emphasizes long-term strategic thinking, a shared vision and visionary leadership, participation in development activities by all the people, strategic management. and national learning. In a nutshell, Vision 2020 states that "by the year 2020, Malawi, as a God fearing nation, will be secure, democratically mature, environmentally sustainable, self-reliant with equal opportunities for and active participation by all, having social services, vibrant cultural and religious values and technologically driven by a middle-income economy".

Malawi Poverty Reduction Strategy (MPRSP). In May 2002, the GoM launched the Malawi Poverty Reduction Strategy (MPRSP) aimed at translating the long-term strategy and perspective of Vision 2020 into medium-term focused action plans. The MPRSP became the over-arching medium-term strategy of the Government for reducing poverty in the country. The goal of the MPRSP is to achieve "sustainable poverty reduction through empowerment of the poor.", and is built around four strategic pillars: (i) **sustainable pro-poor economic growth**, which is aimed at economically empowering the poor by ensuring macro-economic stability, access to credit and markets, skills development and employment generation, (ii) **human capital development**, which aims at ensuring that the poor have the health status and education to lift themselves out of poverty, (iii) **improving the quality of life for the most vulnerable**, which aims at providing sustainable safety nets for those who are unable to benefit from the first two pillars, and (iv) **good governance**, which aims at ensuring that public and private sector organizations, including civil society institutions and systems protect and benefit the poor. In addition, the MPRSP includes the four key cross cutting issues of HIV and AIDS, gender, environment, and science and technology. Climate change is not addressed directly, but it is embedded within environment. The implementation period for the MPRSP was for three years, 2001/02-2004/05.

Malawi Economic Growth Strategy (MEGS). In July 2004, the GoM developed the Malawi Economic Growth Strategy (MEGS) to address some of the shortcomings identified by various stakeholders in the implementation of the MPRSP, especially under the theme "pro-poor growth". Stakeholders noted that: (i) the strategies and actions were insufficient to achieve sustained annual economic growth of at least 6.0% and thus, contribute less to poverty reduction, (ii) housing and land policy issues, among others, were not well articulated to contribute effectively to broad-based growth, and (iii) did not focus on eliminating obstacles to growth on an economy-wide basis, nor did it sufficiently articulate the role of the private sector organizations, including Non-Government Organizations (NGOs). Thus, MEGS was essentially developed to complement and strengthen pillar one through investments that would directly impact sustainable economic growth and development among rural communities.

Millennium Development Goals (MGDS). In 2003, the GoM undertook a thorough review of the Millennium Development Goals (MDGs) and streamlined these to fit local conditions. In brief, the MDGs focus on decreasing poverty through a combination of economic growth, empowerment and food security measures, and decreasing the proportion of people who suffer from hunger and improve their nutritional status. Specifically, the MDGS aims at: (i) reducing by half the people living under poverty, (ii) achieving universal primary education, (iii) promoting gender equality and empowering women, (iv) reducing the under-5 mortality rate, (v) combating the spread of HIV and AIDS, (vi) reducing the incidence of malaria and other major diseases, and the proportion of people without sustainable access to safe drinking water, (vii) ensuring environmental sustainability, and (viii) developing a global partnership for development. The challenge facing Malawi is to achieve these strategic objectives so as to improve the wealth, welfare and sustainable livelihoods of all Malawians by the year 2015.

Malawi Growth and Development Strategy (MGDS). In 2006, the GoM undertook a major policy review and transformation, replacing the direction and objectives of the Malawi Poverty Reduction Strategy (MPRSP) with those of the Malawi Growth and Development Strategy (MGDS) over a period of five years (2006-2011) in order to shift economic emphasis from consumption to sustainable growth and infrastructure development. The main driving force of the MGDS is to institute strategies that will stimulate economic growth and bring about prosperity and improve the welfare of the majority of Malawians, and transforming the country from a predominately importing and consuming to a predominately producing and exporting country. Thus, over the years, a national consensus has emerged that Malawi needs to develop a set of priorities that will enable the country to develop fast enough and move out of poverty by: (i) creating **stable macroeconomic** conditions for growth and to instilling domestic and international confidence in the economy, (ii) developing and strengthening **business enterprises that create wealth,** and thus, contribute positively to economic growth through deep-rooted private sector reforms, focusing on improvements in infrastructure, (iii) enhancing the **production of food crops** to make Malawi a hunger free nation, (iv) developing the **civil service capacity to facilitate private sector based growth and development** in order to contribute effectively to the resuscitation of economic growth, including moving forward the decentralization process to effectively mobilize local resources in the development process, (v) providing **basic health care and industry needs driven-education** to ensure a productive population that will contribute to sustainable economic growth, and (vi) promoting **good governance** practices because they underpin the achievement of all economic growth and social development objectives.

Specifically, the MGDS is focussing on the following sectors of economic growth: (i) agriculture and food security, (ii) irrigation and water development, (iii) transport infrastructure development, (iv) energy generation and supply, (v) integrated rural development, and (vi) prevention and management of nutritional disorders and HIV and AIDS to achieve its goals. It is within the context of these broad policy and strategic frameworks that Malawi intends to address climate change and climate variability. Presently, most of these policy and strategy statements do not explicitly mention climate change, but this is often implied from within the strategies on environmental sustainability, agricultural production, food and water security, and sustainable livelihoods.

1.3.6 Sectoral Policies and Strategies

The Government has put in place a series of legislative frameworks to promote and consolidate the environment, climate change and other socio-economic developmental activities. For example, some of the sectors for which these policies and strategies have been developed include: (i) Agriculture (Food and Nutrition Security Policy, 2005; HIV and AIDS in the Agriculture Sector Policy and Strategy, 2003; National Land Use Planning and Management Policy, 2005; Malawi Irrigation Policy and Development Strategy, 2000), (ii) Water (Malawi National Water Policy, 2004), (iii) Forestry (National Forestry Policy of Malawi, 1996), and (iv) Energy (Malawi Energy Policy), among many others. Despite the fact that Malawi's agriculture, which is the engine of economic growth, is rain-fed and highly vulnerable to climate change, especially floods and drought, not much effort has been done to explicitly mainstream climate change in these sectoral policies and strategies. However, agricultural, water and irrigation policies and strategies endeavour to address issues related to climate change, although in most cases this is not explicit enough. Thus, the revised or updated versions of these documents need to include climate change, which is the greatest challenge of the present times.

1.3.7 Environmental Policies and Strategies

Malawi's current environmental policies, strategies and programmes have been formulated following the Earth Summit in 1992, which are all in response to Agenda 21. Agenda 21 identified poverty, high population, consumption patterns and technologies as the main drivers for environmental sustainability. Agenda 21 also called for rich nations and the international financial institutions to support developing countries to define their national environmental action plans and national strategies for sustainable development. Some of these policy and strategy documents are briefly described below.

National Environnemental Action Plan (NEAP). After signing Agenda 21 in 1992, Malawi prepared the National Environmental Action Plan (NEAP). NEAP, which was launched in 1994, is an operational tool for the implementation of Agenda 21. This action plan was developed through a highly consultative process among a wide cross-section of stakeholders in the public and private sector organizations, NGOs and civil society organizations. NEAP has identified several key environmental concerns that include (i) high soil erosion and low soil fertility, (ii) deforestation and overgrazing, (iii) water resources degradation and depletion, (iv) over-fishing, (v) loss of biodiversity, (vi) human habitat degradation, (vii) high population growth, (vii) air pollution, and (ix) climatic change. It is for this reason that NEAP is used as a framework for all development plans to ensure an environmentally sustainable development in line with the strategic objectives of Vision 2020, MEGS and the MGDS. To operationalize NEAP, Government is implementing the Environmental Support Project (ESP) whose overall objective is to integrate environmental concerns into socio-economic development of the country. Malawi revised NEAP in 2002 to respond to challenges brought up by the democratization and decentralization processes since 1994.

National Environmental Policy (NEP). The National Environmental Policy (NEP) 1996, which was revised in 2004 provides an overall framework through which sectoral policies are reviewed to assess their consistency with the principles of sound environmental management. The policy emphasizes the following: (i) empowering local communities in the management of their natural resources to promote social equity, (ii) minimizing the adverse impacts of climate change, (iii) reducing air pollution, and (iv) reducing GHG emissions through the monitoring of the impacts of climate change on ecosystems, vegetation and carbon sinks; reducing gas emissions from the transport sector and the manufacturing industry, and using climate data to help guide land-use and economic decisions.

National Strategy for Sustainable Development (NSSD). In 2004, the GoM prepared and launched NSSD in response to the requirements of the World Summit on Sustainable Development (WSSD) that was held in Johannesburg, Republic of South Africa in 2002. Through the provisions of the WSSD, Malawi has so far taken a leading role in the implementation of the UNFCCC activities, including the installation of satellite data receiving equipment, public awareness campaigns on climate change issues, and the preparation of the Second National Communication (SNC) of Malawi document.

1.3.8 Compliance with Legal Frameworks

The implementation of various policies, strategies and programmes require an enabling environment with appropriate legal frameworks, including measures and strategies for enforcing compliance of these by various stakeholders. Presently, the enforcement of actions through inspections to determine compliance is minimal. This is because the current legal and policy frameworks lack negotiations with individuals or facility managers, who are out of compliance to develop mutually agreeable schedules and approaches for achieving compliance. However, benefits exist when people comply with policies and laws on environmental management. These include: (i) protecting environmental quality and public health, (ii) building and strengthening the credibility of environmental requirements, and (iii) ensuring fairness. Without enforcement, those who comply voluntarily do not benefit compared with those who violet environmental regulations. Compliance ensures reduction in costs and liability of a healthy environment. However, legal and policy frameworks are influenced by many factors, including: institutional credibility and capacity, socio-economic and psychological factors, technical feasibility and know-how, among many others.

To ensure compliance, Government has put in place the Environmental Management Act of 1996 as its legal instrument for implementing and enforcing compliance with the various regulatory strategies and measures for the protection and preservation of the environment. The Act also provides for the protection of the ozone layer by regulating substances, activities and practices that deplete or are likely to deplete the stratospheric ozone layer, or other components of the stratosphere. Several committees, including the Cabinet Committee on Environment and Health, and the Parliamentary Committee on Agriculture and Environment, have also been put in place to oversee compliance by various stakeholders.

The Environmental Affairs Department (EAD) and the National Council on the Environment (NCE), which is assisted by the Technical Committee for the Environment (TCE), deals with all environmental issues in the country. There is also the National Climate Change Committee (NCCC) with the responsibility of reviewing policies and programmes on climate change, which is chaired by the Department of Meteorological Services (DoMS), with its Secretariat in EAD. In addition, the various Environmental Impact Assessments (EIAs) have been instituted and are promoted as an environmental management tool to ensure that developmental activities are implemented in a sustainable and environmentally-friendly manner. Many public and private sector institutions or organizations are now undertaking EIAs before implementation of their proposed projects. However, there is need to ensure that climate change, which is now "a hot topic", is incorporated in all EIAs.

1.3.9 Institutional Arrangements

The Malawi Government considers environmental management as an integral component of food and water security, poverty alleviation and socio-economic growth and development as central pillars of national development policies and strategies. Addressing climate change forms part of the Government's strategy to spur economic growth and development, thereby reducing poverty, and encouraging sustainable development. The EAD in the Ministry of Natural Resources, Energy and Environment (MoNREE) is responsible for preparing and implementing environmental policies and relevant legislations. It is also responsible for enforcing the regulations and providing guidance on environmental issues, including climate change. In each of the twenty-eight districts, there is a District Environmental Officer (DEO) responsible for coordinating and overseeing environmental issues and the preparation of the district state of environment reports, (SOER). EAD, in collaboration with the Department of Metrological Services (DoMS), is responsible for coordinating climate change issues in the country. The major policy thrust includes the coordination and proper management of the environment and the natural resource base in collaboration with line ministries and departments, the private sector, NGOs, select communities, and other relevant stakeholders at district, national, regional and international levels. Further, officers responsible for environmental management usually create in the people of Malawi what is known as "legitimate expectations", which are protected by Section 43 of the Constitution of Malawi. The principles of administrative law are utilized as a tool for quality decision–making to ensure sustainable management of the environment.

1.4 Responding to the Challenges of Climate Change

Malawi has made some significant steps in addressing climate change and climate change-related issues since the early 1970s when it started experiencing extreme weather events, especially floods and severe droughts. In the late 1990s, Malawi received funding from the United States of America (USA) under the **US Country Studies Program** to prepare an inventory of greenhouse emissions from various sectors, and to develop adaptation and mitigation measures to address the adverse impacts of climate change. In 1999, Malawi received funding from the Global Environment Facility (GEF) through the United Nations Development programme (UNDP) to prepare its **Initial National Communication (INC)** under the "Climate Change Enabling Activities Project". The INC was prepared and submitted to the COP of the UNFCCC in 2003.

Further, in 2004, the Malawi Government received funding from GEF through UNDP to prepare the **National Adaptation Programmes of Action (NAPA)** for Malawi. This marked an important and significant milestone in Malawi's quest to address with urgency the adverse impacts of climate change, especially floods and drought, on vulnerable communities, fragile agro-ecosystems and sectors of economic growth, such as: Agriculture, Water, Energy, Fisheries, Forestry and Product Use, Wildlife, Human Health, Industrial Processes and Product Use, and Waste Management. The NAPA was completed and submitted in 2006, and is being implemented by Government in collaboration with its development partners. The preparation of these two documents facilitated the building-up of institutional capacity and expertise in various public and private sector organizations in the country. It also led to the building of strong technical teams of National Experts (NEs) that prepared the various thematic area technical reports, and the final INC document. The preparation of these documents also increased public awareness among stakeholders on the adverse impacts of climate change on various sectors of economic growth. The submission of the INC in 2003 meant that Malawi was now ready to implement the recommend strategies, and to embark on studies to prepare the Second National Communication (SNC). Thus, in 2006, the Malawi Government received funding from GEF through UNDP to prepare the SNC document.

However, it should be noted that despite the remarkable achievements and progress made in preparing the INC and NAPA documents, none of the proposed measures and strategies for adapting and mitigating climate change have been funded and/or implemented to date. This includes capacity building, where it was proposed to train Malawians in acquiring skills and expertise in computer simulation modeling, the research methodology, and the determination of local emission factors and activity data for estimating GHGs from different sectors. Capacity building was also proposed to train staff in local institutions of higher learning, especially in the fields of crop, soil and climate modeling, systems analysis, and participatory research and extension approaches.

1.5 Second National Communication of Malawi

The Second National Communication (SNC) of Malawi positions the country to squarely reflect on its performance in addressing climate change issues.. Further, the SNC addresses the gaps identified in the INC and also provides an overview of the trends of new events since the country submitted its INC to the COP of the UNFCCC in 2003.

1.5.1 Rationale

As a Party to the Convention, Malawi is obliged to periodically report inventories of greenhouse gas emissions from different sectors, and propose measures and strategies for adapting and mitigating climate change. It is against this backdrop that Malawi has prepared and submitted this report to the COP of the UNFCCC.

1.5.2 Objectives

The purpose of the SNC is to prepare the SNC of Malawi for submission to the COP of the UNFCCC as provided in Articles 4 and 12 of the Convention. Specifically, the SNC aims at: (i) strengthening the technical and institutional capacities of various public and private sector organizations to acquire skills and competencies in mainstreaming climate change issues into their respective sectoral programmes, policies and strategies, (ii) contributing to global efforts in better understanding the various sources and sinks of greenhouse gases, potential impacts of climate change, and effective response measures to achieve the ultimate goal of UNFCCC of stabilizing greenhouse gas concentrations in the atmosphere to a level that would prevent dangerous anthropogenic interference with the climate system. (iii) proposing climate change projects aimed at finding solutions to climate change problems that communities can adapt and/or use to mitigate climate change, (iv) enhancing general awareness on climate change and climate change related issues, and (v) strengthening dialogue, information exchange, networking and cooperation among various stakeholders in the public and private sector organizations, including NGOs, and the university, involved in climate change studies in accordance with Article 6 of the UNFCCC.

Further, there is need to intensify the implementation of measures, strategies and programmes that reduce GHG emissions, or provide sinks for CO_2, in order to avert the negative impacts of climate change (e.g., poverty, hunger, diseases and land degradation) on vulnerable communities and fragile agro-ecosystems. The recommendations made in this document provide insights into the way forward to address the adverse impacts of climate change, including capacity building at individual and institutional levels, in order to achieve the strategic goals and objectives articulated in the Millennium Development Goals (MDGs) and the MGDS.

1.6 Preparing the Second National Communication of Malawi

1.6.1 Preparatory Process

The Second National Communication (SNC) of Malawi has been prepared through a broad consultative and participatory process involving scientists from different public and private sector organization, including NGOs. The preparatory process was initiated by identifying multi-disciplinary teams of National Experts (National Team Leaders and sectoral National Experts) identified based on the level of training and expertise in the various thematic areas of focus, including: (i) National Circumstances, (ii) National Greenhouse Gas Inventory: Energy, Agriculture, Forestry and Other Land-Use, Industrial Processes and Product Use, and Waste Management, (iii) Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change (or Vulnerability and Adaptation (V&A) Assessments): Energy, Agriculture, Forestry and Other Land-Use, Wildlife, Water Resources, Fisheries and Human Health, (iv) Programmes Containing Measures to Mitigate Climate Change (or Mitigation Analysis): Energy, Agriculture, Forestry and Other Land-Use, Industrial Processes and Product Use and Waste Management, (v) Other Information Considered Relevant to the Achievement of the Objectives of the Convention, (vi) Constraints and Gaps, and Related Financial, Technical and Capacity Needs, and (vii) Proposed Climate Change Projects.

Three highly qualified and experienced scientists were identified as National Team Leaders (NTLs) for the three main thematic areas of focus: (i) Greenhouse Gas Inventory, (ii) Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change, (V&A Assessments) and (iii) Programmes Containing Measures to Mitigate Climate Change (Mitigation Analysis). National Experts (NEs) were assigned to sectors in their areas of expertise. These NEs were drawn from government departments and ministries, parastatal organizations, universities of Malawi and Mzuzu, NGOs, and the private sector (individual consultants). To ensure the involvement of all NEs, several meetings were organized, where the NEs presented the results of their findings, and shared information and experiences with each other. What was equally important was data sharing, for example, the findings of Chapter 3 were used in Chapter 5, whereas the findings of Chapter 7 were derived from sectoral and thematic area reports.

The implementation strategy involved: (i) identifying approaches and methodologies for conducting the studies, (ii) literature review to identify the gaps as elaborated in the INC, (iii) data collection from different government departments and ministries, (iv) model selection and use, (v) data analysis and interpretation, and (vi) preparation of nineteen sectoral reports by NEs. These nineteen reports were synthesized and compiled into six thematic area reports by NTLs and Sector Coordinators (SCs). These six reports were further synthesized into one single report: Second National Communication (SNC) of Malawi. Later in 2007, an International Expert (IE) was engaged who assisted with clarifications on model output results, especially from the Vulnerability and Adaptation (V&A) Assessments thematic area. .

1.6.2 Arrangement of Chapters

The SNC of Malawi is a valuable document that contains a series of measures and strategies for addressing climate change and climate variability issues in a coordinated and holistic manner. Although the primary objective of the SNC is to fulfil Malawi's obligation to UNFCCC, this document is also aimed at sensitising the general public, including farming communities, donor communities, public and private sector organizations, including NGOs and civil society, on the adverse impacts of climate change on various sectors of economic growth. The document proposes adaptation and mitigation measures that can be used to adapt to climate change and/or reduce GHG emissions by all stakeholders and engage them in a dialogue to ensure that the proposed and recommended actions are implemented by both public and private sector organizations.

Thus, the SNC document has been arranged in such a way that it gives an expose of Malawi's national circumstances, including natural resources; greenhouse gas emissions from various sectors of economic growth; and adaptation and mitigation measures put in place to adapt to and mitigate climate change. The document further presents information considered relevant to the achievement of the objective of the Convention; identify constraints and gaps, and related technical, financial and capacity needs. Finally, the SNC propose climate change projects designed to address the identified constraints and research gaps, including capacity needs and capacity building at both individual and institutional levels. These have been arranged in the following nine chapters:

Chapter 1 provides a brief overview of the problems facing Malawi, which are presently exacerbated by climate change and climate variability at both national and local levels. The chapter also brings out the institutional set-up and legal framework for environment and climate change, efforts taken by Government to address the challenges of climate change, and finally provides the rationale and objectives of the SNC of Malawi.

Chapter 2 presents Malawi's national circumstances that are relevant to climate change. Specifically, the chapter provides information on the country's geographic, climatic, human, public health, population, economic and sector profiles, and the abundant natural resources, as well as institutional arrangements for dealing with climate change issues.

Chapter 3 provides information on GHG emissions from selected sectors of economic growth, which include Agriculture, Forestry and Other Land-Use, Energy, Industrial Processes and Product Use, and Waste Management for the period 1995-2000.

Chapter 4 gives a detailed overview of the various measures and strategies that can be used by vulnerable communities to adapt to the adverse impacts of climate change in the Agriculture, Fisheries, Water Resources, Wildlife, Energy, Forestry and Other Land-Use, and Human Health Sectors.

Chapter 5 provides information on measures and strategies for mitigating climate change, i.e., reducing GHGs in the Energy, Agriculture, Forestry and Other Land-Use, Industrial Processes and Product Use, and Waste Management sectors.

Chapter 6 outlines other information that is considered relevant to the achievement of the objective of the Convention. This includes information on steps taken to integrate climate change into relevant socio-economic and environmental policies, technology transfer, systematic observation, capacity building, information sharing and, networking activities among different stakeholders involved in climate change issues.

Chapter 7 presents the identified constraints and gaps, and the related financial, technical and capacity needs that affect the smooth implementation of climate change activities, including Global Environment Facility/United Nations Development Programme (GEF/UNDP) portfolios and programmes.

Chapter 8 presents some proposed climate change projects that need to implemented with urgency that they deserve and to assist in preparing future communications. The proposed projects are mostly focussed on the agriculture, energy, forestry and water resources sectors.

Chapter 9 provides a summary of the main findings of the Second National Communication of Malawi.

1.7 Summary

Chapter 1 has highlighted the many social and economic problems faced by Malawi as a nation whose economy is based on rain-fed agriculture. Presently, these problems have been exacerbated by the adverse impacts of climate change (especially the increasing frequency and magnitude of floods and the recurrent and devastating droughts), which negatively impact on food security and the sustainable livelihoods of family households. This chapter has further provided information on global climate change, legal framework for climate change at national and sectoral levels. The chapter has also examined the response of Governments to the problem of climate change through the preparation of various documents on climate-related issues, including the National Adaptation Programmes of Action (NAPA), the Initial National Communication (INC), and presently, the Second National Communication (SNC).

Chapter 2
National Circumstances

2.1 Introduction

This chapter provides information on Malawi's national circumstances that are relevant to climate change. These include: (i) geographic profile, (ii) population profile, (iii) climatic profile, (iv) natural resources, (v) infrastructure, (vi) economic and sector profiles, (vii) human and public health profile, (viii) gender, (ix) other information relevant to the Conference of Parties (COP), and (x) institutional arrangements relevant to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), including the preparation of Malawi's national communications and the Global Environment Facility (GEF) portfolios.

2.2 Geographic Profile

2.2.1 Location and Land Area

Malawi is a land-locked country in southern Africa that lies along a sector of the African Rift Valley south of the Equator between latitudes 9° 22′ and 17° 03′ south, and longitudes 33° 40′ and 35° 55′ east (Fig 2.1). It is bordered by Tanzania in the north and north-east; Mozambique in the south and the east; and Zambia in the west. It is 910 km long and varies in width from 60 to 161 km. It has a total surface area of 11.8 m ha, of which, 9.4 m ha (80%) is land area and the remaining 2.4 m ha (20%) is covered by water. Out of 9.4 m ha, 1.8 is public land, 1.2 is estate land, 0.3 is urban land, and 6.1 is customary land (EAD, 1998; Saka, Green and Ng'ong'ola, 1995, Msiska, 2007). Of the total land area, 31% is suitable for rain-fed agriculture, 32% is marginal, and 37% is unsuitable for rain-fed agriculture.

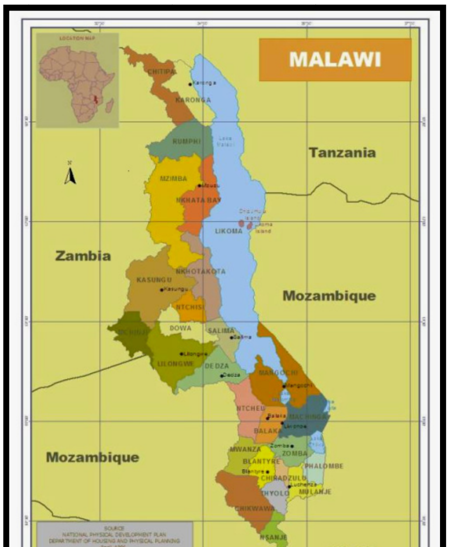
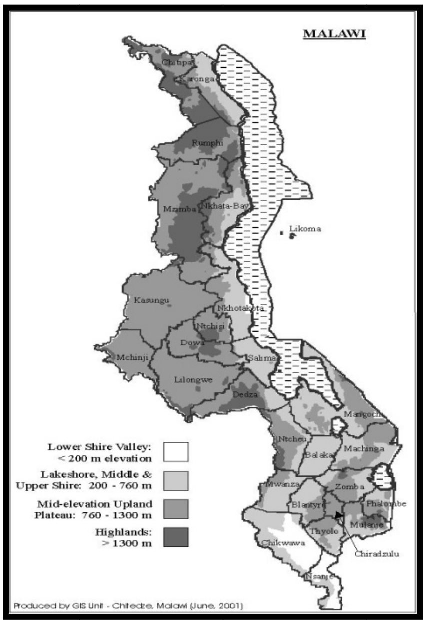


Fig 2.1: Location of Malawi



2.2.2 Relief Units

Malawi exhibits great diversity in terms of relief units, soils, vegetation, rainfall and temperature regimes for a country of its size. The topography is greatly variable, rising from almost sea level (35 m asl) on the Rift Valley Floor in Nsanje district to about 3,000 m asl on the High Altitude Plateau at Sapitwa on Mulanje mountain in Mulanje district.

Four distinct major relief units, or agro-ecological zones (Fig 2.2; Table A2.1 in the Appendix), can be distinguished as follows: (i) High Altitude Plateaus (1,350 to 3,000 m asl) with gentle to moderate slopes bounded by scarps or deeply dissected zones on all sides, and undulating landforms dominated by Lithosols (Inceptisols) and montane type of vegetation, (ii)

Medium Altitude Plateau (1,000–1,350 m asl) with undulating and level crests that are dominated by Latosols on upland sites and Hydromorphic soils on the poorly drained dambos, and *Brachystegia* plateau woodland (*Combretum-Acacia-Bauhimia*), (iii) Lakeshore Plain (450 and 600 m asl) dominated by Calcimorphic Alluvial soils (Entisols) and Hydromorphic soils (Inceptisols) on poorly drained dambo sites, with vegetation types that include baobab and palm trees, and (iv) the Shire Valley (35 to 105 m asl) dominated by Calcimorphic alluvial soils and Vertisols, and some Hydromorphic soils on dambos and along river valleys, with a vegetation type that includes *Acacia* tree species. (Pike and Remington, 1965; EAD, 2008).

It is this great diversity in land forms, soil types and vegetation types that has provided Malawi with a unique potential for tourism, recreation and the production of a variety of crops and livestock species, including exotic tree species in the southern Africa region. Most of the agricultural activities are carried out on the Medium Altitude Plateau, which covers about 75% of the total land area, along the Lakeshore Plain and in the Shire Valley. However, it should be noted that it is agricultural expansion over the last four decades that has significantly contributed to deforestation, soil erosion, and environmental degradation.

2.2.3 Land-Use

Presently, land is utilized as follows: (i) 2.0 m ha (21%) is devoted to agricultural production, (ii) 1.8 m ha (19%) is under forest reserves, game parks and conservation areas, (iii) 0.09 m ha (1%) is devoted to human settlements, and (iv) 3.0 m ha (32%) is covered by swamps, flood plains (dambos) and steep slopes. The major land uses, including areas that are physically constrained in the three regions of the country, are given in Table 2.1

Table 2.1: Existing major land-uses (million ha) in Malawi

Region	Total land area	Estate farms	Smallholder farms	National parks and game parks	Game reserves
Northern	2.7	0.1	0.2	0.4	0.2
Central	3.6	0.4	0.7	0.4	0.2
Southern	3.1	0.2	0.5	0.3	0.3
Malawi	9.4	0.7	1.4	1.1	0.7

Source: Anon., 1984; EAD, 2003.

2.2.4 Land Tenure

Land tenure in Malawi is the basis for land allocation, ownership and utilization. Five distinct land tenure classes can be distinguished: (i) Customary land, (ii) Leasehold land, (iii) Registered land, (iv) Freehold or Certificate land, and (v) Public land. Customary land is the type of land that is held in trust for the people of Malawi by the State President, with delegated authority to the chiefs. Customary land law is quite variable in the country, but with the most important difference being expressed between matrilineal and patrilineal systems of inheritance.

However, in both systems, some common basic principles apply: land which is in use can be held and inherited indefinitely; whereas land that is not used is considered to belong to the community, under the jurisdiction of the chief, rather than to individuals. It is the chief of the area, or the headman, that can allocate any unoccupied land to any individual or a family. However, some modifications to the land user rights have been recommended and incorporated in the new Land Policy for Malawi, especially as regards to land ownership and inheritance by women.

Land ownership has important implications for improved and increased sustainable agricultural production, infrastructural development and tree planting programmes. These impact directly on greenhouse gas emissions (GHGs) and greatly influence the choice of measures and strategies for adapting to, and mitigating the adverse impacts of climate change.

2.3 Population Profile

Malawi's current population is 13,066,320 people, up from 9.9 million in 1998, representing an overall population increase of 32% that is growing at the rate of 2.8% per annum, up from 2.0% in 1998 (NSO, 2008). The population density is 139 persons km^{-2}, up from 105 in 1998, making Malawi one of the most densely populated countries in the world. The spatial population distribution in the country indicates that 45%, 42% and 13% of the people live in the south, centre and north of the country, respectively. Women and men comprise 51% and 49% of the population, respectively; which is the same as reported for the 1998 Population and Housing Census Report (NSO, 2002; 2008). The population of the 18 years and above age-group is 6,216,432, of whom 3,200,000 are females and the remaining are males. The overall average life expectancy is 37 years, which is very low even by African standards. Some basic demographic, health, economic and natural resources indicators are given in Table 2.2.

Table 2.2: Basic demographic, health, economic and natural resources indicators for Malawi, 2008

Indicator	2008	Unit
Demographic indicators		
Population	13.1	Million
Urban population	15.4	% of total
Population density	139	Persons
Population growth	2.8	% per year
Life expectancy at birth (male	38.1	Years
Life expectancy at birth (female)	37	Years
Fertility rate	6.3	Birth per woman
Female headed households	25	% of all households
Literacy	56	% of total population
Health indicators		
Infant mortality	103	Per 1,000 live births
Mortality rate, under-five	193	Per 1,000 live births
HIV prevalence	14	% of female aged 15-24
HIV and AIDS mortality rate	700	Per 100,000 people
Illiteracy rate (males)	25.5	% of males over 15 years
Illiteracy rate (females)	53.5	% of females over 15 years
Poverty rate	52	% of total population
Economic indicators		
Gross Domestic Product (GDP)	1.7	billion (US $)
Gross National Income (GNI) per Capita	170	US $
GDP growth	1.7	% over preceding year
Population in poverty	65	% of total population
Population in absolute poverty	29	% of total population
Natural resource indicators		

Surface area	11.8	million ha
Total land area	9.4	million ha
Potential agricultural land	56	% of total land area
Land area for agriculture	1.8	million ha
Forest area	2.6	million ha

Source: NEC, 2003; NSO, 2000, 2008; RBM, 2005.

2.3.1 Population Growth

The population of Malawi has grown exponentially over the last hundred years from a meagre 737,200 in 1901 to the present 13,066,320 in 2008 (Table 2.3). However, the population growth rates have fluctuated between 2.0% (1998) and 3.7% (1987), mainly as a result of the Mozambican civil war refugees, who peaked at 1.0 million people at the height of the influx in the 1980s. Presently, all the Mozambican refugees have been repatriated, so that the present high population growth rate can be ascribed to a high average fertility rate of about 6.2 children per woman (GOM 2000a; 2005a). The population density increased from 85 persons km^{-2} in 1987 to 105 in 1998, and is presently 139 persons km^{-2}.

Table 2.3: Population growth of Malawi, 1901-2008

Year	1901	1911	1921	1931	1945	1966	1977	1987	1998	**2008**
Population (millions)	0.74	0.97	1.20	1.60	2.18	4.31	5.55	7.99	9.80	13.1
Growth rate (%)	2.2	2.8	2.2	2.9	2.2	3.3	2.9	3.7	2.0	2.8

Source: GOM, 2005b, GOM 2000b; NSO, 2008.

All the major cities have experienced big population increases over the last ten years. For example, the population of Lilongwe City has grown by 50% to the present 669,021, overtaking the City of Blantyre whose current population is 661,444. Similarly, the number of family households has increased by 37%, from 2,273,846 in 1998 to 2,957,683 in 2008.

2.3.2 Fertility Rates

The total fertility rate for Malawi has been declining from 7.6 in 1984 to 6.7 in 1992 to 6.3 in 2000 to 6.0 in 2004. However, these fertility rates are still ranked as some of the highest in the eastern and southern Africa region, but are marginally lower than those for Uganda (6.9 children per woman). There are large differences in fertility rates due to family background and area of residence. Urban women tend to have fewer children (4.2 children per woman) than rural women who average about 6.4 children per woman.

There are also substantial regional variations in average fertility rates: (i) Central Region: 6.4 children per woman, (ii) Southern Region: 5.8 children per woman, and (iii) Northern Region: 5.6 children per woman. Fertility rates also vary with the level of education and economic status of the woman. Women who have attained secondary school education, on average, tend to have 3.8 children per woman, whereas those with little or no education at all tend to have an average of 6.9 children per woman, which is comparable to the Uganda figure. The crude death rate has been declining slowly from 25 per 1,000 in 1977 to 19 per 1,000 in 1998. The infant and child mortality rates declined to 16 and 26%, respectively, in 1998. Some of the basic health indicators are given in Table 2.2.

2.3.3 Population Distribution

The spatial distribution of population is unequal among the three regions. The population in the north grew faster than in other two regions, growing from 911,767 in 1987 to 1,233,560 in 1998, and to 1,698,502 in 2008. In the centre, it has grown from 3,110,986 in 1987 to 4,066,340 in 1998, and to 5,491,034 in 2008, whereas in the south, the population increased from 3,965,734 in 1987 to 4,633,968 in 1998 and to 5,876,784 in 2008 (Table 2,4). These are large increases for a country that has a limited land area of 9.4 m ha and natural resources.

Table 2.4: Population distribution by region in Malawi, 1987, 1998 and 2008

Region	Population census			Population distribution		
	2008	1998	1987	2008	1998	1987
Northern Region	1,698,502	1,233,560	911,787	13.0	12.4	11.4
Central Region	5,491,034	4,066,340	3,110,986	43.0	40.9	38.9
Southern Region	5,876,784	4,633,968	3,965,734	45.0	46.6	49.6
Malawi	13,066,320	9,933,868	7,988,507	100.0	100.0	100.0

Source: NSO, 2002; 2008.

At district level, the highest percentage of the population live in Lilongwe rural (9.0%) followed by Mangochi (6.2%), whereas the least population share is for Likoma district (1.0%). Among the cities, Lilongwe City has the highest population of 669,021, followed by Blantyre with 661,444, Mzuzu with 128,432, and finally Zomba with 87,366.

About 85% of the people live in rural areas deriving their livelihoods from small land holdings of between 1.0 and 5.0 ha per family of five people, with the remaining 15% residing in urban areas. According to the 1977, 1987, 1998 and the 2008 censuses, Malawi has a high population of young people, with more than 40% below 15 years of age. This has brought about a high dependency ratio of 1.01 for each economically active adult (EAD, 2006).

Over the last two decades, there have been substantial migrations from rural to urban areas (at the rate of 3.6% per year), and from densely populated to sparsely populated areas or districts and/or people moving from areas adversely affected by climatic hazards (especially floods and drought) to safer upland areas or other districts.

2.4 Climatic Profile

2.4.1 Climate of Malawi

The climate of Malawi is greatly influenced by altitude and its proximity to Lake Malawi, a huge water body that covers nearly two thirds of its length (Fig 2.1). There are two main synoptic systems, or rain bearing systems, which bring rainfall to the country: (i) the Inter-Tropical Convergence Zone (ITCZ), and (ii) the Congo Air Mass or Zaire Air Boundary. The other factors that equally influence the climate of Malawi include: anti-cyclones, easterly waves, and occasionally tropical cyclones. The deficiency in rainfall may occur if these systems are not active in a season.

Generally, Malawi experiences a tropical continental type of climate that is characterized by two distinct seasons: (i) a single rainy season lasting from November to April, and (ii) a dry season extending from May to October. It is cool and dry from May to August, warm and dry from September to November, and warm and wet from November to April. In some High Altitude Plateaus, such as the Shire Highlands, drizzles, locally known as Chiperoni, are quite common during the months of May, June and July, which are the coldest months in Malawi. Further, Malawi's climate is closely associated with relief units and altitude above sea level, and can conveniently be classified as follows: (i) semi-arid (Shire Valley and some parts along the Lakeshore Plain), (ii) semi-arid to sub-humid (Medium Altitude Plateaus), and (iii) sub-humid (High Altitude Plateaus and hilly areas). The most important climatic variables that are affected, or influenced, by climate are rainfall, air temperature and solar radiation.

Rainfall. The mean annual rainfall in Malawi ranges between 500 mm in low-lying marginal rainfall areas, such as the Shire Valley and some areas along the Lakeshore Plain, to well over 3,000 mm on High Altitude Plateaus, such as Nyika plateau. The mean annual rainfall distribution pattern for Malawi is depicted in Fig 2.3. The rain shadow areas, such as the Shire Valley, the western parts of the Shire Highlands, Lake Chilwa Plain and the north-western parts of the Viphya and Nyika plateaus, receive the lowest total annual rainfall, whereas high altitude plateaus, such as Mulanje, Thyolo, Nyika, Misuku and Viphya plateaus, and some areas along the Lakeshore Plain, such as the Nkhata Bay lowlands and north Karonga receive the highest total annual rainfall. However, the overall total rainfall received over Malawi shows a high degree of inter- and intra-seasonal variability.

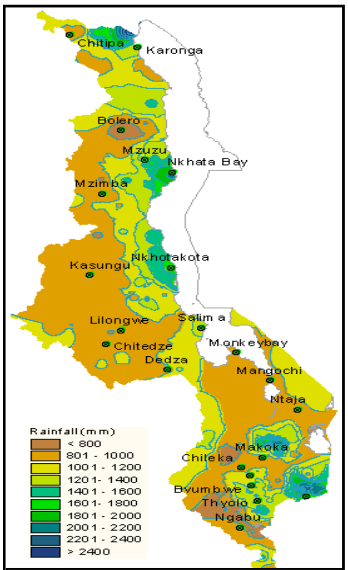


Fig 2.3: Rainfall distribution, Malawi

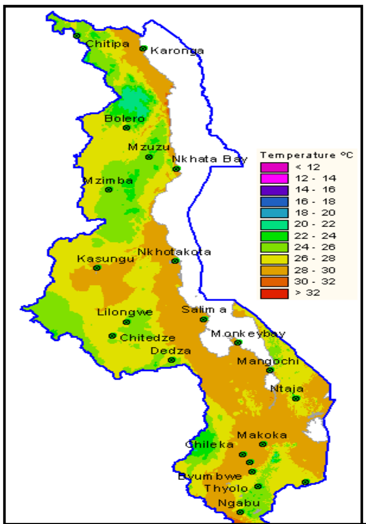


Fig 2.4: Temperature distribution, Malawi

Air temperature: The mean annual minimum and maximum temperatures range from 12 to 32 °C (Fig 2.4). The highest temperatures occur at the end of October or early November, and the lowest in June or July. The highest mean air temperatures are recorded in the Lower Shire Valley (25-26 °C) and some areas along the Lakeshore Plain (23-25 °C). The lowest mean temperatures (13-15 °C) are recorded over the Nyika, Viphya, Dedza, Mulanje and Zomba plateaus, Misuku Hills and the Kirk Range. From May to August, it is relatively cool on most High Altitude Plateaus and hilly areas, such as the Shire Highlands. During the coldest months of June and July, frost may periodically occur on the High Altitude Plateaus, especially along dambos and river valleys. The 1980's have recorded some of the highest surface air temperatures in recent years, and this is closely followed by the 2000s, raising fears in many quarters that climate is really changing at a rate that is faster than at any other time in the past. These changing climatic conditions have normally been associated with the effects of the El Nino

Southern Oscillation (ENSO) system, due to enhanced global warming as a result of (GHG) emissions arising from human activities.

Solar radiation. Solar radiation is one of the most important components of the energy budget of the atmosphere and the earth. The increasing concentration of GHGs in the atmosphere due to man's activity has greatly influenced the solar radiation transfer and balance, as well as the energy budget. However, only a few stations in Malawi routinely record solar radiation, rather they record the number of sunshine hours, which are converted to solar radiation. What is significant is that because of Malawi's proximity to the equator, it receives enough solar radiation that can be harnessed to provide sufficient renewable energy for both domestic and industrial use.

Relative humidity. Relative humidity ranges from 50% to 87% for the drier months of September and October and for the wetter months of January and February, respectively.

2.4.2 Climatic Trends

Rainfall trends. Over the last four decades, Malawi has experienced several climatic variations that have resulted in the occurrence of extreme weather events, ranging from droughts (1991/92) to floods (1996/97) and flush floods (2000/01). When there were floods in the Southern Region during the 1996/97 crop season, some parts of Karonga, along the Lakeshore Plain, experienced drought conditions. These extreme occurrences within the country clearly illustrate that there are large temporal and spatial variations in the occurrence of extreme weather events. In the impacted areas, these droughts and floods caused irreversible and damaging effects on crop and livestock production. Further, there are large decadal rainfall fluctuations, although there is clear decreasing trend for mean seasonal rainfall. This is well illustrated and demonstrated for Karonga for the period 1900-2005 (Fig 2.5).

Similarly, there are large temporal and spatial rainfall variations during the rainy season, which generally runs from October to May in most parts of the country. For example, Fig 2.6 shows 10-day rainfall variations from November to April in 1982/83 and 1994/95 for Salima Boma, which is located on the Lakeshore Plain. High rainfall intensity and large rainfall variations have a direct effect on the occurrences of extreme weather events, such as flush floods. However, although some records exist on extreme weather events at local level in some districts, there is generally lack of information at national level. For example, current national 10-day period rainfall data are so scanty that they have not been used in this study for the Salima and Karonga recording sites.

Temperature trends. There is overwhelming evidence that global and near ground air temperatures are changing and/or fluctuating with time. In Malawi, the evidence for increasing and decreasing maximum air temperature trends is illustrated for Bvumbwe Agricultural Research Station on the Shire Highlands over the last five decades (Fig 2.7). For example, from 1956 to 1982, air temperatures were below the mean, whereas from 1988 to 2000 they were above the mean. On the other hand, from 2000 to 2006, there was a decreasing trend in recorded air temperatures. However, on average, surface air temperatures exhibited an increasing trend at all the sites in the country, as the case was for Bvumbwe (Fig 2.7).

Hence, it can be concluded that over the last four decades, rainfall and air temperatures have exhibited an increasing trend, and that the extreme weather events, especially floods and droughts, have also been increasing in intensity, frequency and magnitude. As a result of these, from 1970 to 2008, Malawi has experienced more than 40 weather-related disasters, with 16 of these occurring between 1990 and 2008. These extreme weather events adversely impact on food security, water security, energy supply, infrastructure, human health and the sustainable livelihoods of family households.

For example, in 1989, more than 400 people died in the Lower Shire Valley, whereas in 1991, over 1,000 people died in Phalombe due to flush floods. These are all signs that climate is changing, and strategies must be put in place to address its adverse impacts. Malawi's Second National Communication (SNC) document is therefore timely in this regard.

2.4.3 Lake Water Level Fluctuations

There is strong geological evidence that supports the view that water levels on Lake Malawi have been fluctuating for time immemorial. For example, Fig 2.8 shows a hydrograph of naturalized and observed Lake Malawi water level fluctuations from 1947 to 2001.

There is further evidence that shows that these lake water levels fluctuated even more considerably during the late Pleistocene period. The recession-refilling cycles between 1500 and 1850, based on sediment core studies, show an erosional hiatus stretching across the southern end of Lake Malawi and going to water depths of up to 121 m.

Oral history by the indigenous peoples living on the Lakeshore Plain also clearly reflect a consistent group memory about the events that happened during this period. This remembered history has recently been supported by carbon 14 (^{14}C) dating of archaeological findings from beach ridge sites surrounding the lakeshore plain areas. These results are also supported by some findings from recent hydrological modelling studies.

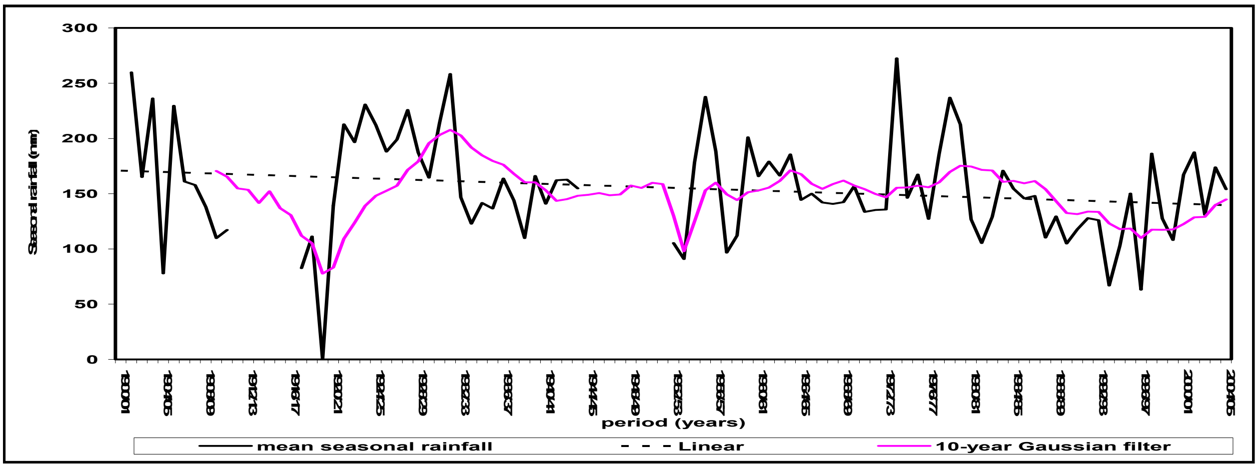


Fig 1.5: Decadal rainfall variability and decreasing trends in mean seasonal rainfall, Karonga Boma, 1900-2005 Source: EAD, 2007.

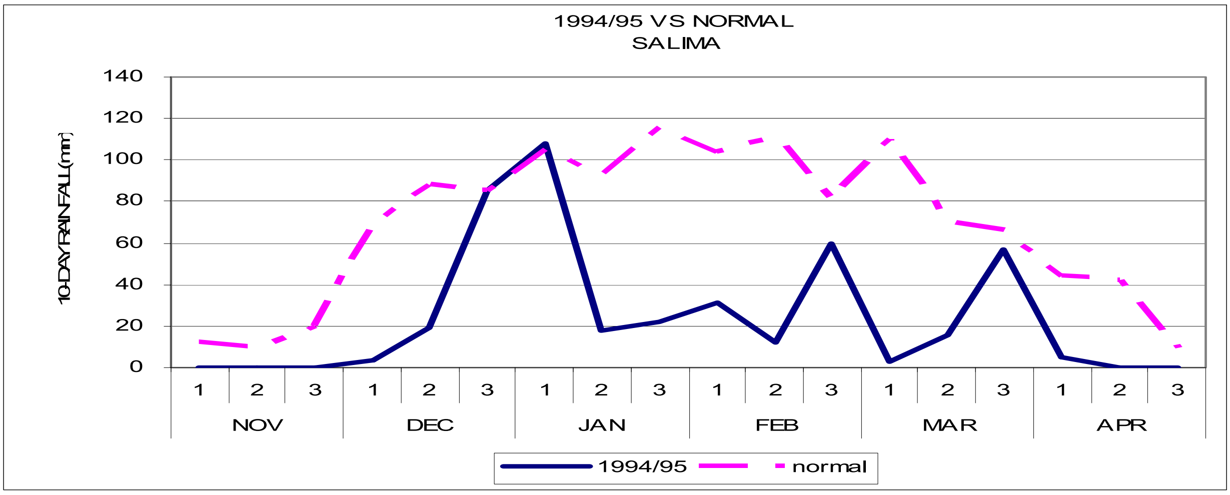


Fig 2.6: Rainfall variation during 10-day period from November to April in 1982/83 and 1994/95
Source: EAD, 2007.

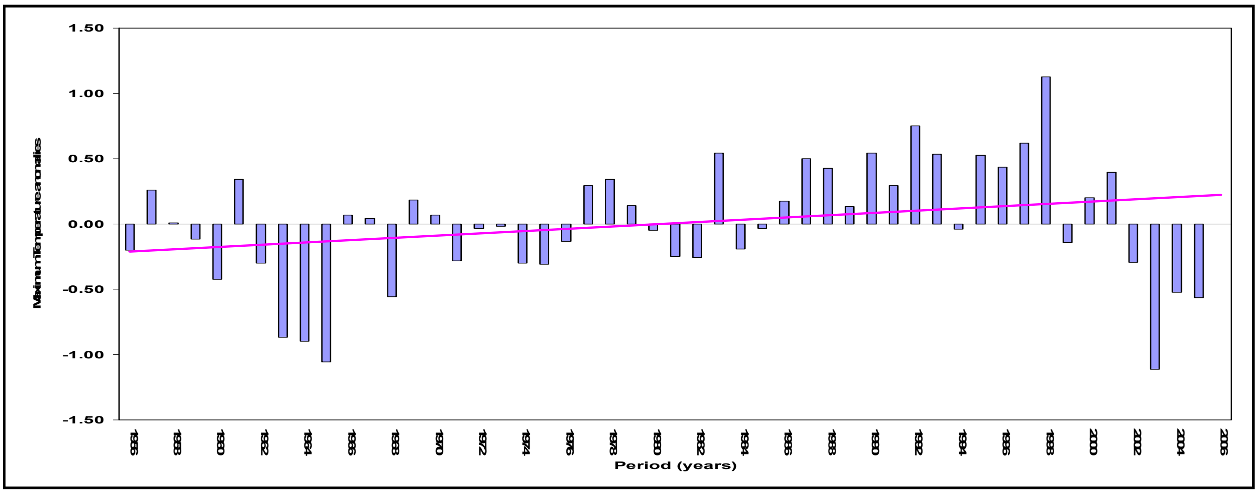


Fig 2.7: Temperature fluctuations at Bvumbwe, Thyolo district, 1956-2006
Source: EAD, 2007.

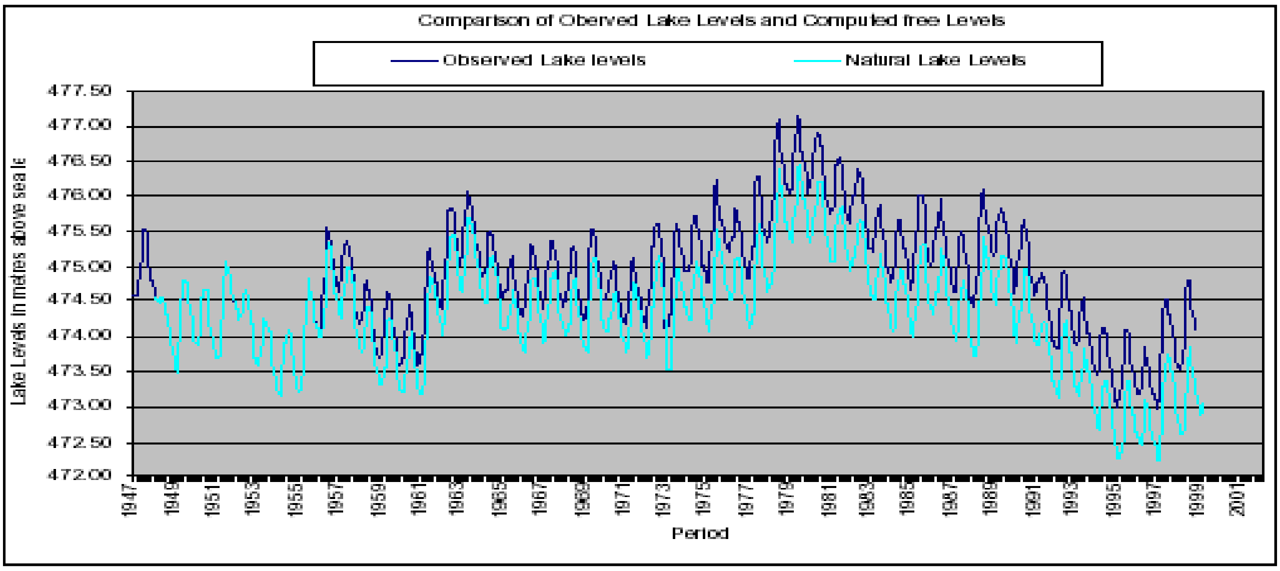
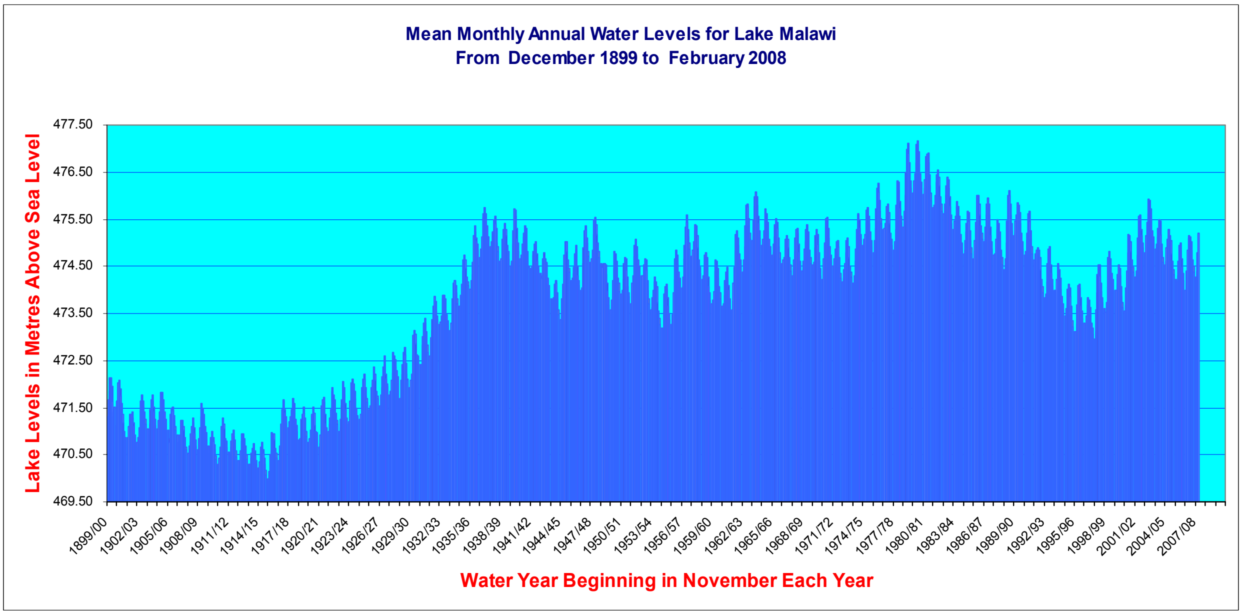


Fig 2.8: Hydrographs of naturalized and observed Lake Malawi water levels
Source: Msiska, 2001; Osborne, 2000l Shela, 2998..

Thus, Lake Malawi water levels can be regarded as a barometer for the sensitivity of water resources occurrence and distribution in the country, which also reflects the balance between water inflows from its tributaries, rainfall and outflow into the Shire River. For example, Fig 2.9 shows a hydrograph of Lake Malawi water levels between 1899 and 2008. This exhibits three distinct water level fluctuation periods. First, from 1900 to 1915, there was an oscillating and declining trend that can be attributed to declining rainfall regimes during this tome period. Second, from 1915 to 1935, the lake levels exhibited a linear ascending



trend that can be attributed to the blockage of the Shire River channels that enabled the lake to fill-up. These blockages were removed in 1935 after the high water levels had re-established the outflows of the Shire River. The average lake water level for the period 1915/16 to the present is 474.20 m asl.

Fig. 2.9: Lake Malawi water level hydrograph, 1899-2008
Source: Shela, 2008.

Third, from 1935 to the present, the outflow through the Shire River has been continuous, with a lake water level hydrograph that was almost uniform. The average lake water level during this period was 474.81 m asl. However, during this period, there were years of low (drought) and high rainfall (floods), which resulted in low and high lake water levels, respectively. Since 1931, the lowest lake water levels of 472.9 m asl were recorded in November 1997 as a result of two severe droughts in the 1991/92 and 1994/95 rainy seasons. The highest recorded water levels were reported for the period 1979 to 1983, when the lake rose to a record 477.21 m asl in May 1980. These high lake levels caused a lot of damage along the lakeshore plain areas where floods damaged property and infrastructure, including hotels, chalets, buildings, settlements, roads, harbours and ports.

These water level fluctuations equally affected the Shire River, the outlet of Lake Malawi to the Indian Ocean through the Zambezi River. The water level fluctuations for the Shire River (Fig 10) are measured at Liwonde, which is taken as the outflow for Lake Malawi (Kidd 1983). The outflows, however, have been controlled on several occasions. From 1956 and 1957, the Shire River was blocked by a bund at Liwonde to allow for geotechnical investigations for the foundation of the present Kamuzu Barrage. The river was also blocked from 1965 to 1966 to allow for the construction of the Kamuzu Barrage. The Barrage was commissioned in the same year and had been used to regulate water flows in the late sixties, mid-seventies and early 1980s to facilitate installation of hydro-power plants on the Middle Shire River Valley. The Kamuzu Barrage has been effectively and efficiently regulated since 1992 to maintain a constant water flow rate for the generation of hydro-electricity on the Shire River. The prolonged regulation is to ensure adequate flows for hydro-power generation, in response to dwindling Lake Malawi water levels, resulting from low rainfall totals and declining groundwater resources. Further, the changing water levels have significant impact on the type and number of fish catches. Lake Malawi has an estimated total catchment area of 125,000 km² that includes a large network of rives, such as the Songwe, North Rukuru, South Rukuru, Dwangwa, Linthipe and Bua on the Malawi side. These rivers are also a source of substantial quantities of fish, including the *Cichlid* spp, (e.g., Mbuna) that have diverged from the original parent population over time in response to climatic conditions and fluctuating water levels.

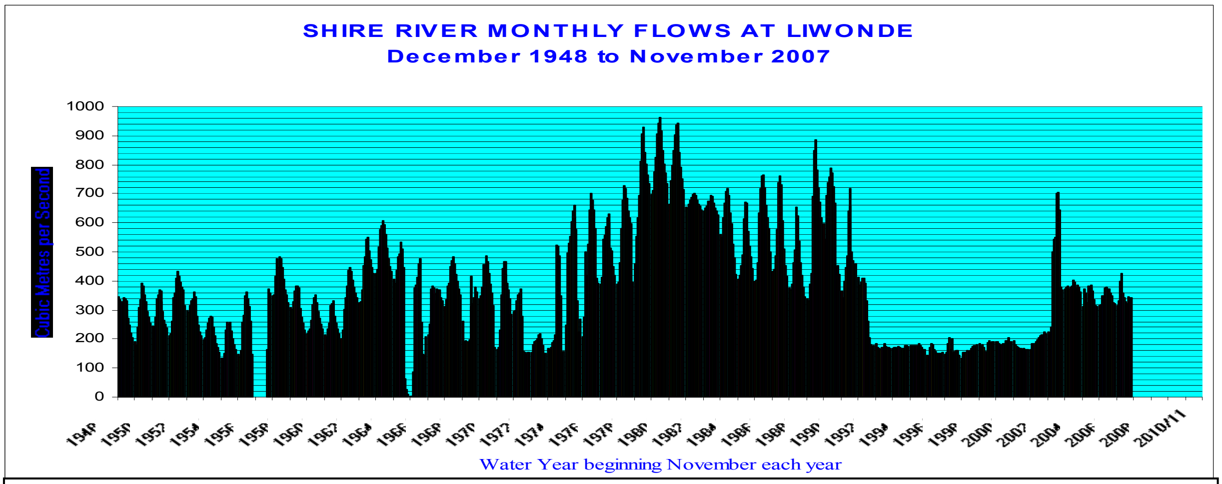


Fig 2.10: Shire River monthly flows at Liwonde, 1948-2007;
Source: Shela, 2008

Thus, the impacts of droughts and floods have significant effect on the changing water levels on Lake Malawi, including the Shire River. The water balance studies have clearly demonstrated that lake water levels are very sensitive to the hydrology of Lake Malawi and the Shire River. It is the changes in lake water levels from inflows (rainfall) and outflows (evaporation and drainage) and ground water losses or gains as influenced by rainfall) that determines the state of lake water levels at any one point in time.

2.4.4 Extreme Weather Events

Occurrence. The main extreme weather events, or climate-related disasters, include: (i) intense rainfall, (ii) floods, (iii) seasonal droughts, (iv) multi-year droughts, (v) dry spells, (vii) cold spells, (viii) strong winds, (ix) thunderstorms, (x) lightening,, (xi) disease and inset pest infestations, (xii) heat waves, (xiii) landslides, (xiv) hailstorms, (xvi) mudslides, (xv) volcanoes, (xvi) earthquakes, (xvii) cyclones, (xviii) avalanches, and (xix) epidemics. However, for Malawi, the most common and pertinent ones for which records are available since December 1946, include: (i) intense rainfall, (ii) floods, (iii) strong winds, (iv) droughts, (v) cyclones, (vi) landslides, and (vii) hailstorms (Table 2.5).

Table 2.5: Extreme weather events recorded in Malawi, 1946-2008

Year	Location	Highest registered rainfall	Severest registered drought	Remarks
December 1946	Zomba Mountain	Storm, 711 mm in 36 h, 254 mm in 1 hr		Rainfall extreme
1948/49	National		Drought	Worst drought
February 1957	Nkhota Kota	Storm 572 mm 24 h..		Rainfall extreme
May 6-7, 1957	Banga (Nkhata Bay)	Unusual storm, 508 mm in 36 hours		Rainfall extreme
!991/01	National		Drought, national disaster	Worst drought
2001/02	National		Drought	Worst drought
February 15, 1961	Zomba Plateau	349		High short duration
December 6, 1980	Dwangwa (Nkhota Kota)	323		"
October 26, 1950	Lujeri (Mulanje)	315		"
February 17, 1950	Namwera (Mangochi)	308		"
October 10, 1961	Blantyre	304		"

Source: Department of Relief, Disaster and Preparedness, 2008

The most unusual rainfall events recorded since 1946 include: (i) a storm of 711 mm within 36 hr (with 254 mm falling in 1 hr) on Zomba Mountain on December 9, 1946 (ii) a storm of 572 mm in 24 hr at Nkhota Kota in February 1957, and (iii) a storm of 508 mm in 36 hr at Banga in Nkhata Bay in May 1957. Other short duration rainfall events, which also cause great havoc, especially the flooding of rivers and streams, have been recorded at various sites throughout the country (Tables 2.5 and 2.6).

Table 2. 6: Occurrence of short duration rainfall events recorded at different sites in Malawi

Station	Short-duration rainfall		Relief unit
	over 6 hr period	over 24 hr period	
Chitipa	111.3	115.8	Medium Altitude Plateau, Chitipa Plain
Karonga	149.4	188.5	Lakeshore Plain, Karonga Lakeshore Plain
Mzuzu	143.8	146.0	High Altitude Plateau, Viphya Plateau
Mzimba	82.2	102.0	Medium Altitude Plateau, Mzimba Plain
Nkhata Bay	168.7	173.0	Lakeshore Plain, Nkhata Bay Lakeshore Plain
Nkhota Kota*	216.0	228.0	Lakeshore Plain, Nkhota Kota Lakeshore Plain
Khola	75.5	75.5	Medium Altitude Plateau, Lilongwe Plain
Lilongwe	97.5	119.1	Medium Altitude Plateau, Lilongwe Plain
Chitedze	127.0	152.7	Medium Altitude Plateau, Lilongwe Plain
Salima	175.4	292.0	Lakeshore plain, Salima Lakeshore Plain
Dedza	81.3	100.3	High Altitude Plateau, Dedza Plateau
Monkey Bay	177.5	230.9	Lakeshore Plain, Mangochi Lakeshore Plain
Mangochi	120.9	161.5	Lakeshore Plain, Mangochi Lakeshore Plain
Zomba	208.0	234.9	High Altitude Plateau, Zomba Plateau
Makoka (Zomba)	101.9	140.9	High Altitude Plateau, Shire Highlands

Chileka (Blantyre)	102.0	108.0	High Altitude Plateau, Shire Highlands
Chichiri (Blantyre)	103.0	213.0	High Altitude Plateau, Shire Highlands
Bvumbwe (Thyolo)	110.7	192.0	High Altitude Plateau, Shire Highlands
Thyolo	79.6	123.7	High Altitude Plateau, Shire Highlands
Mimosa (Mulanje)	168.0	209.3	High Altitude Plateau, Mulanje Plateau
Ngabu (Chikwawa)	90.9	144.1	Shire Valley, Lower Shire Valley
Makhanga (Nsanje)	117.3	137.2	Shire Valley, Lower Shire Valley

* Excluding the 1957 storm; ** Excluding the 1946 storm
Source: DoMS, 2007

Frequency, spatial and temporal distribution. The Department of Disaster Preparedness, Relief and Rehabilitation (DDPRR) has so far recorded more than 251 disasters since the Phalombe flush floods in 1991. Most of the recorded disasters include: accidents, insect pests and diseases, health-related disasters, war-related disasters, and climate-related calamities. Seventy-four per cent (74%) of these, which numbered 186, are climate-related, making climate change a major cause of disasters in the country (Table 2.7).

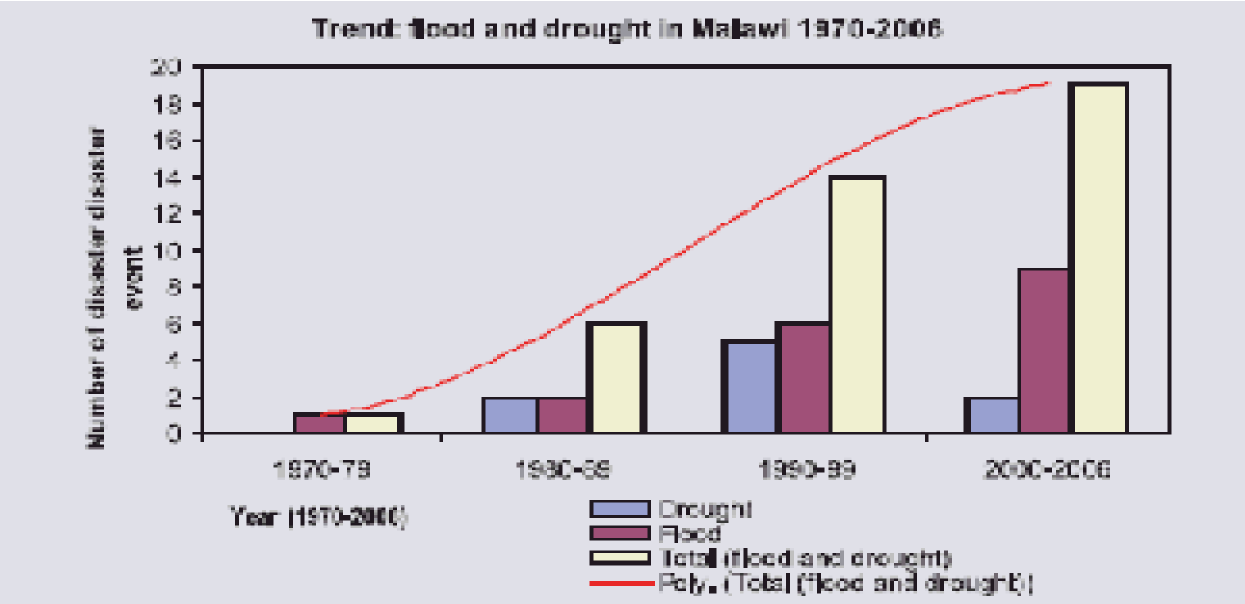
Table 2.7: Distribution of climate related disasters in Malawi, 1946-2008

Type of hazard	Period of occurrence (years)							
	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-08	Total
Cyclone	1	4	-	-	-	1	1	7
Drought	1	-	-	-	1	2	1	5
Floods	-	-	-	5	29	44	61	139
Hailstorm		-	-	-	1	11	-	12
Landslide	1	-	-	-	1	2	-	4
Avalanches	1	-	-	-	1	-	-	2
Strong winds	-	-	-	1	2	8	6	17
Total	4	4	0	6	35	68	69	186

Note: avalanches are locally known as Napolo
Source: DoMS, 2007; Department of Relief, Disaster and Preparedness, 2008

The frequency and distribution of climate-related disasters over time reveals very important trends and patterns. There were no recorded climate-related disasters from 1950-1969. This is perhaps an indication that there were no major disasters worth recording during that decade, or is it that these were decades of upheavals: (i) Malawi was incorporated into the Federation of Rhodesia and Nyasaland from 1953-1963, (ii) there was political unrest that led to the State of Emergency in 1959, (iii) political independence in 1964, which was swiftly and quickly followed by a cabinet crisis, (iv) Malawi attained her republican status in 1966, and finally, (v) Malawi passed through the formative years of a one-party state dictatorship that was finally endorsed in 1970. Whatever might have happened during this period, what is clear is that there is a glaring and serious gap of information that needs to be filled. Floods are the most dominant climate-related disaster (>74%), and show an increasing trend since the 1970s (Fig 2.11).

Considering that this is the first decade in the new Millennium, the chances are very high that these increases will double or even triple by the end of the decade. Closely



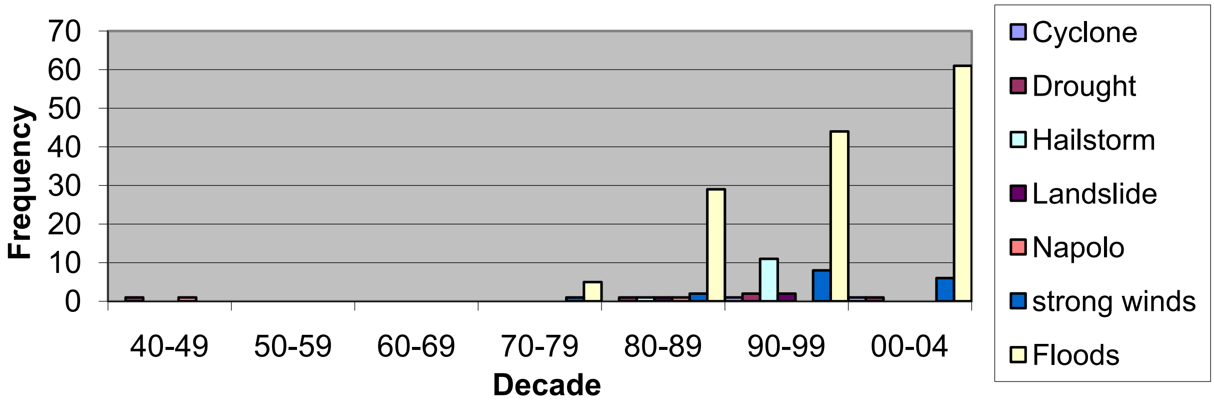
associated with the increasing trend of floods is the incidence of strong winds (Fig 2.12). This association is related

to these two disasters (i.e. floods and strong winds) being linked to the rain bearing systems. Although the frequency is much lower, there has been an increasing trend since 1970.

Cyclones, landslides and water avalanches (or Napolos) are relatively rare events, with frequencies of seven, four and two, respectively, over a period of sixty years (1940s-2000s). However, these can be very devastating as illustrated by the Zomba Mountain storm in 1946 and the devastating Phalombe flush floods in 1991. Long and prolonged droughts are generally rare events, occurring only five times (twice covering the whole country and three times in Karonga, Chikwawa and Nsanje districtd) over the last sixty years. However, once these strike, they have by far devastating and long-lasting impacts on food and water security, and sustainable livelihoods of family households than the other disasters. In addition, it is drought that has the most devastating effects on the Agriculture Sector, greatly reducing crop yields, and adversely impacting on all other sectors of economic growth. Hailstorms appear to be on the increase since they emerged during the 1980s. Although these climate disasters have not occurred during this decade, there is a high probability that these may occur before the end of the decade. The increasing frequency of climate-related disasters, floods, hailstorms and strong winds represent 93 % of all the climate related disasters (Fig 2.12), which clearly indicates that Malawi is highly vulnerable to climate change.

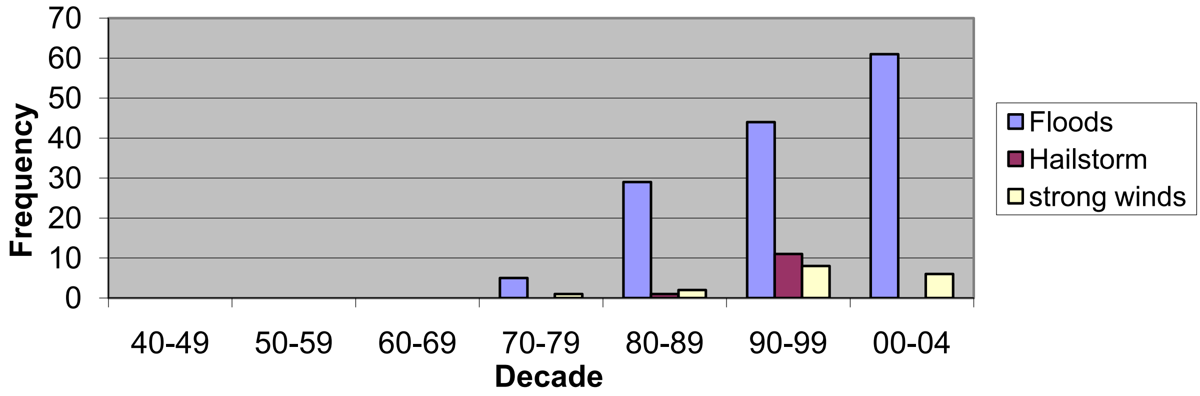
Fig 2.11: Drought and flood trends in Malawi, 1970-2006
Source: ActionAid, 2006.

Fig 2.12: Frequency of climate-related disasters recorded since 1946



Data source: Department of Disaster Preparedness, Relief and Rehabilitation, 2008

Fig 2.13: Frequency distribution of floods, hailstorms and strong winds, 1946-2008



Data source: Department of Disaster Preparedness, Relief and Rehabilitation, 2008

Fig 2.14: Flooded market in Lilongwe

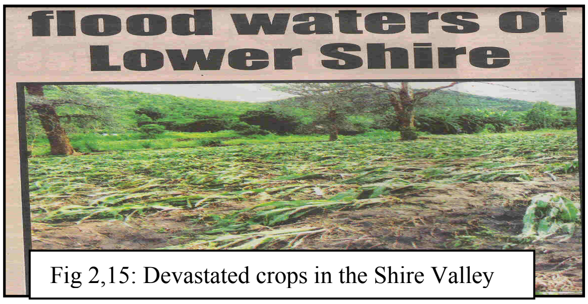


Fig 2,15: Devastated crops in the Shire Valley

Impacts and effects. The most devastating climate-related disasters that negatively impact on the various sectors of economic growth are floods and droughts. In the recent past, the most devastating floods were recorded during the 1996/97 and 2001/02 crop seasons, especially in the Shire Valley and in some parts of Karonga along the Lakeshore Plain. The most devastating and notable droughts at national level occurred during the 1948/49, 1991/92 and 2000/01 crop seasons. However, other localized and short-duration droughts have occurred as follows: 1986/87, 1993/94, 1996/97, 1997/98, 2001/02, 2004/05, 2005/06 and 2007/08. These too have had adverse impacts on crop yields, especially where they occurred during the reproductive growth stages of the crop. The two pictures shown above from the Nation Newspapers of January 2008 clearly illustrate the damaging effects of floods on a market in Lilongwe district (Fig 2.14), whereas a devastated maize field in the Lower Shire Valley in Chikwawa district is depicted in (Fig 2.15).

The droughts of the 1990s and 2000s resulted in severe food shortages, hunger and malnutrition among the majority of rural communities, the urban-poor, female-headed households, the elderly, the orphans and other vulnerable groups. For example, the drought of the 2001/02 crop season resulted in low maize yields (1.7 m tonnes) in the Southern Region, which was far below the previous year's production of 2.1 m tonnes. With an overall consumption requirement of 2 m tonnes, this left a deficit of 300,000 tonnes that was largely covered by commercial food imports and food aid. The severe droughts of the 1991/92, 1993/94, 1994/1995 and 2000.01 crop seasons also significantly contributed to the lowering of Lake Malawi water levels. Thus, over the last four decades, an increasing number and frequency of floods and droughts have increased the number of people who are affected by these calamities (Fig 2.16). Floods also disrupt electricity generation, destroy roads, buildings, crop fields and buildings, and adversely impact on all sectors of economic growth, fragile agro-ecosystems and vulnerable communities.

The most vulnerable areas to climate change are the marginal rainfall lakeshore areas, especially in Salima, Nkhota Kota and Karonga districts, and the Shire Valley, Nsanje and Chikwawa districts, whereas High Altitude Plateaus are less affected by climate change (Munthali et al., 2004; 2007).

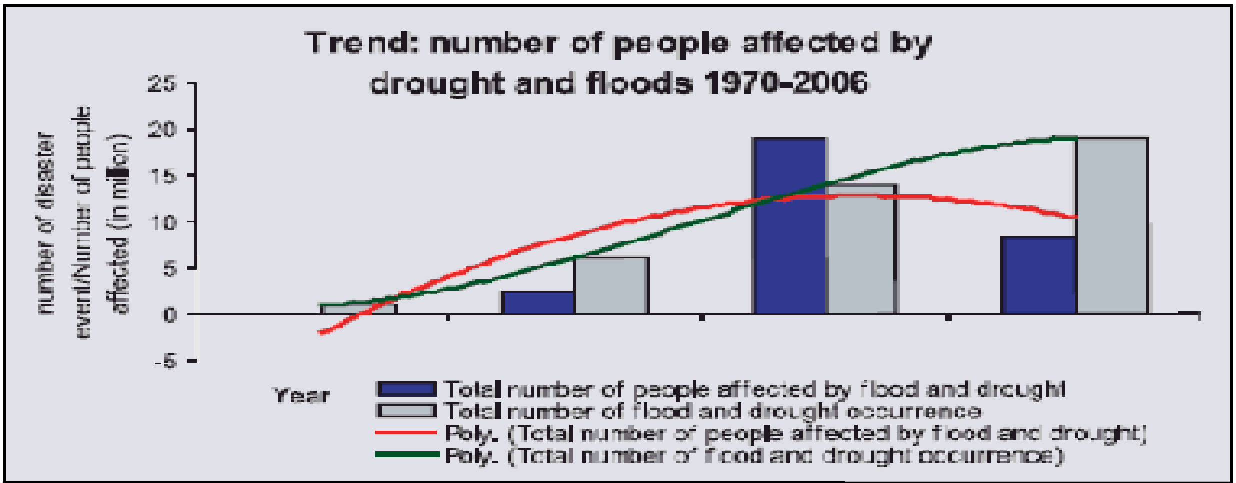


Fig 2.16: Number of people affected by floods and droughts, 1970-2006

2.4.5 Seasonal Weather Forecasting and Early Warning

Seasonal weather forecasting and early warning systems are not fully developed in Malawi. However, the Department of Meteorological Services (DoMS) is responsible for monitoring seasonal forecasts and early warning systems in collaboration with relevant Government departments and/or ministries, such as the Early Warning System (FEWS) in the Ministry of Agriculture and Food Security (MoAFS).

The available climate systems include: (i) seasonal forecasting systems with special emphasis on drought monitoring in collaboration with the Southern African Development Community (SADC) Drought Monitoring Centre based in Harare, Zimbabwe; (ii) early warning system for food security in collaboration with MoAFS, (iii) flood forecasting and warning system for the Lower Shire Valley in collaboration with the Department of Water

Resources (DoWS), (iv) tropical cyclone monitoring and early warning system in collaboration with the Commission for Disaster Preparedness, Relief and Rehabilitation (CDPRR) in the Office of the President and Cabinet (OPC). Unfortunately, out of these four systems, it is only the tropical cyclone and drought monitoring system that is still functional and operational. The other systems are not functioning at all, so that there is need to put these back into operation.

2.5 Natural Resources

Malawi is endowed with abundant and diverse natural resources, which is a basis for sustainable economic growth and development. The natural resources include: abundant water resources, a large variety of wildlife and forest resources (fauna and flora), uniquely rich fish resources, and fertile soils for crop, livestock and tree production. For example, there is abundant water in Malawi's lakes and rivers. What follows is a brief overview of the following natural resources: (i) land, (ii) soils, (iii) minerals, (iv) pastures, (v) water, (vi) forests, (vii) fisheries, (viii) wildlife, (ix) energy, (x) wetlands, (xi) mountain ecosystems, and (xii) tourism. This also includes a brief overview of policy and legal frameworks for environmental management and climate change, because this has already been presented in Chapter 1.

2.5.1 Land Resources

Malawi's total land area of 9.4 m ha is presently supporting a human population of 13.1 m people that is growing at the rate of 2.8% with a population density of 139 persons km^{-2} (NSO, 2008). Out of the 9.4 m ha, (i) 3.70 m ha is forests and woodlands, (ii) 1.85 m ha is permanent pastures, (iii) 3.85 m ha is total agricultural land (0.13 m ha is permanent crops and 1.88 m ha is arable land, and (iv) 7.41 m ha is non-arable land (GoM, 2000a; NSO, 2008)

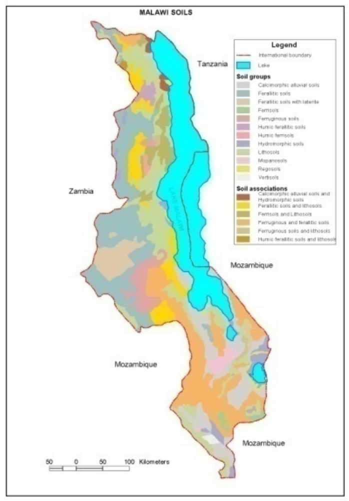


Fig 2.17: Soils of Malawi

Thus, only 31% of the country's total land area is suitable for rain-fed agriculture at traditional level of management, which is highly influenced by topography, slope, rainfall, temperature, soil type and soil depth, a clear indication of the limited nature of the land resource base that is heavily utilized and prone to environmental degradation, hence also highly vulnerability to climate change.

About 56% of the family households own and cultivate small land holdings of less than 1.0 ha, most of which is under the customary land tenure system. However, Malawi's land resource base is under threat from increasing human and livestock population pressures, and the expending agricultural production to marginal areas. These pose the challenges of land and environmental degradation.

The other factors that contribute to land degradation include: (i) insecure and unforeseeable property rights leading to open access exploitation for agricultural production, (ii) limited information on the costs of land degradation and the benefits of conservation, (iii) lack of access to credit for soil conservation and management practices, and (iv) poor agricultural production practices. However, the new Malawi Land Policy (MG, 2007) is addressing some of these constraints.

2.5.2 Soil Resources

Malawi is endowed with fertile soils in their natural state that are ideal for agriculture, recreation, forestry and wildlife production (Young and Brown, 1962; Young 1972; EAD, 2002; MoAFS, 2006; MG, 2007), as illustrated in Tables A2.1 and A2.2 in the Appendix. Five main soil types, using the Inter-African Pedological Classification System (Young and Brown, 1962), can be distinguished and classified as follows: (i) Latosols (subdivided into Ferruginous, Ferrisols and Ferallitic), (ii) Calcimorphic Alluvial Soils, (iii) Hydromorphic Soils, (iv) Lithosols, and (v) Vertisols (see the Appendix, Tables A2.1 and A2.2).

These soils have been correlated with the FAO Classification System (FAO) as depicted in Table A2.2 in the Appendix, which also provides information on occurrence, mineralogy, chemical characteristics and fertility status of the different soil types. However, the soils of Malawi have also been classified using the FAO Soil legend but based on the Soils Map of Malawi using the Inter-African Pedological Classification System to arrive at twenty-five soil classes as shown in Table 2.8 (Lowole, 1995; M.W. Lowole (2008), personal communication). The most predominant soil classes include Lithosols (25%), Xanthic Ferralsols (15%), Eutric Fluvisols, Cambisols (9%) and Ferric Luvisols (7%).

Table 2.8 Soils of Malawi and their estimated areas of coverage based on the Soils Map of Malawi

Soil name (FAO Classification)	Land area (km^2)	% Total land area
1. Ferric Luvisols	6636	7.0
2. Lithosols	23,139	24.5
3. Ferric Luvisols with some Lithoslos	6,552	6.9
4. Lithosols with some Luvisols	1,207	1.3
5. Orthic Ferralsols	3,175	3.4
6. Orthic Ferralsols with Chromic Luvisols	4,990	5.3
7. Xanthic Ferralsols	14,849	15.5
8. Orthic Ferralsols and Xanthic Ferralsols	3,868	4.1
9. Xanthic Ferralsols over massive Laterite	3,730	4.0
10. Xanthic Ferralsols and Lithosols	4,214	4.5
11. Humic Ferralsols	2,223	1.3
12. Humic Ferralsols with Lithosols	861	0.9
13. Dystric Nirosols	615	0.7
14. Dystric Nirosols with some Lithosols	700	0.7
15. Dystric Nitrosols and Lithosols	1,400	1.5
16. Pellic Vertisols	1,946	2.
17. Chromic Vertisols	144	0.1
18. Calcic Phaeozems	201	0.2
19. Orthic Solonetz	1,223	1.3
20. Eutric Regosols	308	0.3
21. Eutric Fluvisols and Eutric Cambisols	6,797	9.3
22. Eutric Gleysols	3,876	4.1
23. Eutric Fluvisols and Eutric Gleysols	600	0.6
Total	94,253	99.8

Source: Lowole, 1995.

Despite the fact that the soils of Malawi are fertile in their natural state, these have over the years been severely degraded owing to continuous cultivation with little or no added external inputs, poor crop husbandry practices and poor soil and water management practices. All these have combined to impoverish the soils making them infertile for agricultural production. Low and/or declining soil fertility, especially under smallholder farm conditions, is one of the greatest challenges facing agriculturists and policymakers that needs to be addressed with the utmost urgency that it deserves to ensure that agriculture continues to steer the Malawi economy to greater heights.

2.5.3 Mineral Resources

Malawi has a wide variety of mineral resources of high economic value (Table 2.9; Fig 2.18). These include gold, platinum, diamonds, coal, bauxite, uranium, rare earths (monazite and strontianite that usually occur in association with pyrochlore, apatite and zircon), and industrial minerals (limestone, marble, vermiculite, kaolinitic clays, corundum, kyanite, glass sands, graphite, phosphorus and heavy mineral sands), which all have potential for exploitation. However, most of these, including platinum and diamonds, are presently not exploited, whereas others, such as gold, are grossly under-exploited.

Nonetheless, several private sector companies have been issued with mining licenses to commence exploitation of these minerals, such as heavy mineral sands, coal and limestones. However, what is of significance is the commencement of uranium mining at the Kayelekera Uranium Mine in Karonga district by Paladin Africa of Australia. Additionally, artisanal and small-scale miners are also engaged in the prospecting and mining of gemstones, rock aggregate crushing, lime burning and salt mining.

Table 2.9 Mineral resources of Malawi with potential for exploitation

Deposit	Location	**Delineated reserves (million tonnes/grade)**
Bauxite	Mulanje	28.8/43.9 % Al_2O_3
Uranium	Kayelekera Karonga/Chitipa	2.4/0.15% Ur_30_8
Monazite/Strontianite	Kangankhunde-Balaka	11.0/8% Sr, and 2% REO
Corundum	Chimwadzulu-Ntcheu	8.0/75.6 g m^{-3}
Graphite	Katengeza-Dowa	2.7/5.8% C
Limestone	Malowa Hill-Bwanje	15/48% CaO, 1.2% MgO
	Chenkumbi-Balaka	10/46.1% CaO, 3.5% MgO
Titanium Heavy Mineral Sands	Nkhota Kota-Salima-Chipoka	700/5.6% HMS
	Mangochi	680/6.0% HMS
	Halala (Lake Chilwa)	15/6.0% HMS
Vermiculite	Feremu-Mwanza	2.5/4.9% (mid+fine)
Coal	Mwabvi-Nsanje	4.7/30% ash
	Ngana –Karonga	15/21.2% ash
Phosphate	Tundulu –Phalombe	2.017/% P_2O_5
Pyrite	Chisepo-Dowa	34/8% S
	Malingunde-Lilongwe	10/12% S
Glass Sands	Mchinji Dambos	1.6/97% SiO_2
Dimension Stone	Chitipa, Mzimba, Mangochi, Mchinji	Black, blue,pink, green granite
Gemstones	Mzimba, Nsanje, Chitipa, Chikwawa, Rumphi, Ntcheu	Numerous pegmatites and volcanics

Source: DoM, 2007: Chipeta, Kanyerere and Kalanda-Sabola, 2008

However, the commencement of large scale mining of uranium is creating new challenges for environmental management, because these activities will directly impact on climate change. For example, the clearing of vegetation cover for mining will induce deforestation and reduce the available sinks for carbon. The dust emanating from mining activities may increase the amount of aerosols in the atmosphere which may enhance the trapping of greenhouse gases (GHGs). The fumes and smoke emitted from the mine will release GHGs into the atmosphere, hence contribute to global warming. Other mining activities include cement manufacturing at the Shayona Cement Factory in Kasungu district, and small limestone processing plants in some parts of central Malawi, especially in Balaka district by LeFarge Cement Company.

Fig 2.18: Minerals of Malawi

Prospects for opening the bauxite mine on Mulanje Mountain are quite high, and so are the prospects of opening another uranium mine in Rumphi district near Chombe along the lakeshore plain (J. Chimphamba, (2008), personal communication) .All these will add to GHG emissions, so that measures need to be put in place for reducing the emissions of GHGs from these activities. However, these concerns are taken care of through the implementation of Environmental Impact Assessments (EIAs) studies before the commencement of any mining activity, as the case has recently been done for the Kayelekera Uranium Mine. The need to develop a viable mining industry for Malawi is clear. So far, the economy is heavily dependent on ran-fed agriculture, which is vulnerable to climate change. Hence, the development of a mining industry is one way of diversifying the economy away from ran-fed-agriculture, thereby also diversifying the foreign exchange base for the country.

2.5.4 Pasture Resources

The available pasture resources in Malawi vary considerably from one agro-ecological zone to another. At altitudes of between 1,500 and 2,100 m asl, the common pastures are the short-tufted to densely tangled grasses of low ground cover. The common species include: *Themeda triandra, Exotheca abyssinica, Monocymbium ceresiiforme*, *Elionurus argenteus, Brachiaria serrata, Andropogon schirensis, Hyparrhenia lecomtei* and *Loudetiasimplex,* whereas at altitudes of over 2,000 m asl, the commonest grass species are the *Exotheca* species, which produce a dense ground cover. *M. ceresiiforme* is commonly found on shallow soils on the High Altitude Plateaus that are characterized by montane grassland. At altitudes of between 600 and 1,500 m asl, which is dominated by *Brachystegia* species (miombo woodland), and the common grass species include *Hyparrhenia filipendula*, *Themeda triandra*, *Andropogon schirensis*, *Bewsia biflora* and *Andropogon amplectens*. On the other hand, tall grasses are associated with low altitude woodlands. The dominant grass species include *Hyparrhenia gazensis, Hyparrhenia variabilis,*and *Hyparrhenia dichroa,* whereas in densely settled and extensively cultivated areas the tall reed-like grasses are replaced by *Urochloa pullulans* and *Urochloa mosambicensis*.

Generally, the grasses have low grazing value with marked seasonal variations in ground cover and carrying capacity. However, the grasses respond to burning and produce fresh re-growth after the dry season bush fires that are highly suitable for grazing. However, it should be noted that savannah grass pastures have low carbon carrying and sequestering capacities. Further, the pasture resources are under threat from over-exploitation through overgrazing by domesticated animals (cattle, goats and sheep), wild animals (especially elephants), and from an expending Agricultural Sector.

2.5.5 Water Resources

The Water Resources Sector is one of the most important sectors for the socio-economic growth and development. "Water is life", as the popular saying goes. In addition, Malawi's water resources support navigation, the fishing industry, tourism, wildlife, and above all rain-fed agriculture, which is the engine of economic growth. Presently, domestic water demand is estimated at 125 litres per day per capita or 157,500 m^3 per day or about 57.6 m m^{-3} per year. Urban areas are estimated to use some 200-360 litres per day per capita, whereas rural areas are estimated to use 27 litres per day per capita. However, the available water supply and improved sanitation services are only accessible to an estimated 73% and 61% of the population, respectively.

The water resources of Malawi are stocked in the country's rich water systems comprising a network of rivers, streams, lakes and groundwater reservoirs. The most dominant water body is Lake Malawi, the third largest lake in Africa, which has a mean water level of 474.2 m asl, and an annual mean live storage capacity of 101 km^3 of water. It has an estimated catchment area of 97,740 km^2 (66% of which is in Malawi, 27% is in Tanzania and 7% is in Mozambique). The lake itself occupies an area of some 28,760 km^2, and is 590 km long varying from 30 to 80 km in width. The other lakes include: Chilwa, Chiuta, Malombe and Kazuni. The mean annual rainfall over Lake Malawi is estimated at 1,549 mm per year, with a total surface inflow of approximately 920 m^3/s, of which, 400 $m^3 s^{-1}$ is from Malawi, 486 m^3s^{-1} from Tanzania and 41 m^3s^{-1} from Mozambique. The most important rivers include the Songwe, North Rukuru, South Rukuru, Dwangwa, Lilongwe, Linthipe, Bua, Shire, Ruo, Phalombe and Mwanza. The Shire River is the second dominant water body with an average flow rate of some 400 m^3/s as it leaves Lake Malawi. It passes an annual average of some 18 km^3 of water out of the country as it enters into the Zambezi River on its way to the Indian Ocean.

There are two main groundwater resources: (i) the extensive but low yielding (1-2 litres per second) weathered basement aquifer of the Middle Altitude Plateau, and (ii) the high yielding (> 15 litres per second) aquifer of the Lakeshore Plain and the Lower Shire Valley. Both surface and groundwater resources depend on rainfall inputs, and they support important wetlands, especially those along the shores of Lake Malawi and Lake Chilwa, Vwaza Marsh near Lake Kazuni, and Ndindi and Elephant Marches in the Shire River Valley, which are habitats for various flora and fauna.

The country's water resources are used for domestic and industrial purposes, generating electricity and for irrigation purposes. A conservative estimate indicates that there are about 90,000 ha of land that is suitable for irrigation with an estimated water demand of about 178 million m^3 per year. However, about 40,000 ha are presently are under irrigation and use an estimated 80 million m^3 per year. The main reason for the low use of irrigation water include (i) lack of an irrigation culture by Malawians, and (ii) inadequate water resources in rivers and streams during the dry season. Some 280 MW of electricity are generated from hydro-power plants constructed on the Shire River. This is more than 99% of the electricity used in the country, and its generation requires an estimated 250-400 $m^3 s^{-1}$, or a maximum of about 12.6 km^3 per year. There is still a further potential to harness about 740 MW on the Shire River, with about 64 MW already installed at Kapichila Hydro-power Station. However, the current and future hydro-power developments depends on maintaining flow rates of at least 250-400 m^3s^{-1} on the Shire River, which has not always been guaranteed. This is because flow rates lower than these have been recorded on the Shire River in the past, such as during the 1996/97 rainy season. It is against this background that the Kamuzu Barrage was constructed at Liwonde with the aim of regulating lake water levels and river flow rates, thereby minimising the likelihood of having flow rates that are lower than those required for generating hydro-electricity down stream on the Shire River.

Although the abundant ground and surface water resources of Malawi are presently sufficient for domestic, agricultural, commercial and industrial use, they are slowly and steadily getting degraded due to many interrelated factors including: (i) ground and surface water pollution from faecal concentrations, industrial and hazardous wastes, untreated municipal wastes and agro-chemical run-off, (ii) sedimentation or siltation from suspended particles and soil erosion, and (iii) drying of perennial rivers from low rainfall and dwindling groundwater resources. All these factors combine in space and time to reduce both water quantity and quality, painting a brink picture for the future against a backdrop of climate change.

2.5.6 Forest Resources

Forests play an important role in the provision of basic socio-economic needs, such as fuel-wood, wood products, food, animal fodder, pharmaceuticals, employment and foreign exchange earnings. As an integral component of the biosphere, forests help in stabilising natural systems, such as the carbon cycle, contribute to biological diversity, and provide habitat for fauna and flora. Forests also help in maintaining air, water and soil quality, influence biochemical processes, regulate run-off and groundwater flows, control soil erosion, reduce downstream sedimentation and flush flooding. Thus, forests are a source of diversity of goods and services that are essential for sustainable economic growth and development.

The forest resources of Malawi are classified into: (i) natural woodland, (ii) forestry plantations, and (iii) woodlots. The natural woodland comprise forest reserves (8,076 km^2), national parks and game reserves (9,680 km^2), and customary forests (8,843 km^2, giving a total of 26,428 km^2 total forest land (Table 2.10).

Table 2.10: Distribution of forest reserves by region in Malawi

Region	Forest Reserve	National Parks /Game reserves	Customary land Forest	Total
North	2,358	3,060	5,813	11,231
Centre	2,507	4.120	677	7,374,
South	3,211	2,500	2,353	7,823
Total	8,076	9,680	8,843	26,428

Source: Kainja et al., 2008; Anon., 2007.

The natural forest is mostly dominated by <u>miombo</u> woodlands, represented by the genera *Brachystegia, Isobernia, Combretum, Julbernardia* and *Acacia*. The other common tree species include: (i) conifers for saw timber and shelter belts [*Pinus caribea* (Caribbean Pine), *Pinus elliottii* (Slash Pine), *Pinus kesiya* (Khasia Pine), *Pinus leiophylla* (smooth–leaved pine), *Pinus oocarpa* (Guatemala Pitch Pine), *Pinus patula* (spreading–leaved Pine), *Pinus taeda* (loblolly Pine), *Cupressus lusitatania* (Mexican cypress)], and *Cupressus toruloza* (Himalayan Cypress), and (ii) hardwoods for fuel wood, poles and shelter [*Acacia albida* (Nsangu; Masngusangu), *Azadirachta indica* (India, Neem), *Cassia siamea* (Cassia), *Eucalpyptus camaldulensis* (Red River Gum), *Eucalyptus citriodora* (Lemonscented Gum), *Eucalyptus cloeziana* (Gympie Messmate), *Eucalyptus grandis* (Flooded Gum), *Eucalyptus maideni* (Maiden's Gum), *Eucalyptus pellita* (Large Fruited Red Mahogany), *Eucalyptus punctata* (Grey Gum), *Eucalyptus saligna* (Sydney Blue Gum), *Eucalyptus tereticornis* (Forest Red Gum), *Gmelina arborea* (Gmelina), *Melia azedarach* (India), *Leucaena leucocephala* (Leucaena), and *Toona ciliat* (Sinderella)]

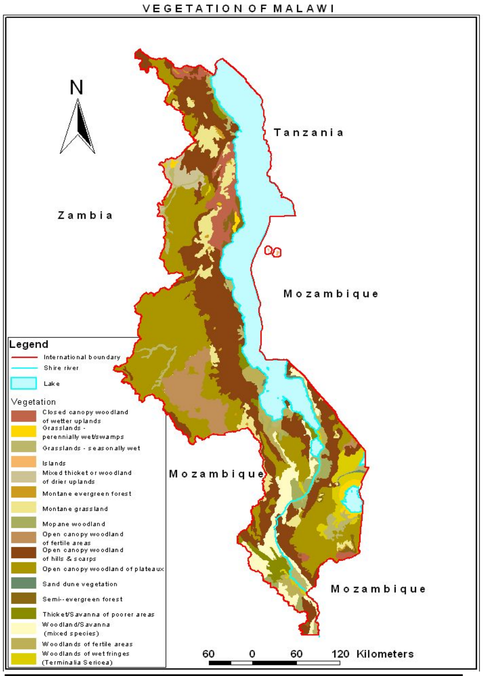


Fig 2.19: Vegetation Map of Malawi

However, Malawi's vast forest resource base has over the last four decades been subjected to considerable exploitation through human activities, including: forest or bush fires, high rates of deforestation, encroachment, increasing demands for fuel-wood, increasing human population pressures and agricultural expansion. For example, high demands for forest products, such as fuel-wood, charcoal, medicines, construction and industrial materials, explain the high rates of deforestation. Between 1972 and 1990, forest cover declined by 41% representing an average 2.4% per year. The current average national deforestation rate is 2.8%, up from 2.4% (MG, 2000). Presently, only 23 and 26% of the total land area is estimated to be under some form of forest cover (Fig 2.19). However, in an effort to protect some endangered tree species from extension, the Government has placed some of these trees under the protection of the Forest Act (Cap. 63:01) of the Laws of Malawi. These include: (i) *Adina microcephala* (Redwood or Mwenya; Chonya; Mngwenya; Mung'ona; Mwina; Mungwina), (ii) *Afzelia quanzensis* (Mahogany Bean or Mkonomwa; Msokosa; Mnangaliondo; Msambamfumu; Mkongwa; Chikunda; Ipapa; Mpapa; Mpapadende), (iii) *Borassus aethiopum* (Palm or Mvumo; Mdikwa; Makoma; Mulal), (iv) *Bridelia micrantha* (Coast Goldleaf or Msopa; Chisops; Mpasa; Mlewezi; Msongamino; Mwisya), (v) *Burkea Africana* (Ash or Mkalakati; Kalinguti; Kawidzi; Nakapanga), (vi) *Colophospermum mopane* (Butterfly tree or Tsanya; Sanya; Ntsano; Mopani; Mpani), (vii) *Cordyla Africana* (Sunbird tree/Wild mango or Mtondo), (viii) *Hyphaena crinita* (Palm or Mgwalangwa; Mkomakoma; Makoma; Mulala), (ix) *Khaya nyasica* (Mahogany or Mbawa; Muwawa; Bulamwiko), (x) *Pterocarpus angolensis* (African Teak or Mlombwa; Mtumbati; Mbira; Nawazi), and (xi) *Terminalia sericea* (yellow Wood or Napini; Nyapini; Mpini; Nalinsi; Mkodoni; Mpululi; Njoyi).

There is a lot of variation in forest cover from district to district, with some districts having forest covers that are less than 5% (e.g., Thyolo, Chiradzulu and Dowa), whereas others have forest covers that are more than 50% (e.g., Karonga, Nkhata Bay and Nkhota Kota). The various forest covers comprise natural forests and planted forests on public and private land. The available forest types reflect their mode of ownership and their primary purpose as follows: (i) customary land forests, (ii) forest reserves, (iii) wildlife forest reserves, (iv) trees on-farm or agro forestry, and (v) plantation forests.

Customary land forests are owned traditionally under the jurisdiction of the chief and cover about 3.1 m ha of land. Presently, there are 93 gazetted forest reserves and 45 proposed forest reserves for gazetting. Some customary land forests are located within leasehold or freehold land that is privately owned, and an estimated 12% of this, are under natural woodland and plantation forests. These customary land forests are effectively not managed with the result that their productivity is exceptionally low.

Forest reserves are managed by the Department of Forestry (DoF) and cover an estimated 1.1 m ha (Table 2.10). Nearly each district has at least one forest reserve, and most of these are mostly located on the High Altitude Plateaus and/or mountainous areas characterized by poor agricultural soils (Lithosols), and are meant to protect the fragile steep slopes from environmental degradation through soil erosion.

Wildlife forest reserves are managed by the Department of National Parks and Wildlife (DoNPW) and consist of an estimated 0.98 m ha which is 19 % of the total land area. There are five national parks: (i) Nyika, (ii) Kasungu, (iii) Liwonde, (iv) Lengwe, and (v) Lake Malawi, and four game reserves: (i) Vwaza Marsh, (ii) Nkhota Kota, (iii) Mwabvi, and (iv) Majete), which are evenly distributed throughout the country. The trees on-farm, or agro forestry, represents an important alternative in the energy equation of smallholders. These trees are either planted or grown naturally in the gardens, around homesteads, farm boundaries, and occasionally along linear features, such as roads. The promotion of agro-forestry technologies has brought a new dimension in the outlook of crop fields.

Some 0.09 m ha has been planted to exotic trees in Government plantations, such as Chikangawa, which are managed by the DoF. These plantations fall into three main categories: (i) rural fuel-wood and pole plantations, established under the Food and Agriculture Organization (FAO) Wood Energy Project from 1975-1985, where the major hardwood tree species planted was *Eucalyptus*, (ii) Local Authority Plantations used for fuel-wood in towns and cities, and (iii) industrial timber forests that constitute 3% of Malawi's closed forest area. Some 85% of the timber forests comprise softwood *Pinus patula*.

There are also several private tree plantations, notably those that are owned by tea and tobacco estates and cover about 0.02 m ha (about 0.4 % of forest area). There is also 0.02 m ha of smallholder woodlots scattered through out the country. Generally, many of the plantations are poorly managed due to lack of operational resources, qualified staff, equipment and other related facilities.

2.5.7 Fish Resources

Malawi is endowed with a large diversity of fish resources. Fish is a vital source of both cash income and animal protein. The Fisheries Sector contributes about 4% to Gross Domestic Product (GDP), and accounts for 60-70% of the animal protein intake. There are between 500 and 1,000 fish species in the different lakes, streams and rivers. Lake Malawi is the main source of fish, which are influenced by its unique biophysical characteristics: (i) long and deep with a narrow basin, (ii) clear water that permits visual detection at depths of up to 17 m, (iii) anoxic water below 250 m that is largely devoid of fish life, (iv) a marked seasonality of weather and lake surface conditions, and (v) large stocks of mostly small-sized fish (EAD, 1994; 2003). The main fish types found in Lake Malawi include: (i) *Oreochromis spp* (Chambo), (ii) *Baplochromis spp* (Kampango), (iii) *Lethrinops spp* (Chisawasawa), (iv) *Clarias spp* (Mlamba), (v) Bathyclarias spp (Bombe), (vi)*Lebeo mesops* (Ntchila), (vii) *Opseridium microlepis* (Mpasa) (viii) *Opsaridium microcephalus* (Sanjika), and (ix) *Haplochromis spp* (Utaka). The rivers on their own have some 30 species of fish. The most endemic fishes (> 50%) are the *Cyprinids* and *Clarias gariepinus* (catfish). Unfortunately, these fish resources are threatened by over-exploitation, water pollution, and the recurrent and periodic droughts.

The total annual fish catches grew slowly between the 1940s to the 1950s, with a total of 7,000 tons recorded in 1957. This figure rose dramatically from 20,000 tonnes in 1965 to 84,000 tonnes in the 1970s, and has since been fluctuating between 60,000 and 80,000, mainly as a result of improvements in the fishing industry, including: (i) large financial investments, (ii) improvements in road communication network and infrastructure, (iii) introduction of the nylon fishing net, and (iv) high local and regional demand for Malawi's fish, especially the tasty and delicious Chambo. However, in the late 1970s to the early 1980s, there was a disruption in the fishing industry resulting from continuous and heavy rainfall events that caused Lake Malawi to rise to unprecedented high levels in recent history. This resulted in a decline in fish catches, so that the total landed fish was only 51,000 tons in 1981, down by 24,000 tons from the 1975 figure.

Nonetheless, with declining lake-levels in subsequent years, as a result of reduced total rainfall during the 1980s, total annual fish catches increased again, reaching a record 88.000 tons in 1987. More than half of this (50,000 tonnes) came from Lake Malawi with an estimated value in the order of US $ 50.0 million. Lake Malawi has a total potential of 80,000 tons of fish per year, with the remaining coming from Lakes Chilwa, Malombe, Chiuta and Kazuni, and the major rivers of Shire, Ruo, Mwanza, Bua, Dwangwa, South Rukuru and North Rukuru. In the late 1990s, large-scale commercial fishermen were responsible for between 10% and 15% of the total landed fish catches, especially in Mangochi on the southern shores of Lake Malawi. Commercial fishermen use various fishing gears, including: (i) bottom trawling, (ii) mid-water trawling, and (iii) ring netting. Small-scale fishermen were responsible for the remaining 85-90% of the landed fish catches, who mostly use the following fishing gears: (i) Chilimila net, (ii) Gill net, (iii) Kambuzi seine, (iv) Chambo seine, (v) Mosquito seine, (vi) Usipa seine, (vii) Longlines, (viii) Handlines, and (ix) Cast nets, some of which have small mesh sizes, whereas others use dynamite, fish poisoning and blocking the rivers. However, besides fishing in the lakes, streams and rivers, Government has also introduced fish farming in fish ponds throughout the country.

Fish farming in Malawi started at Domasi and Kasinthula Irrigation Schemes in southern Malawi in 1957 and 1971, respectively. These were primarily established as hatcheries to supply fingerings to subsistence smallholder farmers throughout the country. However, the location of these in the Southern Region meant that fish farming was better developed in the south than the centre and/or the north. However, since 2000, fish farming has been introduced in all the regions as follows: (i) Northern Region: Chitipa (Chisenga), Rumphi (Mphompha and Nchenachena), Mzimba (Mzuzu) and Nkhata Bay (Chikwina and Limphasa), (ii) Central Region: Mchinji, Dedza, Ntcheu, Ntchisi and Dowa, and (iii) Southern Region: Chikwawa, Mwanza, Zomba, Mangochi, Machinga, Mulanje and Thyolo. Nationally, there are about 3,000 fish farmers in the country who own 7,000 ponds and produce some 570 tons of fish per year.

Thus, it can be concluded that the fish resources of Malawi are faced with increasing threats of: (i) over-fishing from an increasing number of fishermen, non-compliance with "off-season" regulations and inappropriate fishing methods (nets with small mesh size and the use of mosquito netting, dynamite fishing, fish poisoning, use of fish traps at river outlets, fishing by blocking rivers, fishing at breeding grounds, and fishing during breeding seasons), and (ii) degradation of ecological niches and destruction of breeding areas (reduction in water flows and increased sedimentation arising from increased agricultural expansion and deforestation, water pollution from human waste, agricultural waste and run-off, and industrial waste, and prevention of fish migration in rivers because of breeding site obstructions).

Further, there are legal and institutional constraints, which include: weaknesses in the fisheries regulation, low enforcement capacity of the Fisheries Act, breaking-up of traditional systems of management for the control and exploitation of fish resources, lack of awareness and information on fishery regulations and compliance. Hence, there is need for the proper management of the lake ecosystems, to include climate change adaptations measures and strategies. The use of the time series approach to model annual fish stock variations in Lake Malawi with climate change would be desirable for effective planning in the Fisheries Sector. However, the implementation of the Decentralization Policy over the last five years has created an opportunity to empower rural communities to manage their fish resources, including the enforcement of the Fisheries Act.

2.5.8 Wildlife Resources

Malawi is endowed with diverse and abundant flora, fauna and micro-biota that play an important role in the socio-economic growth and development of the nation. These resources offer a diversity of potential benefits, including: aesthetic, scientific, cultural and recreational. They are also a source of great genetic diversity, providing food, trophies, timber, besides being a great tourist attraction. There are about 4,000 fauna, 5,300 species of indigenous plants and 1,000 species of micro-organisms that have so far been described and catalogued. Of the fauna, about 1,500 species are vertebrates that have been identified as follows: (i) 163 mammals, (i) 92 reptiles, (iii) 54 amphibians, (iv) 92 reptiles, (v) 538 fish species, and (vi) 620 bird species. The spatial distribution of these resources is highly variable and influenced by topography, climate, vegetation type, and more importantly, human activities.

However, in an effort to preserve and conserve this rich biodiversity, the Government, through the Department of National Parks and Wildlife (DoNPW), has created five (5) national parks (Nyika, Kasungu, Liwonde, Lengwe and Lake Malawi) and 4 game reserves (Vwaza Marsh, Nkhota Kota, Mwabvi and Majete) that cover approximately 21% of the total land area (Table 2.11). The Lake Malawi National Park, which was established in 1980, has now been declared a United Nations (UN) World Heritage Site (WHS), and is the first freshwater and underwater national park in Africa.

Table 2.11: Size and location of different wildlife forest reserves in Malawi

Category	Total area (km^2)	National park and game reserve, and district
National Parks	3134	Nyika (Rumphi district)
	2316	Kasungu (Kasungu district)
	887	Lengwe (Chikwawa district)
	548	Liwonde (Machinga district)
	94	Lake Malawi (Mangochi district)
Game Reserves	1802	Nkhota Kota (Nkhota Kota district)
	784	Majete (Nsanje district)
	340	Mwabvi ((Nsanje district)
	100	Vwaza Marsh (Rumphi/Mzimba districts)

Source: MG, 2000a, 200b.

However, Malawi's wildlife resources are under threat. They have been subjected to over-exploitation by an increasing human population on a limited land resource base. Over the years, wildlife protection areas have been encroached upon with increased poaching. For example, due to poaching, Rhinoceros (*Diceros bicornis*), is presently close to extinction, and is only available owing to its re-introduction in the Liwonde National Park. There are several other rare animal species that are endemic and endangered and need to be protected. These include: (i) *Cercopithecus albogularis* (Nyani or Blue Monkey), (ii) *Loxodonta Africana* (Njobvu or African Elephant), (iii) *Kobus ellipsiprymnus* (Waterback), (iv) *Kobus vardoni* (Puku), (v) *Hippotragus* (Sable Antelope), (vi) *Rhynchocyon cirnei* (Checkered Elephant), (vii) *Tragelaphus angusi* (Nyala), (viii) *Neotragus moschatus* (Suni), (ix) *Glareola nuchalis* (Rock Pratincole), (x) *Diceros bicornis* (Black Rhinoceros or Chipembere), (xi) *Lycaon pictus* (Wild Dog or M'mbulu or Mpumpu or Mpupi), (xii) *Opsaridium microlepis* (Lake salmon or Mpasa), and (xiii) *Acinonyx jubatus* (Cheetah). Further, climatic factors, such as drought, have exacerbated the situation as the natural habitant has been destroyed by severe heat and water stress. For example, wildlife was adversely affected in Lengwe National Park during the 1990/91 drought season.

2.5.9 Energy Resources

Malawi has large quantities of energy sources that include: (i) biomass, (ii) coal, (iii) fast flowing perennial rivers, (iv) solar energy, (v) wind energy, (vi) hot springs, and (vii) uranium deposits. These energy sources have been classified into the following categories: (i) biomass (firewood, charcoal, crop and industrial residues), (ii) electricity (hydro and thermal), (iii) liquid fuel and gas (petrol, diesel, paraffin, ethanol, gel-fuel, avigas and JetA1), (iv) coal and peat, and (v) renewable energy resources (solar, wind, biogas, mini- and micro-hydro-electric power). However, Malawi's main energy mix comprise: (i) firewood (biomass), 93%, (ii) petroleum products, 3.5%, (iii) hydro-electricity, 2.3%, (iv)

Fig 2.20: Malawi's biomass mix (MEP, 2002)

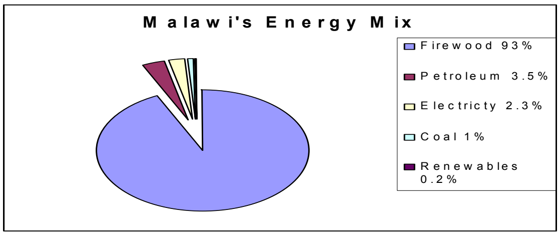
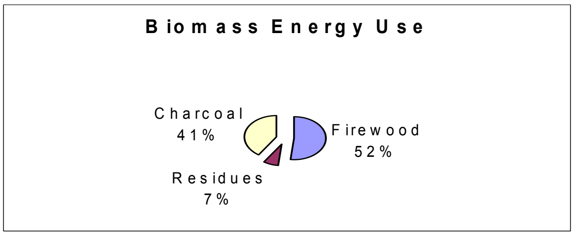


Fig 2.21: Malawi's biomass use (MEP, 2002)



coal, 1.0%, and (v) renewable energy, 0.2% (Fig 2.20). Biomass dominates, with charcoal, firewood and residues contributing 41%, 52% and 7%, respectively (Fig 2.21). The renewable energy sources include: (i) solar systems, (ii) biogas, (iii) wind energy, and (iv) mini- and micro-hydro systems. Solar home systems, especially photovoltaic, dominate the renewable energy technology (RETs) industry. However, there is low uptake of these technologies, which can largely be attributed to high initial costs, the absence of appropriate institutional delivery mechanisms and a poor maintenance track record, as exemplified by the large numbers of non-operative systems (MEP, 2002). The cost of conventional energy sources, such as petroleum, electricity (current costs for grid connection) and coal are unaffordable for the majority of the people in Malawi, a situation that has pushed most family households into permanent dependency on the use fuel-wood as the main source of energy in the absence of cheaper alternatives.

Energy consumption. Although information on Malawi's total annual energy consumption is not readily available from the Department of Energy Affairs (DoEA) and the National

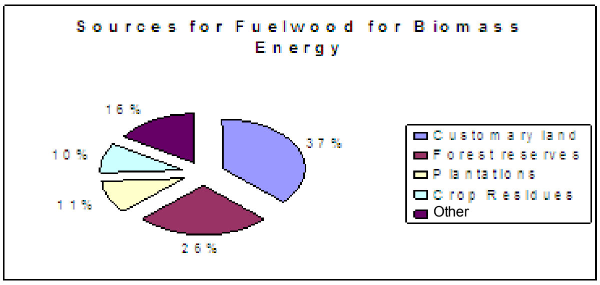


Fig 2.22: Sources of fuel-wood for biomass energy

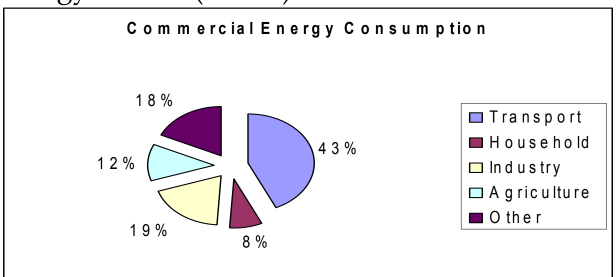


Fig 2.23: Commercial energy consumption

Statistical Office (NSO), the total energy consumption per capita was estimated at 29 kg of oil equivalent in 2001. The annual electricity consumption per capita in 2004 was 100 kWh, whereas the electrification rate was 7%. This means that about 12.0 m out of 13.1 m people are without electricity (UNDP, 2007). However, the efforts of Government are aimed at electrifying as many households as possible under the Rural Electrification

Programme (REP), which has been contracted to the Electricity Supply Corporation of Malawi (ESCOM) for implementation. Presently, several areas in the country, including Rural Growth Centres (RGCs) and areas lying along the major power lines, have been electrified. Efforts are also under way to connect Malawi to the Malawi-Mozambique Grid Connection at Cobrabassa Dam on the Zambezi River in Mozambique.

The **t**ransport sub-sector is the main consumer (43%) of the available **commercial energy** sources (liquid fuels, electricity and coal), followed by the manufacturing industry and mining (19%), other services (18%), agriculture (12%) and households (8%) (Fig. 2.23). The transport sector accounts for 50% of the liquid fuel needs, while the manufacturing industry and household needs account for 40% and 10%, respectively. Paraffin (kerosene) is widely used for lighting in urban areas, including some households that also have access to electricity. It is also used for lighting in rural areas, although it is wood-fuel that dominates. Some 6% of the households use paraffin for cooking in rural areas.

The bulk of the energy needs by the majority of Malawians, especially in rural areas, is derived from **wood energy.** Over 50% of the wood energy comes from customary land forests and woodlands, 36% from forest reserves, 15% from plantations, 14% from crop residues and 22% from other sources of biomass (Fig 2.24). It is estimated that two thirds of the total wood consumption is for cooking and heating in rural areas, whereas the balance is composed of urban wood fuels for cooking and industrial requirements, building poles, tobacco and tea curing and building requirements, and other miscellaneous uses (Fig 2.25). The per capita wood consumption is estimated at 680 kg per year for rural populations, and 1,120 kg wood equivalent per year for urban populations (includes conversion from charcoal). Wood demand is about 8.5 million m^3 per year, growing at 2% per year, whereas sustainable wood supply is 5.2 m ha (FAO, 2004), a clear indication of forest depletion.

Energy production. Of the country's installed capacity of 304 megawatts, 91% is hydro-electricity, and 9% is thermal energy generated by diesel engines, which are servicing about 7% of the population. However, an important source of energy in the future may be uranium, especially in the face of the discovery and exploitation at the Kayelekera Uranium Mine in Karonga district . It is presently estimated that only 30% of the urban population and less than 1% of the rural population have access to public electricity supply systems. This is a very low coverage even by Southern African Development Community (SADC) regional standards, whose average coverage rate is about 20%. However, it is estimated that in the short-term, the demand for electricity in Malawi will be growing at an annual average rate of 6% compared with the average annual regional growth rate of 3.5% (MEP,2002). It is further expected that the estimated growth in demand will rise if the potential major development activities, such as bauxite mining on Mulanje Mountain, and various other mining and manufacturing activities that are in the pipeline in Balaka and Rumphi districts (MEP,2002) commence their operations.

Fig 2.24: Wood consumption pattern

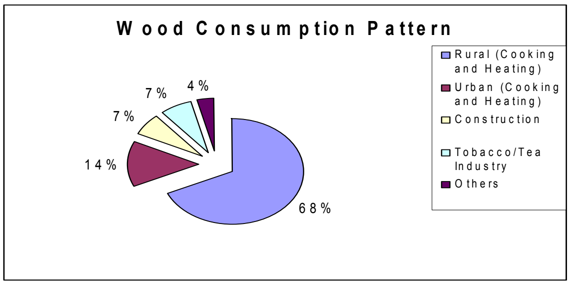
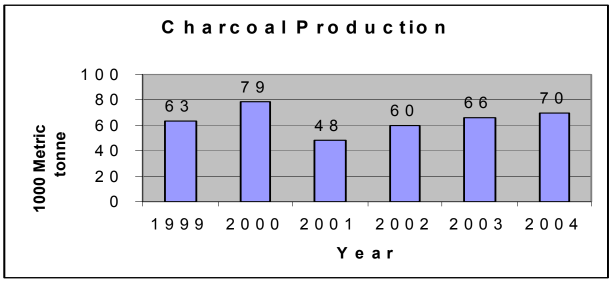


Fig 2.25: Charcoal production in Malawi



One of the major sources of energy in Malawi is **coal**. Coal is mined at the Mchenga Coal Mine in Rumphi district, northern Malawi, with a production capacity of 52,000 tonnes per month. Coal for the local market is mostly used in the tobacco, sugar, beer brewing and textile industries. Exported coal, which commenced in 1997, is destined for the southern region of Tanzania where it is used in the cement and paper manufacturing industries. Nonetheless, some coal is still imported from Moatize in Mozambique to meet some local demand, especially in southern Malawi. This is because Mchenga Coal Mine is some 900 km from Blantyre, whereas Moatize in Mozambique is only 90 km away, making the landed cost of Mchenga coal in Blantyre more expensive than that from Moatize in Mozambique..

The **hydro-power energy** potential is concentrated on the Shire River, whose estimated total capacity is about 600 MW, which can provide nearly 3,500 GWh of electrical energy. In addition, Malawi has several rivers that have the potential for the installation of mini- and micro-hydro power generating stations. Currently, only one mini-hydro power station has been installed on the Wovwe River in Karonga district, Northern Region, which was commissioned in 1996. Its capacity is 4.5 MW and it currently providing electricity to Karonga, Rumphi, Mzuzu and Mzimba in northern Malawi, and the districts of Lundazi and Chama in the Eastern Province of the Republic of Zambia.

Another potential source of energy in Malawi is **wind energy**. Wind speeds of more than 4.7 m s^{-1} have been recorded in Chitipa, Rumphi and Mzimba districts in northern Malawi, Balaka and Blantyre districts in southern Malawi (Kamdonyo, 1998). Wind speeds of more than 4.7m/s have the potential to generate electricity for various purposes, especially for domestic purposes. Presently, some wind mills have been installed in some parts of the country for the express purpose of pumping groundwater from boreholes for drinking and irrigation purposes.

Then there is **solar energy**. Solar energy is estimated at 21.1 MJ m^{-2} day^{-1} (5.86 kWh day^{-1}). Up to 27 MJ m^{-2} day^{-1} during the dry season has been estimated for the Shire Valley in southern Malawi. This means that Malawi is well placed to utilise solar energy for a range of applications, from photovoltaic conversion to electrical energy and direct thermal usage for heating water. In 2004, there were 6,413 solar systems that were utilized as follows: (i) 4,007 units (63%) for home use (2,391 for lighting and television sets), (ii) 591 units (9%) for heating water, (iii) 113 units (2%) for pumping water, and (iv) 202 units (3%) for refrigeration.

The **biogas energy** technology is based on bio-degradation of organic materials in anaerobic conditions by the putrefactive bacteria at suitable and stable temperatures. In 2000, there were about 20 to 30 biogas digesters in Malawi, and presently most of these are mal-functioning. Since Malawi has a large and increasing number of cattle, there is need to intensify extension delivery services to enhance the uptake of the biogas technology for use by smallholder rural communities.

Ethanol. Ethanol in Malawi is produced from sugar molasses by two companies: (i) Ethanol Company of Malawi (ETHCO) at Dwangwa in Nkhota Kota district, which produces 7.0 m litres of ethanol per year, and (ii) Presscane ETHCO that is located at Nchalo in Chikwawa district, which produces 10.8 m litres per year. This ethanol is blended with petrol, thereby contributing about 3% to the liquid fuel requirements of Malawi. As the campaign for the use of biofuels intensifies, Malawi is better placed to further exploit the use of this sugar by-product, as the best alternative to the use of maize, the main staple food for the majority of the people in the country.

The challenge facing Malawi to day is to reduce its overdependence on biomass for its energy needs. The extensive use of wood for fuel as the main source of energy source imposes a serious burden on the country's indigenous forest resources. It also has serious implications for on rapid depletion of forests, land and soil degradation, and environmental degradation.

2.5.10 Wetland Resources

The main wetland ecosystems in Malawi include the following areas: (i) Lake Chilwa, Zomba district, (ii) Shire River [e.g., Elephant March and Ndindi Marsh (Fig 2.26) in Chikwawa and Nsanje districts, respectively], (iii) Lake Kazuni (e.g., Vwaza Marsh), Mzimba and Rumphi districts, (iv) Lake Chiuta, Machinga district, and (v) Lake Malawi lakeshore districts. However, the main and most notable wetland area is Lake Chilwa, with large quantities of fish, but completely dries up during years of severe droughts, such as the 1991/92 drought year.

Fig 2.26 Wetlands along the Shire River; Shire Valley, Source: EAD, 2003

It contains over 3,500 to 4,000 plant species, and more than 1,000 species of animals and micro-organisms. Malawi designated the Lake Chilwa Wetland as its wetland of "international significance" under the Ramsar Convention because of its physical, biological, ecological and socio-economic attributes to people and the environment. However, climate change, especially in the form of droughts, adversely affects the flora and fauna in these wetlands. Although these wetlands are a habitat of a diversity of fish, they are also a source of natural methane (CH_4) gas emissions, which is greenhouse gas that contributes to global warming.

2.5.11 Mountain Ecosystem Resources

The High Altitude Plateaus (1,350 to 3,000 m asl) comprise the mountain ecosystem. The most prominent among these are: (i) Misuku Hills, (ii) Nyika Plateau, (iii) Viphya Plateau, (iv) Dedza

Mountain, (v) the Kirk Range, ((vi) Zomba Plateau, and (vii) Mulanje Mountain. Mulanje Mountain, at 3,000 m asl, has been colonized by six different plant communities, including the Afro-montane forests near the summit of the mountain. The Mulanje Mountain massif (Fig 2.27) accounts for a large number of flora and fauna that are endemic, endangered and/or threatened by extinction, therefore requiring protection. It is because of this that Mulanje Mountain is one of the 200 global eco-regions in the world that has been selected for the conservation of its biodiversity, and has so far been designated as an Afro-montane Regional Centre of Endemism (AMRCE). The massif also serves as a source of the headwaters of nine rivers, and represents an important source of timber and other forest products, including the commercially valuable Mulanje Cedar. However, the Mulanje mountain biodiversity is threatened from unsustainable exploitation resulting from high population pressures, encroachment, agricultural expansion, uncontrolled bush fires, invasive by alien species and the increasing demand for forest products. The massif is also surrounded by tea plantations and is prone to landslides following intense and continuous rainfall. There is presently the Mulanje Mountain Conservation Trust (MMCT), established in 1994, whose objective is to preserve the unique biodiversity and ecosystems of this mountain system. Similar efforts should be extended to other mountain ecosystems, such as the Nyika Plateau that is an outstanding tourist attraction, and especially when it is also close to the Vwaza March Wetland area near Lake Kazuni in Mzimba/Rumphi districts.

However, it should also be borne in mind that the proposal to mine bauxite on Mulanje Mountain may have some undesirable impacts on the environment and its flora and fauna. Thus, proper planning, including EIA's, need to be conducted before this is done so as to ensure that the mining activities do not disturb the environment of this great mountain ecosystem.

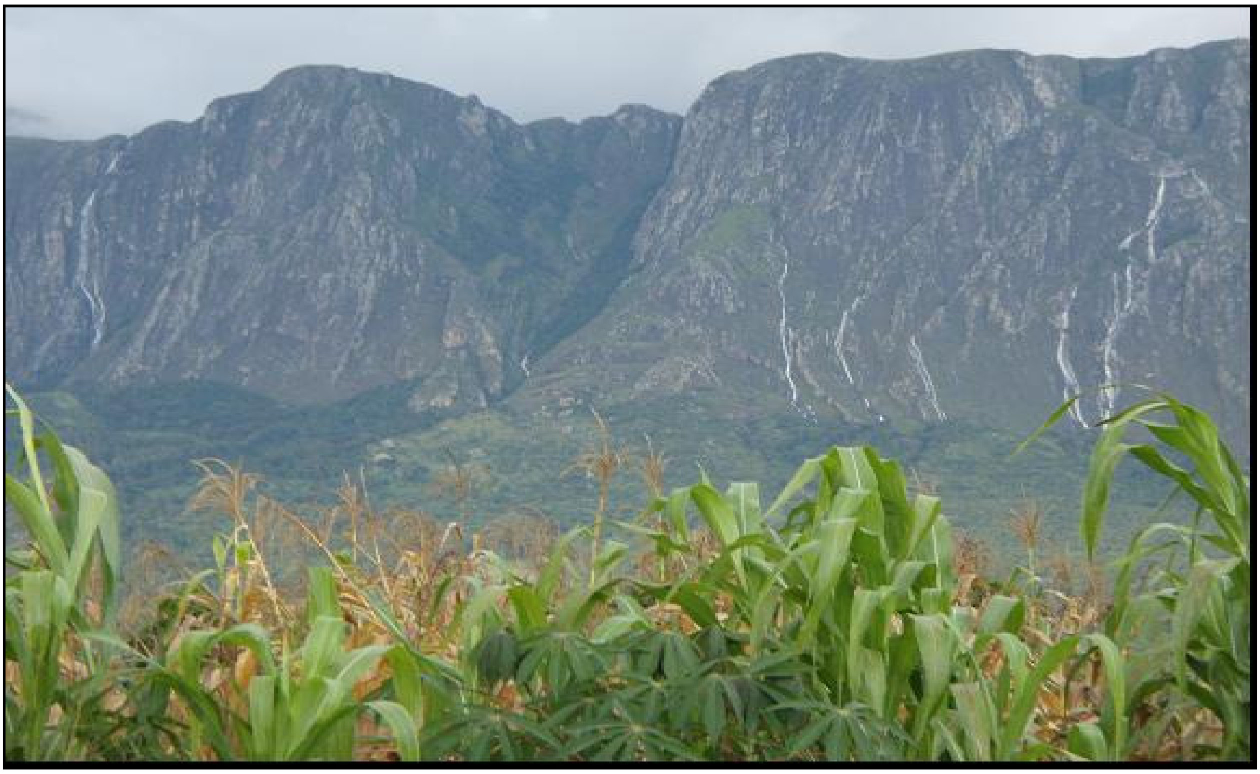


Fig 2.27: The Mulanje Mountain massif, Mulanje district, southern Malawi

2.5.12 Tourism

Tourism has very high potential for scenic Malawi, yet it is still one of least developed and exploited natural resources. A thriving tourist industry will greatly contribute to increased productivity, a diversified economy, and spearhead an export-led growth economy. To achieve this, there is need to improve infrastructure, including the road network and the construction of high quality hotels. However, the economic activities from these will contribute towards the emission of GHGs, hence impacting negatively on the other sectors of economic growth. The need for developing adaptation and mitigation measures is clear.

2.6 Infrastructure

Infrastructure is important for the achievement of Government's strategic objectives of poverty alleviation and food and water security as stipulated in the Malawi Growth and Development Strategy (MGDS) of 2006 (MG, 2006). Malawi's infrastructure development strategy is focused on the following: (i) transport (road, rail, air and water), (ii) energy (electricity), (iii) water and sanitation, (iv) telecommunication technologies, (v) information technology, (v) science and technology, and (vi) buildings or built environment. The aim is to ensure: (i) easy access to markets, hospitals and schools, and (ii) reduce the incidence of water borne diseases, land and environmental degradation, air and water pollution, and the adverse impacts from poor water usage and sanitation. However, all these are highly vulnerable to climate change, especially in the form of high intensity rainfall, land slides, mudslides, floods, droughts, cyclones and strong winds.

2.6.1 Transport

Road transport. Transport facilities (roads, rail, water and air) are generally in adequate and in poor condition to adequately meet the needs of a growing and vibrant population estimated at 13.1 million and growing at the rate of 2.8%. This situation is exacerbated by the fact that Malawi has no "direct access" to the Indian Ocean. However, over the last decade, Malawi has been promoting the development of transport corridors through the neighbouring countries of Tanzania and Mozambique to the Indian Ocean as one way of facilitating the transportation of goods and services, and attracting investments into the country. So far, the following corridors have been established: (i) the Zambia–Malawi–Mozambique Growth Triangle (ZMM-GT), launched in November 2000 with Zambia and Mozambique; (ii) the Nacala Development Corridor (NDC), launched in September 2000 with Zambia and Mozambique, and (iii) the Mtwara Development Corridor (MtwDC), launched in December 2004 with Zambia, Mozambique and Tanzania. Malawi had a total of 96,146 registered vehicles in May 2007 (Table 2.12, Fig 2.28), which shows an increase of 76,146 from 20,000 recorded vehicles in 1992. However, this figure does not include Government, illegal and vehicles that are not roadworthy. The distribution of vehicles, by category type (Fig 2.29), indicates that the goods vehicles dominant the market, although this trend is currently declining. The increased number of vehicles is adding substantial quantise of GHGs to the atmosphere. This situation is exacerbated by the fact that most of the so called imported vehicles are "second hand vehicles", a situation that is further aggravated by the fact that a lot tyres imported into the country are also second hand. Roads in Malawi, the bulk of which are not bituminized, are highly vulnerable to flooding.

Table 2.12: Registered number of vehicles by category, as of May 7, 2007

Vehicle category	Registered vehicles	Percentage (%)
Motorcycle (less than 3 wheels)	8,018	8.34
Motor Tricycle	641	0.67
Light passenger vehicle (less than 12 persons)	38,796	40.35
Heavy passenger vehicle (12 or more persons)	8,312	8.65
Light load vehicle (GVM 3500 kg or less)	22,452	23.35
Heavy load vehicle (GVM>3500 kg, not to draw)	9,912	10.31
Heavy load vehicle (GVM>3500 kg, equip to draw)	4,555	4.74
Trailer	2,171	2.26
Agricultural tractor	1,177	1.22
Agricultural trailer	106	0.11
Unknown	6	1.01
Total	96,146	100.00

Source: Malawi Road Traffic Directorate, 2007.

Fig 2.28: Total and cumulative number of registered vehicles from 1999 to 2007

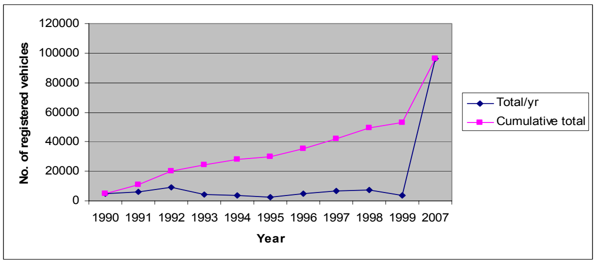
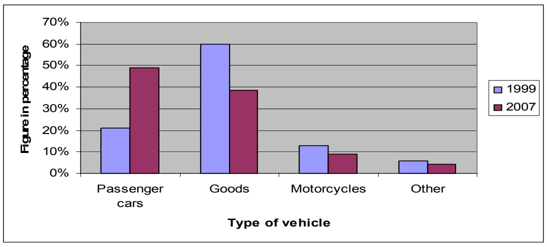


Fig 2.29: percentage of registered vehicles by type, 1999 and 2007



Water transport. Lake Malawi provides the main water transport from Mangochi in the south to Karonga in the north, with port facilities at Monkey Bay in Mangochi, Chipoka in Salima, Nkhota Kota, Likoma Island, Nkhata Bay, and Chilumba in Karonga. Apart from the four development corridors cited above, Malawi is presently exploring the practical possibility of linkages to the Indian Ocean through the Shire and Zambezi Rivers, under the Shire-Zambezi Waterway (SZW) Initiative. The realization of the SZW will be one of the major breakthroughs in the 21st century that will enable Malawi to have direct access to the Indian Ocean, and Malawi will no longer be a "land locked country" in the southern Africa region.

Rail transport. There are some 810 km of railway line track in Malawi. The railway line links Nsanje in the south with Mchinji in the centre through Chiromo, Lunchenza, Blantyre, Balaka, Salima and Lilongwe. This railway line also connects Malawi to the port of Beira in Mozambique. Unfortunately, this portion has been out of order since the beginning of the civil war in Mozambique in the 1970s. Another line links Liwonde Township in southern Malawi to the port of Nacala in Mozambique. Recently, efforts have been under way to revitalize the following non-functioning railway lines; (i) Nsanje to Beira, (ii) Nsanje to Blamtyre, and (iii) Mchinji to Chipata in Zambia. Similar efforts are required to link the Central Region with the Northern Region, so as to link with the Tanzania-Zambia Railway

Line at Tunduma in Zambia or Mbeya in Tanzania. This line is more urgent now than at any other time in the past because of the increased coal mining activities at Mchenga Coal Mine in Rumphi district, the manufacturing of wood and wood products at Raiply at Chikangawa in Mzimba district, and presently, the mining of uranium at Kayelekera Uranium Mine in Karonga district. However, the railway lines are highly vulnerable to flooding, especially in the Shire Valley and along the Lakeshore Plain.

Air transport. Malawi has five main airports: (i) Chileka in Blantyre, (ii) Kamuzu International Airport (KIA) in Lilongwe, (iii) Mzuzu Airport in Mzuzu, (iv) Karonga Airport in Karonga, and (vi) Club Makokola in Mangochi. There are also some aerodromes, which are presently rarely used, such as Chitipa, Mzimba, Kasungu, Dedza and Nsanje. However, aircraft operation is affected by heavy rains, fog and clouds that interfere with aircraft navigation. These climatic calamities are expected to increase in frequency and magnitude in the future in response to changes in climate. .

However, since Malawi's transport system of roads, rail, water and air are in a poor state and inadequate, this results in high costs of production, where transportation represents 55% of costs, compared with 17% in other less developed countries (MG, 2006). It is against this background that Malawi is seriously considering the establishment of the Shire-Zambezi Water Way to link Malawi directly to the Indian Ocean, thereby greatly reducing the current transportation costs.

2.6.3 Energy

The main thrust in the energy sector is for people to use alternative sources of energy to firewood and charcoal, especially electricity and other renewable energy sources, such solar and wind energy. The salient features of the energy sources in Malawi, including production and consumption trends are presented under Energy Resources (see Section 2.5.9).

2.6.4 Water Supply and Sanitation

The salient features of the Water Resources Sector are is presented in Section 2.5.5, which indicates that Malawi has abundant water sources stocked into its various lakes, streams, rivers and groundwater aquifers. The water is presently sufficient to meet the requirements for domestic and industrial purposes, including agricultural production (irrigation), industrial and domestic waste disposal, and for the generation of electricity. At domestic level, the challenge is to: (i) increase water access to all Malawians to within 500 m distance of their homesteads, (ii) improve the quality of surface and groundwater resources, (iii) improve skills, technologies and techniques for water quality monitoring and pollution control, and (iv) prevent the use of toxic substances and aquatic plants that pollute the water resource base. However, the future estimates of water availability are quite bleak. Most computer simulation models are predicting reduced rainfall totals, increased droughts, and diminished groundwater sources. This has serious implications for the agriculture sector, hence food and water security, and the sustainable livelihoods of family households.

2.6.5 Information, Communication and Technology

To be competitive regionally and globally, Malawi needs to be competitive in providing information, communication and technology (ICT) to its growing human population. The current ICT facilities, which include radio, television, postal services, internet and e-mail services, are inadequate to meet the current and future needs, and at the same time expensive for the bulk of the rural and urban-poor entrepreneurs. Thus, there is need to develop affordable and efficient telecommunications systems by opening more radio and television stations, e-mail and internet cafes and facsimile services, improving the educational standards of the people, and most importantly eradicating poverty. ICT has important implications for weather forecasting initiatives and providing early warning systems to agriculturists and policymakers, and to farming communities in areas prone to floods, such as the Shire Valley and areas along the Lakeshore Plain.

2.6.6 Science and Technology

Malawi has remained largely an under-developed country because it has not fully embraced or harnessed her human and physical resources to use science and technology to develop and utilize modern technologies for technological advancement. There is need to put science into action, and research findings into technologies. This means developing user-friendly technologies resulting from various scientific research programmes conducted in the country. It is only through the packaging of scientific research findings into technologies that Malawi can truly become a middle economy income with a technological edge to improve industrial productivity and the quality of goods and services as articulated in Malawi's Vision 2020. However, this technological advancement will be accompanied by enormous emissions of GHGs. Hence, concurrent with these efforts should be those for reducing GHG emissions through the use of some renewable sources of energy, and/or planting more trees in plantations and on-farm under agro-forestry systems.

2.6.7 Buildings and Other Urban Structures

These include all types of buildings and structures, such as urban dwelling and commercial houses, public and industrial buildings, pavements and roads. These buildings are built with different types of materials, which either absorb or reflect solar radiation. Some 34% of the buildings are made of permanent or semi-permanent materials, such as iron sheets, which highly reflect solar radiation (NSO, 205b; 2008). From these buildings, solar energy is radiated back into the atmosphere and contributes to the warming up of urban areas. In addition, industrial activities and fumes from vehicles within urban areas contribute to the heating up of the created urban micro-climates. However, 66% of the houses in Malawi are built of traditional materials, such as tree poles and are thatched with grass, which, unfortunately also contribute to deforestation. The effect of cutting down trees for construction purposes is twofold: (i) carbon dioxide (CO_2) emissions into the atmosphere, which contributes to global warming, and (ii) the removal of trees which absorbs CO_2 c from the atmosphere, hence reduces global warming.

2.7 Economic and Sector Profiles

2.7.1 Economy

The United Nations (UN) has classified Malawi as a Least Developed Country (LCD), with one of the lowest Human Development Index (HDI) values (0.464 in 2000) in the world (EAD, 2002). It ranked 163 out 174 countries in the world in 2000. The Gross Domestic

Product (GDP) per capita was estimated at US $ 182.00 in 1999, which is the lowest in the 14 SADC member countries. Thus, with a narrow economic base, high population density, land-locked status, unexploited minerals resources and prohibitive costs of external trade, Malawi is predominantly dependent on rain-fed agriculture. The economy is dominated by a few agricultural crops (tobacco, tea, sugar, maize, beans, cotton and coffee), and a few natural resources (fisheries, forests and wildlife), which account for 35-40% of the GDP and 90% of the export earnings (with 65-70% contributed by the tobacco industry), employs more than 80% of the total labour force, and contributes 60-70% of the inputs to the manufacturing industry..

Malawi's GDP per capita was about US$ 133.00 in 2002, lower than the estimated US$ 139.00 for the year 2003. However, revised real GDP in 2002 rose by 1.8%, from a low of about 0.4% in the year 2001. In 2004, the estimated contribution of the agricultural sector to the GDP was estimated at 54.8%, whereas industry and commerce was at 19.2%, and services at 26 %. According to the 2003 labour estimates, 90% were employed in the agriculture sector. Some 55% of the people lived below the poverty line in 2004, whereas the average year by year inflation rate for 2002 was around 14.8%, representing a drastic decline from the previous year's inflation rate of 22.7% (ILO/GOM, 2004b). Thus, with an undiversified natural resource-based economy, a debt burden of 156% of the GDP, a high population growth rate of 2.8%, unequal distribution of income and wealth, the development challenge facing Malawi to day is formidable, especially when viewed against the increasing threats of climate change.

2.7.2 Current Policies and Strategies

Since the late 1990s, development in Malawi has been guided by the following national and sectoral policy and strategy documents: (i) Vision 2020 of 2000, (ii) Malawi Poverty Reduction Strategy (MPRSP) of 2002, (iii) Malawi Economic Growth Strategy (MEGS) of 2004, (iv) Malawi Growth and Development Strategy (MGDS) of 2006, (v) National Environmental Action Plan (NEAP) of 1994 and revised in 2002, and (vi) National Environmental Policy of 1996, Presently, the Malawi Agriculture Development Programme (ADP) of 2007 has been prepared and developed to operationalise the agricultural components of the MGDS. The goals and objectives of the various policies and strategies are presented in Chapter 1.

2.7.3 Poverty and Social Profiles

Poverty is widespread and prevalent among rural and urban-poor communities. The level of poverty has not changed significantly over the last five years when Malawi communicated its Initial National Communication (INC) to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2003. According to the 2008 Population and Housing Census (NSO, 2008), the current status of poverty shows that 52.4 % of the population still live below the poverty line. This translates into about 6.9 million Malawians who are poor, with the poorest people living in rural areas, (where poverty rates are at 25%). The poor continue to register poor socio-economic indicators, with food insecurity as a continuing major threat to sustainable livelihoods (Table 2.2). Female-headed households are worse off, and income inequality persists with the richest 10% of the population having a median per capita income that is eight times higher than for the poorest 10%.

However, the overall poverty figure masks fluctuations in poverty in the country. Over the last decade, 30% of the poor moved out of poverty during the period, whereas another 30% in the non-poor category moved into poverty. This suggests that there is continued economic vulnerability of the communities. In general, communities have experienced a decline in social and economic growth over the last 10 years since the last census was undertaken in 1998. In addition, social indicators have not improved significantly in the past several years (Table 2.2). Some of the main factors contributing to poverty include: (i) low levels of education, (ii) ill-health and insufficient access to health service, (ii) inadequate infrastructure, including limited access to markets, (iv) limited employment opportunities, ((v) poor access to credit facilities, (vii) low and/or declining soil fertility, increasing soil erosion hazards and continuous cultivation using inappropriate agricultural technologies with little added external inputs, and (viii) high population density on a limited land resource base, and unequal access to productive resources. However, both the MGDS and the ADP have been formulated to reduce poverty to between 40 and 45% during the period 2006-2011 by creating appropriate opportunities for development, such as liberalization of the economy, creation of new jobs, and increased spending on vital social services, such as education and health, reducing external debt, reducing the inflation rate, and increasing agricultural productivity while conserving the natural resource base.

2.7.4 Sector Profiles

The main sector profiles of focus include the following: (i) high growth sectors, (ii) core sectors of growth, (iii) conserving and protecting natural resources, (iv) social development, and (v) social protection and disaster management.

High growth sectors. The MGDS has identified: (i) tourism, (ii) mining, (iii) manufacturing, (iv) integrated cotton industry, and (v) agro-processing as potential high growth sectors of the Malawi economy for special focus for the period 2006-2011. All these sectors affect and are affected by climate change. Currently these sectors face specific constraints that hinder their ability to produce to their fullest potential. Thus, Government's objective is to address the identified constraints and positively engage the private sector and the international donor community in the implementation of the proposed measures in these sectors of high growth. It is envisaged that in the coming years, Malawi will be established as a principal and leading eco-tourism destination in Africa. Domestic tourism will also be greatly increased. Thus, there is need to increase the capacity to service additional tourists in internationally competitive accommodation, improved transportation links to tourist destinations, increased attractiveness of national parks for tourism and eco-tourism and improved marketing at regional and international levels. Thus, tourism will be promoted to increase productivity, diversify the economy and improve export-led growth, as briefly outlined in Section 2.5.12.

In Malawi, **mining** is a relatively new area but with great potential for growth, especially with the commencement of the mining activities at the Kayelekera Uranium Mine in Karonga district, the production of cement at Shayona in Kasungu, and with the high prospects of mining bauxite on Mulanje Mountain. This will entail increased mining and processing activities by both public and private sector organizations to add value, increase the participation of small, medium and large scale miners. The establishment of an

integrated cotton industry will boost cotton production in all cotton growing areas, especially the Shire Valley and in areas along the Lakeshore plain, and revamp the struggling local cloth manufacturing industry. This will require the development of local textile industries to increase the flow of locally produced cotton from growers and the ginners to manufactures, thereby also opening up textile products for the export markets.

The **manufacturing** of local products, especially agricultural products, will: (i) enhance the quality of consumer goods and the productivity of both labour and machines, (ii) enhance skills through better integration of science and technology into vocational training, (iii) improve the standard of certification capacity in the country, and (iv) develop additional incentives for investment and for supporting institutions. The aim is to increase manufacturing output with growing value addition, export development and employment creation. Currently the manufacturing sector is small, output has stagnated and there is low capacity utilization across all sub-sectors. There are difficulties in accessing markets due to low product quality which normally does not meet international standards, and also due to high costs of inputs and imported parts. The industry is also highly dependant on infrastructure (which is currently poor and inadequate), and is negatively impacted upon by the discretionary system of taxes, rebates and incentives. Finally, **agro-processing**, which includes food processing, has been identified as a high growth potential sector. Activities in this sector will firstly focus on the four key export crops of tea, tobacco, sugar and cotton. This is aimed at increasing the contribution of agro-processing to the value chain of these key cash crops. The agro-processing of fruits and vegetables, rice, cassava, macadamia, cashew nuts, Irish potatoes and spices also has great potential for growth, but each of these is relatively small at the present moment.

Thus, all the activities in the "**high growth sectors**" will directly impact on climate change and climate variability. Increased mining, cotton production and processing, agro-processing and manufacturing emit GHGs into the atmosphere, such as CO_2 and N_2O, so that concurrent with these efforts, strategies and measures for reducing and/or limiting emissions of these gases should be put in place. Increasing tourism and human population will impact directly on all sectors of economic growth, food and water security, and the sustainable livelihoods of family households. Hence, the need to develop coping and adaptation strategies.

Core sectors of growth. The core sectors of growth are in the agriculture sector, the engine of economic growth. These are: (i) tea, (ii) tobacco, and (iii) sugar, which account for more than 90% of Malawi's export earnings. The main thrust in the agriculture sector is to increase smallholder crop and livestock productivity while orientating them to greater commercialization and international competitiveness, opening up of new markets and the provision of demand-driven extension services. The strategy is to enhance both rain-fed and irrigated smallholder agriculture. Of special focus is the promotion of smallholder irrigation using low-input irrigation systems (such as treadle pumps, stream/river diversions and drip irrigation).

This initiative will further be enhanced by the newly promoted **Greenbelt Initiative (GBI)** that is aimed at creating a greenbelt of irrigated maize (and other crops) along the Lakeshore Plain and river valleys starting from Karonga/Chitipa in the north to Nsanje in the south during the dry (winter) season. The implementation of the Malawi GBI will significantly contribute food security and poverty reduction in the country.

In Malawi, **tea** ranks next to tobacco as a major export crop. The aim is to increase tea production, especially clonal tea varieties that are competitive on the world market. The shift to clonal tea varieties reflects the limited prospects for growth from current tea cultivars, and taking advantage of current market demands. The increased production will have to come from increased estate and smallholder production through improvements in production technologies, use of improved and disease and drought tolerant cultivars, and increased investments in the tea industry. Secondly, **tobacco** is the main export crop, accounting for 60-70% of the total export earnings. Despite the world wide anti-smoking campaigns, there is still a huge demand for tobacco and tobacco products on the world market. The main strategy is to increase the production of all tobaccos and the rationalization of fees by creating a more efficient and competitive marketing system between farmers and the buyers, strengthening contract farming and exploring additional markets for tobacco and tobacco products. However, there is need to improve the quality and quantity of tobacco by smallholder farmers. The appropriate strategies to achieve these include the establishment of cooperatives, providing farmers with cheaper farm inputs and better extension services, and the provision of irrigation facilities to ensure early planting. The other constraints to tobacco production that need to be addressed include: widespread use of low quality seed, increased incidences of uncontrolled insect pests and diseases due to inadequate crop rotation, and post-harvest losses due to inadequate tobacco curing barns. In addition, the tobacco industry in Malawi faces regional competition from cheaper tobacco production by her neighbours.

In the past, there has been a decline in tobacco production and the profitability, especially under smallholder farm conditions. However, the most significant step in the tobacco industry in the recent past has been the Government\s strategy of ensuring minimum tobacco prices that take into account the cost of production. Further, Government has extended the Farm Inputs Subsidy Programme (FISP) to include subsidized fertilizer for tobacco production. Through these strategies and initiative, smallholder farmers in Malawi have for the first time in the history of tobacco production been able to sell their tobacco at good and profitable prices, a situation that has directly put money in the pockets of resource-poor tobacco growers, thereby greatly reducing their poverty and significantly contributing to the achievement of the MDGs and MGDS.

Thirdly, **sugar** is the third most important export crop for |Malawi. For sugar to be competitive at the international market, the local sugar industry must be profitable and be able to re-invest in new production technologies and agro-processing of raw sugar and its by-products. The poor linkage of Malawi to the Indian Ocean ports is a major challenge in moving large export volumes in accordance with the timetables of overseas customers. The siltation of the port at Beira is presently at critical levels so that large ships (>20,000 tons) are not able to fully load due to draft problems. Thus, sugar has to be exported through both Beira and Nacala, creating a real and high level threat to market growth and profitability. Freight costs to markets are Malawi's biggest challenge, so that the implementation of the proposed Shire-Zambezi Water Way (SZW) will be one of the most timely initiatives in Malawi's history. **Conserving and protecting natural resources.** Sustained economic growth requires that Malawi conserve her abundant, but limited, natural resources through proper management and utilization. These natural resources include land, soils, water, air, fisheries, forests, wildlife and the natural environment, and have been fully covered in Section 2.5 above. The goal is to improve the management of these natural resources and reduce environmental degradation, while contributing to economic growth and sustainable socio-economic development. However, land, soil, water and environmental degradation are driven by poverty, which reduces the ability of the poor to survive, thus creating more pressure on the environment and encroachment on the limited land resource base, which leads to more natural resource degradation and depletion. Land degradation is exacerbated by poor cultivation practices, lack of proper soil and water conservation practices, including poor water control and harvesting measures. Thus, managing Malawi's natural resources is an essential aspect of environmental sustainability, which does not only consider the management of forestry, fish resources, but also the enforcement and education of environmental standards, and seeks to identify areas, such as eco-tourism, which have a positive spill-over affect on economic sustainability.

Social development. Social development focuses at improving human capital by addressing the negative impacts of diseases, low levels of quality education and low labour productivity. It is through a healthy and educated population that Malawi seeks to achieve and sustain economic growth and realize the MDGs as localized to the Malawi context. The strategy recognizes the interrelated nature of the many social development issues, such as: (i) human health, (ii) education, (iii) HIV/AIDS, (iv) nutrition, and (v) gender, with the overall goal of developing human capital for full participation in the socio-economic growth and development of the country.

The main thrust under **human health** is to increase life expectancy, decrease maternal mortality rates, decrease child morbidity and mortality, including deaths caused by diarrhoea and cholera, especially in children under 5 years of age. However, improving health requires a multi-faceted approach with a combination of preventive, educational and clinical measures. This can be achieved by increasing and retaining a large number of well-qualified health personnel, increasing the availability of drugs, decreasing theft of drugs, improving health facilities, equipment, financial management, monitoring and supervision of health care personnel and facilities. The various health issues are presented in Section 2.8 below.

The emphasis on **education** will be at all the three levels of primary, secondary and tertiary education as follows: (i) primary education: equip students with basic knowledge and skills to enable them to be useful citizens, (ii) secondary: provide the academic basis for gainful employment in the informal, private and public sectors of the economy, and (iii) tertiary education: produce high quality professionals with relevant knowledge and skills in all fields of the educational spectrum. This will be done by reducing absenteeism, increasing net enrolment, reducing dropouts among both boys and girls, improving learning outcomes, and improving curriculum to respond to national needs. Further, this will require improving the quality of teachers, increasing the number of training institutions, and providing good quality learning materials. The importance of education in the socio-economic growth and development of Malawi cannot be overemphasized. Education is the key and cornerstone of all socio-economic development endeavours. However, low and poor educational levels have always been an area of policy concern in the country. What has even been more disturbing is the male-female disparity in literacy levels. Nationally, conservative estimates indicate that only 34% of females aged 5 years and above attend school compared with 54% for the males. There are many factors that are responsible for these low enrolment levels, including the preference of parents to invest more in male than female children. Further, the low level of education, or low literacy levels, among females is one factor that contributes to high total fertility rates (6.7 children per woman). This is because a large number of children offer an attractive alternative form of future socio-economic security and stability. The need to improve the educational standards, as clearly outlined in the MGDS, needs all the attention and urgency it deserves in developing Malawi. The preparation of future national communications requires highly qualified scientists trained up to tertiary level of education.

The main thrust on **HIV and AIDS** is on: (i) preventing the spread, prevalence and incidence of infections, (ii) providing access to treatment for infected people and mitigating the health, socio-economic, and psycho-social impacts on individuals, families, communities and the nation, (iii) decreasing the negative impacts on people living with AIDS and reducing the economic and social consequences for those who care for people living with AIDS, and (iv) ensuring an active and healthy life for all. This will be done through increasing the number of people accessing ARVs, adopting safer reproductive health practices, increasing the number of women accessing the Preventive Mother to Child Transmission (PMTCT) services, promoting high quality community home-based care services, good nutrition, nutrition therapy and building capacity at all levels with special focus on local service delivery. Most of the issues concerning HIV and AIDS are presented in Section 2.8 below.

The focus on **nutrition** will be on the effective utilization and consumption of a variety of high quality and nutritious foods, reduction in the levels of under-nutrition that lead to ill-health and malnutrition, which is a consequence of poverty, reduced incidences of dietary related non-communicable diseases and micro-nutrient disorders. This will be done by: (i) promoting appropriate diet and health lifestyles through education, (ii) promoting the control, prevention and treatment of micro-nutrient deficiency disorders, particularly those caused by vitamin A, iodine and iron, (iii) promoting the control, prevention and treatment of diseases that have direct input on nutrition and health status, (iv) increasing access and availability of services and information to prevent consumers from health hazards, (v) harmonizing and improving food and nutrition security information systems, (vi) reviewing and including nutrition in curricula of all learning and training institutions, (vii) enhancing co-ordination of nutrition programmes, (viii) building capacity for nutrition, dieticians, and community nutrition workers, and (ix) monitoring and managing dietary related non-communicable maladies. Issues dealing with nutrition are intrinsically related to human health and are further briefly presented in Section 2.8 below..

Finally, **t**he overall goal of the social development paradigm is to mainstream **gender** in the national development process to enhance the participation of women and men, girls and boys in all socio-economic development devours. This is because gender issues are an integral part of the overall national development agenda, and it has been recognized that there are gender inequalities in accessing productive resources, development opportunities and decision making processes. Hence, gender must be mainstreamed in sectoral and national development policies and strategies. The key areas of concern include: education and training; reproductive health, HIV and AIDS, food and nutrition security, natural resources management and environment, human rights, and economic empowerment. This will be done by: (i) strengthening the institutional capacity for effective co-ordination of gender policy implementation, (ii) implementation of an affirmative action to increase women and children decision makers in high levels of public and private sector organizations, (iii) lobbying and advocacy to include gender equality provisions in the Constitution, and (iv) breaking the cultural/traditional factors that create and perpetuate gender inequalities. Further details on gender are presented in Section 2.9

Social protection and disaster management. The key critical areas in this regard are: (i) protecting the vulnerable, and (ii) improving disaster risk management. Protecting the most vulnerable groups in the country will require concerted efforts and actions by all Malawians, especially in the following critical areas: (i) caring for the most vulnerable with limited factors of production (specially the malnourished under five children, school going children, orphans, the elderly, pregnant and lactating mothers and destitutes), (ii) preventing the vulnerable from slipping into poverty due to economic shocks, (iii) increasing the assets of the poor to enable them engage in income generating activities, and (iv) preventing disasters where possible, and reducing the negative impacts of disasters of the most vulnerable groups in the country. The thrust will be on protecting the most vulnerable and improving disaster risk management strategies and approaches.

The strategy of **protecting the vulnerable** is designed to ensure that the most vulnerable are cushioned against disasters. This encompasses improved health and nutritional status for the most vulnerable. The strategy will focus at providing efficient and effective support to the most vulnerable through improved planning and integration of knowledge on the needs of the chronically poor, and the provision of opportunities for the poor rural communities to graduate from poverty by facilitating their integration in mainstream agricultural productivity and enabling them to accumulate wealth. The implementation of the Malawi Farm Input Subsidy Programme (FISP) that has provided subsidized farm inputs (fertilizers, seeds and crop protection products) to resource-poor family households throughout the country over the last two years has greatly improved food security status and availability in the country. Further, improved producer prices of various crops, especially tobacco, have directly benefited smallholder farmers, thereby contributing to poverty alleviation and sustainable economic growth and development.

Secondly, **improving disaster risk management** is aimed at reducing the socio-economic impact of disasters on the people, as well as building strong disaster risk management strategies. The key strategy will be to enhance disaster management, planning, and response. Efforts will have to be put in place to promote the integration of disaster risk management into sustainable development planning and programming at all levels. So far, Malawi has experienced a lot of disasters, including floods, droughts, cyclones, landslides and high intensity rainfall. Over the last four decades, these climate-related disasters have increased in frequency and magnitude. Hence, the need for concerted efforts to address these calamities, especially among the most vulnerable resource-poor communities, is more urgent now than at any other time in the past.

2.8 Human and Public Health Profile

2.8.1 Human Health

The human health situation in Malawi has generally continued to decline over the years as indicated by several low health indicators of maternal mortality rate, child mortality rate, child and maternal malnutrition, life expectancy, and access to health facilities over time (Tables 2,2; 2.13). The life expectancy at birth has in the recent past declined to 37 years, mainly as a result of the impact of the HIV and AIDS, and other communicable diseases, such as tuberculosis and diarrhoeal diseases. The infant mortality and child morbidity rates, as indicators of socio-economic development, have remained high at 104 and 189 per 1,000 live births, respectively (MG, 2007). The maternal mortality rate, which reflects access and coverage of maternal health care services, and also as a proxy for general socio-economic conditions and nutrition, is at 984 deaths per 100,000 live births (NSO, 2005a; 2008). This is an increase from a rate of 620 recorded in the previous 10 year period. It is estimated that 49% of children under the age of five years may be clinically malnourished or stunted (NSO 2001; 2008). This poor health situation reveals a socio-economic development situation that is highly vulnerable to any changes in climatic conditions, requiring the implementation of adaptation measures in the health sector.

Table 2.13: Situation analysis of the Human Health Sector in Malawi, 1999- 2006

Selected health indicators	Situation for the period from 1999 to 2008
Crude birth rate per 1,000 population	46
Population growth rate (%)	2.8
Maternal mortality rate per 100,000 live births	984
Antenatal care coverage (%)	91.4
Total HIV positive population (NAC 2003)	700,000-1,000,000
Contraceptive prevalence rate (DHS 2000)	25
Percentage of low birth weight babies	13.1
Children under 5 years chronically malnourished	49
Children 12-23 months fully immunized	70
Immunization: BCG	89.2
Immunization: measles	64.2
Population per physician	101,000
Public health expenditure (PPP/US$) Private/Public	11

Source: NSO, 2001; 2005a; 2008.

Mortality and morbidity. Child mortality and morbidity are mostly caused by preventable diseases, which include malaria, diarrhoeal diseases (e.g., cholera), and acute respiratory infectious diseases (e.g., tuberculosis). The incidence of these diseases is mainly associated with climatic and environmental factors, such as rainfall, temperature and relative humidity, although these are equally diseases that are directly associated with poverty. The HIV and AIDS epidemic also constitute one of the greatest threats to human health. It is presently estimated that between 70,000 to 80,000 children aged under 15 years are infected, and HIV and AIDS related conditions account for over 40% of all in-patient admissions (MG, 2002; 2003). Sexually Transmitted Infections (STIs) are also a major problem closely associated with the spread of HIV and AIDS. Despite concerted efforts by the Ministry of Health and

Population Services (MoHPS) and its partners, tuberculosis, once thought to be on the decline, has of late reportedly increased five-fold in the past five years. However, over the same time, a lot of efforts have been put in place to fight these diseases. Commendable progress has been made, although some of the health indicators still remain among the worst in the world. For example, for every 100,000 live births, 1,120 mothers die due to limited access to quality reproductive and health services, infant mortality and child morbidity are also estimated at 76 and 133, respectively, per 1,000 live births due to malnutrition and limited access to health services. Thus, to address the problems of child and maternal mortality, there is need to: (i) improve access to essential healthcare services (such as integrated management of childhood illness plus immunization, oral re-hydration therapy, antibiotics for diarrhoeal diseases and acute respiratory infections), (ii) increase access to clean water and sanitation, (iii) improve the nutritional status of children and ensure food security, (iv) improve the antenatal care and basic emergency obstetric care, and (v) economic empowerment of women.

Access to health services. Access to health services in Malawi is modest with inadequate and acute shortage of human resources and essential drugs. It is estimated that some 54% of the rural and 84% of the urban population, respectively, access formal health services within a 5-km radius. There are about 617 health facilities in Malawi, out of which 60% are operated by the MoHPS, 25% are managed by the Christian Hospital Association of Malawi (CHAM), and the remaining 15% are operated by private practitioners (MG, 2002). However, there are only 2 doctors, 56 nurses and 58 health providers for every 100,000 inhabitants, respectively, against the World Health Organisation (WHO) recommendation of 20 doctors, 100 nurses and 228 health providers for 100, 000 inhabitants, respectively. About half of the 165 medical doctors working in the country are located in central hospitals located in urban areas, leaving severe shortages in rural areas where nurses are severely lacking with a vacancy rate of more than 60%. The sector fails to retain workers due to low incentives, such as basic salary, long working hours, non-conducive environment and huge workloads, among many others constraints.

HIV and AIDS. HIV and AIDS is a socio, cultural, economic, development and health issue, which has brought havoc to all sectors of the Malawi economy (GOM, 2006). It is a social problem because of its negative consequences on the communities and social structures. It is a cultural issue because some cultural practices and beliefs fuel its spread and encourages discrimination and stigma, thus lobbing the nation of its labour force and negatively impacting on the economic growth and development. It is a political problem because a sick person will not contribute to the political development of the country. It is a health issue because it affects directly a large number of people and the healthcare system itself. HIV and AIDS is an economic issue as it leads to reduction in economic growth by reducing the productivity of the labour force and drains investments in all sectors; and it a development issue because it affects negatively all sectors of economic growth, and finally, it is a health issue because it compromises the immune system and increases the susceptibility of those affected resulting in low food intake, mal-absorption and metabolic alterations.

Thus, HIV and AIDS is eroding decades of development gains, undermining economic progress, threatening food security, and destabilizing sustainable livelihoods of family households. Presently, Malawi has one of the highest HIV infection rates in southern Africa.

Recent estimates by the National AIDS Commission (NAC) indicate infection rates in women attending antenatal clinics varying from 10% in rural areas to nearly 30% in urban areas. The high infection rate of HIV in women of childbearing age suggests that many children are infected at birth. The HIV infection in people aged 15-49 is concentrated in the economically productive younger age groups (15-24 years), particularly women. Most of these HIV infected individuals do not yet know their status. These infection rates seem to continue growing in spite of the apparent high awareness of HIV and AIDS amongst the general population through the Voluntary Testing and Counselling (VTC) programme.

The **impact of HIV and AIDS** infections continues to cause illness and deaths in most of the rural communities, thereby affecting the productivity of all sectors of economic growth. The impact of HIV and AIDS has been experienced through: (i) reduction in labour supply, (ii) changes in land use patterns, (iii) loss of income and workers in sectors of economic growth, (iv) increased food and nutritional insecurity, (v) loss of physical assets and disruption of safety nets, (vi) disruption of social order, (vii) social exclusion and stigmatization, (viii) changes in demographics of the farming communities, and (ix) gender discrimination and disparities.

In **response to the burden of the HIV and AIDS** epidemic on the formal health care system, Government has encouraged communities and households to take up the challenge of providing home-based care and support. At present, public organizations, community-based organizations (CBOs), non-governmental organizations (NGOs), faith based organizations (FBOs) and public and private sector organizations are engaged in various ways of fighting the epidemic, including activities and interventions that seek to mitigate its impact on individuals, families, communities and institutions. This has led to a dramatic increase in the number of community groups providing home-based care as well as an increased number of trained community home-based care providers. In order to institutionalize nutrition and HIV and AIDS activities, the Department of Nutrition and HIV and AIDS was created in the Office of the President and Cabinet (OPC) to coordinate nutrition activities and oversee the HIV and AIDS initiatives. Finally, it is the **role of ARVs**. Over the last five years, Malawi introduced free ARVs to those infected with HIV and AIDS, provided they underwent through Voluntary Testing and Counselling (VCT), and were diagnosed as such. This has had a tremendous impact in that many lives are being saved and HIV and AIDS related deaths have declined considerably. Conservative estimates indicate that about 70% of the people who were diagnosed as HIV positive some five years are still alive to day, whereas as it is only 30% that have died. This may also partially explain why there has probably been a 32% increase of the population from 9.9 million (1998) to 13.1 million (2008), with a population that is growing at the rate of 2.8% per year.

Malaria: The MGDS is tackling malaria through improvement of essential health care services, realizing efficiency gains. It is expected that malaria incidence will decrease while the treatment of malaria will improve. And it is malaria that is highly influenced by climate change, especially increased rainfall and air temperatures, hence climate change.

Nutrition. Nutrition has significant influence on human health and general wellbeing, subsequently on the capacity and productivity of an individual (MG, 2007). Nutrition and its association to health, is paradoxical in the sense that over- and under-nutrition can lead to ill-health. Over- and under-nutrition, usually referred to as malnutrition, is both a cause and a consequence of poverty in developing countries, and continues to retard economic growth and development. While obesity in Malawi is estimated at 25%, especially in urban areas, under-nutrition is a common condition, especially among women and children in rural areas. The effect of under-nutrition is under-weight, stunting and mental retardation, which has far reaching consequences. A poorly nourished body is highly susceptible to infections, such as tuberculosis, malaria, diarrhoea, acute respiratory infections, and to HIV and AIDS.

Under-nutrition is associated with protein energy, micronutrient and iodine deficiencies. Protein energy malnutrition (PEM) is very high with under-five children stunting close to 50%, wasting at 6%, increasing to 9% during the lean periods; and under-weight at 25%. Micro-nutrient malnutrition, such as sub-clinical Vitamin A deficiency, is at 60% for pre-school children, 38% for school age children, 57% for child bearing women, and 38% for men, whereas anaemia is at 80% for pre-school, 22% for school age children, 27% for non-pregnant women, 78% for pregnant women, and 17% for men. Iodine deficiency disorders are also common despite Malawi's adoption of the Salt Iodization Act (SIA) due to porous borders that allow non-iodized salt entry into the country, coupled with weak enforcement mechanisms. Consequently, cretinism is not an uncommon phenomenon. It is estimated that 64% of the children have low Intelligent Quotient (IQ) in areas with iodine deficiency. Coupled with this, the prevalence of dietary related non-communicable diseases, such as hypertension, diabetes, gout, arthritis and cancer, among others, is on the increase (MG, 2007).

The problem of under-nutrition is alarming and is primarily caused by inadequate dietary intake, which is caused by a combination of many underlying factors, including: (i) household food insecurity resulting from inadequate food production and low incomes, (ii) poor child feeding and care practices, (iii) inadequate education and lack of knowledge, leading to poor food processing and utilization, and (iv) some cultural beliefs which limit women and children consuming high nutritive value foods, such as eggs. Infections are also a major cause of under-nutrition. In addition, poor institutional coordination of nutrition programmes has also been a major constraint. Climate change has a great influence in all this.

2.8.2 Public Health and Waste Management

Public health. Public health issues are becoming a major concern, the majority of which are emanating from poor domestic and industrial waste management. In Malawi, wastes are classified in at least four different ways. First, based on their origin: (i) household, (ii) industrial, (iii) commercial, (iv) clinical, (v) municipal, or (vi) agricultural. Second, based on their way in which they exist: (i) liquid, (ii) solid, (iii) powder, or (iv) gaseous. Third, based on their intrinsic properties: (i) toxic, (ii) reactive, (iii) acidic, or (iv) alkaline. Fourth, based on legal description of what wastes are. Such classifications have implications on how wastes can be managed, and it also alludes to its potential magnitude of the effects on the environment, including climate changes. Wastes generated from different sources have different volumes and are therefore handled differently.

Managing waste. The landfill method is often the most used in managing industrial wastes. This is where wastes are dumped on open land or in areas excavated for road construction or quarrying. However, this method has some environmental negative effects because: (i) the leachate from the wastes has potential of polluting groundwater or river water, and (ii) methane gas emissions from the open pit contributes to global warming. Another popular method for managing waste is incineration. This involves the burning of wastes into ashes. This method reduces the volume of the wastes to about 10% of the original size, with no methane emissions into the atmosphere. The bottom ash could be utilized as fertilizer for agricultural purposes, and the method is highly suitable for infectious, volatile and highly flammable wastes. However, the amount of gaseous emissions into the atmosphere, especially CO_2 is quite high (> 90%), which subsequently contributes to global warming, hence climate change.

2.9 Gender

Gender is an integral component of Malawi's overall national development strategy and agenda for sustainable economic growth and development. It is a cross-cutting development issue that needs to be mainstreamed in national and sectoral policies and strategies. However, women, who constitute 51% of the total population, are marginalized in social and economic spheres. Malawi's Gender Development Index (GDI) of 0.374 is a clear indication of the large disparities between men and women, especially in terms of access to and control of productive resources and opportunities for participation in the development process. The abuse of human rights, or gender based violence, is tilted towards women, children and other vulnerable groups, and has accelerated other factors in disfavour of them, such as the spread of sexually transmitted diseases (STDs) and HIV and AIDS.

Thus, the strategy on gender is to implement targeted programs for women, such as business development, to enable them to be part of the socio-economic growth and development paradigm. The strategy should further directly mainstream gender into Government programs and disaggregates information by gender. Climate change and climate variability have undesirable effects on human communities because it negatively impacts on all sectors of economic growth, with resource-poor rural communities being the most vulnerable. However, men and women, in any given community, or socio-economic grouping or setting, are impacted upon differently. For example, women are primarily responsible for collecting water for household use, so that during drought periods, they have to travel long distances to collect water for drinking and domestic use. In addition, the changing demographics, as a result of the impacts of the HIV and AIDS epidemic, have meant that women take up greater responsibilities, such as taking care of the sick and orphans. Thus, there is need to empower women so that they have easy access to water and energy sources by drilling boreholes and planting trees on-farm, woodlots and farm boundaries, and at national level, by making electricity accessible through the Rural Electrification Programme (REP).

2.10 Transfer of Technologies and Funding Mechanisms

This is the information that is considered relevant to the achievement of the United Nations Framework Convention on Climate Change (UNFCCC), especially as it relates to Article 4.8, 4.9 and 4.10 of the Convention. Article 4 is about commitments, and sections 4.8, 4.9 and 4.10 cover funding, insurance and the transfer of technologies. The other relevant information include: (i) education, training and public awareness, (ii) research and systematic observation, (iii) communication, and (iv) scientific and technical research and learning institutions. All these are fully covered in Chapter 6.

2.11 Institutional Arrangements for Climate Change

This is a new activity in the preparation of national communications by Non-Annex I Parties to the COP of the UNFCCC. Thus, this was not included in the Initial National Communication (INC), but will be included in this communication.

2.11.1 Preparing National Communications

Following the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in April 1994, Malawi conducted several studies aimed at fulfilling her obligations under the Convention with funding from GEF through UNDP. This culminated in the preparation and submission of the INC to COP of the UNFCCC in December 2003, and the preparation of several other climate change related documents, including: (i) Research and Systematic Observation in 2005 (EAD, 2005), (ii) Technology Transfer and Needs Assessment in 2003 (EAD, 2003), (iii) National Adaptation Programmes of Action (NAPA) in 2006 (EAD, 2006), and (iv) National Capacity Self-Assessment in 2006 (EAD, 2006). Some of the findings in these reports were not included in the INC. Hence, these, plus the new findings and updates of the INC, will be presented in this document.

2.11.2 Institutional Arrangements

The Malawi Government considers environmental management as an integral component of the food security and poverty reduction paradigm as presented in Chapter 1. The current policies and strategies further recognize the importance of cross-cutting issues, such as climate change, gender and HIV and AIDS, as important components of an over-arching and sustainable development strategy. The Ministry of Lands and Natural Resources (MLNS) is responsible for preparing and implementing environmental policies and relevant legislation.

It comprises an Environmental Directorate, which among other things, is responsible for the preparation and coordination of environmental policy and climate change issues. It is responsible for enforcing any contravention against environmental laws and policies. It is also responsible for giving guidance on environmental issues, and serves as the Secretariat for the National Climate Change Committee (NCCC). In each of the twenty-eight districts in the country, there is an Environmental Officer (EO) who is responsible for coordinating and overseeing environmental issues, and preparing "District State of Environment Reports" that are further consolidated into the "National State of the Environment Report".

In addition, the Department of Physical Planning and Land and Valuation, in the MLNR, is responsible for spatial planning, policy and legislation, administration and management of land and other natural resources issues. The District Assemblies (DA) are well positioned to implement climate change related issues through the District Environmental Office. In addition, the Department of Planning and Development (DPD) are responsible for planning and monitoring developmental activities in each district. The DPD in each district develop implementation plans and monitor progress of such activities in partnership with non-governmental organizations (NGOs) operating in the district, especially those working on environmental issues, such as the Coordination Unit for Rehabilitation of Environment (CURE) and the Wildlife and Environmental Society of Malawi (WESM). In the final analysis, the District Assemblies submit their annual reports to their respective ministries at national level.

The District Environmental Affairs' Office also prepares District Socio-Economic Profiles where issues of the economy, social services with objectives and strategies for developmental activities are outlined. Such activities include those related to fisheries, water, forest, wildlife, agriculture, transport, trade and infrastructure, and the environment. Although these activities do not have clear and explicit programmes on climate change and climate change related issues, the district structure provides opportunities for developing a sound logical framework with narrative summaries, key performance indicators, means of verification with underlying assumptions on climate change mitigation and adaptation measures and strategies.

2.12 Conclusion

Malawi's national circumstances relevant to climate change have highlighted the national development goals, objectives and priorities that are a basis for addressing climate change and its adverse impacts on the various sectors of economic growth, vulnerable communities and fragile agro-ecosystems. However, Malawi's abundant, but finite, natural resources are under threat from exploitation and depletion by an increasing human population of 13.1 m people that is and growing ay the rate of 2.8%, and from unsustainable utilization and management practices by the majority of family households in the country. . Thos, concerted efforts are required to ensure that these finite and limited natural resources are exploited wisely and sustainably to the benefit of all Malawians. All the sectors of economic growth are vulnerable to the adverse impacts of climate change. Thus the needed to develop adaptation measures for the sectors that are threatened at present is most appropriate in the face of changing climatic conditions in the future. It is also clear that although the amounts of GHGs emitted by these sectors is small at global level, Malawi still needs to be put in place and measures for reducing GHG emissions the various sectors, especially Agriculture, Energy, Forest and Other Land-Use, Industrial Processes and Product Use, and Waste Management, which contribute GHGs than other sectors at national level. .The case to protect the natural resources and their sustainable utilisation is quite clear.

APPENDICES

Appendix 1: Table A2.1: Environmental characteristics of Malawi

Agro-ecological zone	Altitude (m asl)	Land form	Soils	Vegetation	Typical areas
• **The High Altitude Plateaus**	1,350 3,000 mainly above 1,800 m asl)	Gentle to moderate slopes bounded by scarps or deeply dissected zones on all sides	Lithosols	Montane grassland with evergreen forest remnants	• Nyika and Viphya . • Dedza and Changoni and the Kirk Range • Mulanje and Zomba p
• **The High Altitude Hills**	1,200 – 1,800 m asl	This comprises all steeply sloping which rises above the medium Altitude plateau	Shallow stony soils , but some areas, such as Misuku, Nchenachena, Livingstonia, Dowa and Dedza hills have areas of deep soils suitable for agriculture	*Brachystegia* woodland	Represented throughout the country, but mostly in northern and central Malawi, and include Misuku, Nchenachena, Livingstonia, Dowa and Dedza hills
• **The Medium Altitude Plateau (also known as the Central African Plateau)**	750 and 1,350, mainly between 1,000 to 1,300 m asl, although they are partly down warped to 600 m asl in the south	Level crests and gently sloping sides leading down to broad valleys	Latosols hydromorphic soil	*Brachystegia* plateau woodland, |Combretum-Acacia-Bauhimia woodland and grassland associated with the broad valleys (dambos)	• Mzimba and Chitipa • Liongwe- Mchinji-Kasungu plain • Chilwa/Phalombe plain, Shire Highlands, and Namwera plateau
• **The Rift Valley Escarpment**	500-1,200 m asl	Hilly country, associated with rift faulting and has a predominance of steep slopes escarpment	Stony soils	*Brachystegia* hill woodland mixed with low-altitude woodland savanna on the foothills. It varies in width from 3-30 km,	This stretches throughout the country
• **The Lakeshore Plain**	450 and 600 m	Comprises erosional landforms (dissected plains, piedmont zones, raised bench remnants) and depositional land forms of alluvial deposits	calcimorphic alluvial soils	*Acacia-Adansonia-Hyphaene-Sterculia savanna and Cobretum* thicket, with Brachystegia woodland in higher rainfall areas.	Bwanje Valley
• **The Shire Valley**	• Upper shire Valley • Middle Shire valley • Lower Shire valley (30-150 m asl)	• Upper shire Valley (depositional landform similar to lakeshore plain)	• Upper shire Valley • Middle Shire valley • Lower Shire valley calcimorphic alluvial	Low altitude savanna similar to the lakeshore plain, including Mopane woodland	• Upper shire Valley • Middle Shire valley • Lower Shire valley (Ndindi and Elephant

		• Middle Shire Valley (a belt of broken country through which the Shire river drops by a series of falls and rapids) • Lower Shire valley (depositional and flat. includes Ndindi and Elephant marshes).	soils, vertisols, and some hydromorphic		marshes).)

Source: DARS, 1962, Young, 1072

Appendix 2: Table A2.2: Occurrence, mineralogy, chemical, and fertility status of Malawi soils

Soil type	Occurrence	Soil pH	%BS	CEC (me%)	Clay minerals	Fertility status
Ferruginous Latosols [Good correlation: Chromic Luvisols; Chromic Cambisols] Limited correlation [Luvic Phaeozems]	Ekwendeni Area, Lilongwe Plain, Dedza Hills, Shire Highlands, Ntchisi-Dowa Hills, Kirk Range	5.0-5.5; acid to moderately acid	50-60	4-10	1:1 kaolinite and halloysite; Fe and Al oxides; some 2:1 weatherable minerals	Moderate to high fertility
Ferrisols [Limited correlation: Cambisols; Acrisols; Nitosols; Perric Phaeozems]	Mulanje, Nkhata Bay, Thyolo,	4.0-5.0; strongly acid to acid	20-40	2-5	1:1 kaolinite and halloysite; Fe and Al oxides; some	Low fertility
Ferallitic Latosols [Good correlation: Humic Acrisols;Ferralic Arensols and Gleyic Lixisols; Limited correlation: Haplic Lixisols; Ferralic Cambisols; Haplic Ferralsosls; Umbric Cambisols; Gleyic Cambisols	Southwest Mzimba and Kasungu Plains, Mchinji, Central Dedza, Shire Highlands	4.5-5.5; Acid to weakly acid	30-50	3-8	1:1 kaolinite and halloysite; Fe and Al oxides; some	Low fertility
Calcimorphic Alluvial	Lower Shire Valley, Phalombe, Bwanje and Lakeshore Plain	6.5-8.5; Near neutral to alkaline	90-100	10-25	2:1 illites and micas	Moderate to high fertility
Hydromorphic Soils [Good correlation: Gleysols]	Dambos and other seasonally water-logged sites throughout the country	6.0-7.5; Near neutral to alkaline	80-100	13-20	2:1 illites and micas	High fertility, but with poor site drainage
Lithosols [Good correlation: Leptisols; Lithic; Limiited correlation: Cambisols; Regosols; Phaeozems]	High Altitude Hills and Mountains	4.5-5.9; Acid to weakly acid	70-90	4-10	1:1 kaolinite and halloysite; 2:1 illites; Fe and Al oxides;	Low soil fertility
Vertisols	Shire Valley	7.0-8.5; Neutral to alkaline	100	25-40	2:1 montimorillonitic clays	High fertility, but poor rainfall

Note : Soil pH - Soil reaction; BS - %Base saturation; CEC - %Cation exchange capacity
Source: Brown and Young, 1962; Young and Brown 1865; M.W.Lowole (Soil Surveyor; personal communication, 2007).

Chapter 3:
Greenhouse Gas Emissions for the Period 1995-2000

3.1 Introduction

The contribution of global greenhouse gas (GHG) emissions by African countries is very small, estimated at a meagre 3%. However, Africa is rated as the most vulnerable continent on Earth to the adverse and negative impacts of climate change because of widespread poverty and low levels of adaptive capacity. Malawi is already experiencing severe adverse effects of climate change, especially as manifested through the recurrent frequent droughts and devastating floods, despite the fact that the levels of GHGs that it emits are quite low. However, as a Least Developed Country (LDC), Malawi is not obliged to reduce her levels of GHG emissions at the expense of her emerging economic growth and development. Nevertheless, as a signatory to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), Malawi is keen to join the international community in undertaking positive and concrete steps to reduce GHG emissions from various sectors of economic growth and development.

Further, as a Party to the COP of the UNFCCC, Malawi is obliged under Article 4.1 (a) to "develop, periodically update, publish and make available to the COP in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol using comparable methodologies agreed upon by the COP". Following this obligation, Malawi prepared its first GHG Inventory under the United States of America (USA) Country Studies Program using 1990 as the base year. This was later followed by the second GHG Inventory with funding from the Global Environment Facility/United/Nations Development Programme (GEF/UNDP) using 1994 as the base year. The GHG sectoral emissions from these studies are presented in Appendix 1(Table A3.1) and Appendix 2 (Table A3.2), which clearly shows that Malawi was a net emitter of carbon dioxide (CO_2). The sectors which emitted most of the GHGs are the Forestry and Land-use Change and Energy. It is the Forestry and Land-Use Change Sector that was the only carbon sink.

Based on these findings, and the current trends in Malawi's socio-economic development agenda, the following five sectors were considered for the current GHG Inventory: (i) Energy, (ii) Agriculture, (iii) Forestry, (iv) Industrial Processes, and (v) Waste Management. However, since this study has employed the 2006 IPCC Guidelines, these sectors have been re-arranged into following four sectors: (i) Energy, (ii) Agriculture, Forestry and Other Land-use (AFOLU), (iii) Industrial Processes and Other Product Use (IPPU), and (iv) Waste Management. The main re-grouping has been the combining of the agriculture and forestry sectors and adding the other product use to the Industrial Processes Sector. As was the case in the previous GHG inventories, the following greenhouse gases (GHGs) were estimated from the four sectors: (i) carbon dioxide (CO_2), (ii) carbon monoxide (CO), (iii) methane (CH_4), (iv) nitrous oxide (N_2O), and (iv) the oxides of nitrogen (NO_X). The present GHG Inventory, which has used the year 2006 as its base year, has been prepared as a contribution to Malawi's Second National Communication (SNC) to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC). Malawi communicated its Initial National Communication (INC) to the COP of the UNFCCC in December 2003.

3.2 General Approach and Methodology

A team of ten National Experts (NEs), from the fields of energy, agriculture, forestry, environment, industrial processes and waste management was commissioned to prepare the GHG Inventory in the four identified sectors. These were coordinated and directed by the GHG Inventory National Team Leader (NTL) under the overall guidance and supervision of the Project Manager (PM). Participatory research and extension approaches were employed to solicit and gather information from individuals and institutions in different public and private sector organizations. The activities included: (i) desk studies to review the literature, including earlier GHG Inventory reports for the base years 1990 and 1994, various UNFCCC/IPCC documents on energy and the 2006 IPCC GHG Inventory Manual, (ii) identification of appropriate levels of the methodologies, (iii) data collection using formal and informal surveys, focused group discussions and interviews, including the collection of emission factors and activity data that were adopted from the IPCC Reference Manual and the Gerald Leach and Marcia Gowen's Household Energy Handbook, (iv) data analysis, (v) data presentation using appropriate graphics and tables, and (vi) preparation of sectoral reports. The sectoral reports were synthesized by the GHG National Team Leader (NTL) to produce the GHG Thematic Area Report. It is the GHG Thematic Area Report that was further synthesized to produce this Chapter. What follows are the specific approaches and methodologies used in specific sectors, and the findings for the 2000 GHG Inventory.

3.3 Energy Sector

The Energy Sector plays an important role in the socio-economic growth and development of the country. It is the backbone of the mining and manufacturing industries, power generation, agriculture production, transportation and various industrial and domestic enterprises. Through these activities, the sector contributes significantly to GHG emissions. Most of the GHGs arise from: the combustion of liquid and solid fossil fuels, combustion of biomass and fugitive emissions.

3.3.1 Source Category Emissions

The GHG emissions were determined from the following source categories or sub-sectors: (i) the combustion of liquid fossil fuels in the transportation sub-sector (road, rail, marine and aviation), (ii) combustion of solid fossil fuels (industrial heating and steam generation), (iii) combustion of biomass, and (iv) fugitive emissions from fuels and coal mining. Biomass accounts for over 90% of the fuel supply and is used for cooking, water heating and sometimes steam generation. Biomass is mainly used in the form of firewood, charcoal, crop residues and agro-industrial wastes. .Fugitive emissions are defined as GHGs emissions that are released during extraction, processing and delivery of fossil fuels to the point of use. For Malawi, the relevant sub-sector or source category is the surface mining of coal from Mchenga Coal Mine in Rumphi district.

3.3.2 Methodology

Fuel combustion. In the fuel combustion category, GHGs were determined from the following: (i) liquid fossil fuels: (a) motor gasoline (petrol) used in road transport, (b) aviation gasoline used in the aviation sub-sector, (c) jet gasoline used in the aviation sub-sector, (d) jet kerosene (paraffin) used in the aviation sub-sector, (e) other kerosene used in households, (f) gas and diesel oil used in road transport, and (g) liquefied petroleum gas (LPG) used for cooking in public and private institutions, including family households, (ii) solid fossil fuels, which cover coal that is used for steam generation in manufacturing industries. The methodology outlined in the 2006 IPCC Guidelines was used to determine the GHGs in this source category. The approach used was the IPCC Reference Approach (top-down methodology) owing to the non-availability of a comprehensive data base in the Energy Sector. Finally, although the 2006 IPCC Guidelines recommends the determination of CO_2 emissions from the injection and geological storage, this sub-sector is presently not applicable to the Malawi situation.

3.3.3 Results and Findings

Carbon dioxide (CO_2) emissions. The total CO_2 emissions from the Energy Sector for the period 1995-2000 by source category are presented in Table 3.1.

Table 3.1: CO_2 emissions from different source categories in the Energy Sector, 1995-2000

Sub-sectors	Year					
	1995	1996	1997	1998	1999	2000
Motor gasoline	199.7961	205.0338	222.5320	236.7364	229.0157	189.9797
Aviation gasoline	0.0000	0.0000	0.5432	0.5439	0.5348	0.4340
Jet gasoline	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jet kerosene	2.7642	2.7957	24.9228	24.1191	3.8059	21.9712
Other kerosene	88.0825	85.5315	52.1397	71.3155	114.4626	79.0332
Gas/diesel oil	340.9593	349.7957	309.5691	326.1022	319.2221	302.0286
LGP	2.0375	2.0968	2.0539	2.3852	2.2558	2.5783
Lubricants	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sub-bituminous coal	109.2369	107.1611	195.9277	182.0701	112.5331	130.1059
Total	724.8764	752.4146	8076884	843.2724	781.8301	726.1310

The total amounts of CO_2 emissions increased steadily from 724.9 Gg in 1995 to a maximum of 843.3 Gg in 1998 then decreased steadily to 726.13 Gg in 2000, as illustrated in Fig 3.1. This increasing and decreasing trend can conveniently be described by the following quadratic equation:

$$Y = 12.92 x^2 + 116.4 x + 551.98 \quad [3.1]$$

Where:
Y= CO_2 emissions (Gg)
x = time (year)

The three main source categories responsible for the bulk of GHGs emissions in the Energy Sector are: (i) gasoline and diesel, (ii) motor gasoline, and (iii) sub-bituminous coal. These are distantly followed by kerosene (paraffin), which is mostly used in the aviation industry and for domestic cooking and lighting. The total sub-sectoral contributions of GHG emissions (CO_2 equivalent) are given in Table 3.2. These exhibit a steady increase of 1937.86 Gg from 1996 to a maximum 2124.05 Gg in 1997 and thereafter a decrease to 871.50 Gg in 2000. The main contributors to the observed GHG emissions are the biomass and the liquid fossil fuels. These are followed by the solid fossil fuels, whereas the contribution from fugitive emission sub-sector, as expected, is negligible. Of all the source category emissions from the combustion of fossil fuels, diesel contributed cumulatively 41%, followed by motor gasoline 27.6%, and then coal 18% (Fig 3.2).

Thus, all the mobile sources combined contributed some 68.7% of the total emissions. The above analysis emphasizes the significance of the carbon dioxide emissions from the motor vehicles and non-CO_2 emissions from biomass combustion activities. With the number of vehicles increasing on the roads of Malawi, CO_2 emissions from the transport sub-sector will continue to increase unabatedly. It is now time for Malawi to institute measures for reducing CO_2 emissions from the transport sub-sector through appropriate legislation that must be complied with by all operators.

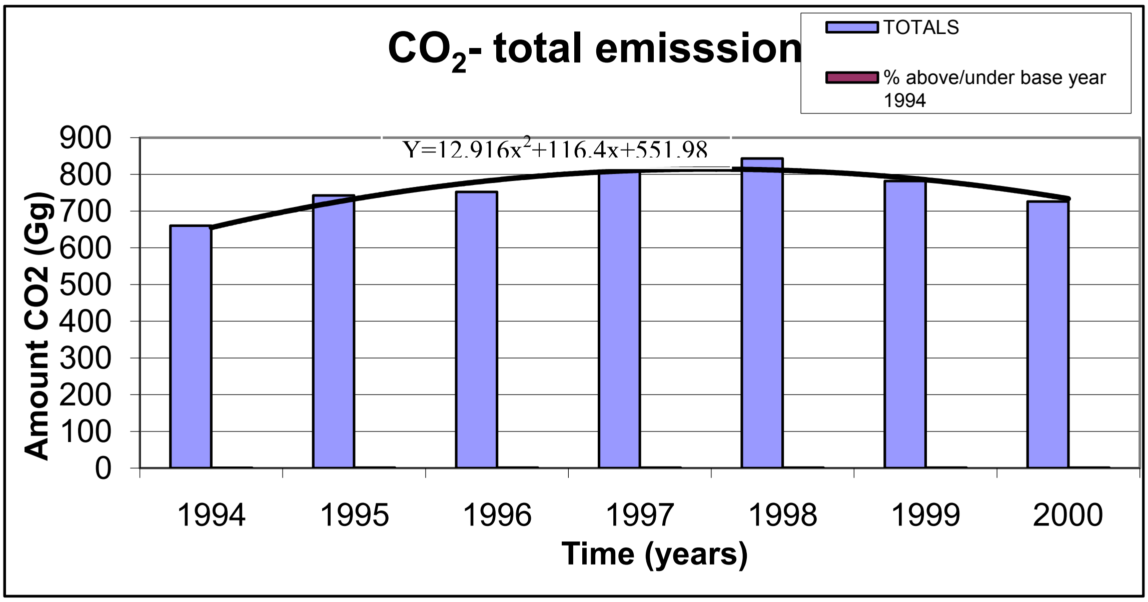


Fig 3.1: Total amounts of greenhouse gas emissions in the Energy Sector, 1994-2000

Table 3.2: Sectoral emissions of carbon dioxide (CO_2) from different sub-sectors, 1995-2000

Sub-sector	Year					
	1995	1996	1997	1998	1999	2000
Liquid fossil fuel	633.48	645.25	611.76	661.2	669.3	596.02
Solid fossil fuel	109.24	107.16	195.93	182.07	112.53	130.11
Biomass	1194.57	1185.58	1315.34	1117.02	845.42	1144.69
Fugitive emissions	0.57	0.57	1.02	0.95	0.58	0.68
Total	1937.86	1938.56	2124.05	1961.24	1627.83	1871.50

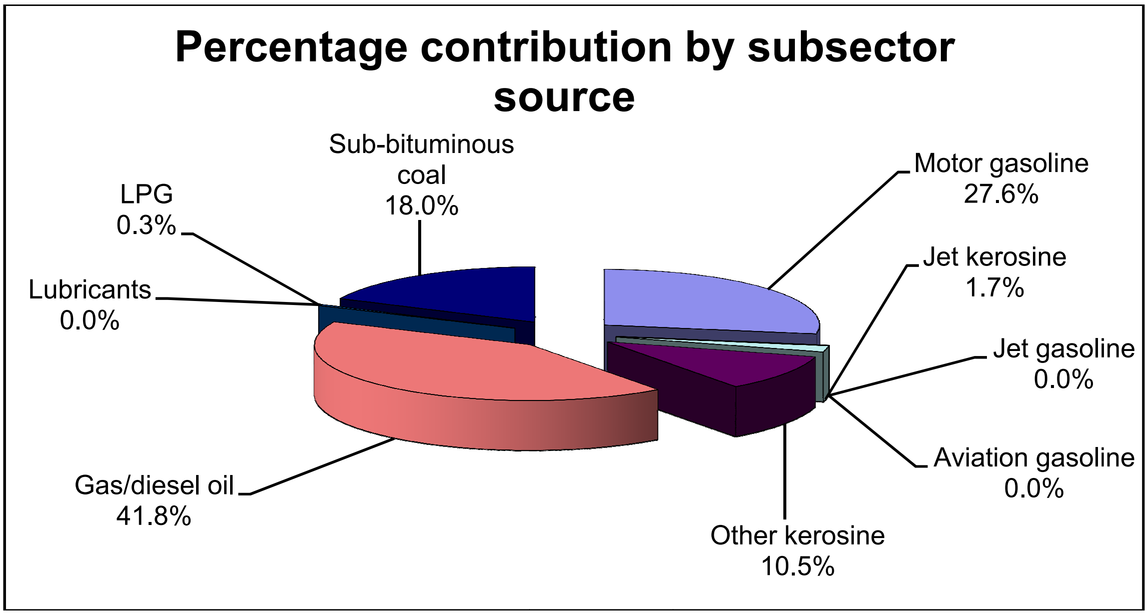


Fig 3.2: Greenhouse gas emission contributions from different sub-sectors in the Energy Sector, 1994-2000

Methane (CH_4) emissions. Table 3.3 presents methane (CH_4) emissions from different source categories in the Energy Sector from 1995 to 2000.

Table 3.3: CH_4 emissions from different source categories in the Energy Sector, 1995-2000

Sub-sectors	Year					
	1995	1996	1997	1998	1999	2000
Motor gasoline	0.00860	0.00890	0.00960	0.01020	0.00070	0.00850
Aviation gasoline	0.00000	0.00000	0.00002	0.00002	0.00000	0.00002
Jet gasoline	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Jet kerosene	0.00012	0.00012	0.00105	0.00101	0.00001	0.00092
Other kerosene	0.00368	0.00357	0.01218	0..00298	0.00034	0.00330
Gas/diesel oil	0.01380	0.01416	0.01253	0.01320	0.00096	0.01223
LGP	0.00003	0.00003	0.00003	0.00004	0.00000	0.00004
Lubricants	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sub-bituminous coal	0.00114	0.00112	0.00204	0.00189	0.00011	0.00135
Biomass	19.08666	18.94131	21.02391	17.84648	22.24778	5.27371
Fugitive emissions	0.02465	0.02464	0.04423	0.04109	0.02540	0.02936
Total	1913872	1899382	2109562	1791697	227530	5321916

If we exclude biomass combustion, which accounts for over 99% of the CH_4 emissions, the trend of emissions is similar to that reported for CO_2, i.e., the emissions steadily increased from 1995 to 1998 and thereafter decreased steadily up the year 2000. In general, the quantities of CH_4 produced are comparatively smaller than those of CO_2. However, CH_4 has a higher Global Warming Potential (GWP) of 24.4 compared with that of CO_2, which is 1. Hence, CH4 contributes quite a lot more to global warming in relative terms. The fugitive emissions of CH_4 were released from surface mining and handling operations. These emissions are depicted in Table 3.4. These exhibit an increasing trend from 0.0247 Gg in 1995 to a maximum of 0.0442 Gg in 1997, and thereafter decreasing trend to 0.0294 in 2000.

Table 3.4: Total fugitive emissions of methane (CH_4) gas from the Energy Sector, 1995-2000

Year	Methane emissions over a period of five years	
	Total methane emission (G t)	Total CO_2 equivalent (G t)
1995	0.0247	0.5669
1996	0.0246	0.56672
1997	0.0442	1.01729
1998	0.0411	0.94507
1999	0.0254	0.58420
2000	0.0294	0.67528

Nitrous oxide (N_2O) emissions. Table 3.5 shows the various fossil fuel source categories that contributed to the emissions of nitrous oxide (N_2O) in the Energy Sector from 1995 to 2000. These results exhibit a similar trend to those of CH_4 gas emissions. Similarly, when biomass, which accounts for over 99% of N_2O emissions is excluded, the trend is similar to that of CO_2 emissions as well, i.e., the emissions increase steadily from 1995 to 1998 and thereafter decrease up to the year 2000. In general, the quantities of N_2O produced are comparatively smaller than those of CO_2. However, N_2O has a GWP of 320, which means that its warming potential is 320 times higher than that of CO_2, hence it is more potent in warming the atmosphere. These results indicate that the GHG emissions in the Energy Sector are generally on the decline. However, to ensure economic growth and development, Malawi has for the next five years vowed to implement the MGDS, which places a lot of emphasis on mining and manufacturing, agro-processing, and the growing of more high value cash crops. Coupled with this, will be the increasing number of vehicles on the road. All these will add significant quantities of GHGs into the atmosphere. It is for this reason that Malawi should prepare to institute strategies and measures that are aimed at reducing GHGs or capturing CO_2 in the atmosphere.

Table 3.5: N_2O emissions from different sub-sectors in the Energy Sector, 1894-2000

Sub-sectors	Year					
	1995	1996	1997	1998	1999	2000
Motor gasoline	0.00173	0.00178	0.00193	0.00205	0.00198	0.00011
Aviation gasoline	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Jet gasoline	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Jet kerosene	0.00002	0.00002	0.00021	0.00020	0.00003	0.00001
Other kerosene	0.00074	0.00071	0.00044	0.00060	0.00096	0.00005
Gas/diesel oil	0.00276	0.00283	0.00251	0.00264	0.00258	0.00018
LPG	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Lubricants	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sub-bituminous coal	0.00171	0.00167	0.00306	0.00284	0.00176	0.00020

Biomass	2.54496	2.52557	2.80324	2.37956	2.67602	0.07876
Total	2.55191	2.53259	2.81139	2.38790	2.68334	0.07931

Further, there were some challenges that were encountered during the preparation of the Energy Sector Inventory. The most critical ones were the non-availability of a comprehensive data base and lack of local emission factors and activity data for use in making the various GHG estimations. These are the two critical issues that need to be addressed before the commencement of the Third National Communication (TNC) of Malawi. Further, the sector is facing an increasing threat from an increasing importation of second hand vehicles and used tyres from Europe, the Middle East and the Far East. The reduction of GHGs emissions from mobile sources is perhaps the greatest challenge that is facing Malawi today, but can also be controlled through the application and implementation of appropriate legislation. Thus, there is need to designate one public institution, such as the DoEA, to coordinate energy data collection and storage in formats that are user-friendly in the estimation of GHGs, and the implementation of research activities aimed at determining emission factors and activity data.

3.4 Industrial Processes and Product Use Sector

At global level, the Industrial Processes and Product Use (IPPU) Sector is one of the main non-energy contributors to GHG concentrations in the atmosphere. For most developing countries, including Malawi, whose economies are dependent on the production and sale of primary agricultural products, the industrial sector is generally very small and contributes very little to the total GHG emissions. The scope of the GHG inventory in the IPPU Sector, as outlined in 2006 IPCC Manual, covers the following categories or sub-sectors: (i) 2A mineral industry, (ii) 2B chemical industry, (iii) 2C metal industry, (iv) 2D: non-energy products from fuels and solvent use, (v) 2E electronics industry, (vi) 2F product use as substitutes of ozone depleting substances, (vii) 2G other product use and manufacture, and (viii) 2H other. However, the sub-sectors that are relevant to the Malawi context are: (i) 2A mineral industry: 2A1: cement production and 2A2: lime production, (ii) 2D non-energy products from fuels and solvents use, 2D: lubricant use, (iii) 2F product use as substitutes of ozone depleting substances: 2F6: other applications, (iv) 2H: other: 2H2 food and beverage industry.

3.4.1 Source Category Emissions

Greenhouse gas (GHG) emissions will be estimated from the following sources categories: (i) CO_2 emissions from cement and lime production, (ii) CO_2 emissions from ethanol production, (iii) CO_2 and CH_4 emissions from biogas digesters, (iv) CO_2 and N_2O emissions from fertilizer production, (v) non-methane volatile organic compounds (NMVOC) emissions from paints and solvents, and (vi) CO_2 and NMVOC emissions from the use of lubricants, substitutes of ozone depleting substances and the food and beverage industry.

CO_2 emissions from cement and lime production. Cement production is probably the most notable industrial process that is responsible for the emission of large quantities of CO_2. There are two cement factories in Malawi: (i) LaFarge Portland Cement Company (since the

1960s), and (ii) Shayona Cement Company (since 1999). One of the major steps in the cement manufacturing process involves the burning of limestone at high temperatures, a process through which clinker is formed as summarized in the equation below (Equation 3.1).

$$\underset{\text{Limestone}}{CaCO_3} \xrightarrow{\text{Heat}} \underset{\text{Lime/clinker}}{CaO} + \underset{\text{Carbon dioxide}}{CO_2} \quad \text{......} \quad [3.1]$$

The process of making lime is exactly the same as that for making clinker. The net effect of this is the release of large quantities of CO_2 from these two processes into the atmosphere.

CO_2 emissions from ethanol production. Ethanol (CH_3CH_2OH) belongs to the family of organic compounds known as alcohols. It is produced by micro-organisms through the fermentation of sugars and their by-products, grains and their products (starch, malt) and cellulose. In the case of Malawi, the raw material used in the production of ethanol is molasses, which is a by-product from sugar processing industry. This approach is preferred as the disposal of molasses is in itself an environmental concern. Micro-organisms break down sugars to obtain energy, and in the process, release CO_2 and ethanol as by-products. The actual fermentation of molasses to produce ethanol is a two-step process: (i) the micro-organisms reduce the molasses (sucrose) to simple sugars (glucose), and (ii) the simple sugars are further broken down and in the process release of CO_2 and ethanol, as summarised in Equations 3.2 and 3.3.

$$\text{Molasses} \rightarrow \text{Simple sugars} \rightarrow \text{Alcohol + Carbon dioxide} \quad \text{......} \quad [3.2]$$

$$\underset{\text{Molasses}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{2\ C_6H_{12}O_6}$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{zymase}} \underset{\text{Ethanol}}{2\ CH_3CH_2OH} + \underset{\text{Carbon dioxide}}{2\ CO_2} \quad \text{......} \quad [3.3]$$

These were meant to utilize the by-products of the ethanol production process to generate biogas, which could in turn be used as a source of energy to run the plant. Unfortunately, the plant never really developed from the experimental stage and was eventually decommissioned.

CO_2 and CH_4 emissions from biogas digesters. A few biogas digesters have been installed in Malawi, although presently only a limited number of these are functioning. A major undertaking was the installation of two bio-reactors (4,000 cubic metres each), at the Dwangwa Ethanol Plant in Nkhota Kota . These were meant to utilize the by-products of the ethanol production process to generate biogas, which could in turn be used as a source of energy to run the plant. Unfortunately, the plant never really developed from the experimental stage and was eventually decommissioned.

CO_2 and N_2O emissions from fertilizer production. There are two fertilizer manufacturing companies in Malawi: (i) Optichem Malawi (2000) Limited at Ginnery Corner in Blantyre City, and (ii) the Malawi Fertilizer Company (MFC) at Liwonde in Machinga district. The Optichem factory has the capacity to granulate fertilizers, but has presently discontinued this activity, and is instead only blending compound fertilizers from high analysis fertilizers. Similarly, MFC has blending facilities only. Hence, the CO_2 emissions from fertilizer plants, is virtually negligible. However, plans are currently underway to commence fertilizer manufacturing in Lilongwe using locally available raw minerals, such as rock phosphate. This is because in the absence of commercially exploitable minerals, apart from uranium, Malawi will continue to rely on imported fertilizers for rain-fed agriculture, upon which the economy of the country depends.

GHG emissions from paint and solvent production. Malawi has several paint manufacturing plants, including Plascon Malawi, Dulax, Crown Paints, and Spectrum Paints, among many others. The manufacturing of paints and solvents releases GHGs into the atmosphere, especially CO_2.

GHG emissions from the use of lubricants, substitutes of ozone depleting substances and the food and beverage industry. Malawi has several industries that are involved in: (i) the use and manufacture of lubricants, (ii) use of appliances containing ozone depleting substances (although efforts are under way to phase these out), and (iii) operating restaurants and breweries (such as Malawi Carlsberg Brewery Limited, Malawi Distilleries Limited, and Chibuku Breweries Limited), which all emit some GHGs into the atmosphere. However, these GHGs were not estimated in this study due to lack of data on the exact amounts of oils and lubricants imported in the country, insufficient data on the production of food and beverages, and lack of data and information on the use of non-ozone depleting substances (ODS) that have replaced the ODS. This was further compounded by the fact that Malawi's subsidiary legislation on the replacement of ODS came into force in January 1998 and the compilation of the substitutes only commenced in 2004, which is beyond the baseline year of 2000.

3.4.2 Methodology

The methods for the determination of CO_2, CH_4 and N_2O in the various sub-sectors of the Industrial Processes and Product Use Sector, as outlined and recommended by IPCC, were used in this study (IPCC, 1995; 1996, 2006).

CO_2 emissions from lime and cement production. **The CO_2 emissions from lime and cement production are computed using Equation 3.4. :**

*C*OE = P x EF ………………………………………………….,………………………… [3.4]
Where:
COE = CO_2 emission
P = Production volume
EF = Emission factor
NB: the IPCC default emission factor of 0.5071 was used for clinker, and 0.4985 for cement.

The data on cement production, for the period 1995-2000, that were used to compute CO_2 emissions were obtained from the Portland Cement Company (which is now called Lefarge Cement Company Limited) and the Department of Mines (DoM).

CO_2 emissions from ethanol production. The equivalent CO_2 emitted from the sector was computed using the 1995-2000 ethanol production data obtained from the Sugar Corporation of Malawi (SUCOMA) now renamed ILLOVO at Nchalo in Chikwawa district, and Dwangwa Sugar Corporation (DWASCO) at Dwangwa in Nkhota Kota district. Unfortunately, the IPCC does not specify a methodology for this process. Nonetheless, computations were done using Equations 3.5 and 3.6:

Ethanol production for the period 1995-2000 (t) = (volume in litre x specific gravity) /1000 ……. …[3.5]

Mass of CO_2 emitted (t) = (molar weight of CO_2}/ (molar weight of CH_3CH_2OH) x volume of ethanol (t) …………………………………………………………………………………………………….
[3.6]

Alternatively, the amount of CO_2 released can be estimated from the total tonnage of molasses. According to Clancy (1996), one tonne of molasses produces 280 kg of ethanol. The total amount of molasses used for ethanol production between 1995 and 2000 is 298,514 tonnes. The maximum ethanol yield= 28% x tonnage of molasses (1995-2000) = 83,583 tonnes. Hence, the maximum CO_2 yield = 44/46 x 83,583 tonnes = 79,950 tonnes; which is equivalent to 79.95 Gg of CO_2

CO_2 and CH_4 emissions from biogas digesters. The methodologies described in the 1996 IPCC and 2006 Guidelines were employed. Data on molasses production were collected from Dwangwa and Nchalo Sugar Estates.

CO_2 and N_2O emissions from fertilizer production. Since the major activity in the fertilizer manufacturing industry is blending of high analysis fertilizers to make compound fertilizers, no attempt was made to determine GHG emissions from this source category.

GHG emissions from paints and solvents. The 1996 and 2006 IPCC methodologies were employed in estimating GHG emissions from paints and solvents. Data on total paint and solvent production were obtained from paint manufacturing companies in the country.

3.4.3 Results and Findings

CO_2 emissions from lime and cement production. The amount of CO_2 emitted from lime production dropped from 0.507 Gg in 1995 to 0.128 Gg in 1996, but increased steadily up to

3.132 Gg in the year 2000 (Table 3.6). This reflects an increasing production of lime, hence increasing CO_2 emissions, over the years.

Table 3.6: Carbon dioxide (CO_2) emissions from lime production, 1993-2000

Year	Amount of lime produced (t)	Emission factor (CO_2/t of lime produced)	CO_2 emitted (t)	CO_2 emitted (Gg)
1995	1000	0.5071	507	0.507
1996	252	0.5071	128	0.128
1997	1060	0.5071	538	0.538
1998	1445	0.5071	733	0.733
1999	3100	0.5071	1572	1.572
2000	6177	0.5071	3132	3.132

The CO_2 emissions from cement production decreased from 59.022 Gg in 1995 to 37.388 Gg in 1997. However between 1997 and 2000, there was a linear increase up to 56.081 Gg in the year 2000 (Table 3.7). Thus, a total 59.213 Gg of CO_2 were emitted from cement and lime production in the year 2000.

Table 3.7: Carbon dioxide (CO_2) emissions from cement production, 1994-2000

Year	Cement produced (t) [A]	Emission factor (CO_2/t cement produced [B]	CO_2 emitted (t) [C=AxB]	CO_2 emitted (Gg) [D=C/100]
1995	118400	0.4985	59022	59.022
1996	93200	0.4985	46460	46.460
1997	75000	0.4985	37388	37.388
1998	94900	0.4985	47308	47.308
1999	111800	0.4985	55732	55.732
2000	112500	0.4985	56081	56.081

The CO_2 emissions from cement and lime production (Gg) in 1994 and 2000 are compared in Table 3.8. The 2000 production figures show that there was a slight decrease of 0.94% in the CO_2 emission from the cement industry. This can be attributed to the declining production capacity of limestone at the Changalume cement factory. During this period, the high demand for cement in the country was partly met by imports from Zambia, Zimbabwe and Tanzania. There was a 78% CO_2 emissions increase from lime production from 1.76 Gg in 1994 to 3.13 Gg in 2000. However, it should be noted that since some CO_2 is re-absorbed during the cement utilization process, this cannot be incorporated into the computations because the present version of the methodology does not include this. .

Table 3.8:A comparison of CO_2 emissions (Gg) from cement and lime production between 1994 and 2000

Sub-sector	Year		% Change
	1994	2000	
Clinker production	56.6152	56.0812	-0.94 (decrease)
Lime production	1.7551	3.13	+78.34 (increase)

CO_2 emissions from ethanol production. The CO_2 emissions from ethanol production are presented in Table 3.9. The trend of CO_2 emissions from ethanol production reveals a gradual drop from 10.0 Gg in 1995 to 9.0 Gg in 2000, with a small peak of 12.0 Gg in 1997.

Table 3.9: CO_2 emissions (Gg) from ethanol production, 1993-2000

Year	Ethanol produced (Litres)	Specific gravity (g/cm³)	Ethanol produced, t	Molar weight of CO_2	Molar weight of ethanol	CO_2 emitted (t)	CO_2 produced (Gg)
1995	13,124,584	0.7898	10366	44	46	9915	10.0
1996	13,702,555	0.7898	10822	44	46	10352	10.0
1997	15,420,497	0.7898	12179	44	46	11650	12.0
1998	11,859,969	0.7898	9367	44	46	8960	9.0
1999	12,188,374	0.7898	9626	44	46	9208	9.0
2000	11,900,000	0.7898	9399	44	46	8990	9.0

However, for the plant-based raw materials, it is assumed that CO_2 is re-absorbed during plant growth so that net emission is practically assumed to be zero.

CO_2 and CH_4 emissions from biogas digesters. The CO_2 and CH_4 emissions from molasses and ethanol production are presented in Table 3.10.

Table 3.10: Carbon dioxide (CO_2) production (t) from molasses, 1993-2000

Year	Molasses (t)	Conversion factor	Amount ethanol produced (L)	Maximum CO_2 Produced (t)	Maximum CO_2 produced (Gg)
1995	48,249	0.28	13,510	12,922.3	12.92
1996	56,390	0.28	15,789	15,102.7	15.10
1997	45,601	0.28	12,768	12,213.1	12.21
1998	47,002	0.28	13,161	12,588.4	12.59
1999	48,746	0.28	13,649	13,055.5	13.06
2000*	-	-	-	-	-

Note: * - missing production figure for 2000

Carbon dioxide generated from molasses has on average remained constant. This has varied between 12.92 and 15.10 Gg, reflecting a constant production of molasses over the five-year period.

CO_2 and N_2O emissions from fertilizer production. There are presently no data on CO_2 and N_2O emissions from fertilizer manufacturing plants. This is because the major activity in the fertilizer manufacturing industry is blending of high analysis fertilizers to make compound fertilizers. The blending process does not emit greenhouse gases. However, plans are presently underway to establish a fertilizer manufacturing plant Lilongwe, which will certainly contribute to GHG emissions.

NMVOC emissions from paints and solvents. The non-methane volatile organic compounds (NMVOC) emitted from the manufacturing of paints and solvents are presented in Table 3.11, which depicts a similar trend to that reported for CO_2 emissions.

Table 3.11: Emission of NMVOC from paints and solvents, 1994-2000

Year	Litres of paint	Mass of paint (1 litre : 1.2 kg)	Conversion factor (kg CO_2 / kg of paint)	Mass of NMVOC (Gg)
1995	72758	87310	0.75	0.07
1996	176488	211786	0.75	0.16
1997	808223	969868	0.75	0.73
1998	339493	407392	0.75	0.31
1999	461468	553762	0.75	0.42
2000	555470	666564	0.75	0.50

Source of the emission factors: Emission Inventory Guidebook, 2006 (Page: B610-22).

Unfortunately, the previous inventories using 1990 and 1994 as base years did not include NMVOC emissions from the use of paints and solvents (such as white paraffin). However, for this study, which is using 2000 as the base year, shows that 2.19 Gg were emitted from this category source.

The GHG emissions from the Industrial processes and product Use Sector has shown that a total of 390.77 Gg of CO_2 equivalent were emitted from this sector. The largest contributor is cement production (301.55 Gg), followed by lime production (6.61 Gg), and finally paint and solvent production (2.18 Gg). However, the contributions of ethanol processing will have to be subtracted from this figure because it is assumed that the CO_2 is re-absorbed during sugarcane growth and development. Thus, the net emission from the sector is 310.79 Gg from lime and clinker production.

Thus, there is need to put in place operational and institutional frameworks to coordinate the collection and storage of activity data from relevant industries to ensure that future inventories are as complete as possible. This can be taken on board as part of a comprehensive data base development strategy for compiling GHG inventories for Malawi in the future. .

3.5 Agriculture Sector

The Agriculture Sector contributes significantly to GHGs concentrations in the atmosphere. The key GHGs include: (i) carbon dioxide (CO_2), (ii) nitrous oxide (N_2O), (iii) methane (CH_4), and (iv) carbon monoxide (CO). The CO_2 fluxes between the atmosphere and the ecosystems are primarily controlled by the uptake of carbon (C) through plant photosynthesis and release of CO_2 via respiration, decomposition and the combustion of organic matter (OM). Nitrous oxide (N_2O) is primarily emitted as a by-product of nitrification and denitrification, whereas CH_4 is emitted through methanogenesis under anaerobic conditions from soils and stored manure through enteric fermentation, and during incomplete combustion of organic matter (IPCC, 2006). Globally, agricultural production contributes substantially to GHG emissions.

For example, in 1991, agriculture contributed 45% of the total methane emissions, mainly under rice cultivation in flooded paddy rice fields in wetland ecosystems (Conway and

Pretty, 1991). In Malawi, the 1990 GHG Inventory identified several major agricultural source categories that substantially contribute to GHG emissions. These include: (i) livestock and manure management (35.8 Gg of CH_4), (ii) field burning of agricultural residues (25.9 Gg of CO_2), and (iii) rice cultivation (13.6 Gg of CH_4) (Phiri et al., 2000). In this study, GHGs will be estimated from the following source categories: (i) livestock and manure management, (ii) rice production, (iii) open burning of agricultural residues, and (iv) agricultural soils.

3.5.1 Source Category Emissions

CH_4, CO_2 and N_2O emissions from livestock and manure management. Livestock production results in CH_4 emissions from the enteric fermentation of manure management. On the other hand, CO_2 emissions from livestock are not estimated because the annual net CO_2 emissions are assumed to be zero (the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2). The CH_4 is produced in herbivores as a by-product of enteric fermentation, a digestive process through which micro-organisms break down carbohydrates into simple molecules for absorption into their bloodstream. The amount of CH_4 that is released from enteric fermentation depends on the type, age, and weight of the animal. In general, ruminant animals emit the largest quantities of GHGs because they are able to digest cellulose as a result of the presence of specific bacteria in the rumen (Phiri et al., 2000).

The main ruminant animals in Malawi are goats, sheep and cattle (Table 3.12). Cattle and goats are the dominant ruminant animals in the country. Cattle are the most important source of CH_4 because of their large numbers, large sizes and large ruminant digestive systems. There are approximately one and half million goats (Table 3.13), which together with other livestock, are raised on approximately 15% of the total land area (1.5 m ha.) classified as either non-arable or unused land. Most of the livestock are traditional breeds and are generally raised by smallholder farmers under traditional management systems. In 2004, the main livestock types were estimated as follows: (i) cattle: 707,771, (ii) goats: 1.460,503, (iii) sheep: 981,221, and (iv) poultry: 12,086,630 (DAES), 2004), indicating a slight decline in the number of cattle, but a substantial increase in the number of sheep and poultry.

Livestock manure is principally composed of organic material. When this organic material decomposes in an anaerobic environment, it releases CH_4 gas. The main factors that affect CH_4 emissions from animal manure are the amount of manure produced and the portion of the manure that decomposes anaerobically. Anaerobic conditions often occur where large numbers of animals are managed in a confined environment (e.g. dairy cows and beef feedlots), where manure is essentially stored in large piles or disposed of in lagoons.

Table 3.12: Types and total numbers of livestock in Malawi, 1996-2000

Livestock Types	Years					
	1996	1997	1998	1999	2000	Mean
Dairy cattle	7,590	7,680	7,720	7,840	8,150	7,796
Non-dairy cattle	780,100	589,180	715,390	711,680	763,720	712,008
Sheep	93,018	97,916	102,671	103,095	111,539	101,656
Goats	974,028	1,566,514	1,597,536	1,427,134	1,689,485	1,450,927
Mules and asses	4,038	N/A	N/A	N/A	N/A	4,038
Pigs	312,925	420,772	427,314	444,381	468,140	414,719
Poultry	12.807 m	10.005 m	10.366 m	12.088 m	7.065 m	10.466 m

Source: DoAHLD, 2007

In Malawi, domestic livestock waste is from livestock kraals, pasture fields and rangelands, and as solid storage in dry-lots. In most cases this manure is then applied to agricultural soils. N_2O is also emitted from manure management, but this varies significantly between different types of manure management systems.

CH_4 emissions from rice cultivation. Anaerobic decomposition of organic materials in flooded paddy rice fields produce CH_4, which is released into the atmosphere, primarily by transport through the rice plants (Takai, 1970; Cicerone and Shetter, 1981; Conrad, 1989; Nouchi et. al., 1990). The annual amount of CH_4 emitted from a given area is a function of the number and duration of the crops grown, water regimes before and during the cultivation period, and organic and inorganic soil amendments (Neue and Sass, 1994; Minami,1995). Soil type, temperature and rice cultivar also affect CH_4 emissions. In Malawi, rice is mainly produced in areas along the Lakeshore Plain and river valleys, under three water production regimes: (i) rain-fed with intermittent irrigation during the wet months of December to May, (ii) flood irrigation during the dry months of May to October, and (iii) rain-fed in upland areas during the wet months of October to March. However, upland rice cultivation is a new development, and contributes very little to the total national rice production. The intermittent flooding system constitutes nearly 80%, whereas flood irrigation rice is grown on the remaining 20% of the total land area (Table 3.13).

Table 3.13: Total harvested land area for rice by water management type, 1996- 2000

Water management	Harvested area (ha)					Mean
	1996	1997	1998	1999	2000	
Continuously flooded	7,170	2,338	2,662	6,553	10,631	5,870.80
Intermittently flooded	34,053	38,020	39,124	39,258	31,911	36,473.20
Total	41,223	40,358	41,786	45,811	42,542	42,344.00

Source: Kumwenda and Mazengera, 1989.

The length of the growing season in Malawi varies between seasons, dry *versus* wet seasons as a result of temperature and varietal differences (Phiri et al; 2000). The average growth period for the main rice varieties during wet season with an average temperature of 23 °C is 150 days, whereas under intermittent flooding in the dry season with an average temperature is 25 °C, the average growth period is 140 days (DARS, 1997; Eschweiler and Nanthabwe, 1988).

CO_2, CH_4, CO, N_2O and NO_x emissions from open burning of agricultural residues. Agriculture produces a lot of wastes in the form of crop residues, which are usually burnt in the field. About 80% of the crop residues are burnt in the field in developing countries, and 50% in developed countries (IPCC, 1996). The open burning of crop residues is carried out for several reasons: (i) to clear the field in readiness for ridging, (ii) to control insect pests and diseases, and (iii) as part of the harvesting process, such as sugarcane burning before harvesting. The field burning of agricultural residues emits CO_2, CH_4, CO, N_2O and NO_x into the atmosphere. However, the 2006 IPCC Guidelines assumes that the amount CO_2 emitted into the atmosphere in one season is re-absorbed by the vegetative growth in the next season. Hence, the methodology does not include computations for CO_2, but only calculates the net non-CO_2 GHGs (CH_4, CO, N_2O and NO_x) emitted into the atmosphere,

N_2O emissions from agricultural soils. Nitrous oxide (N_2O) is produced naturally in soils through nitrification and denitrification processes. Nitrification is the aerobic microbial oxidation of ammonium into nitrates, and denitrification is the anaerobic microbial reduction of nitrates into nitrogen gas (N_2). N_2O is a gaseous intermediate in the reaction sequence of denitrification, and is a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic nitrogen in the soil (IPCC, 2006). This study has estimated N_2O emissions from human-induced nitrogen additions to agricultural soils, such as the application of synthetic or inorganic fertilisers, deposited manures, crop residues or the mineralization of N in soil organic matter following water drainage. N_2O emission from agricultural soils is the sum of direct and indirect emissions.

The direct emissions are from the soil, animal manure and urine deposited on the soil, whereas indirect emissions arise from nitrogen used for crop and fibre production. This study has estimated N_2O emissions from these two main source categories from different agro-ecological zones, soil types and farming systems. The total cultivated land area is 3.13 m ha, comprising 1.98 m ha under smallholder farm conditions and 1.15 m ha under large-scale estate farms.

3.5.2 Methodology

The quantities of GHGs emitted from the different source categories were estimated using the 2006 IPCC Guidelines, which are an improvement over the 1996 IPCC Guidelines. The use of the 2006 IPCC Guidelines has ensured that emissions contained in this report are consistent and comparable across the various sectors. Since no national emission factors are available for Malawi conditions, default emission factors sourced from the IPCC Guidelines were used in the computations. The primary data used in calculating gas emissions were obtained from public and private sector organizations, including the Ministry of Agriculture and Food Security (MoAFS) and the Department of Meteorological Services (DoMS). However, data on savanna burning are not available for the years 1996-2000; hence this source category was omitted. The inventory has been organized into four major source categories as follows: (i) Livestock and manure management, (ii) Rice cultivation, (iii) Open burning of agricultural residues, and (iv) Agricultural soils.

CH_4 emissions from livestock and manure management. The Tier 1 approach was selected for the estimation of CH_4 emissions from enteric fermentation in the livestock source category. Data on livestock population for the years 1996-2000 were obtained from the Department of Animal Health and Industry (DoAHLD) [Table 3.11]. All the default emission factors for enteric fermentation were obtained from the IPCC Guidelines. The total amount of CH_4 emitted was calculated as the product of the selected emission factors for each animal species with the associated livestock population, and then summed up to estimate the total amount of CH_4 emissions. The CH_4 emissions from livestock manure management were estimated as the product of the livestock category emission factor and the sub-category population figure, which were then summed up across all the categories. The total CH_4 emissions were obtained by adding the emissions from enteric fermentation and manure management from livestock.

CH_4 emissions from rice cultivation. The Tier 1 approach was used to calculate CH_4 emissions from rice cultivation. Since there are no country–specific emission factors and activity data, default values from the IPCC Guidelines were used in the calculations. The emissions of methane from rice fields were calculated using Equation 3.5.

CH_4 flux (Gg) = (Area harvested) x (cultivation period) x (daily emission factor) ……..……………… [3.5]

The 2006 IPCC Guidelines differ from the 1996 IPCC Guidelines and the 2000 GPG because they incorporate various new changes, including: (i) revised emission and scaling factors derived from updated analysis of available data, and (ii) use daily, instead of seasonal emission factors, to allow for more flexibility in separating cropping season and fallow periods.

CO_2, CH_4, CO, N_2O and NO_x emissions from open burning of agricultural residues. The step by step calculations to determine the amount of CO_2, CH_4, CO, N_2O and NO_x involved the following steps: (i) calculating the amount of residues produced by crops whose residues are burnt in the fields (Table 3.13), (ii) estimating the amount of dry residues by multiplying the dry matter fraction and the amount of residues for each crop, (iii) estimating the total amount of biomass burnt in the field, taking into account the amount of dry residues, the fraction actually burnt in the field or the fraction removed for other domestic uses and animal feeding and the combustion efficiency, and (iv) calculating the amount of each non-CO_2 emissions by multiplying the biomass burned with the IPCC default emission and combustion factors. The calculation of non-carbon dioxide emissions into the atmosphere for the major crops whose residues are burnt in the field was calculated using the formula:

$L_{fire} = A. M_B. C_f.G_{ef}.10^{-3}$ .... [3.7]

Where:

L_{fire} = amount of green house gas from fire, tones of each greenhouse gas, e.g., CH_4, CO, etc

A = area burnt, ha

M_B. = mass of fuel available for combustion, tones ha^{-1}

C_f = combustion factor, dimensionless (IPCC default values from Table 2.6)

G_{ef}. = emission factor, g kg^{-1} of dry matter burnt

Most of the data for the calculations of non-CO_2 emission were obtained from the Famine Early Warning System (FEWSNET) of the MoAFS, whereas the data for sugarcane were downloaded from the Food and Agriculture Organization Databank [FAO, 2007 (faostat.org)] In calculating gas emissions, all crops whose residues are burned in the field was taken into account. The IPCC default values for crop combustion factors and gaseous emission factors were used because local values are not available. The values of burnt biomass in the field were obtained from Agricultural Development Divisions (ADDs). This excludes the biomass taken out of the fields for domestic use and animal feeding. Table 3.14 shows crop production and area under cultivation under smallholder farming conditions.

Table 3.14: Annual crop production (m t) under smallholder farm conditions in Malawi, 1996-2000

Crop	Year				
	1996	1997	1998	1999	2000
Maize	1793461	1772382	1534326	2478058	2501311
Wheat	2315	1842	1842	1665	1815
Rice	72629	68823	68808	92911	71633
Groundnuts	40327	101378	97228	131543	122281
Tobacco	68978	94062	94062	84555	98675
Cotton	82591	36381	32336	51321	36527
Sorghum	54710	41473	41473	41403	36799
Millet	20262	19638	19638	20224	19508
Pulses	183094	61298	208895	237628	266956
Guar beans	1238	1560	1540	3653	3976
Cashew nuts	148	153	153	142	434
Macadamia	5	1985	214	940	667
Sesame	291	219	219	359	355
Sunflower	17832	1818	1818	2441	2997
Coffee	12	1647	858	530	1000
Chillies	882	1876	1825	3461	1227
Cassava	534549	834755	829821	906430	2794617
S potatoes	596469	1447994	1432383	1702399	1918489
Irish potatoes	106422	120996	120338	160178	160264

Source: MoAFS, 2007; FEWSNET, 2007, FAO, 2007.

N_2O emissions from agricultural soils. The estimation of N_2O from agricultural soils involved calculating both direct and indirect emissions. The steps for estimating direct emissions included (i) calculation N_2O emissions from synthetic fertiliser, F_{SN}, based on the quantities of fertilizers used in Malawi from 1996 to 2000 (Table 3.15), (ii) calculation of N_2O emissions from manure management (animal wastes) based on the quantities of dry lot manure storage for the main livestock types kept in Malawi (Table 3.12), (iii) calculation of N_2O emissions from crop residues, $F_{CR.}$ from dry biomass of pulses and soybeans and dry biomass production for other crops (Table 3.17), and (iv) calculation of N_2O emissions from grazing animals on pasture, range and paddocks ($N_2O_{ANIMALS}$, kg yr^{-1}).

The total number of livestock kept in Malawi between 1996 and 2000 are shown in Table 3.11 The indirect emissions of NH_3 and NO_x were calculated for the following sources: (i) atmospheric deposition of ammonia (NH_3), and oxides of nitrogen, (NO_x) (kg N_2O yr^{-1}), calculated from the total amount of synthetic nitrogenous fertilisers used (Table 3.15), and (ii) the annual amount of N_2O-N produced from the leaching of nitrogen fertilisers from managed soils (kg N_2O-N yr^{-1}) calculated from the amount of nitrogen fertilisers used in Malawi between 1996 and 2000 (Table 3.16).

Table 3.15: Inorganic fertiliser use in Malawi, 1996-2000

Year	Nitrogenous fertilisers (ton)	Phosphate fertilizers (ton)	Potash fertilizers (ton)	Total (ton)
1995	28202	10317	5000	43519
1996	37900	14300	6000	58200
1997	41200	12600	3000	56800
1998	34800	11900	3500	50200
1999	30000	16600	3500	50100
2000	34588	11461	3787	49836

Source: http://faostat.fao.org/site/422/DesktopDefault.aspx?

Table 3.16: Above ground dry biomass of selected field crops in Malawi, 1996-2000

Crop	Year				
	1996	1997	1998	1999	2000
Maize	1793461	1772382	1534323	2478058	2501311
Wheat	2315	1842	1842	1665	1851
Rice	72629	68823	68808	92911	71633
Groundnuts	40327	101378	97228	131543	122281
Tobacco	68978	94062	94062	84555	98675
Pulses	18304	61298	208895	237628	266956
Guar beans	1238	1560	1540	3653	3976
Irish potatoes	106422	120996	120338	160178	160264
Sweet potatoes	49574	1447996	1432383	170239	167118

Source: MoAFS, 2007

3.5.3 Results and Findings

CH_4 emissions from livestock and manure management. A total of 31.64 Gg of methane was emitted from domestic livestock in 2000, with enteric fermentation contributing 94.7% and manure management 5.3% (Table 3.17). This total emission is about the same as that reported for the 1994 GHG Inventory (31.95 Gg). This is in spite of the fact that the total number of livestock had increased during the period 1996-2000, especially goats, sheep and pigs, compared with the previous periods. This can perhaps be attributed to the fact that the 2006 IPCC Guidelines recommends the use of lower default emission factors than those used in the 1996 IPCC Guidelines computations.

Table 3.17: CH_4 emissions from enteric fermentation and manure management in Malawi

Animal type	CH_4 emissions from enteric fermentation (Gg/year)	CH_4 emissions from manure management (Gg/year)
Dairy cows	0.31	0.008
Other cattle	21.45	0.502
Sheep	0.51	0.02
Goats	7.25	0.319
Horses	0.0004	0.000089
Mules/Assess	0.04	0.0048
Swine	0.41	0.415
Poultry	-	0.209
Total	29.0704	1.6679
Grand Total		31.54

CH_4 emissions from rice cultivation. A total of 5.13 Gg of CH_4 were emitted from rice cultivation as shown in Table 3.18 over a five year period (1996-2000). About 80% of this was emitted from the intermittent flooded rice source category, whereas the continuously flooded rice source category contributed 20%. The CH_4 emissions from continuously flooded rice were generally lower because of the low hectarage grown to rice under this system of cultivation. The CH_4 emissions for the 1994 GHG Inventory of 14.89 Gg is more than double the present emission value of 5.13 Gg. This large difference can be attributed to the fact that the default emissions factors of 1.30 and 0.78 were used for continuously flooded and intermittently flooded rice, respectively for the 2000 GHG Inventory (that used the 2006 IPCC Guidelines), whereas emission factors of 5.56 and 3.50, respectively, were used in the 1994 GHG Inventory (that used the 1996 IPCC Guidelines).

Table 3.18: CH_4 emissions from rice cultivation, 1996-2000

Year	Methane emissions (Gg)
1996	5.107
1997	4.608
1998	4.791
1999	5.565
2000	5.558
Mean	5.126

CO_2, CH_4, CO, N_2O and NO_x emissions from open burning of agricultural residues. The non-CO_2 gaseous emissions (CH_4, CO, N_2O and NO_x) from the open burning of crop residues source category are presented in Table 3.19, which shows that the dominant gas emitted is CO. CO emissions increased from 32.73 Gg in 1996 to a 60.22 Gg in 2000. The first three values are lower than those reported in the 1994 GHG Inventory, whereas the last two are of the same order of magnitude. This increase in emissions can be attributed to increased crop production in 1999 and 2000 (with > 2.0 million metric tones of maize). The emissions of CH_4, N_2O and NO_x are of similar magnitude to those reported in the 1994 GHG Inventory. However, there is a general increase in the amounts of emissions, which can be attributed to increased crop production that is in turn proportional to the amount of crop residues realized.

N_2O emissions from agricultural soils. Table 3.20 shows that the direct emissions from synthetic fertilisers and grazing animals on pasture, range and paddocks contributed the largest share of the total N_2O emissions. From 1996 to 2000 there was a gradual decrease in the amount of N_2O emissions.

Table 3.19: Non- CO_2 gaseous emissions from the open burning of crop residues, 1995-2000

Year	Non-CO_2 emissions from open burning of crop residues			
	CH_4	C0	N_20	N0x
1996	0.9606	32.73183	0.024905	0.889451925
1997	1.0494	35.75766	0.027206	0.97167551
1998	0.8801	29.98902	0.022817	0.814919055
1999	1.7777	60.57308	0.046088	1.646007702
2000	1.7672	60.21648	1.565624	1.636315207

Table 3.20: N_2O emissions from agricultural soils, 1966-2000

Type of N input into the soil	Amount of N_2O emitted (Gg)				
	1996	1997	1998	1999	2000
Direct emissions					
• F_{SN}		6.474286	5.468571	4.714286	5.435257
• F_{MM}	5.955714	0.913952	0.946038	1.074371	0.701310
• F_{CR}	1.091631	1.114968	0.956749	1.717668	1.389148
Subtotal	0.821241	8.503206	7.371358	7.506325	7.525715
	7.868586				
Grazing animals					
• **Pasture, range &**		2.90804	3.010121	3.25494	0.750733
paddocks	3.473371				
Indirect emissions					
• F_{ATD} NH_3, NO_X		0.064743	0.054686	0.047143	0.054353
• **Leaching**	0.059557	0.145671	0.123043	0.106071	0.122293
Subtotal	0.134004	0.210414	0.177729	0.153214	0.176646
	0.193561				
Total N_2O emissions	11.535518	11.62166	10.559208	10.933869	8.453094

Key: F_{SN}–synthetic fertilizers; F_{MM} –manure management; F_{CR}- crop residues; F_{ATD}

The emissions from other source categories are relatively small compared with those from synthetic fertilisers and grazing animals on pasture, range and in paddocks. However, although these emissions look small, they have a big impact on global warming. This is because N_2O has a larger Global Warming Potential (GWP) of 310 compared with 1 for CO_2. .

Thus, the field burning of agricultural residues contributed more CO_2, than any other source category, a result that is similar to the findings of the 1994 GHG Inventory. This was closely followed by the CH_4 emissions from the livestock and manure management source category. The N_2O emissions from agricultural soils was the third highest at 8.45 Gg compared with 5.65 Gg reported in the 1994 GHG Inventory. N_2O has a GWP of 310 relative to 1 for CO_2; therefore its impact on global warming is much higher than portrayed by the small figure in the inventory. These emissions in the agriculture sub-sector are a cause of concern to policy makers. With changing climatic conditions, and expanding agricultural production in response to an increasing human population, future inventories are likely to show even higher N_2O emissions. This situation will be exacerbated by the use of subsidized mineral fertilizers under the Farm Inputs Subsidy Programme (FISP). It is important, therefore, that policies are put in place aimed at improving fertiliser use-efficiency. Such policies would not only reduce N_2O emissions, but would also improve returns to fertiliser use.

3.6 Forestry and Other Land-Use Sector

The forest resource of Malawi is estimated at 22 % of the total land area of 9.4 m ha. This comprises of (i) 11% forest resource under National Parks and Game Reserves, (ii)10% under forest reserves and (iii) 7% under customary land. The main source category is land-use change and management that significantly contribute to GHG emissions, especially through: (i) forest clearing for agricultural production and/or pasture establishment, (ii) grassland conversion for crop production and/or pasture establishment, (iii) abandonment of managed lands, which results into re-growth of forests and/or grasslands, and (iv) managed forests, such as forest reserves and forest plantations. In Malawi, clearing of forests is often achieved by cutting undergrowth and the felling trees, followed by burning on-site and/or off-site as fuel wood. Through this process, some of the biomass is burned while some remains on the ground where it decays slowly over a period of time. Of the burned materials, a small fraction is converted into charcoal, which may resist decay for over a period of 100 years or more, whereas the remainder is released instantaneously into the atmosphere as CO_2. CO_2 is also lost from the soils after clearing, especially when the land is cultivated. This loss may occur over a period of many years.

Land-use change and the emissions of GHGs are highly related to agricultural production (crop and livestock) activities. For Malawi, whose economy is agro-based and heavily dependent on small scale subsistence farmers, the sub-sector has the potential of being both a sink and a source of GHGs. The challenge is, therefore, how to implement human activities so that the basic needs are met without increasing the emissions of GHGs. Thus, the present inventory examined some activities that are sources and/or sinks of GHGs. These include the processes of photosynthesis and utilisation of woody biomass, conversion of forests to other land-uses, and land-use change from other uses to forestry using the year 2000 as the base year.

3.6.1 Source Category Emissions

As outlined in the background, the main source categories include: (i) changes in forestry and other biomass, (ii) forest conversion, (iii) abandonment of managed lands, and (iv) managed forests. Every year, forests and woody biomass are subjected to exploitation as a result for the unmet demand for fuel-wood, poles, timber and increasing agricultural expansion. The **changes in forestry and other woody biomass** release large quantities of CO_2 into the atmosphere. **Forest conversion** is the land-use change that occurs when forests are converted to other land-uses, such as crop production or pasture production. This is commonly referred to as deforestation. Deforestation is a major concern in Malawi. Currently, deforestation is occurring at the rate of 2.8 % per year, resulting in an estimated loss of 50,000 ha of forests every year. While agricultural expansion is one of the main causes of deforestation, infrastructure development, such as roads and rail, settlements and dams also significantly contribute to deforestation and land degradation

The **abandonment of managed lands** refers to managed lands, such as cropland or rangelands, which have been abandoned and where the forest has been allowed to grow again. Because the growth rates of trees slows down over time, the periods considered are land abandoned during the 20 years prior to the preparation of the inventory and land abandoned for more than 20 years. Only lands that re-grow are considered in these computations. The **managed forests** source category deals with CO_2 emissions and removals due to plantations, managed forests and any other trees affected by human activities.

3.6.2 Methodology

The methodology for calculating GHG emissions employed the 2006 IPCC Guideline approaches and methodologies, covering all the source categories in the Forestry and Other Land-Use (FOLU) sub-Sector. .

Changes in forestry and other biomass. From the growing stock, calculations of CO_2 removal were estimated as the difference between the absorbed CO_2 during the year through the process of photosynthesis and CO_2 released through woody biomass removal through harvesting for timber, firewood and/or construction materials. In this case, there is no land-use change, so that CO_2 removal is a direct result of woody biomass utilization. The GHGs were assessed based on four calculations that aim at capturing CO_2 emissions resulting from: (i) decay of biomass left on site, (ii) biomass that is burnt on site, (iii) commercial timber that is taken away, and (iv) charcoal that results from biomass that is burnt on site.

Forest conversion. The GHGs in this source category were calculated from a set of three calculations that estimate CO_2 emissions as follows: (i) carbon emitted by burning above ground biomass (immediate emissions happening in the year of clearing), (ii) carbon released from the decay of aboveground biomass (delayed emissions occurring over a period of ten years), and (iv) carbon released from soil (delayed emission occurring over a 25 year period). The data on forest areas cleared for crop production or rangeland management, abandoned lands (crop lands or rangelands) that have re-grown tree cover, and the number of trees growing outside forests were collected from the Department of Forestry (DoF) in the Ministry of Lands and Natural Resources (MoLNR). The data included the amounts of biomass burned on site, off-site and left on the ground to decay. However, there were no data for grassland changes due to other land-uses. The conversion factors, which were either based on Malawi data or default factors provided in the IPCC Guidelines, were used to calculate CO_2 emissions. The emissions of non-carbon gases CH_4, N_2O, CO and NO_x were calculated from on-site burning using a conversion factor provided in the IPCC Guidelines.

Abandonment of managed lands. Four sets of calculations were done to estimate CO_2 emissions: (i) annual carbon uptake in aboveground biomass (land abandoned in the last 20 years), (ii) annual carbon uptake in soils (land abandoned in the last 20 years), (iii) annual carbon uptake in aboveground biomass (land abandoned for over 20 years), and (iv) annual carbon uptake in soils (land abandoned for over 20 years). The sum of the four sets of calculations results in the estimate of CO_2 emissions in abandoned managed lands.

Managed forests. Emissions and/or removals of carbon from plantations, managed forests and trees growing outside forest were estimated by calculating annual increment of biomass in plantations, forests and trees growing outside forests. Wood harvested for fuel-wood or commercial timber is also estimated from commercial harvest statistics or traditional consumption estimates. The inclusion of trees outside forests is a very important factor since many people are now using products and services of trees outside forests. These are the trees that grow in gardens and around homesteads, the most important are multi-purpose tree species grown in agro-forestry systems, a practice that emerged during the late 1970s.

The GHG emissions from **forest soils** were estimated from three processes: (i) changes in carbon stored in soil litter, (ii) litter of mineral soils due to changes in land-use practices, and (iii) carbon emissions from organic soils converted to agriculture or plantation forestry. The methodology for accounting CO_2 emissions from mineral soils are based on an accounting of changes in soil and litter carbon as a function of the changes in carbon stocks over a 20 year inventory period. The calculations of CO_2 emissions in organic soils were done using annual emission estimates, which depend on climate and land-use. This requires data on the extent of organic soils under current land-use. The emission rates and factors were obtained from the IPCC Guidelines.

3.6.3 Results and Findings

Table 3.21 presents a summary of GHG emissions from the source categories of the Forestry and Other Land-Use (FOLU) Sector. This sub-sector is essentially both a net source of CO_2 (19,242.86 Gg) and a sink of CO_2 (889.4 Gg). Much of the sink is occurring over the entire forest and woody biomass category, including individual trees grown outside forests and on abandoned croplands that have been allowed to regenerate or are grown to trees under agro-forestry systems. Natural trees have the capacity to recover if protected from fires and browsers. It has been observed that within a two year-period of forest protection, a bare area can recover substantial quantities of tree vegetation cover. In practice, there are relatively few areas that actually respond this way because of the so many other detrimental factors that come into play, such as over-grazing or the cutting down of small re-growths or re-generating trees for building and construction purposes. Further, because of the increasing human population, increasing poverty and the unsustainable utilization of forest resources under traditional management practices, such as shifting cultivation, the re-growth of trees from abandoned croplands is declining at a very fast rate.

Table 3.21: GHG emissions and CO_2 removals (Gg) from the FOLU, 2000

Forestry and other land-use	Greenhouse gas emissions and CO_2 removals					
	CO_2 emissions	CO_2 removals	CH_4	CO	N_2O	NO_x
Changes in forestry and other woody biomass	18,043.95	-	-	-	-	-
Forest conversion	2,088.31	-	-	-	-	-
Abandonment of managed lands	-	889.4	1.39	1.03	0.49	1.76
CO_2 emissions from agricultural soils	-	-	-	-	-	-
Net CO_2 emissions and/or removals	19,242.86	889.4	-	-	-	-

Note: - means computations were not done due to insufficient data

There was an increase of 10% in GHG emissions from 17,512.02 Gg in the 1994 to 19.242.86 Gg in 2000. This percentage increase is more or less the same as the population increase of 12.7% over the same period of time (1994-2000). Thus, it is most likely that the increasing levels of CO_2 emitted are directly proportional to the increasing human activities. However, there are two sources of CO_2 emissions that were not captured in this inventory. These are contributions from forest soils and forest fires. This is because of lack of activity data. However, information available in the DoF indicates that 1,000 ha of forest plantations are destroyed by fire every year. The worst year on record is 1995 when about 5,000 ha of forest cover were destroyed by forest fires, which was estimated at a loss of MK 104.0 m. So far, it has not been possible to quantify such huge losses in terms of CO_2 emissions. However, what is clear is that although some of the fires are caused by natural causes, such as lightening, the majority are caused by human activities, such as through wildlife hunting, harvesting honey, and sometimes mere arson. If the forest fires observed in the forest plantations, such as Chikangawa in Mzimba and Chongoni in Dedza, reflect what might also be happening under natural forests, then the resultant CO_2 emissions are enormous, and these need to be taken into account in the preparation pf the Third National Communication (TNC).

Thus, this study has clearly shown that forests and woody biomass are the major sources and sinks of CO_2 in Malawi. Considering that these cover about 22% of the total land area of the country and that these are perennial plants, the potential for the reduction of GHG emissions through photosynthesis is huge. Although the assessment shows that this sub-sector is a net emitter of CO_2, the potential of the sector to remove CO_2 from the atmosphere is also enormous because of the current extent of protected areas and the potential for increased adoption of agro-forestry practices under smallholder farm conditions. Thus, effectively, the whole country has the potential to contribute in removing CO_2 from the atmosphere and storing it in the growing trees. There is also a possibility of increasing CO_2 removals from protected areas through the selective harvesting of trees and woody biomass in order to stimulate photosynthetic activity from young woody biomass. At the moment, tree harvesting is not encouraged in protected areas.

However, since wood-fuel is the major source of energy in Malawi, accounting for over 90% of the entire national energy budget, reducing GHG emissions is an up-hill challenge. This is because there is lack of other economically viable and widely accepted alternative sources of energy in the short- and medium-term that can be used by rural communities. Efforts to reduce GHGs should, therefore, capitalise on increasing the CO_2 sinks rather than reducing GHG emissions. The focus should be on the management of protected areas and the promotion of tree growing, especially the growing of multi-purpose tree species on-farm under agro-forestry practices. This will have an added benefit of improving the food security status of family households. There is presently great concern about the effects of forest fires on CO_2 emissions. There is no research being conducted on forest fires although the subject has come up several times during the National Forest Research Committee meetings. The reason for not conducting research on forest fires is squarely on the lack of resources and expertise in the DoF in the Ministry of Lands and Natural Resources (MoLNR), and the Ministry of Agriculture and Food Security (MoAFS). .Further, the huge water resources of lake Malawi have not been evaluated as a potential sink/source for CO_2. This should be seriously considered when preparing the Third National Communication (TNC) of Malawi.

3.7 Combined GHG Emissions from the Agriculture, and Forestry and Other Land-Use Sectors

The agriculture and forestry were treated as two separate sectors during the preparation of the 1994 GHG Inventory reported in Malawi's Initial National Communication (INC) of Malawi of 2003. However, in the 2006 IPCC Guidelines these two sectors have been combined into one sector: Agriculture, Forestry and Other Land-Use (AFOLU) Sector". It is envisaged that combining these two interrelated sectors will reduce the duplication and enhance the complementarily of the two sub-sectors. Thus, the emissions from the two the agriculture and forestry source categories were combined according to the 2006 IPCC Guidelines. The GHG emissions arising from the AFOLU Sector due to (i) enteric fermentation, (ii) manure management, (iii) land-use change and forestry, (iv) biomass burning, (v) use of synthetic fertilisers, (vi) rice cultivation, and (vii) harvested woody products, are summarised in Table 3.22.

Table 3.22: Total GHG emissions from the AFOLU Sector, 1995-2000.

Sub-sector	Source category		Year					
			1995	1996	1997	1998	1999	2000
3A Livestock	3A1	Enteric fermentation		30.175	27.315	31.414	30.473	33.475
	3A2	Manure management		1.594	1.582	1.730	1.740	1.775
3B Land	3B1	Forest land						
	3B2	Cropland						
	3B3	Grassland						
	3B4	Wetland						
	3B5	Settlement						
3C Aggregated sources	3C1	Biomass burning						
		CH_4		0.961	1.049	0.880	1.778	1.767
		CO		32.732	35.758	29.989	60.573	60.216
		N_2O		0.026	0.027	0.023	0.046	0.046
		NOx		0.889	0.972	0.815	1.646	1.636
	3C2	Liming		NE	NE	NE	NE	NE
	3C3	Urea		NE	NE	NE	NE	NE
	3C4	Direct N_2O from soils		5.956	6.474	5.469	4.714	5.435
	3C5	Indirect N_2O from soils		0.134	0.145	0.123	0.106	0.122
	3C6	Indirect N_2O from manure		1.091	0.914	0.946	1.074	0.701
	3C7	Rice cultivation		5.107	4.608	4.791	5.565	5.558
	3C8	Other		NA	NA	NA	NA	NA
3D Other	3D1	Harvested products						

Note: The shaded area indicates source categories that were not computed owing to lack of data.

The data shows that the amounts of GHGs emitted by the various source categories in 2000, except for rice cultivation, are of the same order of magnitude. The methane emitted by rice cultivation in 2000 is much lower than that reported for the 1994 GHG Inventory (5.76 Gg CH_4 in 2000 vs. 14.89 Gg CH_4 in 1994). This can be attributed to the new and improved estimation procedures provided in the 2006 IPCC Guidelines, which used much lower default emission factors. The GHGs emitted by field burning of agricultural residues remained high in 2000 as it was the case in 1994. A total of 60.22 Gg CO were emitted by this source category, which is a cause of concern. Therefore, there is a strong case for developing mitigation measures and strategies aimed at reducing these emissions from the burning of agricultural residues. Except where there is a requirement to burn field residues for pest management purposes, the residues should either be incorporated into the soil to improve soil organic matter or used as animal feed.

3.8 Waste Management Sector

Waste treatment and disposal lead to the emission of GHGs into the atmosphere. The main GHGs emitted from the Waste Management Sector (WMS) are: (i) methane (CH_4), (ii) carbon dioxide (CO_2), and (iii) nitrous oxide (N_2O). This study focuses on the emissions of the following GHG source categories: (i) solid waste disposal, (ii) biological treatment of solid waste, (iii) incineration and open burning of waste, and (iv) waste water treatment and discharge. By and large, most of the CH_4 emissions are from solid waste disposal sites (SWDS) and wastewater treatment plants (WWTPs) (IPCC, 2006). These sub-sectors contribute 3.0 to 4.0% of the annual global anthropogenic gas emissions (IPCC, 2001).

The CO_2 produced in the WMS is of both biogenic and fossil origin. Biogenic CO_2 is considered to be re-absorbed by vegetation for photosynthesis. Thus, it is accounted for in the Agriculture, Forestry and Other Land Use (AFOLU) Sector. The N_2O emissions from SWDS, anaerobic digestion of organic matter, and mechanical–biological (MB) treatment are considered insignificant (IPCC, 2006). Composting emits N_2O in the range of 0.5 to5% of the initial nitrogen content in the material (Peterson et al., 1998; Hellebrand, 1998; Vesterinen, 1996). However, data on these emissions are very scarce because compositing data are not systematically collected and catalogued. The N_2O accounted for in the WMS is from open burning and domestic wastewater treatment.

3.8.1 Source Category Emissions

Solid waste disposal. Solid waste (SW) is generated from refuse accumulated in households, offices, shops, markets, restaurants, public institutions, industrial installations, waterworks, sewage facilities, construction sites, demolition sites, and agricultural production farms (IPCC, 2006). Solid waste is generally categorized into: (i) municipal solid waste (MSW), (ii) sludge, and (iii) industrial and other waste. MWS includes household waste, commercial and institutional waste. Sludge includes materials from domestic and industrial wastewater treatment plants, whereas industrial waste includes organic solids from construction debris, and the other waste includes clinical, hazardous and agricultural wastes.

Municipal solid waste mainly comprises food waste, garden park waste, paper, cardboard, wood, textiles, rubber, leather, plastics, metal, and glass (pottery and china), among many others (IPCC, 2006). In Malawi, solid waste, on average, constitutes: (i) organic matter (90%), (ii) plastic and rubber (4%), (iii) paper (4%), (iv) metal (1.0 %), (v) textile (0.5%), and (vi) glass (0.5%) (Chinyama and Mandhlopa, 1999). The treatment and disposal of municipal, industrial and other solid waste releases large amounts of methane ($CH_{40)}$ (IPCC, 2006). Methane produced at solid waste disposal sites contributes some 3 to 4% of the annual global anthropogenic GHG emissions (IPCC, 2001). Further, degradable organic carbon

(DOC) is decomposed by bacteria, which in the process produces methane. Generally, methane production starts one or two years after waste is deposited in landfills (Chipofya, 2003).

Biological treatment of solid waste. Biological treatment of organic matter (OM) is done in two ways: (i) anaerobic digestion, and (ii) composting. Anaerobic treatment is linked to methane recovery and combustion that is aimed at generating energy. The GHG emissions from this process, are therefore, reported under the Energy Sector (IPCC, 2006). The mechanical-biological (MB) treatment of waste aims at reducing the volume of waste and gas emissions from disposal sites (IPCC, 2006). The MB treatment of waste reduces the amount of organic material by 40 to 60% as the waste material undergoes through composting, anaerobic digestion, separation, shredding and crushing (Kaartinen, 2004). However, MB treatment of waste is most common in European countries and not in developing countries. However, in Malawi there is an increasing trend of making compost manure to make organic manure for enhancing soil organic matter and improving soil fertility.

Incineration and open burning of waste. Incineration and open burning of waste are also important sources of GHG emissions. Incineration refers to the combustion of solid or liquid waste in controlled incineration facilities. Open burning of waste refers to combustion of unwanted materials in open dump sites where smoke and other emissions are directly released into the air, and are mainly as a result of incomplete waste combustion.

Wastewater treatment and discharge. Wastewater originates from domestic, municipal and industrial processes. The combined wastewater is treated at various sewage work sites where flow-measuring devices are incorporated (Chipofya, 2003). However, wastewater is a source of methane (CH_4) when treated or discharged an aerobically. Although the discharge systems for wastewater differ between countries, areas and users, sewers are either open or closed, and consist of networks of open canals, gutters and ditches, and contain organic compounds, whose concentrations vary with the source or origin. Rivers and streams with large quantities of organic compounds, especially those from the food processing industries, quickly deplete the available oxygen [biochemical oxygen demand (BOD_5)] in the water as organic matter decomposes. The BOD_5 is the amount of oxygen required by micro-organisms to oxidize OM .Once the oxygen is depleted, then anaerobic conditions develop resulting into the release of methane gas. Both wastewater and its sludge produce methane, whose release is enhanced by increasing temperatures. Because of increasing temperatures, open sewers emit more methane than closed ones (Doorn et al., 1997). On the other hand, domestic wastewater is treated on site (uncollected) in pit latrines, septic systems or centralized plants, or disposed of in unmanaged lagoons or waterways, where they also emit methane.

3.8.2 Methodology

Data on waste management were collected from the cities of Lilongwe (Central Region), Blantyre and Zomba (Southern Region) and Mzuzu (Northern Region), and randomly selected districts in the country: (i) Karonga in the Northern Region, (ii) Kasungu and Salima in the Central Region, and (iii) Thyolo (Luchenza), Balaka and Machinga (Liwonde) in the Southern Region. Data were collected using a structured questionnaire and one-on-one interviews covering the following aspects: (i) waste management, (ii) solid waste disposal, (iii) biological treatment of solid waste, (iv) incineration and open-burning of waste, and (v) wastewater treatment and discharge.

Solid waste disposal. Methane (CH_4) emissions from solid waste disposal sites (SWDS) were estimated using the First Order Decay (FOD) method (IPCC, 2006). Where local data were not available, default values were obtained from the IPCC Guidelines, which included: (i) degradable organic carbon (DOC) = 0.28, (ii) fraction of DOC which decomposes (DOC_f) =0.5, (iii) conversion rate = 1.33, equivalent to 16/12, and (iv) recovered methane = 0. The fraction of C-Cf_4 to C-biogas = 0.5, was determined by Chipofya (2003).

Biological treatment of solid waste. Composting is the only method that is practiced for the biological treatment of solid waste. However, data on composting are not available. Hence, this source category for GHG emissions was not considered in the present GHG Inventory.

Incineration and open burning of waste. The methane (CH_4) emissions from incineration and open burning of waste were calculated using the Equation 3,8:

CH_4 emissions = IW x EF x 10^{-6} ……………………….…………………………………………… [3.8]

Where

IW = amount of solid waste incinerated (Gg/yr)

EF = aggregate factor (kg CH_4/Gg of waste)

The fraction of the population of the burning waste (P_{frac}) has been taken as the population whose waste is collected and disposed of in open dumps and burnt, whereas: (i) the fraction of the amount of waste that is open-burned (B_{frac}) was taken as 0.5 because a relatively large part of the waste is left unburned when a substantial quantity of waste in open dumps is burned, and (ii) the CH_4 emission factor was taken as 6,500 g/tonne MSW wet weight. Unfortunately, data on incineration of waste are not readily available. Hence default values from the 2006 IPCC Guidelines were used. The CO_2 and N_2O emissions were estimated as follows (Equations 3.9 and 3.10):

CO_2 emissions = Total amount of waste open burnt x DM x CF x FCF x OF x conversion factor…. [3.9]

Where:

DM = dry matter

CF = fraction of carbon in dry matter

FCF = fraction of fossil fuel carbon in total carbon

OF = oxidation factor

Conversion factor = 44/12 (=11/3)

N_2O emissions = Total amount of waste open burnt x EF ……………………………..…...………… [3.10]
Where
EF = 150 kg N_2O/t dry waste

Wastewater treatment and discharge. Domestic wastewater methane (CH_4) emissions were determined using the Tier 1 method. The data on domestic wastewater treatment and discharge were inadequate, hence the default values from the IPCC Guidelines and other credible sources were used as follows (Eq 3.11):

Methane emissions = ∑ (U×T×EF)×(TOW - S)-R …………………………………………………….…… [3.11]

Where
S = 0, R = 0 (default)
BOD_5 value= 37/person/day (Doorn and Liles, 1999)
TOW= 0.001 x 365 x P x BOD x I, 1=1.0 (default)
EF= B_o x MCF (B = 0.6 kg CH_4/kg BOD)
MCF = 0.5 (default).

The CO_2 emissions from the wastewater treatment source category were not considered because they are of biogenic origin. On the other hand, wastewater N_2O emissions arise from sources that include urea, nitrate and proteins, and were estimated as indicated in Equations 3.12 and 3.13:

N_2O émissions = $N_{effluent}$ × N_2O $EF_{Effluent}$ × 44/28 …………………………………………………… [3.12]

$N_{effluent}$ = (P × Protein × F_{NPR} × $F_{NON-CON}$ × $F_{IND-COM}$) - N_{SLUDGE}, …………………………………...…… [3.13]
Where:

P	= human population
Protein	= annual per capita protein consumption
F_{NPR}	= fraction of nitrogen in protein, default = 0.16 kg N/ kg protein
$F_{NON-CON}$	= factor of non-consumed protein added to the wastewater
$F_{IND-COM}$	= factor of industrial and commercial co-discharged protein into the sewer system,
N_{SLUDGE}	= N removed with sludge, default = 0, 44/28 is the conversion factor kg N_2O-N into N_2O.

3.8.3 Results and Findings

Solid waste disposal. The methane (CH_4) emissions (Gg) for the years 1995 to 2000 were as follows: 6.5303, 6.8083, 7.0905, 7.3845, 7.6806 and 8.0249 Gg, respectively (Table 3.23). These depict a linear increasing trend in methane emissions over the years, an indication of increasing human activity in the generation of waste in urban areas. Among the cities, Blantyre recorded the highest methane emissions, whereas among the townships Liwonde recorded the highest followed by Mangochi. This can be attributed to increasing business activities from an increasing human population pressure. In 1995, Liwonde Township emitted more methane than Mzuzu City. However, the methane emissions for Mzuzu were more than those of Liwonde starting from 1996. The lowest recorded emissions across all the years are for Luchenza Township.

Table 3.23: Annual CH_4 emissions from cities and selected townships, Malawi, 1995-2000

City or Township	Year					
	1995	1996	1997	1998	1999	2000
Mzuzu	0.2343	0.2524	0.2719	0.293	0.3158	0.3403
Blantyre	3.4664	3.5559	3.648	3.7421	3.8364	3.9331
Lilongwe	1.3942	1.4914	1.5866	1.6878	1.789	1.9143
Karonga	0.1747	0.1799	0.1852	0.1906	0.1961	0.2017
Kasungu	0.187	0.2019	0.218	0.2355	0.2529	0.2759
Luchenza	0.0223	0.0398	0.0575	0.0752	0.0822	0.1104
Liwonde	0.2361	0.2422	0.2485	0.2549	0.2613	0.2679
Balaka	0.1985	0.2035	0.2089	0.2143	0.2198	0.2269
Salima	0.1397	0.1506	0.1616	0.1726	0.1836	0.1945
Zomba	0.1453	0.1507	0.1563	0.1622	0.1776	0.1843
Dedza	0.1158	0.1208	0.1257	0.1308	0.1358	0.1408
Mangochi	0.2162	0.2192	0.2223	0.2255	0.2301	0.2348
Total	6.5305	6.8083	7.0905	7.3845	7.6806	8.0249

There were both temporal and spatial variations in methane (CH_4) emissions. These emissions were also influenced by the type of source category, composition and length of time the waste has been exposed. Blantyre City recorded the highest human population and methane emissions over the years. Luchenza Township had the lowest population and recorded the least methane emissions, suggesting that solid waste generated, and the subsequent methane emissions, are greatly influenced by climate-related activities.

Open burning. CO_2 is emitted in the largest quantities under open burning, which is closely followed by methane (CH_4.) The CO_2 emissions increased linearly from 42.7052 Gg in 1995 to 54.0936 Gg in 2000, whereas the N_2O emissions also increased steadily from 0.1336 Gg in 1995 to 0.1693 Gg, in 2000 (Table 3.24).

Table 3.24: Annual CO_2 and N_2O emissions from cities and selected townships, Malawi, 1995-2000

Year	Carbon dioxide	Nitrous oxide
1995	42.7052	0.1336
1996	44.5972	0.1396
1997	46.6669	0.1460
1998	48.5174	0.1518
1999	50.7593	0.1588
2000	54.0936	0.1693

CH_4 emissions emitted from open burning in cities and selected townships increased linearly from 0.0585 in 1995 to 0.074 Gg in 2000 (Table 3.25). However, although the CH_4 emission figures are much smaller than those of CO_2,, CH_4 has a higher warming potential than CO_2 (44 vs. 1).

Table 3.25: Annual CH_4 emissions from cities and selected townships in Malawi, 1995-2000

City or Township	Year					
	1995	1996	1997	1998	1999	2000
Mzuzu	0.0007	0.0010	0.0014	0.0017	0.0020	0.0024
Blantyre	0.0422	0.0433	0.0444	0.0456	0.0467	0.0479
Lilongwe	0.0075	0.0080	0.0086	0.0091	0.0096	0.0118
Karonga	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Kasungu	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004
Luchenza	0.0002	0.0004	0.0005	0.0006	0.0007	0.0009
Liwonde	0.0019	0.0019	0.0020	0.0020	0.0021	0.0021
Balaka	0.0016	0.0016	0.0017	0.0017	0.0017	0.0019
Salima	0.0011	0.0012	0.0013	0.0014	0.0015	0.0015
Zomba	0.0009	0.0010	0.0012	0.0012	0.0016	0.0017
Dedza	0.0011	0.0012	0.0013	0.0014	0.0015	0.0015
Mangochi	0.0009	0.0010	0.0012	0.0012	0.0016	0.0017
Total	0.0585	0.0610	0.0640	0.0663	0.0695	0.0740

Biological treatment of solid waste. In Malawi, composting as a way of disposing of waste is generally not practiced at all, and so are anaerobic digestion and mechanical-biological (MB) treatments. Hence, CO_2, CH_4 and N_2O emissions from composting were not estimated from this source category. As alluded to earlier, the composting of crop residues is presently widely practiced under smallholder farm conditions as part of the strategy for soil fertility improvement.

Wastewater treatment and discharge. The CH_4 emissions increased from 0.1203 Gg in 1995 to 0.1493 Gg in 2000 (Table 3.26). These results exhibit a gradual but increasing trend of CH_4 emissions as time progressed. The total N_2O emissions, summed across all the cities and townships increased from 0.0406 Gg in 1995 to 0.0502 Gg, in 2000 (Table 3.27). These emissions also exhibit a gradual increasing trend as time progressed. This is an indication of the increasing NO_2 in municipal wastewater from pit latrines and septic tanks. However, this study did not consider industrial wastewater discharged from townships separately because there are no wastewater processing facilities in townships.

Table 3.26: Annual CH_4 emissions from wastewater treatment and discharge, 1995-

City or Town	Year					
	1995	1996	1997	1998	1999	2000
Mzuzu	0.0086	0.0093	0.0100	0.0108	0.0116	0.0125
Blantyre	0.0657	0.0674	0.0692	0.0710	0.0728	0.0746
Lilongwe	0.0365	0.0391	0.0416	0.0442	0.0469	0.0502
Karonga	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006
Kasungu	0.0005	0.0005	0.0006	0.0006	0.0007	0.0007
Luchenza	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003
Liwonde	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007
Balaka	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006
Salima	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005
Zomba	0.0060	0.0063	0.0065	0.0067	0.0074	0.0076
Dedza	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004
Mangochi	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Total	0.1203	0.1256	0.1311	0.1369	0.143	0.1493

Table 3.27: Annual N_2O emissions (Gg) from the wastewater treatment and discharge, 1995-2000

Year	Nitrous oxide
1995	0.0406
1996	0.0424
1997	0.0441
1998	0.0461
1999	0.0480
2000	0.0502

3.8.4 Total GHG Emissions from the Waste Management Sector

The total CH_4, N_2O and CO_2 emissions (Gg) from the WWS are graphically depicted in Fig 3.3. CO_2 and CH_4 are of similar magnitude and exhibit a gradual linear trend, whereas the N_2O is low and almost a constant or uniform trend. The total GHG emissions (CO_2 equivalents) are summarised in Table 3.28.

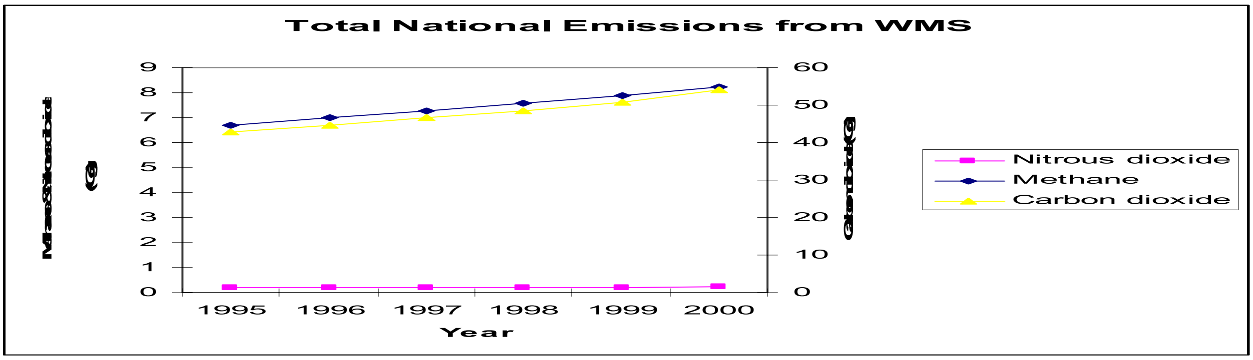


Fig 3.3: CO_2, CH_4 and N_2O emissions in the Waste Management Sector

Table 3.28: CO_2, CH_4 and N_2O emissions (Gg) from the Waste Management Sector

Category	Year	CO_2	CH_4	N_2O
Solid waste disposal	1995	-	150.20	-
	1996	-	156.59	-
	1997	-	163.08	-
	1998	-	169.84	-
	1999	-	176.65	-
	2000	-	184.57	-
Open burning of waste	1995	42.71	1.35	39.55
	1996	44.60	1.40	41.32
	1997	46.67	1.47	43.22
	1998	48.52	1.52	44.93
	1999	50.76	1.60	47.0
	2000	54.09	1.70	50.11
Wastewater treatment and discharge	1995	-	2.77	12.02
	1996	-	2.89	12.55
	1997	-	3.02	13.05
	1998	-	3.15	13.65
	1999	-	3.29	14.21
	2000	-	3.43	14.86

Note: the CO_2 equivalent conversion factors used were 23 and 296 for CH_4 and N_2O, respectively.

3.8.5 Summary

Thus, the total GHG emissions from the Waste Management Sector are as follows: (i) CH_4 emissions: 6.7093, 6.9949, 7.2856, 7.5877, 7.8931 and 8.2482 Gg, for 1995, 1996, 1997, 1998, 1999 and 2000, respectively, (ii) CO_2 emissions: 42.7052, 44.5972, 46.6669, 48.5174, 50.7593 and 54.0936 Gg, for 1995, 1996, 1997, 1998, 1999 and 2000, respectively, and (iii) N_2O emissions: 0.1742, 0.182, 0.1901, 0.1979, 0.2068 and 0.2195 Gg for 1995, 1996, 1997, 1998, 1999 and 2000, respectively. All these exhibit an increasing trend as time progressed against a background of increasing human population, presently numbering 13.1 million and growing at the rate of 2.8% per year. The solid waste source category contributed up to 60% of the total emissions, followed by the incineration and open burning category, 34% of the emissions. Over the years, there was an increase in the emission levels corresponding with increase in human activities that produce wastes (Table 3.29).

Table 3.29: Source category emissions (Gg) from the Waste Management Sector, 1995-2000

Sub-sector	Year					
	1995	1996	1997	1998	1999	2000
Solid Waste	150.20	156.59	163.08	169.84	176.65	184.57
Biological Treat.	NE	NE	NE	NE	NE	NE
Incineration & OP	83.60	87.32	91.36	94.97	99.36	105.90
Wastewater	14.79	15.44	16.07	16.80	17.50	18.29

Note: Treat – Treatment; OP – Open burning

The sector category emissions of CO_2, CH_4 and N_2O (Gg) over the period 1995-2000 reveal that the solid waste category was responsible for 98.5% of all the total CH_4 emissions, followed by incineration and open burning, 0.9% and then finally wastewater, 0.6% (Table 3.30). However, the incineration and open burning sources category accounted for 52.6% of

N_2O emissions, whereas the remaining 47.4% was derived from the wastewater category. The incineration and open burning source category was also responsible for 100% of the non-bionic CO_2 emissions.

CH_4 was responsible for 13% of the total emissions in the WMS, which was 56% of the total contribution in CO_2 equivalent. N_2O contributed only 1% of the total mass emissions, which is about 28% of the total contribution in CO_2 equivalents. These results clearly indicate that although the CH_4 and N_2O emissions appear to be small, they have a high potential of warming the atmosphere. Based on these findings, it is recommended that a comprehensive data base should be compiled for all urban centres in the country. Research also needs to determine emission factors and activity data, such as for: (i) waste composition, (ii) degradable organic carbon, (iii) fractions of municipal solid waste deposited in SWDS, (iv) solid waste incinerated in hospitals and/or clinics, (v) composting, and (vi) domestic and industrial wastewater treatment, for use in the determination of GHG emissions from the sector.

Table 3.30: CO_2, CH_4 and N_2O emissions (Gg) by gas type, 1995-2000

Sub-sectors	Gas type	Year					
		95	191996	1997	1998	1999	2000
Solid Waste	CH_4	6.5305	6.8083	7.0905	7.3845	7.6806	8.0249
Biological treatment	NE	NE	NE	NE	NE	NE	NE
Incineration & OP	CO_2	42.7052	44.5972	46.6669	48.5174	50.7393	54.0936
	N_2O	0.1336	0.1396	0.1490	0.1518	0.1588	0.1693
	CH_4	0.0585	0.061	0.064	0.0663	0.0695	0.074
Wastewater	N_2O	0.1203	0.1256	0.1311	0.1369	0.143	0.1493
	CH_4	0.0406	0.0424	0.0441	0.0461	0.048	0.502

Note: OP – Open burning; NE – Data not available

3.9 Overall Summary of Malawi's GHG Inventory

Table 3.31 provides a national picture of GHG emissions and sinks in the following sectors: (i) Energy, (ii) Industrial Processes and Product Use (IPPU), (iii) Agriculture, Forestry and Other Land-Use (AFOLU), and (iv) Waste Management from various sub-sectors (or source categories) over a period of six year period (1995-2000) following the format recommended in the 2000 IPCC Guidelines.

The GHGs were determined in four sectors of economic growth only. In other sectors emissions of GHGs are much smaller than the four sectors. Although at national level GHG emissions are substantial in the four economic sectors, they are tiny at regional level, and negligible at global level. Despite Malawi's contribution is very small, the ultimate challenge is to emit zero emissions, which is an enormous challenge, given the ambitious development agenda for the next five years (2011-2016). However, the need to reduce GHGs is clear. It is for this reason that mitigation measures for climate change (mitigation analysis) have been investigated and presented in Chapter 5. Furthermore, it is important to note that while Malawi's contribution to global GHG emissions is quite small at the regional and the global level, all the economic growth sectors, fragile agro-ecosystems and vulnerable communities, are highly vulnerable to the adverse effects of climate change caused by GHGs. It is therefore quite clear to develop adaptation measures to climate change and climate variability. For Malawi, the proposed strategies and measures for adapting to climate change are presented in Chapter 4.

Table 3.31: GHG Inventory for Malawi (in terms carbon dioxide equivalent, Gg), 1995-2000.

Sector and Sub-sector	Year						
	1995	1996	1997	1998	1999	2000	Total
1 Energy Sector							
1A Fuel combustion activities	742.88	752.41	807.69	843.27	781.83	726.13	4654.21
1B Fugitive emissions from fuels	0.57	0.57	1.02	0.95	0.58	0.68	4.37
1C Carbon dioxide transport and storage	NA	NA	NA	NA	NA	NA	NA
Sub-total	743.45	752.98	808.71	844.22	782.41	726.81	4658.58
2 Industrial Processes and Product Use (IPPU)							
2A Mineral industry	59.53	46.59	37.93	48.04	57.30	59.18	308.57
2B Chemical industry	NA	NA	NA	NA	NA	NA	NA
2C Metal industry	NA	NA	NA	NA	NA	NA	NA
2D Non-energy from fuels and solvent use	0.07	0.16	0.73	0.31	0.42	0.50	2.19
2E Electronics industry	NA	NA	NA	NA	NA	NA	NA
2F Product use as substitutes of ODS	NE	NE	NE	NE	NE	NE	NE
2G Other product manufacture and use	NA	NA	NA	NA	NA	NA	NA
2H Other	NA	NA	NA	NA	NA	NA	NA
Sub-total	59.60	46.75	38.66	48.35	57.72	59.68	310.76
3 Agriculture, Forestry and Other Land-use							
3A Livestock	747.30	730.69	664.63	762.31	740.90	810.75	4456.58
3B Land	17800.00	18089.00	18377.00	18666.00	18954.00	19243.00	111129.00
3C Aggregate sources and non-CO_2 emissions	2459.67	2406.59	2514.03	2195.06	2174.69	2280.55	13994.59
3D Other	NE	NE	NE	NE	NE	NE	NE
Sub-total	21006.07	21226.28	21555.66	21623.37	21869.59	22334.30	12961.27
4 Waste Management							
4A Solid waste disposal	150.20	156.59	163.08	169.84	176.65	184.57	1000.93
4B Biological treatment of solid waste	NE	NE	NE	NE	NE	NE	NE
4C Incineration and open burning of waste	83.60	87.32	91.36	94.97	99.36		456.61
4D Waste water treatment/discharge	14.79	15.44	16.07	16.80	17.50		80.6
4E Other	NE	NE	NE	NE	NE		NE
Sub-total	248.59	258.35	274.13	281.61	293.51		1356.19
Total emissions	22052.71	22284.56	22677.16	22797.55	23003.23		23439.51

Appendices

Appendix A3.1: Table A3.1: Total greenhouse gas (GHG) emissions (Gg) for 1990

Greenhouse gas sources and sink categories	Greenhouse gas emissions and removals					
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_X	CO
Energy (Reference Approach)	619.13	0.00	276.23	0.72	27.12	895.95
Industrial Processes	50.12	0.00	4.02	0.00	0.00	0.00
Agriculture	0.00	0.00	50.83	0.36	1.58	30.78
Land Use Change and Forestry	21200.30	-1320.81	0.86	0.01	0.21	7.50
Waste Management	0.00	0.00	4.33	0.00	0.00	0.00
Total emissions and removals	21869.54	-1320.81	336.26	1.09	28.92	934.23

Source: EAD, 1999

Appendix A3.2: Table A3.2: Total greenhouse gas (GHG) emissions (Gg) for 1994

Greenhouse gas source and sink categories	Greenhouse gas					
	CO_2 Emissions	CO_2 Removals	CH_4	NO_2	NOx	CO
1. Energy - Reference Approach (Below)	**660.88**	**0.00**	**135.09**	**0.71**	**24.03**	**879.58**
A. Fossil fuels						
Liquid Fossil Fuels	529.43					
Solid Fossil Fuels	131.01					
B. Fugitive Emissions (Solid fuels)	0.44					
C. Biomass			135.09	0.71	24.03	879.58
2. Industrial Processes	**58.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Cement Production	56.62					
Lime Production	1.76					
Industrial digesters	0.00					
3. Agriculture	**0.00**	**0.00**	**48.50**	**7.05**	**2.24**	**72.20**
Enteric Fermentation			30.10			
Manure Management			1.34	0.17		
Rice Cultivation			14.89			
Agricultural Soils				6.81		
Prescribed Burning of Savannas			0.42	0.01	0.19	11.06
Field Burning of Agricultural Residues			1.75	0.06	2.05	61.14
4. Land Use Change and Forestry	**18528.02**	**-1016.00**	**0.02**	**0.01**	**0.04**	**0.02**
Changes in Forestry and Other Woody Biomass	14003.02					
Forests and Grassland Conversion	2183.00		0.02	0.01	0.04	0.02
Abandonment Managed Lands		-1016.00				
CO_2 Emissions and Removals from Soils	2342.00					
5. Waste	**0.00**	**0.00**	**4.29**	**0.00**	**0.00**	**0.00**
Solid Waste Disposal on Land			3.88			
Waste Water Handling			0.41			
Total National Emissions and Removals	19247.28	-1016.00	187.90	7.77	26.31	951.80

Chapter 4:
Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change

4.1 Background

4.1.1 Introduction

The first vulnerability and adaptation (V&A) assessments aimed at identifying and developing measures to adapt to climate change in Malawi were carried out in 1996 under the United States of America (USA) Country Studies Program (CSP), while the second assessments were undertaken as part of Malawi's Initial National Communication (INC) from 1999 to 2003. The INC covered several sectors, including: (i) Agriculture, (ii) Wildlife, (iii) Water Resources, (iv) Forestry and Land-Use, and (v) Energy; and used a 30-year baseline period from 1960-1990. Four General Circulation Models (GCMs) from MAGICC/SCENGEN (Model for the Assessment of Greenhouse Gas Induced Climate Change/Scenario Generator): (i) HADCM2, (ii) CSIRO-TR, (iii) ECHAM2, and (iv) CGCM1-TR were selected and used to project future temperature and rainfall changes for the years 2020, 2075 and 2100. The results revealed a projected temperature increase of between 1.0 ^{0}C and 3.0 ^{0}C by the year 2100, whereas the rainfall pattern was rather mixed, with an increase of up to 22% in some areas, and a reduction of up to 16% in others by the year 2100.

The development of climate change scenarios and the running of the associated simulation models for the various sectors were faced with a number of challenges and limitations, including: (i) insufficient model input data, (ii) lack of explicit IPCC Guidelines for some areas and sectors, (iii) lack of finer resolution of the MAGIC/SCENGEN models, (iv) lack of methodologies for the simulation of extreme weather events, especially droughts and floods, (v) lack of models on cost-benefit analysis, and (vi) lack of training in model selection and use. The current V&A Assessments aims at addressing two objectives of the United Nations Framework Convention on Climate Change (UNFCCC): (i) assessing the vulnerability of major ecosystems and socio-economic sectors to the adverse impacts of climate change, (ii) and developing technical options to reduce vulnerability of vulnerable communities.

4.1.2 Definition of Terms

The IPCC Working Group II has defined 'Vulnerability' as the degree to which a system will respond to a given change in climate, including beneficial and harmful effects (IPCC, 2001). Vulnerability is essentially "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and weather extremes'. In the context of climate change, 'vulnerability' to climate change usually means the risk that climate change will cause a decline in the well being of poor people and underdeveloped poor countries.

Adaptation is a process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented. In natural and human systems, it is a response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities. Other definitions on climate change and climate change related terminology are given in Appendix 1 (Glossary of Terms) on page 275.

4.2 General Approach and Methodology

The overall objective of the study was to review and update the findings and information reported in the Initial National Communication of Malawi (INC) of Malawi as follows: (i) assess the impacts of climate change in the socio-economic sectors of Agriculture, Fisheries, Forestry and Other Land-Use, Water Resources, Energy, Wildlife and Human Health, and (ii) evaluate adaptation strategies and policy options to reduce vulnerability to the impacts of climate change. These sectors were selected based on the findings of the INC and the fact that although Malawi does not emit a lot of GHGs, it is vulnerable to the adverse effects of climate change.

The assessments were undertaken by teams of National Experts (NEs) drawn from Government, the universities, and other non-state actors. The experts were supervised by the National Team Leader (NTL) for the V&A Assessments, who was in turn guided and supervised by the Project Manager (PM) for the Second National Communication (SNC) of Malawi Project. Although most of the team members had no previous training on V&A Assessments, approaches and methodologies, including the development of climate change scenarios and computer simulation modelling, some had at least participated in the preparation of the National Adaptation Programmes of Action (NAPA), and this proved very useful. As part of the process, frequent consultative meetings, briefings and workshops with stakeholders were conducted for all the team members in order to guide the preparation process. Special attention was made to ensure that the study addressed the key shortfalls that were identified through the review of the INC. These included the following aspects: (i) some critical socio-economic sectors, particularly energy and human health that were not included in the INC, (ii) critical areas of study in each sector were identified based on a broad set of criteria: (a) scale of vulnerability, (b) relevance to national development priorities, (c) development benefits, (d) availability of data, and (e) country driven-ness, (iii) for each sector, three baseline scenarios were developed and used: (a) climate baseline, (b) environmental baseline, and (c) socio-economic baseline, and (iv) adaptation strategies or policy options were developed, outlining the proposed adaptation measures and the implementation of strategies and plans.

As alluded to earlier, the MAGICC/SCENGEN model was used as the main tool in all selected sectors of economic growth. Four types of General Circulation Models (GCMs) were selected from MAGICC/SCENGEN, whose outputs were the inputs into sectoral models to assess the impacts of climate change in the selected sectors. The models used were those recommended by the Inter-governmental Panel on Climate Change (IPCC). This report presents the results and findings of the assessment study in the country, from the following sectors: (i) Agriculture, (ii) Energy, (iii) Forestry and Other Land-Use, (iv) Fisheries, (v) Wildlife, (vi) Human Health, and (vii) Water Resources.

4.3 Current and Future Impacts and Vulnerabilities

4.3.1 Climate Change Scenarios and Trends

The current methods for predicting future climate changes require the specification of a number of plausible future climates, which are referred to as "climate change scenarios".Climate change scenarios represent possible expressions of what may happen in the future, especially as a result of increased GHG concentrations, and selected to provide spatially compatible, mutually consistent, coherent, systematic, freely available and physically plausible descriptions of future climate. The data from these are used as inputs into impact simulation models and/or in impact assessments studies.

The current study used General Circulation Models (GCMs), which provide broad-scale sets of possible future climatic conditions following the methodology adopted by the Inter-governmental Panel on Climate Change (IPCC) (Carter et al., 1995). GCMs are basically three-dimensional numerical models of the global climate system that provide estimates of regional climate change. Seventeen (17) of these are currently available in the "Model for the Assessment of Greenhouse Gas Induced Climate Change" (MAGICC) using the Scenario Generator (SCENGEN). Four of these were used for the present study using two critical variables, temperature and rainfall, to generate future scenarios for selected stations and sites in Malawi.

Projected rainfall. Climate projections for the period 2010-2075 (GoM, 2007) exhibit climate changes that are relevant to crop growth and development. The mean cumulative rainfall during the growing season decreases over most parts of Malawi, ranging from -4.8 to -0.7% in annual rainfall changes (Fig 4.1-4.5). The rainfall change is predicted to be worse in the Lower Shire Valley (-4.8% annual rainfall change); around Lake Chilwa, Bvumbwe, Makoka and Liwonde National Park (-3.5% annual rainfall change), with little change for most parts of the northern Malawi.

The general trend is that the mean monthly rainfall will decrease with time. As a result of this, annual rainfall amounts are expected to decrease over time as well. In summary, simulation models forecast a decrease in annual rainfall with time at all the stations or sites in Malawi with the highest percentage decrease predicted for the year 2020. The magnitude of the warming increases with time for all the stations used in the analysis, and the highest percentage rise is for the year 2075. However, when temperature and rainfall are compared, the changes in temperature are of a higher magnitude than that for rainfall.

Fig 4.1: Rainfall projections for Ngabu Agricultural Experiment Site, Chikwawa district, southern Malawi

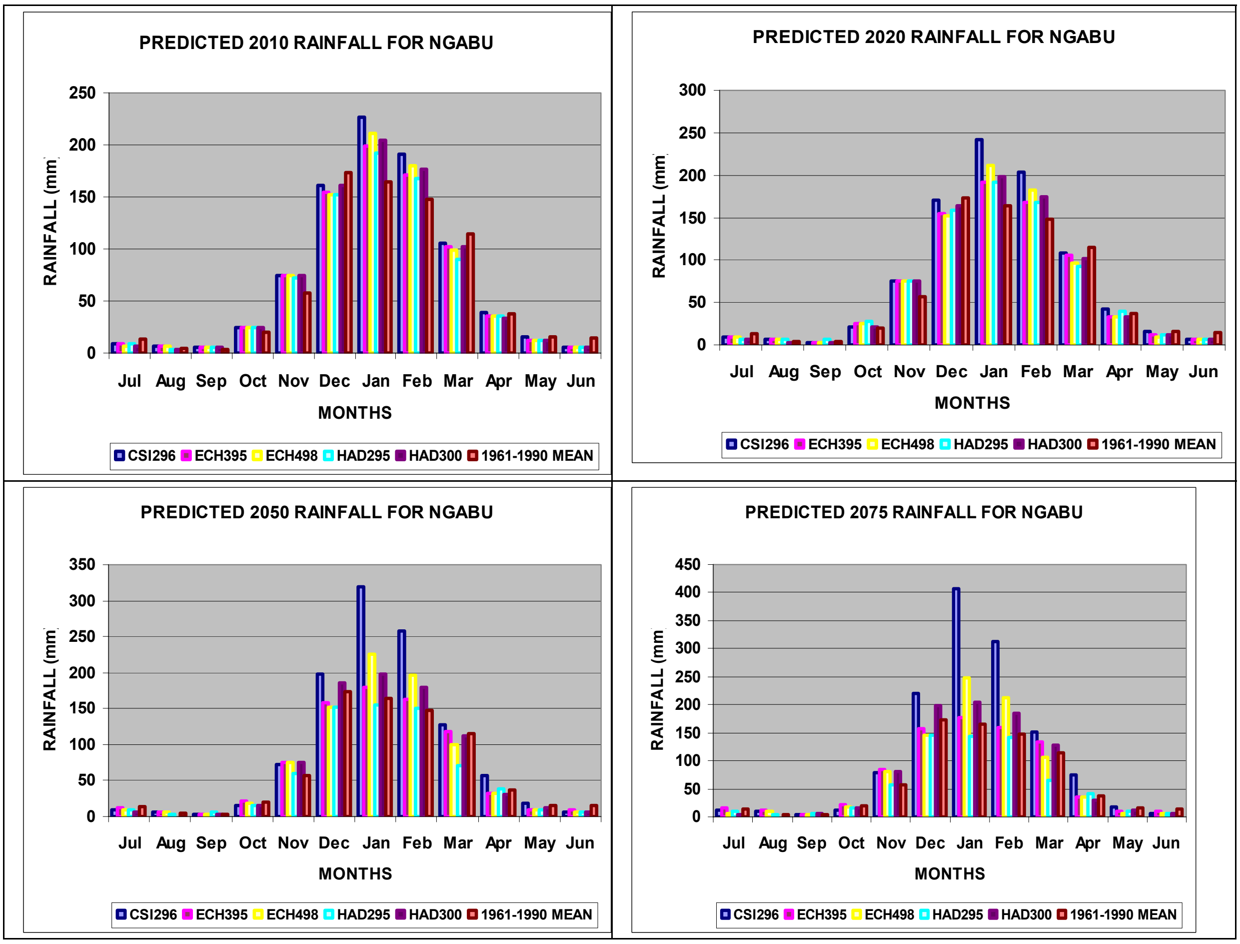
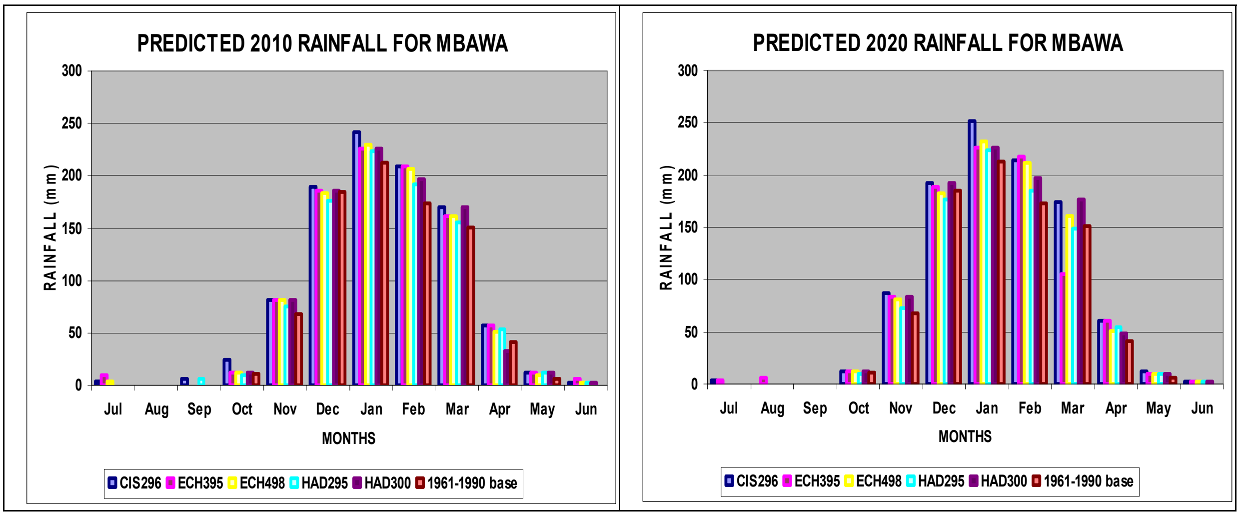


Fig 4.2: Rainfall projections for Mbawa Agricultural Experiment Station, Mzimba district, northern Malawi



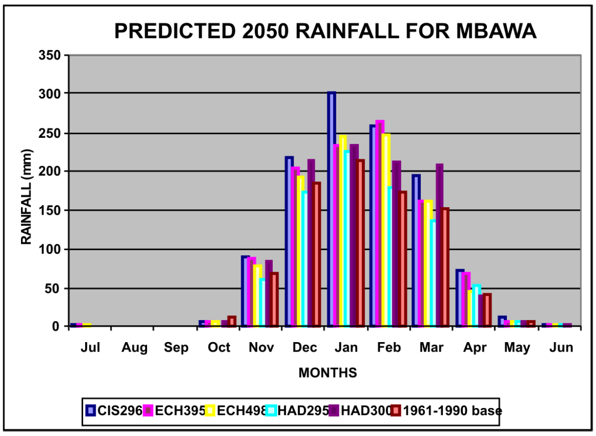


Fig 4.3: Rainfall projections for Dzalanyama Forest, Lilongwe district, central Malawi

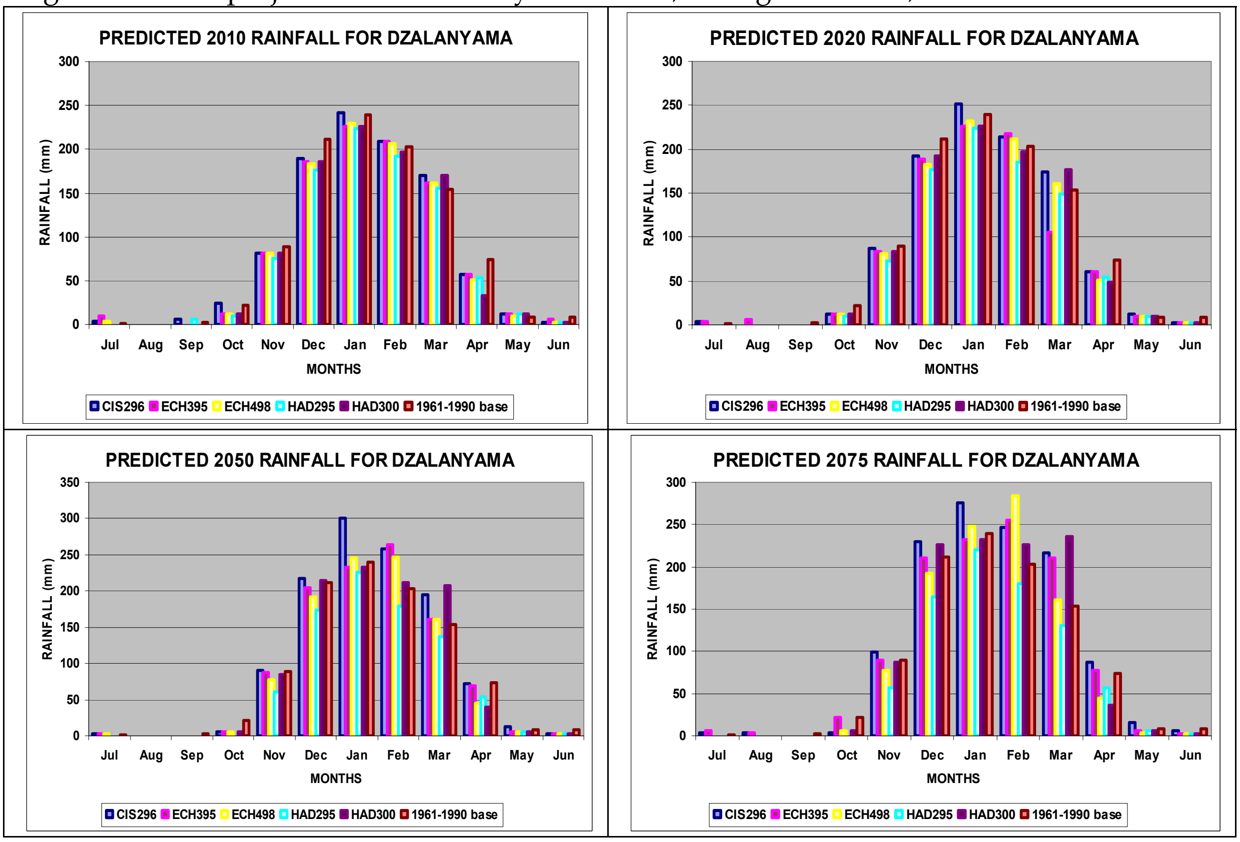
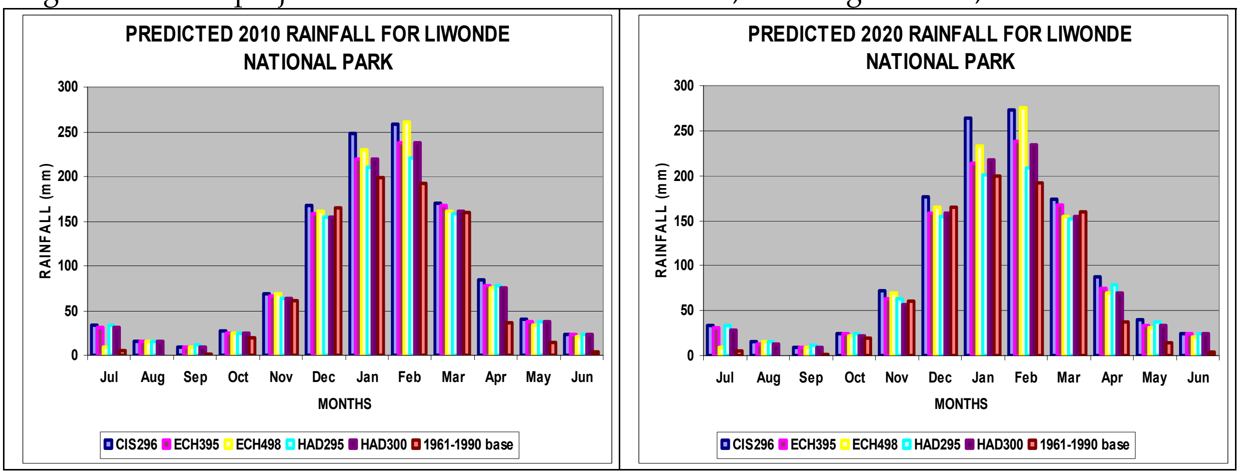


Fig 4.4: Rainfall projections for Liwonde National Park, Machinga district, southern Malawi



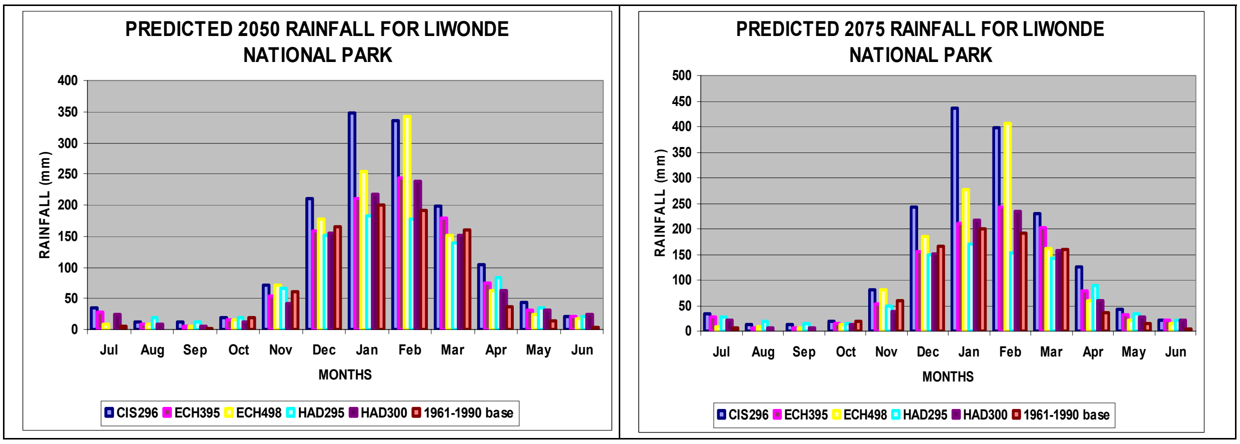
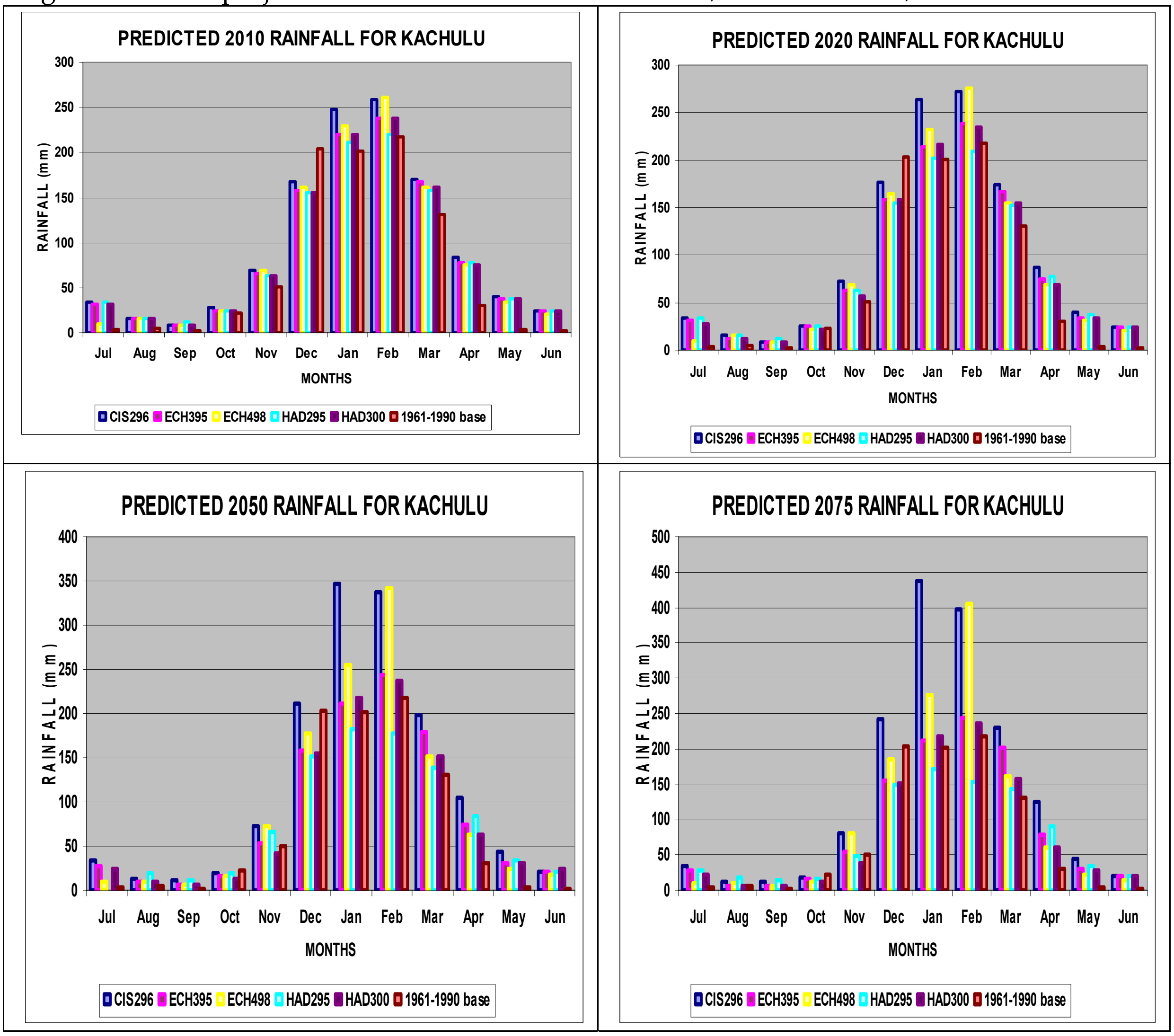


Fig 4.5: Rainfall projections for Kachulu on Lake Chilwa, Zomba district, southern Malawi



Projected temperature. Mean growing-season temperatures show increases throughout the country from its baseline values (21.7-26.5 ^{0}C), most markedly around Ngabu (22.5-24.7 ^{0}C) and Bvumbwe (24.6-26.5 ^{0}C)) between the period 2010 and 2075 (Fig 4.6-4.10). The variability of mean temperature increases over most of Malawi (by up to 2.7 ^{0}C) by 2075. Areas that have been regarded as having low temperatures, for example Bvumbwe and Lunyangwa, have shown a moderate change in temperature to the year 2075 (Table 4.1). Generally, model simulation results for all the stations and sites predict significant warming, forecasting slightly warmer winters and hotter summers.

Fig. 4.6: Temperature projections for Ngabu Agricultural Experiment Site, Chikwawa district, southern Malawi

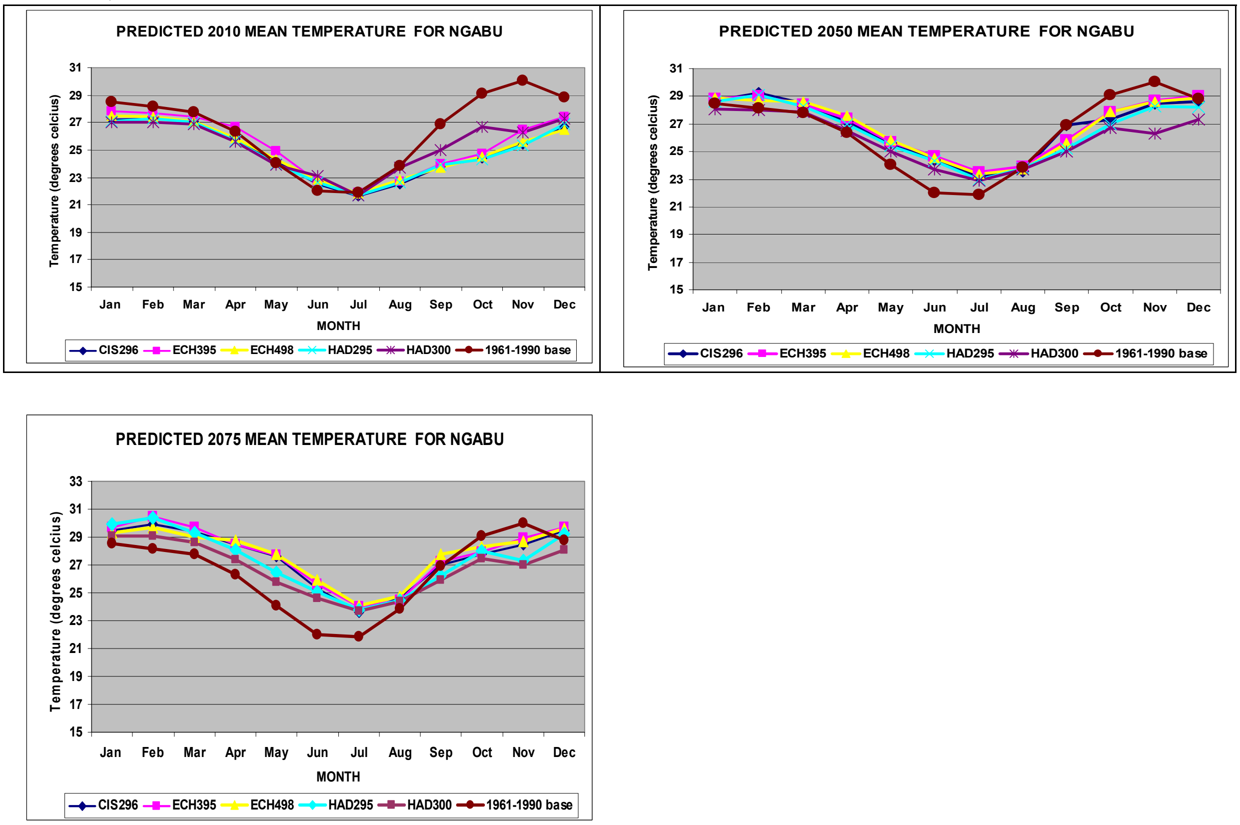


Fig 4.7: Temperature projections for Mbawa Agricultural Experiment Station, Mzimba district, northern Malawi

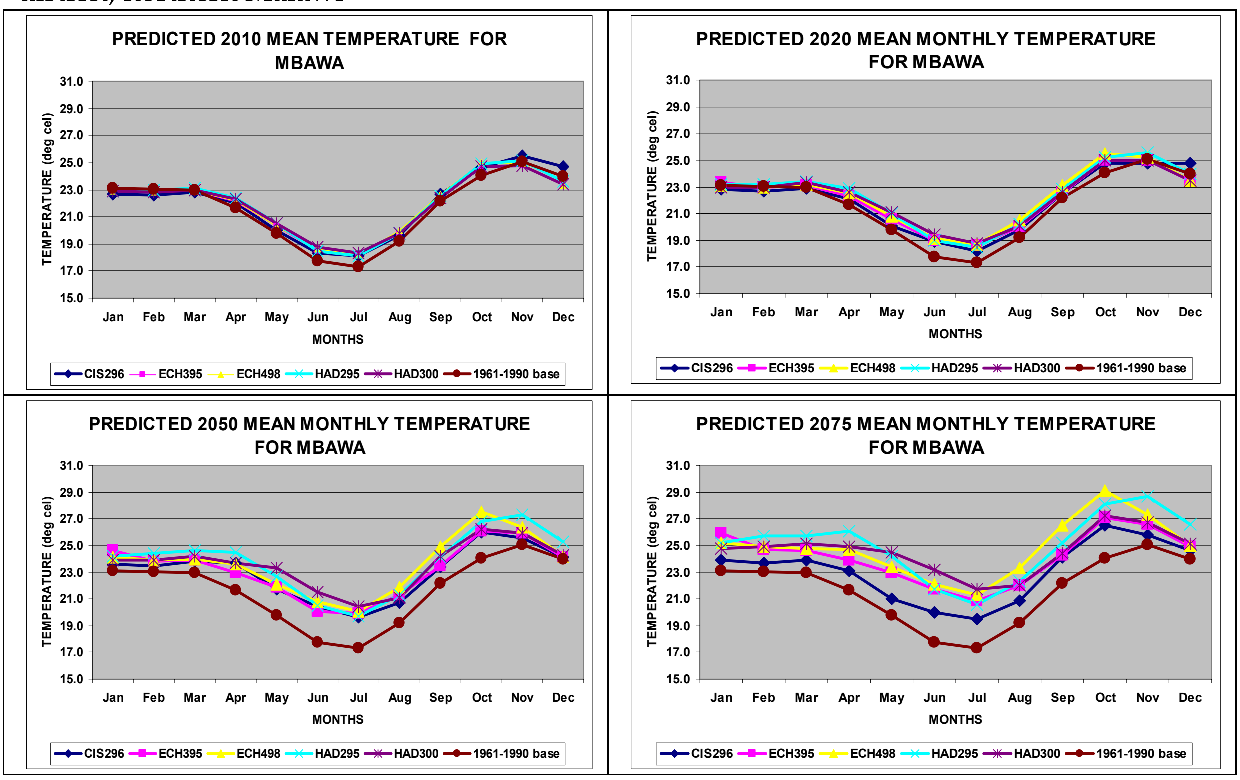


Fig 4.8: Temperature projections for Dzalanyama Forest, Lilongwe district, central Malawi

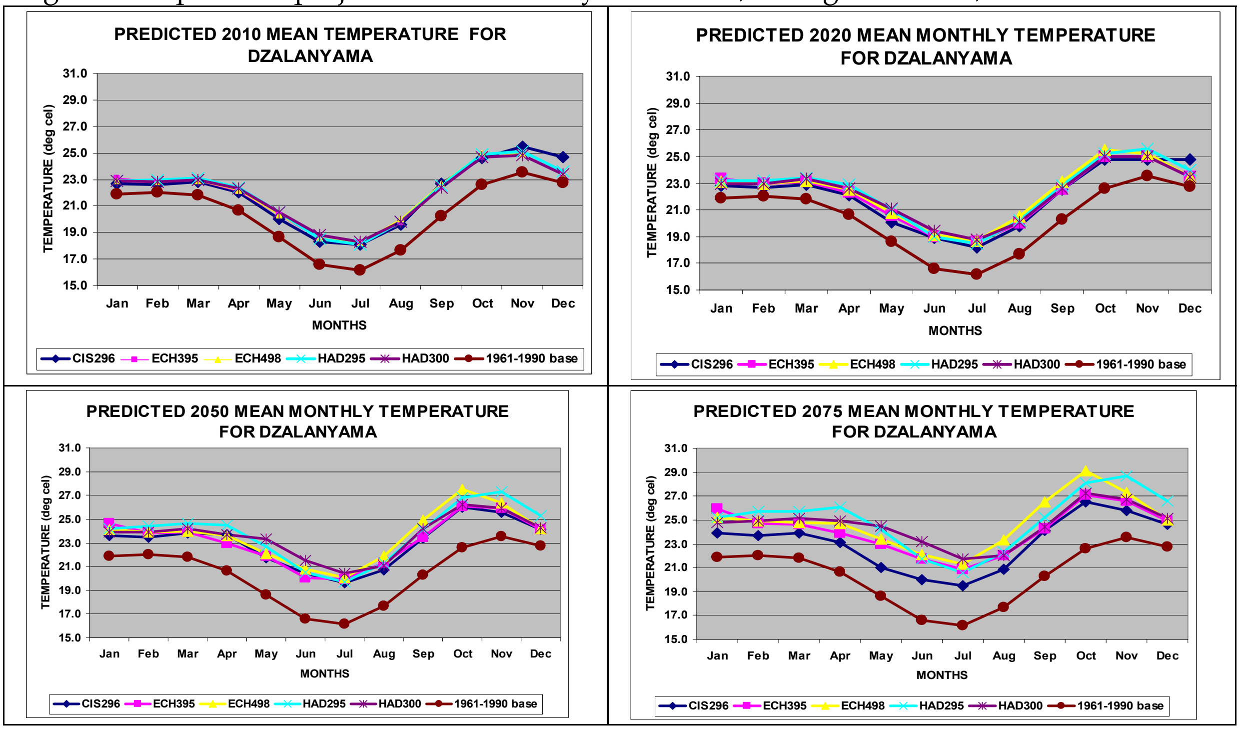


Fig 4.9: Temperature projections for Liwonde National Park, Machinga district, southern Malawi

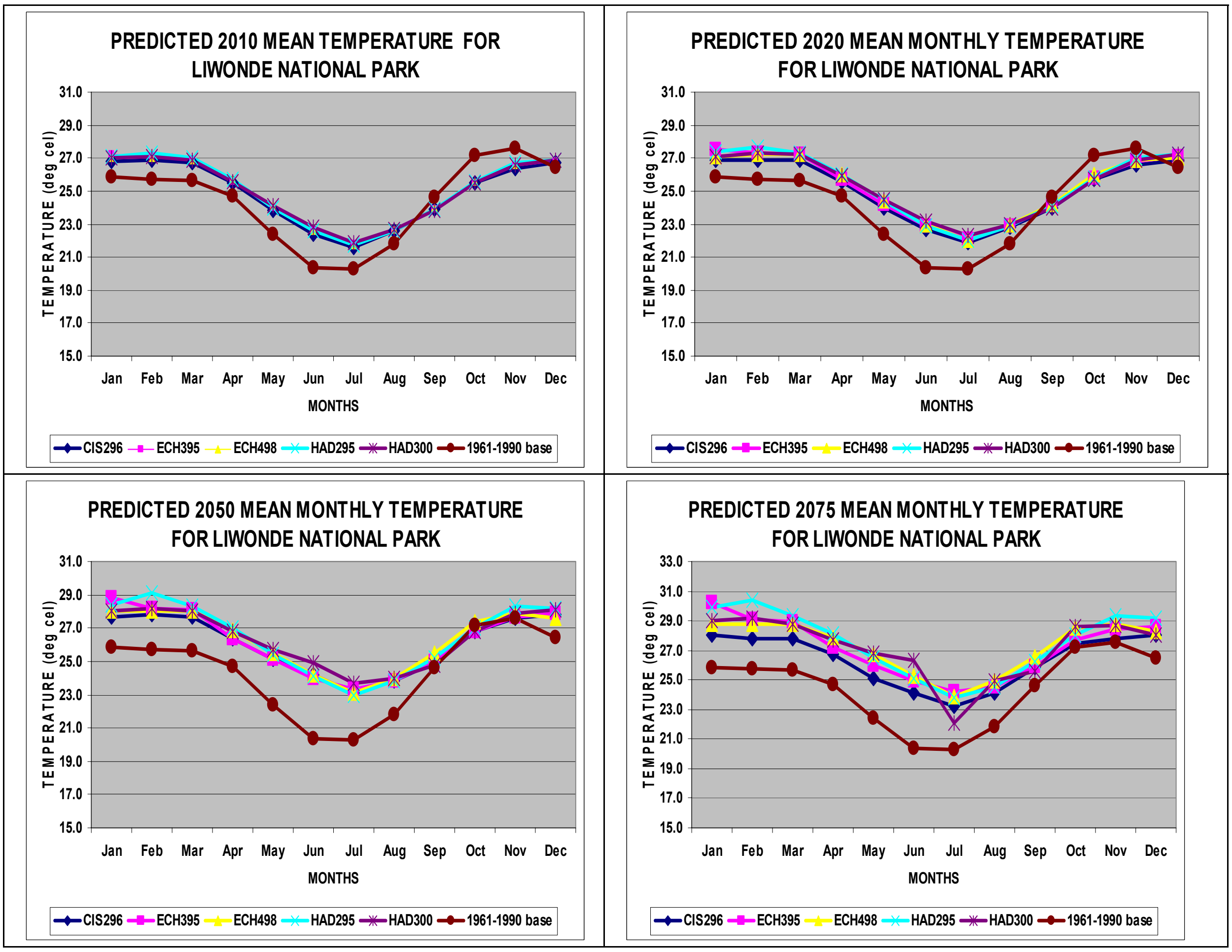
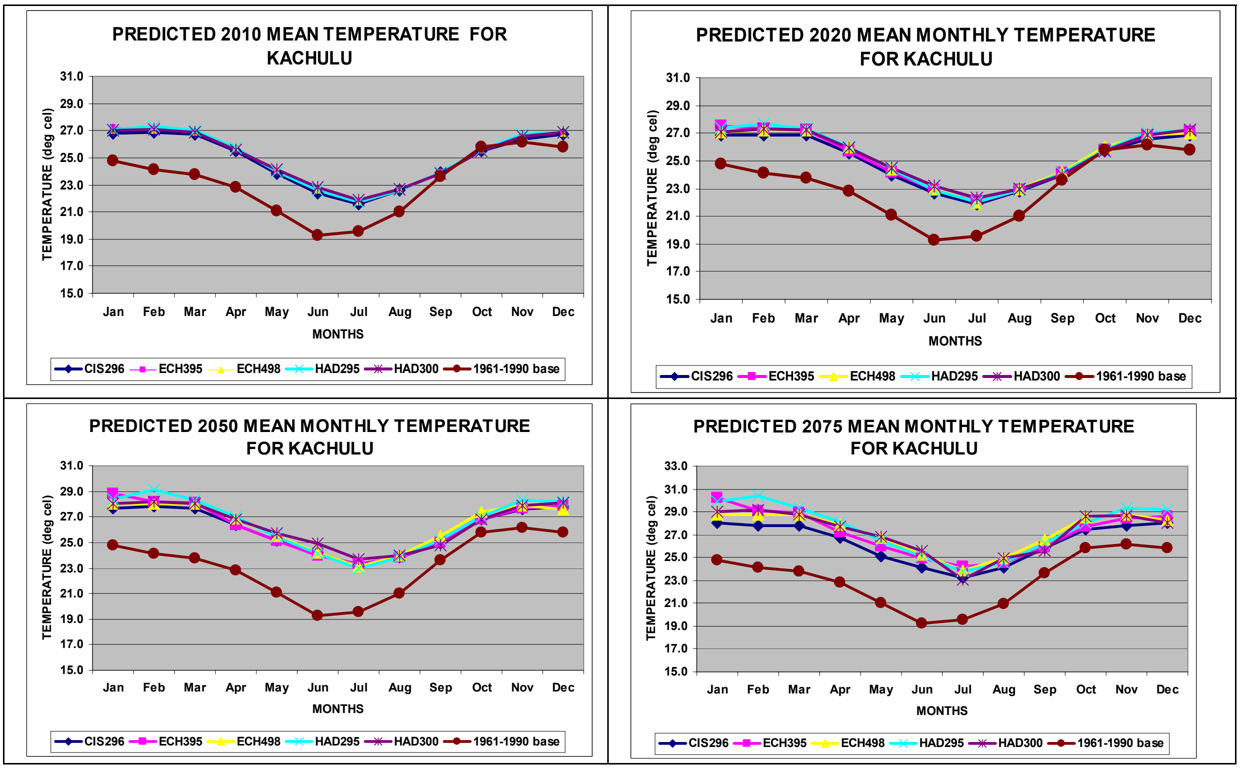


Fig 4.10: Temperatureprojections for Kachulu on Lake Chilwa, Zomba district, southern Malawi



Thus, the rainfall and temperature projections generally suggest that, in future, a greater part of the country will experience a reduction in rainfall, and conversely, most areas will experience an increase in temperatures. Since these models were developed at global level, the results need to be interpreted with care when applied to regional situations. Uncertainties in some of the model input parameters, and the uncertainties arising from the simplified structure of the MAGICC model itself, lead to uncertainties in the final outputs and outcomes. Thus, it would appear that the main source of uncertainty is in defining climate sensitivity when running the models. Climate change is a long-term phenomenon, and as such, it is important that it is factored into all national development policies, plans and strategies. Extreme climate events that are associated with climate change, such as droughts and floods, are likely to have an adverse impact on the economy. It is, therefore, imperative that the planning and decision making processes take into account climate change that impacts on all sectors of economic growth, including agriculture, food security and sustainable livelihoods of family households.

4.3.2 Agriculture Sector

The Agriculture Sector comprises the two sub-sectors: (i) Crops, and (ii) Livestock. Within the crops sub-sector, the focus will be on maize, the staple food crop; whereas for livestock, the focus will be cattle, although these is presently an increasing tendancy to focus small ruminamnts.

4.3.2.1 Crops sub-sector

The crops sub-sector focuses on the vulnerability of arable crops, but with special focus on maize, the staple food crop that is grown on more than 90% of the cultivated land area in Malawi.

Methodology. The study used the Century Model (Version 4.0) to evaluate the impacts of temperature and rainfall changes on maize dry matter and grain yields (Metherell et al., 1993). The Century Model is a tool for ecosystem analysis and for evaluating the effects of management changes on climate and ecosystems. Further, the model simulates (i) the long-term dynamics of carbon (C), nitrogen (N), phosphorus (P), and sulphur (S) for different soil-plant systems, including the dynamics of grassland systems, agricultural crop systems, forest systems, and savanna systems (Metherell et al., 1993), (ii) the effects of changes in atmospheric CO_2, and (iii) the effects of CO_2 on crop production.

Future climate risk. The model simulation results presented below were based on the assumption that rainfall decreases by 10 or 20% and that temperature increases or decreases by 2%. The results are also based on the assumption of containing an economic yield of carbon (g m^{-2}), total monthly carbon (g m^{-2} $month^{-1}$) and carbon in grain (g m^{-2}).

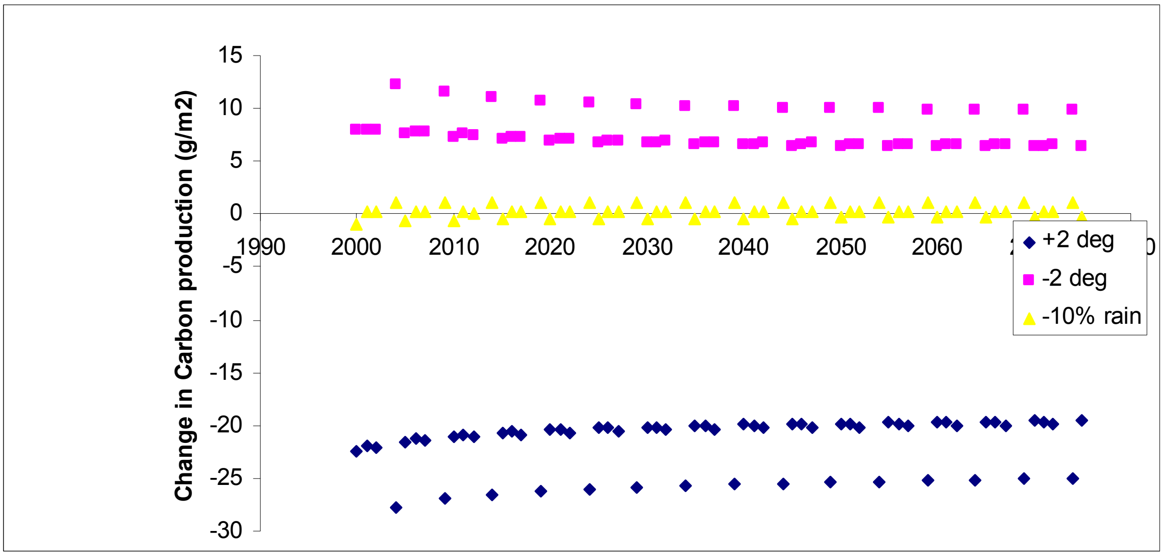


Fig 4.11: Change in carbon production when rainfall is decreased by ten percent (10%)

The findings indicate that decreasing rainfall by either 10 or 20% has a lesser effect on carbon production (g m^{-2}) than changes in temperatures (Fig 4.11). A decrease in temperature of 2 ^{o}C results in a 10% decrease in the grain. If the C produced by the plant (stem and grain) per month is used, an increase in temperature results in a 53% decrease in C produced, whereas a decrease in temperature of the same magnitude, results in a 19% increase in the amount of C produced. Fig 4.12 presents simulation results of carbon in the grain (g/m^2). The trend indicates that a decrease in temperature by 2^0 C will result in a grain C reduction of 15%, whereas an increase of 2% inn temperature will result in an increase of 2% in grain C.

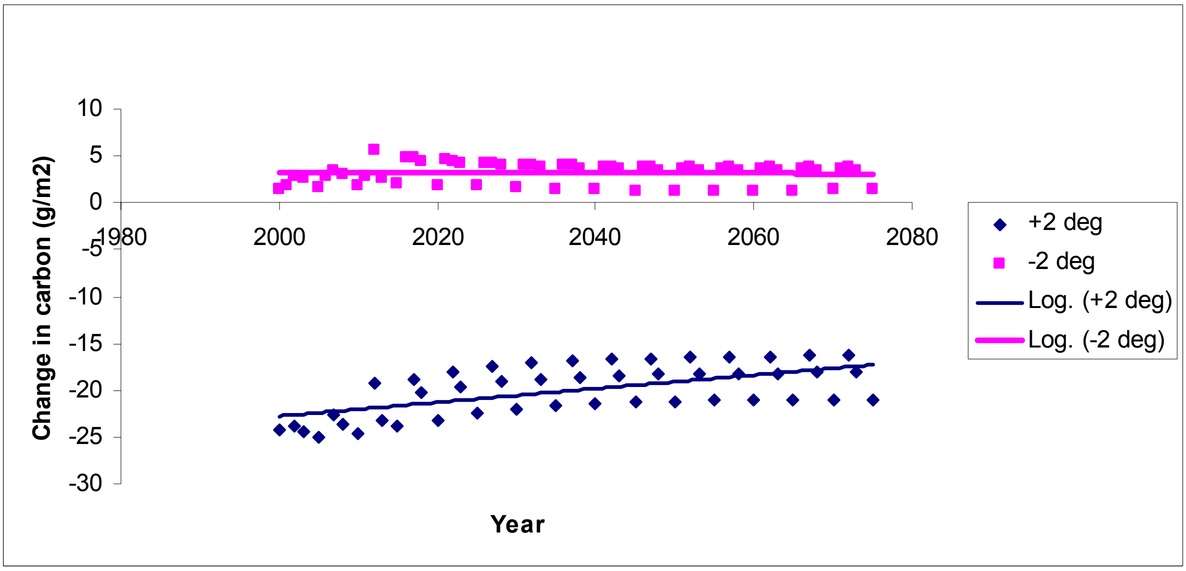


Fig 4.12: Change in carbon gain (g m^{-2}) versus change in rainfall and temperature

It should be noted that decreasing and increasing temperatures has both negative and positive impacts of crop performance. Previous findings have shown that increasing T_{max} up to 35 ^{0}C enhance biomass production for most maize cultivars. In addition, temperature also accelerates the developmental rates for both anthesis and maturity (Bannayan et al., 2004). However, they further noted that an increase above 35 ^{0}C had a negative impact on biomass production. This shows that if climate is altered by increasing temperature, the damage caused can not be completely reversed if somehow we manage to bring back the initial climate conditions. That is if temperature is increased and then decreased to the initial value, there shall be a net negative change in crop yield. These results are also in agreement with the findings from previous studies. For example, in Burkina Faso, an increase in temperature and a reduction in rainfall inevitably resulted in a reduction in farm incomes (CEEPA, 2006). These results clearly show that a change in temperature (especially increased temperatures) will have a great impact on carbon produced.

However, the impacts of increased CO_2 on crop production are many. First, increasing CO_2 has a direct effect on carbon availability by stimulating photosynthesis and reducing photorespiration. Second, the effects of increasing CO_2 concentration results in a decrease of stomata conductance, which reduces the transpiration rate per unit leaf area. Reduced transpiration will also increase the leaf temperature that can further increase photosynthesis. Third, the major effect of increasing CO_2 is a decrease in the plant nitrogen concentration in C3 species. Fourth, the effect of increasing CO_2 is on plant growth, which affects soil organic matter levels and increase root growth. The various effects of CO_2 described above are controlled by CO_2 concentrations and crop/grass or tree-specific parameters. These parameter values are set using reference concentrations of 350 and 700 ppm CO_2 for ambient and doubled CO_2, respectively.

Further, the above findings indicate that a decrease in rainfall will have an impact on maize yields, since both economic and monthly carbon production levels are affected. This change is equally evident when temperature is either decreased or increased. However, it is the change in temperature that will have a greater impact on biomass and grain yields of maize. The changes due to temperature and rainfall patterns (averages and variability of rainfall) are predicted for some semi-arid areas of the Shire Valley, such as Ngabu, and the Lakeshore

Plain are likely to become even hotter and drier with less predictable rainfall patterns. These changes, according to IPCC (2001), will directly affect crop yields, and produce changes in ecosystem distribution of species. This will dramatically affect the livelihoods of many poor people, particularly through declining food security and sustainable livelihoods.

Several reports have revealed that the impacts resulting from reduced rainfall and changes in temperature may likely include increases in urban food prices and greater problems with services, such as water supply and sanitation (exacerbating pressures that rapid urbanization will bring) that affect the urban-poor. Malawi has already witnessed a rising urban population currently growing at 7% per year (UNHabitat, 2006; NSO, 2008). This will not only affect food production, but will also impact on land and other natural resources, especially soil and water bodies. For example, dangers of erosion, landslides and flush floods will also increase.

Bio-physical and socio-economic impacts. The current findings have both bio-physical and socio-economic implications at national, regional and local levels. For example, at national level, Malawi is faced with both spatial and temporal weather variability, such as changes in the amounts and duration of rainfall over time and agro-ecological zones. This influences the type of crops that can be recommended or promoted within the framework of current agricultural and water policies. As noted previously, more rains, as the case was during the 2007/2008 crop season, adversely affected maize yields irrespective of the type and amount of fertilizers applied. This leads to low food and fiber production, including household sales, and the loss of some nutrients that are potentially harmful to the environment and groundwater aquifers. Another impact is on soil erosion that leads to siltation and negative impacts on hydro-electric power generation n rivers and streams. This results in reduced amounts of land for crop production as well as for folder production. Indirectly, these impacts affect river banks and other natural resources, including loss of biodiversity and the disturbance of the aquatic environment. Intra-seasonal distribution of rainfall affects the timing and duration of the possible cropping season, and the periods of drought stress during the crop growth stages. This can easily have an impact on farmers who practice relay cropping systems of cultivation, such as in Thyolo and Mulanje districts where beans and other legumes are grown soon after maize has reached physiological maturity. This affects the yields of the relay legume crop as both nutrients and soil-water maybe inadequate or not available in sufficient quantities for plant growth. This can also lead to low crop yields owing to either shortened or prolonged crop season. Extreme climatic events, such as droughts and floods, as well as major biotic problems, may have a major impact on the availability of, and access to, seed. This could result from poor performance of seed breeding programmes, especially those involving small-scale farmers. This will not only have an impact on crop performance, but also on the farmers involved in the implementation of the programmes.

The implication of properly managing the available water resources for crop production is also quite clear. Numerous studies have shown and demonstrated that farmers face the daunting challenge of effectively and efficiently managing the available water resources (Cooper, 2004). Even though participatory research and extension approaches between scientists and farmers have shown some commendable local successes in developing efficient rain-water harvesting techniques, this has not been undertaken with any much success at country level, so that there is need for more concerted efforts by scientists to work closely with policymakers and farming communities, as further recommend by Ellis-Jones and Tengberg (2000).

This study has taken note that most areas in Malawi are vulnerable to the adverse impacts of droughts, floods, high temperatures, soil infertility, deforestation and soil-water stress and availability. Thus, climate change will continuously affect farming communities in the country. For example, food supply may be reduced during periods of short-duration rains where long-duration crop varieties are promoted and grown. Crop yields can drastically be reduced mainly as a result of erratic rains, floods, droughts and soil infertility. Most of the areas in the country are highly vulnerable to climatic hazards, a situation that is exacerbated by increasing land degradation, deforestation, and extreme salinization against a background of increasing human population pressures. Unpredictable and short-duration droughts, especially those occurring during the reproductive growth stages, are perhaps the most limiting factors for crop production in most parts of the country, especially those in marginal rainfall areas, such as the Shire Valley and some areas along the Lakeshore Plain. These areas experience severe water shortage so that the increasing population pressures will result into competition for the limiting water resource that may even make the effects of the successive droughts more severe.

Water availability is sensitive to climate change, and severe water-stress conditions seriously affect crop productivity, particularly that of vegetables and long-duration maturity crop varieties. The combination of increased temperatures and decreased rainfall can cause reductions in irrigation water availability and an increase in evapo-transpiration rates, leading to severe crop water-stressing conditions, a situation that is applicable to many parts of the country. These climate changes may also result in rising salt concentration in some parts of the country. A study by Mkwambisi et al. (2007) has identified salinity as one of the major problem in some parts of |Malawi, especially those targeted for irrigation in the Upper Shire Valley (e.g., Mangochi) or the Lower Shire Valley (e.g., Chilkwawa and Nsanje) characterized by saline and sodic sols. Excessive soil salinity severely reduces the productivity of many agricultural crops, and there is need to accurately determine the salinity levels before large investments are initiated, and later instituting a soil and water monitoring programme for monitoring salinity levels. Based on field visits and these findings, there is need for rural communities to undertake activities that will enhance their adaptation to climate change. The communities are faced with many challenges and risks from climate change. The risks are apparent not only in crop production, but also in other sectors of growth, such as fisheries, wildlife, energy, forestry, and many others that constitute sustainable livelihoods of rural populations in developing countries (Adger et al., 2003).

4.3.2.2 Livestock sub-sector

This section considers the impacts of climate change on livestock, including small stock, such as poultry. However, more attention will be focused on cattle (beef and dairy), mostly raised under smallholder farm conditions on communal grazing areas.

Methodology. The study considered two key livestock study areas: (i) the Shire Valley (Ngabu), and (ii) the Medium Altitude Plateau on the Lilongwe Plain (Likasi). Both areas are under the communal livestock production system in which all classes of livestock are grazed together on unimproved rangelands. In this study, a predictive simulating production and utilization rangeland model, SPUR–2 (Version 2, field–scale version), was selected to evaluate the effects of climate change on livestock production (Baker et al., 1993). Unfortunately, the model could not be evaluated owing to lack model input data. Furthermore, the generic assumptions of the SPUR-2 Model did not fit Malawi's environmental circumstances, so that the model could not be appropriately applied without first calibrating and validating using local model input data and parameters.

For instance, the model as formulated applies to moderate stocking rates. The Malawi situation is such that the stocking rate in the Shire Valley, now estimated at 1 Tropical Livestock Unit (TLU) per 8 ha of land, is relatively high. The SPUR-2 Model also assumes that the relative abundance of forage classes, such as warm season grasses, cool season grasses, forbs and shrubs have little effect on diet compositions at moderate stocking rates. This assumption is also not valid under the situation where forage availability and accessibility fluctuates with seasons; with very little standing forage during the dry season and limited accessibility to grazing land during the rainy season owing to the growing crops in the fields. The model also assumes constant grazing pressure on a particular locations, which is also not valid in the case of communal grazing systems in which mixed grazing is practiced and yearling steers are not separated to graze in separate locations. Consequently, only expert judgment was used to assess the effects of climate change on livestock productivity in the country.

Current vulnerability of the Livestock sub-sector. Livestock production in Malawi is vulnerable to climate change and climate variability, especially as the increasing human population growth rate is forcing grazing areas to expand to marginal and fragile agro-ecosystems. Upland grazing has generally been declining over the years as a result of agricultural expansion and increasing cropping activities brought about by intensive land use cultivation practices. Dambos (seasonally water-logged wet areas) are increasingly being used for grazing during the rainy season, whereas in the past these were mainly used for dry season grazing (NLDMP, 1999). This makes the dambos even more vulnerable to the adverse impacts of climate change. Besides, livestock farmers in general stick to one particular eco-system of raising their livestock. For example, farmers in the Shire Valley do not relocate to higher ground despite the increasing frequency of floods. This inflexibility in the livestock management system makes is extremely difficult to adapt to climate change, and coupled with poor quality forage in this low altitude rangeland areas, livestock productivity is severely affected during the drought periods.

Effects on animal health. Extreme weather events, such as droughts, high temperatures and floods create conditions suitable for the emergence of new health challenges. These include new diseases, such as the deadly Rift Valley Fever (RVF), other haemorrhagic fevers and tick-borne diseases have taken new epidemiological dimensions in recent years in Malawi, as well as neighbouring countries, due to heavy rainfall. Excessive rains, or wet conditions, promote optimal reproductive conditions for ticks, worms and other disease vectors, such as mosquitoes and tsetse flies, because of the favourable microenvironments that results in high reproductive efficiency of these pathogens and vectors. As a result of this, livestock productivity is severely compromised with high mortality rates of young stock, reduced conception, calving and growth rates. Research has clearly demonstrated that the direct effects from heat and water stress on grazing or browsing livestock is most likely to be manifested as decreases in feed intake, milk production and the low reproduction rates.

A good example is that of extreme temperature conditions that cause severe heat stress in dairy animals with resultant decreases in milk production of as much as 25% (Radostits et al., 1985). Severe heat stress can also lead to financial losses in dairy cattle. An estimated 80% of these losses are associated with productivity, and 20% to health, reproduction and immunity issues. These translate into increased mortality and mastitis frequency, decreased fertility, retained placenta and early calving with consequences on the calves' live weight and health (Rochet et al., 2008). On a positive note, climatic restrictions on vectors, such as ticks in some parts of the Shire Valley, disturbed environmental habitats by human activity, such as settlements that clear bushes, severely limit the reproduction rates of disease vectors, such as tsetse flies, and hence disease causing agents are suppressed to levels where they can no longer sustain disease conditions in livestock (Walker, 1991). An assessment of diseases incidences over the past few years shows that most livestock diseases occurred during the years of weather stress or climatic extremes (Table 4.1)

Effects on animal growth and reproduction. Droughts, floods and high temperatures as predicted by the MAGGIC/SCENGEN model for the years 2010, 2020, 2050 and 2075 (Figs 4.1-4.10)) will affect the availability of forage and feed grain for livestock impacting negatively on their potential to reproduce and maintain high productivity levels. The direct effects of climate change on forage quality are well documented in Malawi (Hodges et al., 1983). The natural grasslands in Malawi tend to be of low feeding value because they are dominated by early-flowering grasses that have low protein values and low digestibility once they mature. In general, the digestibility of tropical grasses is about 13 units lower than that of temperate grass species. This difference is closely associated with climatic differences, digestibility being depressed by higher temperatures (McIlroy, 1972). Besides, many of the local grasses remain dormant during the cold dry months and do not respond to out-of season rains (Hodges et al., 1983). Consequently, most cattle lose weight during the dry season because of the low feed value of the native grasses. During droughts, highly fibrous and lignified grasses predominate, severely constraining ruminant nutrition.

Table 4.1 Location and timing of foot and mouth disease (FMD) outbreaks in Malawi, 1957-2003

District	Year	Month of first case	Serotype
Karonga, Lakeshore Plain	1957	August	0
Karonga, Lakeshore Plain	1959	August	SAT 2
Karonga, Lakeshore Plain	1962	September	0
Karonga, Lakeshore Plain	1966	July	A
Karonga, Lakeshore Plain	1970	November	SAR 1
Karonga, Lakeshore Plain	1975	September	SAT 2
Karonga, Lakeshore Plain	1961	August	0
Chitipa Lakeshore Plain	1982	October l	0
Karonga, Lakeshore Plain	1998	September	0
Karonga, Lakeshore Plain	1999	January	0
Mzimba, Medium Altitude	2000	April	SAT 1

Plateau			
Mzimba, Medium Altitude Plateau	2001	January	SAT 1
Nsanje/Chikwawa Shire Valley	1973	August	A
Nsanje Shire Valley	1974	April	0
Nsanje/Chikwawa Shire Valley	1976	August	SAT 3
Nsanje, Shire Valley	1985	January	0
Nsanje, Shire Valley	2003	April	SAT 2

Source: DoAHLD, 2008.

Socio-economic impacts. Climate change that affects the communal grazing areas has also clearly put pressure on wildlife habitats and the available resources. In the Shire Valley, an area that is prone to droughts and floods, these climatic changes have forced wildlife to graze together with livestock. Some wildlife species, such as elephants and buffalos, have caused considerable destruction to farmland, creating conflict situations between man and animals. Close contacts between domestic livestock and wildlife has triggered outbreaks of livestock diseases of great economic importance to the local population. Table 4.1, which shows the location and timing of foot and mouth disease (FMD) outbreaks in the country, shows that nearly all outbreaks, except for a few, occurred during the dry season confirming that dry season weather or drought conditions, is a significant epidemiological factor in the occurrence of FMD outbreaks in the country. This is perhaps because cattle tend to congregate together with wildlife to access watering points and limited forage and pastures during the dry season.

Livestock production and consumption in Malawi is inherently linked to socio-economic circumstances. For instance, rapid population growth puts severe strain on the quantities of food requirements for Malawi, including livestock products. It is estimated that the current annual beef requirement demand) of 70,000 t will jump to 216,000 t in the future, assuming that there will be no significant shift in the current per capita beef consumption of just less than 6 kg. Yet annual beef supply is very low, estimated currently at only 50,000 t (DoAHLD, 2007). Fig 4.13 shows the price trends (MK/kg) for beef, pork and goat meat from 1989-2007, which generally shows an increase in the livestock commodity prices regardless of changing climatic events, except during the 2001/02 crop season drought when prices stabilized as a result of increased supply of livestock due to increased off-take for cash requirements.

However, these can be assumed to be normal inflationary price increases in the meat commodities owing to devaluation trends of the Malawi Kwacha over the years, and increased demand for beef and beef products by a growing human population. Under this scenario of increased livestock by-product demand, Malawi will have to import more beef and other livestock by-products to bridge this anticipated production gap, hence continuing upward price increases in the foreseeable future. This socio-economic scenario, of high population growth and moderate income growth, will not be conducive to investment in technological developments in the communal livestock sub-sector. This will increase the vulnerability of the communal grazing livestock system to climate change with livestock communities having reduced ability to adapt to extreme weather events.

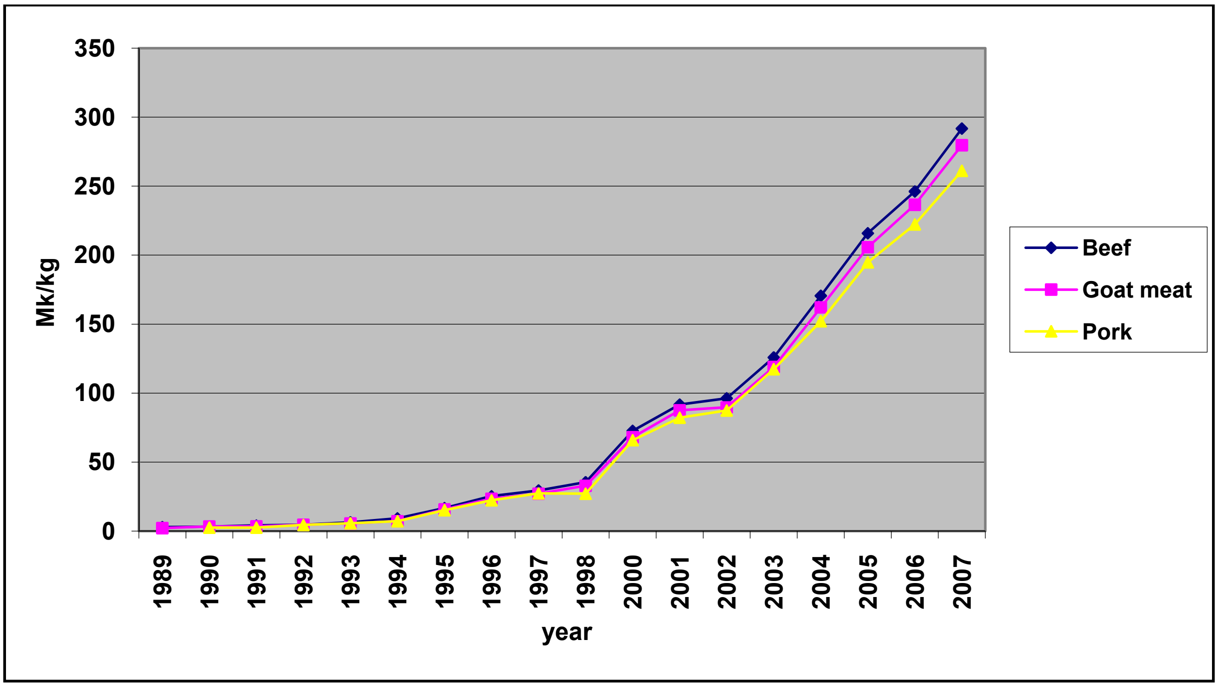


Fig 4.13: Price trends of various livestock commodities, 1989-2007

However, moderate increases in urban incomes and improvements in literacy levels will trigger a situation in which urban livestock producers will resort to short-cycle intensive production systems and feedlot commercial production systems capable of withstanding the shocks of extreme weather events.

Future climatic risk. Livestock productivity is basically a function of nutrition, age, disease incidence and genetics, which are greatly influenced by the effects of extreme weather events and climate change. Cattle productivity coefficients, or parameters, such as growth rates, conception rates, mortality rates and weaning weights are either directly or indirectly affected by climatic change and climate variability, especially floods and droughts. Since comprehensive data sets, with sufficient information for conclusive evaluation of cattle productivity are scarce and inadequate for evaluating computer simulation models, the analysis that follows is based on an examination of past trends in livestock production and expert judgment of the possible future situations for the two agro-ecologically different sites of Ngabu in the Shire Valley, southern Malawi, and Likasi on the Lilongwe Plain, central Malawi.

Effects on cattle nutrition. During droughts, rangeland pastures become extremely dry, low nutritional value and highly vulnerable to bush or forest fires. There are virtually no irrigated pastures for livestock use during the dry season or rainless periods. This situation results in indigenous pastures of very low biomass yield and crude protein content during the drought periods. The weather changes predicted by the MAGICC/SCENGEN model are likely to further exacerbate the pasture yield and quality status in the two study areas. The rainfall scenario is less severe for the Lilongwe Plain at Likasi compared with Ngabu in the Shire Valley; whereas the temperature scenarios are more or less the same.

In general terms, this implies that both areas will be vulnerable to climate change in the future, but the Shire Valley will be more prone to these extreme weather events and climate change. Extreme weather events, such as droughts and floods will also severely affect the availability of forage for cattle to maintain its genetic growth potential. Weaning weights for young stock and maturing periods for breeding stock will likewise be negatively affected, resulting in higher calving intervals with general low productivity of the national communal herd.

Effects on disease incidences The future scenario will result in an increase in the epidemiological proportions of various livestock diseases, including the new and emerging ones. The future rainfall and temperature scenarios will exacerbate the situation, leading to more frequent outbreaks of FMD with devastating socio-economic consequences, especially in the Shire Valley, unless the African buffalo is separated from cattle and a dedicated FMD vaccination strategy is put in place. The situation for the Lilongwe Plain will be better than the one in the Shire Valley because of low wildlife population (in fact, the African buffalo is only recorded in Kasungu National Park on the expansive Lilongwe-Kasungu Plain). However, the slightly lower rainfall decline on the Lilongwe Plain will perhaps not entirely decrease the emergency of new challenges, such as increased incidence of tick–borne and tsetse fly transmitted diseases, sanitation related diseases, and more importantly, maiden outbreaks of the Rift Valley Fever (RVF), which is currently prevalent in the south-eastern African region due to the recurrent and frequent floods. Being a zoonotic disease (transmissible to man), RVF will pose a big challenge to the Human Health Sector, and there will be need in the future to allocate more resources for emergency preparedness plans, risk assessment and disease control contingencies to contain the RVF epidemic..

4.3.3 Forestry and Other Land-Use Sector

Forests play an important role in the socio-economic growth and development of the country. Forests supply about 93% of the country's energy needs, provide timber and poles for construction and industrial use, supply non-timber forest products for food security and income, support wildlife and biodiversity, and provide recreational and environmental services. Among the environmental services provided by forests is carbon sequestration. Carbon sequestration is the uptake and storage of carbon on land which reduce atmospheric accumulation, and thus delays its impact on global climate. Despite the important role that forests play in Malawi, the forest resources are under threat. For instance, in 1975, 57% of Malawi was classified as forest, while in 2000, only 28 % was classified as forest, and the present estimate is 23% .Other records show considerable reduction in forestland from 4.4 m ha in 1972 to around 1.9 m in 1992 (EAD, 1998; 2001).

The major causes of deforestation and the general degradation of the environment in Malawi are attributed to agricultural expansion, high population growth, increased wood-fuel demands, and forest fires. The rapid expansion of agriculture from the mid 1970s to the late 1980s led to extensive deforestation. Estate land increased from 67, 000 ha in 1967 to 850,000 ha by 1998. It is estimated that 95% of the rural households have only a hectare or less for farming. Hence, smallholder farmers migrate and encroach steep slopes, riverbanks and/or forest reserves in search of farmland, thereby, causing further forest and land degradation. However, it is estimated that the rate of deforestation has been declining. During the period when estate land was increasing, deforestation was around 3.5% per year. During later years, this rate declined to 1.6%, probably because of lack of more arable land that could be deforested. The deforestation rate is now estimated at 2.8% per year, but is highest in northern Malawi, where the rate is estimated at around 3.4% per year (EAD, 2001). Wild or forest fires destroy considerable amounts of forest resources every year. For example, in 2001, 64 fire-devastating incidences were recorded nation-wide, damaging a total of 1,520.04 ha. This represented a decrease in the area burnt since 1998, 1999, and 2000, when the total forest area burnt were 5,026.1, 1,912.34 and 1,657.8 ha, respectively (DoF, 2002). The destruction of forests through burning and the decaying of woody biomass results directly into significant contributions to CO_2 concentration in the atmosphere. However, the expansion of forests, and the maintenance of existing stands can capture C from the atmosphere and maintain it on land over decades. Thus, it is important for Malawi to identify mitigation options in the forest and land use sector (se Chapter 5 for mitigation options) that would reduce carbon accumulation in the atmospheric, thereby delaying its impact on global climate change, and developing measures and strategies for adapting the climate change. The proposed adaptation measures and strategies are discussed in this chapter.

Methodology. The study approached the analysis by first looking at climate change impacts on forest types for the whole country. In this regard, the whole country was the study site. A detailed study on the impact of climate change on individual tree species was done for the Dzalanyama Forest Reserve, representing the indigenous forest resources of Malawi that cover about 90% of the forest resources of Malawi. Plantation forests were represented by the Chongoni Forest Plantation, which was selected because of its high incidence of forest fire damages experienced over many years.

The Holdridge and Gap Models were used to study and evaluate the impacts of climate change on the forests of Malawi. The Holdridge Model was used to assess climate change impacts on various forest types, whereas the Gap Model was used to assess the impacts of climate change on individual tree species. Climate change variability was assessed using the time series analysis of climate variables. The Holdridge Model relates the distribution of major ecosystem, as a climatic variable, of bio-temperature, mean annual temperature and the ratio of potential evapo-transpiration (PET) to rainfall (US Country Studies Program, 1994). The Holdridge Model assumes that PET is proportional to bio-temperature. The PET ratio, therefore, depends on two primary variables: (i) annual rainfall, and (ii) bio-temperature. The Gap Model is an individual species based model of forest dynamics that simulates the response of basic plant processes to environmental conditions. The model is site-specific and requires detailed information on the attributes of species and site-specific factors. It evaluates the temporal dynamics of a given forested site (less than 1 ha) in response to climate changes on an annual time step. Because the model can predict changes in species composition, forest structure and productivity, it is possible to incorporate forest management practices (e.g., selective cutting) which allows for adaptive strategies. A 'time series' analysis of climate related disasters was conducted in order to study patterns of climate-related disasters in the country. This study was a highly consultative process involving various stakeholders at different levels from local communities, to public servants in Government and the private sector.

Current vulnerability of the Forestry and Other Land-Use Sector. With more than 74% of the disasters representing climate related disasters, Malawi is very vulnerable to climate change and climate variability, a situation that has been getting worse since the 1970's. The

1970's coincides with the period of rapid estate sector expansion that resulted in massive forest clearing to pave way for tobacco and maize production. The increasing frequency and magnitude of floods, strong winds and hailstorms, calls for urgent adaptation measures that must be put in place to minimise loss of life, destruction of property and food insecurity that are becoming a perpetual reality as of now. Priority future assessments should include vulnerable areas in as many districts as possible, including Karonga, Nkhota Kota, Salima, Mangochi, Zomba, Nsanje and Chikwawa, all of which lie along the Great East African Rift Valley.

Although flooding, strong winds and hailstorms are the major climate-related disasters; their impact on the forest sector has been limited to one recorded incident of strong winds that destroyed 600 ha of pine forests on Zomba Mountain. On the other hand, there is no indication of permanent land-use change that can be associated with climate change or climate variability. In Karonga and the Shire Valley, flooding results in the temporary shifting of people from flood plains to upland areas. However, as soon as the floods recede, the people return back to the flood plains. One reason why people return to the flood plains is that they do not want to abandon their fertile farm lands. Although a lot of land-use changes are taking place in the country, as manifested in agricultural expansion, infrastructural development, and road and dam construction, these changes are not associated with climate-related events. However, the main climate-related disaster that is causing a lot of damage to the forest resources of Malawi is "forest fires" during the months of June to November when leaf biomass is dry enough to reach combustible temperatures. Since records of forest fires from softwood plantations show an increasing trend of fires with time, there is need for urgent adaptation measures to safeguard the economic viability of the sector and sustain the livelihoods of the many local communities that depend on the forest resources for sustenance. The priority areas for softwood plantation adaptation measures include Chongoni in Dedza district and Chikangawa in Mzimba district, whereas priority areas for fuel-wood plantations include the Blantyre City Fuel-wood Plantations in Blantyre district.

Future vulnerability of the Forestry and Other Land-Use Sector. Model simulation studies using the Holdridge Model were conducted on 15 grid location points that cover most forest areas of Malawi. Although Malawi can conveniently be covered by 34 grid points associated with forest cover, only 15 of these were used in the present assessment. This is because the model fails to produce data for almost half the land area surrounding the Lake Malawi because the model forms a corridor surrounding it. Hence, the failure of the model to generate climate data sets that can be used in model verification and evaluation studies. Model simulations were conducted for conditions that represent mild and extreme climatie change scenarios. A comparison of current and simulated climate data from the general circulation models (GCMs) indicate that there are no significant differences between these models, suggesting that all the four models simulate current climate data quiet well. Climate data simulated using the HadCMS Model was used to assess the impact of climate change on the forests of Malawi. The Holdridge Model was used to assess the changes in forests that might take place if climate change took place. Two climate change scenarios, namely: (i) a moderate (2.5^{o} C), and (ii) an extreme climate scenario (4.5^{o} C) were used. The results in Figs 4.14–4.20 show current and simulated climate for the years 2020, 2075 and 2100.

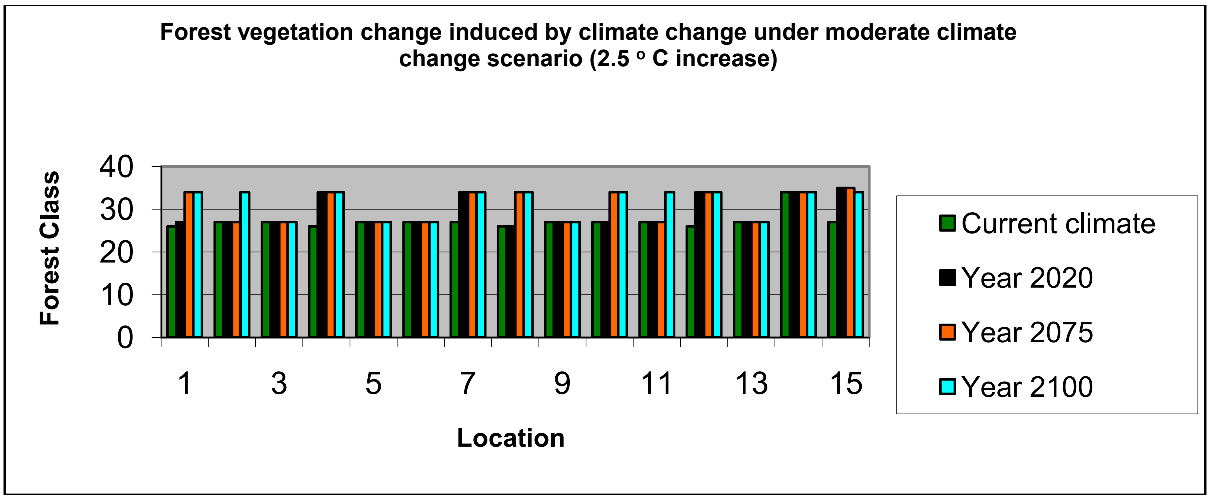


Fig 4.14: Climate change induced forest vegetation under the moderate climate change scenario

Key: Location 1= Karonga north area, 2= Vwaza north area, 3=Nyika area, 4=Vwaza south area, 5=Kafukule north area, 6=Viphya area, 7= North of Kasungu Game Reserve area, 8= south of Kasungu Game Reserve area, 9= north of Namizimu Forest Reserve area, 10=Dzalanyama Forest Reserve area, 11= Neno area, 12=Majete Gam Reserve/Blantyre City Fuel-wood Project Area, 13=Mulanje area, 14=Chikwawa area, and 15=Mwabvi Game reserve area.

Under the moderate climate change scenario, different forest areas in the country will respond differently to the adverse impacts of climate change. The response will range from no change in forest types, such as those found on the Nyika and Viphya Plateau areas to drastic changes for forest types, such as those found on the north of Kasungu Game Reserve and south of the Vwaza Marsh area. The change reflects increasing dry conditions with forest types progressively changing to drier forest types. The implication is that there will be species change in favour of tree species better adapted to drier environments. These changes in forest types could come as early as 2020. In some areas, however, the change will take place by the year 2075. The time lag for the impacts of climate change on forest types reflects the differences in vulnerability to climate change. The most vulnerable forests under the moderate climate change scenario are south of the Vwaza Marsh area, north of the Kasungu Game Reserve, the Chikwawa area, the Mwabvi Game Reserve area and the Majete/Blantyre City Fuel-Wood Project area.

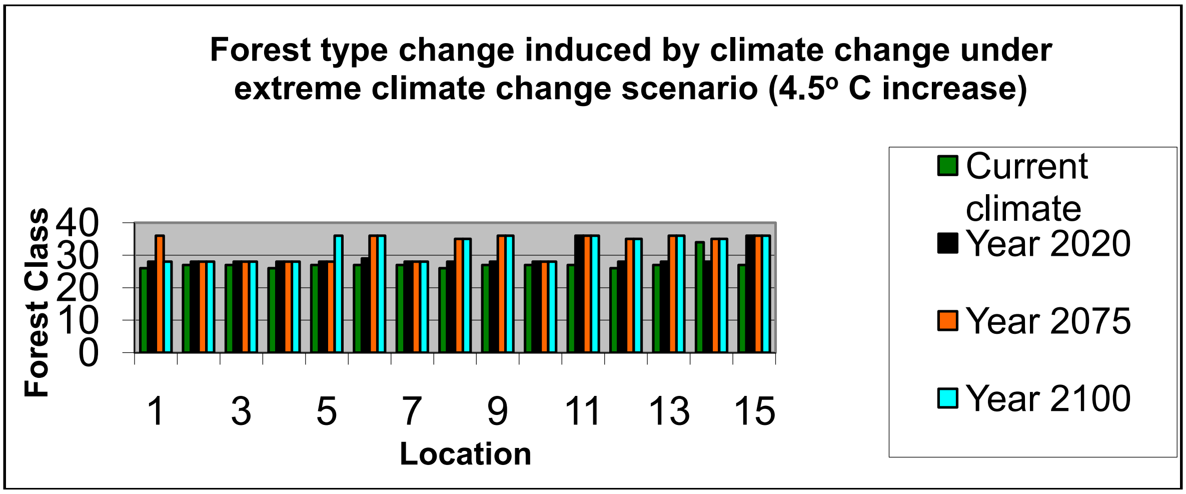


Fig 4.15: Climate change induced forest vegetation change under extreme climate change scenario.

Note: Location sites are the same as in Fig 4.14.

The extreme climate change scenario will result in the vulnerable areas of Neno and Mwabvi Game Reserve changing their forest types as early as 2020. Out of the 15 locations used for this study, 10 of these will have changed forest types by the year 2075. These changes in forest types have implications on the biodiversity of the forests. Climate change will favour forest species that adapt to increasing dry or drought conditions. There are, however, some locations that will be subjected to relatively less forest type changes. These include the Vwaza Marsh area, Nyika Plateau area, Kasungu Game Reserve area and the Dzalanyama Forest Reserve area. These represent forest areas that are relatively less vulnerable to climate change. Model simulation results using the Gap Model (productivity assessment) for the Dzalanyama Forest Reserve under current climate, mild climate change, moderate climate and extreme climate changes are compared in Figs 4.16-4.20. These data indicate that the Dzalanyama Forest Reserve area is relatively less vulnerable to forest type change.

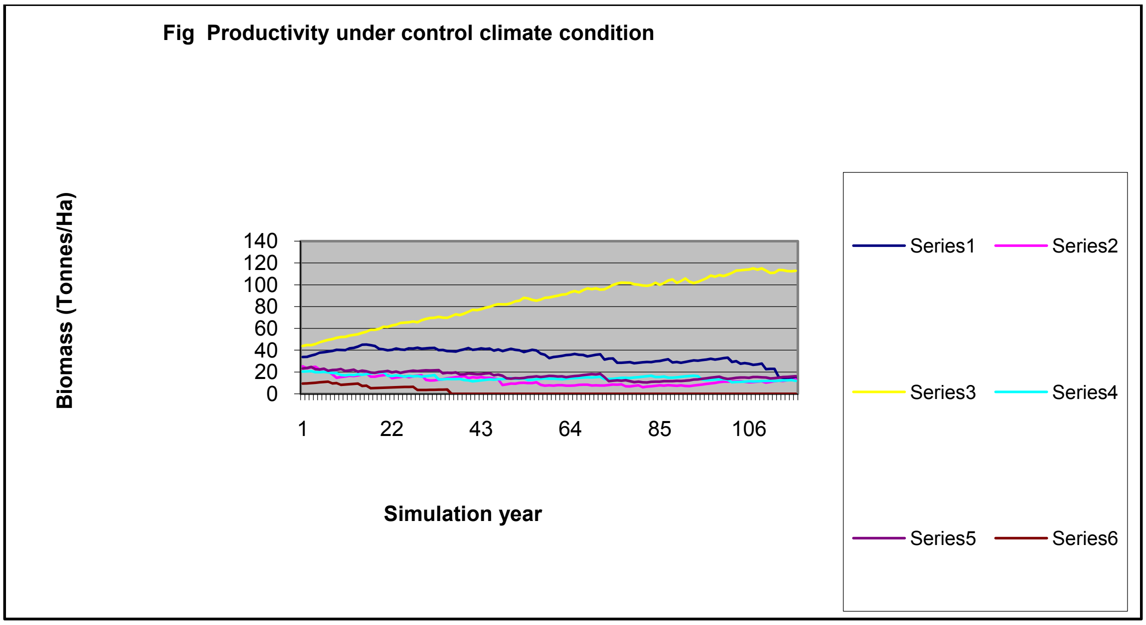


Fig 4.16: Biomass productivity for six tree species under mild climate change scenario. Key: Series 1= *Julbernadia panicula*, series 2= *Uapaka kirkiana*, series 3= *Parinari curatellifolio*, series 4=*Apodytes dimidiata*, series 5 = *Combretum apindicula* , series 6 = *Dodonaea viscosa*

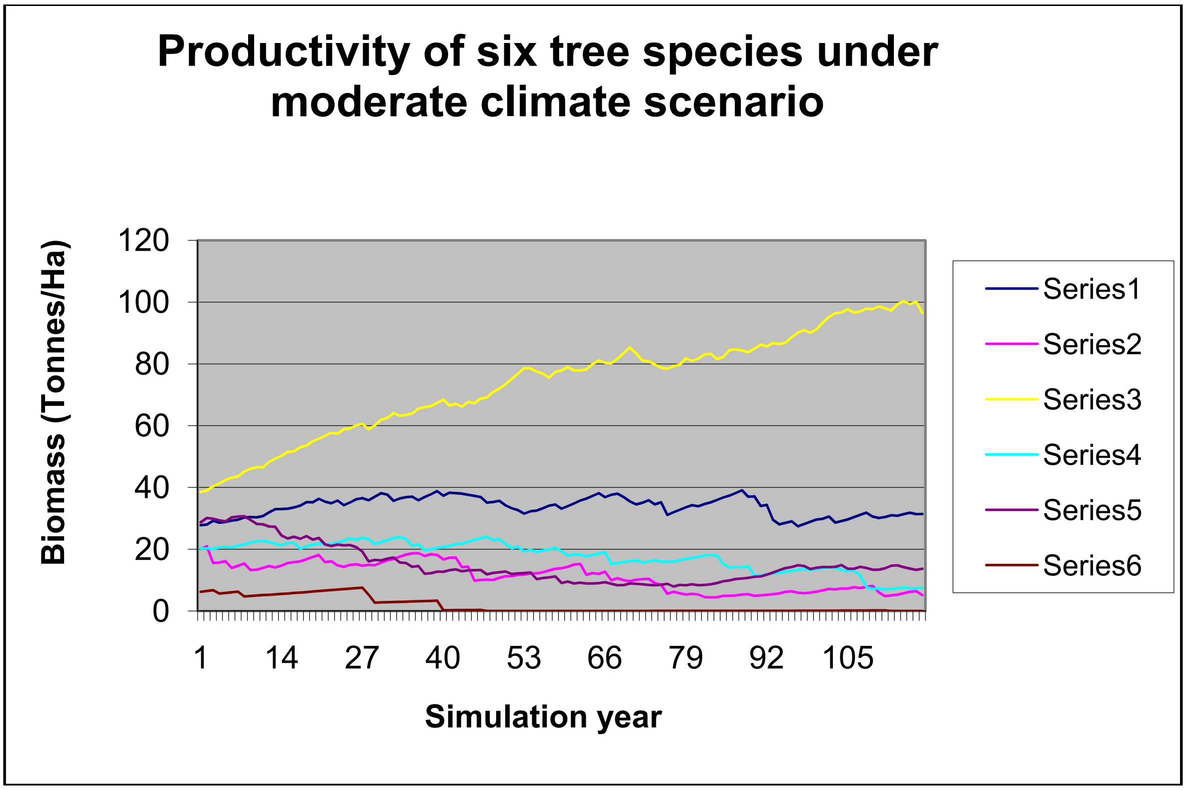


Fig 4.17: Biomass productivity for six tree species under moderate climate change scenario

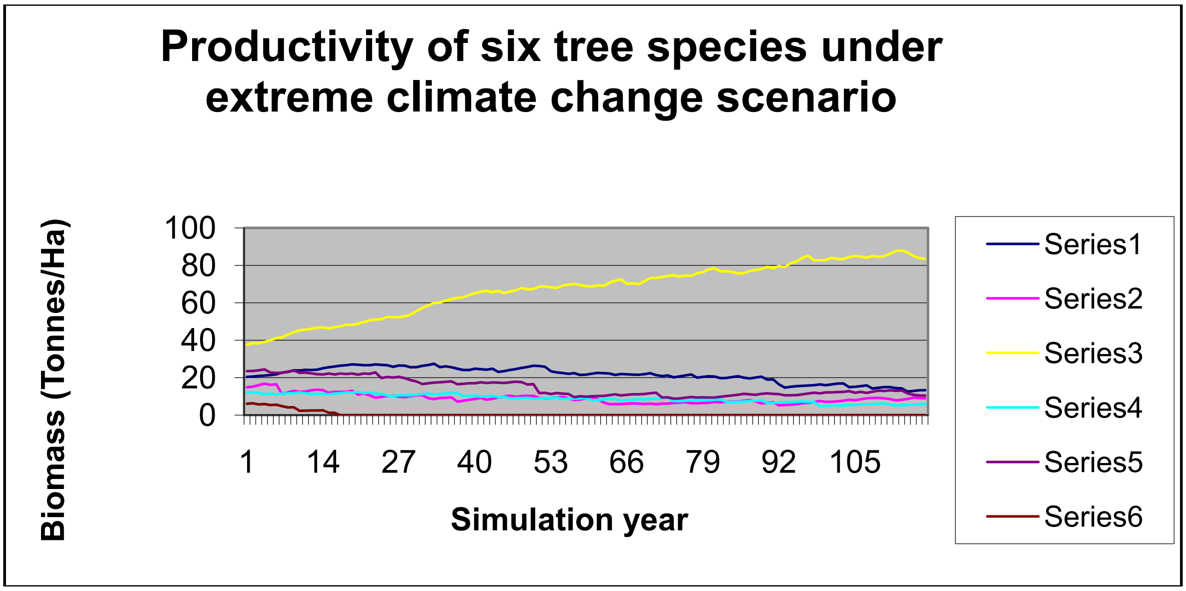


Fig 4.18: Biomass productivity for six tree species under extreme climate change scenario

Key: Series 1 = *Julbernadia panicula*, series 2 = *Uapaka kirkiana*, series 3 = *Parinari curatellifolio*, series 4 = *Apodytes dimidiata* , series 5 = *Combretum apindicula* , series 6 = *Dodonaea viscosa*

The Gap Model was used to analyse the performance and behaviour of six tree species only, out of 100 known species, from Dzalanyama Forest Reserve in Lilongwe district, central Malawi. The six species comprised: (i) three tree species that are the commonest in the reserve, and (ii) three tree species that are the rarest in the forest reserve. The simulation results indicate that climate change will lead to a decline in wood productivity over time. The magnitude of wood productivity decline will depend on the climate scenario selected. The percentage of productivity loss will range from 0 % to as much as 37% per ha as the time progresses from 2020 to 2100. The main potential change in wood production resulting from climate change is less specific on the trend of production, but is more on the magnitude of wood production. There is no indication from this study that the structure or composition of the forests will change. There is an indication, however, that the dominant and under story tree species will maintain their positions under condtions of climate change.

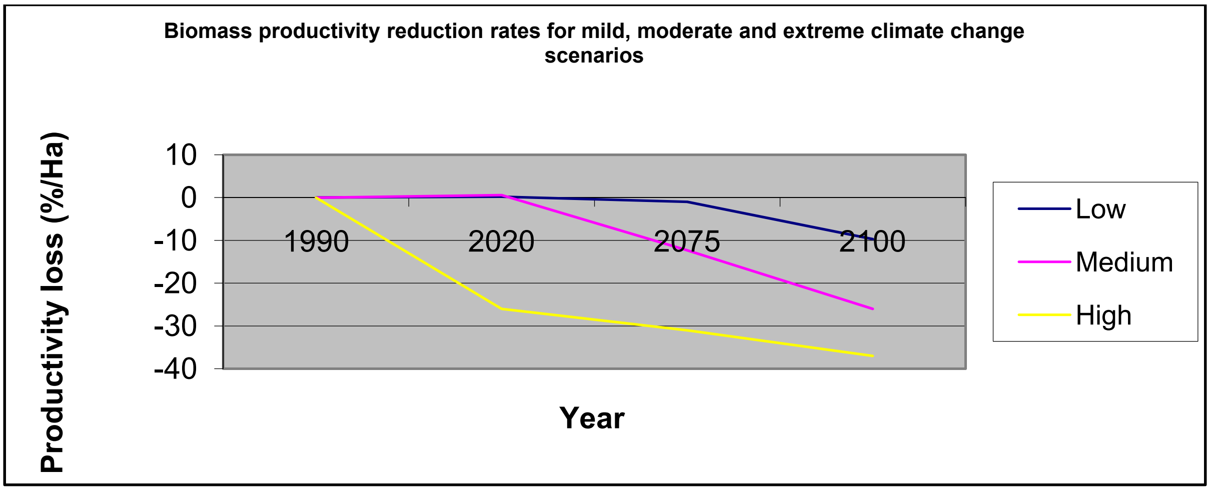


Fig 4.19: Productivity for mild, moderate and extreme climate change scenarios, 2020, 2075 and 2100

Note: The reference year is 1990

The moderate climate change scenario, which is considered to be the more likely to occur, indicate that there will be negligible production loss by the year 2020. However, in 2075, there will be a wood production loss from 2 m^3 (mean annual productivity for natural forest) to 1.98 m^3 ha^{-1} $year_{-1}$. In 2100, the production will come down to 1.8 m^3 ha^{-1} $year^{-1}$. Under the extreme climate change scenario, the production decline will be drastic. In 2020, the mean annual increment will be 1.48 m^3 ha^{-1} $year^{-1}$, whereas in 2075 and 2100 the mean annual increments will be 1.38 m^3 and 1.26 m^3 ha^{-1} $year^{-1}$, respectively (Table 4.2).

Table 4.2: Mean annual changes in wood productivity, Dzalanyama Forest Reserve, Lilongwe

Climate change scenario	Year		
	2020	2075	2100
Low	0.00	1.98	1.80
Med	0.00	1.80	1.48
High	1.48	1.38	1.26

Over the entire forest reserve (98, 934 ha), the annual wood production loss is quite significant. Under the moderate climate change scenario, 24,000 m^3 of wood would be lost by 2075, whereas under the extreme and mild climate change scenarios these would be about 61,000 and 2,000 m^3, respectively. With this decline in mean annual increment, sustainable wood yields will likewise decline. Fig 4.20 shows the expected wood production losses associated with climate change.

An assessment using the Holdridge Model shows that the Dzalanyama Ranch is among the least vulnerable forest reserves to climate change. The impact of climate change in the more vulnerable forest reserves will even be greater, so that the potential impact of climate change cannot be ignored. Forest goods and services are the second largest contributor to rural livelihoods. With the change in forest types, there will be loss in biodiversity, resulting in the reduction of a range of goods and services available to rural communities. With the reduction in wood productivity, the amount of wood products will decline at a time when the demand is increasing. The poor, who have limited resources will be most affected and impacted upon by these developments. The end effect will be the increasing levels of poverty, food insecurity and hardships of unmeasurable proportions. Thus, climate change is a threat to the effective implementation of all poverty reduction strategies.

The situation is more desperate when the effects of all human activities are considered. The impact of a high population growth rate of 2.8% per year (NSO, 2008) will be most felt through increased deforestation, currently estimated at 2.8 % per year. The impact of climate change alone is very dramatic, making forests in Malawi very vulnerable to its effects.

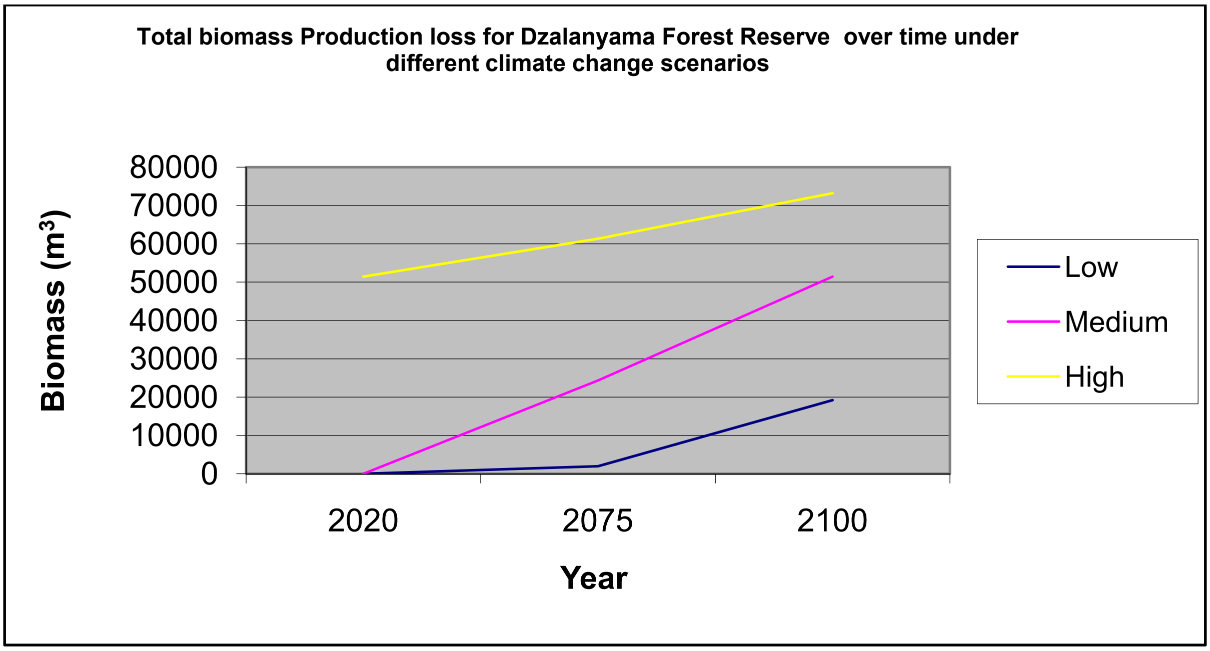


Fig 4.20: Wood production for Dzalanyama Forest over time under different climate change scenarios.

Further, a time series analysis was conducted to evaluate the impacts of climate-related disasters (floods, strong winds, drought, cyclones, landslides, hailstorms, water avalanches and forest fires) on the performance and resilience of the forests of Malawi. Forest fires were analysed separately because these have only been recorded for a short period of time (since 1980), whereas the records for the others go back to as far back as 1946 (Figs 4.21 and 4.22).

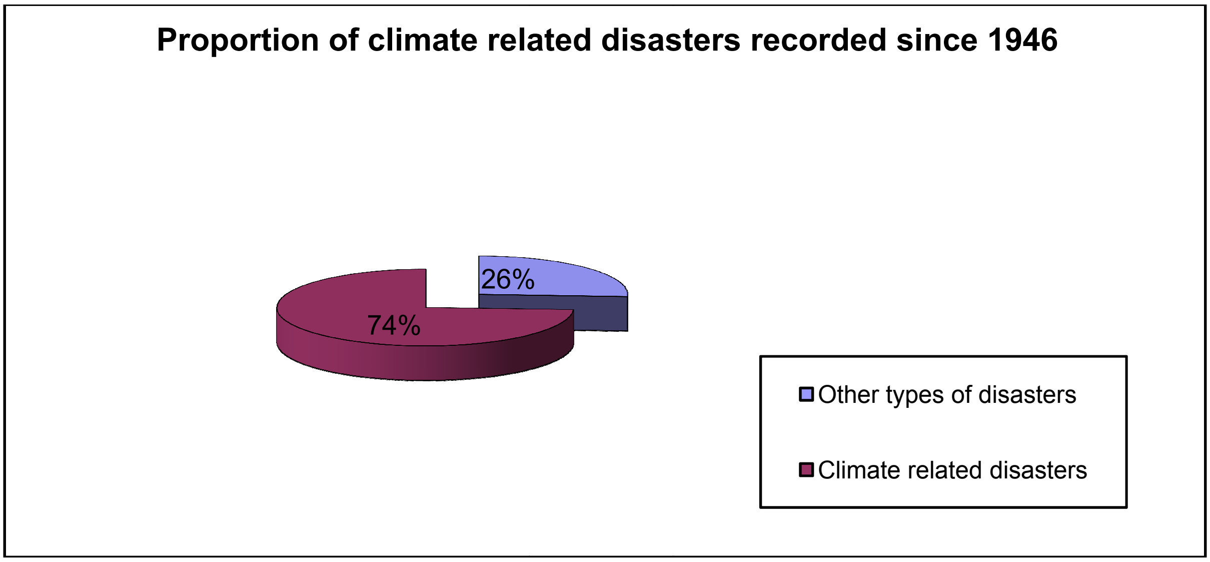


Fig 4.21: Proportion of climate related disasters recorded since 1946 in Malawi

Note: The total number of recorded disasters is 25

Data source: Department of Disaster Preparedness, Relief and Rehabilitation, 2008/

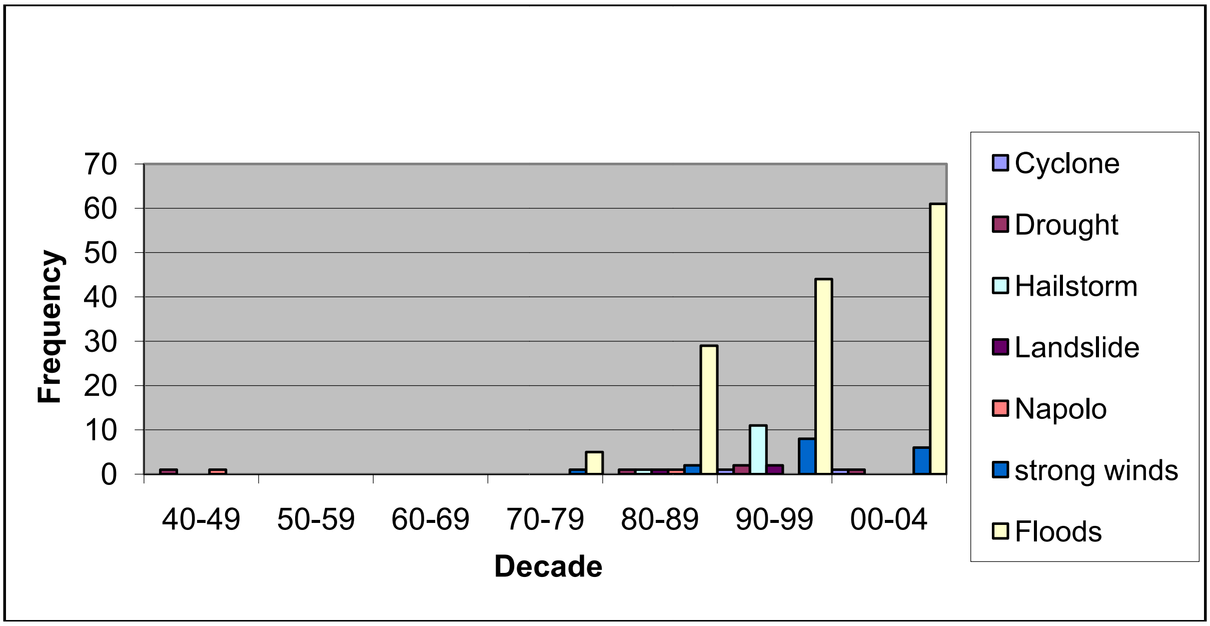


Fig 4.22: Frequency of climate-related disasters recorded in Malawi

Note: A total of 186 climate related disasters have been recorded since 1946
Data source: Department of Disaster Preparedness, Relief and Rehabilitation, 2008.

The Department of Disaster Preparedness, Relief and Rehabilitation (DoDPPR) has recorded a total of 251 disasters to date. These include accidents, health related disasters, insect pests, displacement of people due to wars and climate related disasters. Existing data shows that of all the disasters so far recorded, 74% are climate-related, making climate change a major cause of disasters in the country (Fig 4.21). The climate disaster pattern and trends show that Malawi is vulnerable to a number of climate disasters with varying frequencies. Floods, hailstorms and strong winds represent 93 % of all the climate related disasters (Fig 4.22).

4.3.4 Energy Sector

Malawi's Energy Sector comprises five main sub-sectors: (i) electricity, (ii) wood fuel (biomass), (iii) petroleum products, (iv) coal, and (v) other renewable energy sources (MG, 2003a). However, the National Energy Policy of 2003, clearly highlights Malawi's overdependence on wood-fuel (i.e., charcoal and firewood), which accounts for nearly 93% of the country's aggregate energy demand. The high dependence on wood-fuel results in increased deforestation in the form of uncontrolled felling of natural woodlands. As more prime forest areas continue to dwindle, there is an increasing incidence of fragile eco-systems erosion, resulting in flash floods and river bank siltation, which in turn affects hydro-electric power generation. Inevitably, the Energy Sector is also affected by extreme weather events, such as droughts and floods, which negatively impact on hydro-electric power generation along the Shire River, a major source of energy for Malawi. The water flow disruptions have been exacerbated by siltation caused by poor and unsustainable agriculture practices, deforestation, and noxious weeds, including water hyacinths.

Methodology. The study used the LEAP (Long Range Energy Alternative Planning System) Model, a widely-used software tool for energy policy analysis and climate change mitigation assessment developed by the Stockholm Environment Institute (SEI). The LEAP model is an integrated modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. The study used baseline data from the Urban Household Energy Demand Side Strategy Report of March 1996. This is the only authoritative and comprehensive assessment of the Energy Sector for four main cities of Malawi to date. The study used consumption per capita energy balance data for urban households. The population projections for urban areas were obtained from the Malawi National Statistical Office (NSO) in Zomba. The estimated annual energy consumption was used as an input into the LEAP model. The study assumed a constant energy mix over time because the current data for urban areas are inadequate and incomplete. These data were used to produce total biomass energy demand projections under different climate change scenarios (Kainja and Kamoto, 2003). Further, Malawi's dependency on run-of-river (ROR) hydro-electric power generation on the Shire River requires that the results from the Energy Sector are included in energy assessments studies. Unfortunately, vulnerability and adaptation assessments have not been conducted for Malawi's water bodies, Hence, this study used biomass energy data from the Dzalanyama Forest Reserve to evaluate biomass energy demand on the overall total energy budget of Lilongwe City. .

Current vulnerability of the Energy Sector. The current vulnerability of the Energy Sector is evaluated and viewed within the context of: (i) electrical power supply, (ii) biomass energy supply, (iii) petroleum products, (iv) coal, and (v) other renewable energy sources. The poor quality of **electrical power supply** has hindered growth and development of many socio-economic sectors in the country. The major factors contributing to power shortage include environmental degradation, insufficient capacity, liquidity problems and vandalism. For instance, the Shire River is now experiencing unprecedented environmental degradation, which has resulted in trash from aquatic weeds and silt being swept into the river channel. Upon reaching the power generating stations, the trash blocks water flow into the turbines, which eventually leads to clogging and the damaging of the equipment. The Electricity Supply Corporation of Malawi (ESCOM) spends more than MK 3.5 million every month to clear the weeds and remove the trash above the Kamuzu Barrage at Liwonds. Siltation has also reduced the water-holding capacity of the intake dams of the power generating stations by about 50%. Additionally, the poor water quality caused by the unprecedented levels of silt in the water accelerates the wear and tear of the turbines, causing severe and costly outages in power generation. Electricity shortages, due to water level fluctuations also adversely affect hydro-power generation, which in turn affects water supply to the City of Blantyre. This directly impacts on the production capacity of manufacturing industries, such as those that manufacture cement, beverages and textiles. These industries depend on constant power supply generated from the Shire River. Because of the problems being experienced on the Shire River, a case has been put forward to develop micro- and small-scale hydro-power generating plants to overcome the cost of large-scale generation systems. These hydro-power generating plants will require a defined minimum level of runoff to ensure a constant supply of power. Thus, reductions in total rainfall, especially due to the recurrent and frequent droughts, will significantly lessen the number of viable micro-hydro power generating stations that can be installed on the rivers and streams. The **biomass energy supply category** has both upstream and downstream elements. The upstream element deals with the production of wood energy resources in man-made plantations, woodlots and natural woodlands, whereas the downstream element includes the harvesting, marketing and utilisation of wood and wood products. However, the Energy Sector is confined to downstream activities because the others are taken care of by the Forestry and Other Land-Use Sector. Over the last 25 years, forest reserves have declined tremendously from 47% to 22%, of which 21% are in protected forest reserves. This deforestation has affected and damaged catchment areas, which has in turn led to siltation and/or seasonal drying up of streams. As alluded to earlier, the subsequent siltation of Lake Malawi and the Shire River, for instance, interferes with hydro-electric power generation. In addition, the sedimentation of the lakes and rivers contribute the loss of biodiversity. Further, flash floods, bedside threatening the lives of people, destroy roads, bridges and buildings. Because of fuel-wood shortages around homesteads, women have to walk long distances to collect firewood, which is an extra labour burden and robes them of their precious time for other economic activities, including household chores. There are already indications of negative energy supply balances as many households have already started utilizing agricultural crop residues and animal wastes for household cooking and heating. On the other hand, Malawi is obliged to import refined **petroleum products** since it lacks domestic refining capacity. Further, limited storage capacity for imported fuels makes Malawi very vulnerable to oil price fluctuations and flooding in neighbouring countries, which adversely interrupt fuel supplies. Supply disruptions are mainly caused by (i) poorly maintained roads and rail systems in Tanzania, Mozambique and Malawi, (ii) flooding of routes during the rainy season, and (iii) delays at the ports of entry. However, recent studies have, however, shown that domestic capacity would not be improved even with the construction of pipelines from the Indian Ocean in Mozambique or Tanzania because this would financially not be viable in the short- to medium-term owing to the relatively low demand for liquid fuels in Malawi. The fluctuations in the production of **coal** have had a negative impact on the supply and utilization of energy from other sources as well. The coal industry in Malawi is faced with the following challenges: (i) stiff competition from cheaper imports from Zambia, Zimbabwe and Mozambique; (ii) lack of competition from within the industry; (iii) low productivity, (iv) high production costs owing to the use of inefficient technologies; and (v) lack of an appropriate regulatory framework to regulate downstream marketing, transportation and utilisation. Uncompetitive prices can also be partly attributable to the high cost of transporting coal by road from Mchenga Coal Mine in Rumphi district, northern Malawi to industrial sites that are located 500 km and 800 km away in Lilongwe City in central Malawi, and Blantyre in southern Malawi, respectively.

Another challenge in the coal industry is the problem of water and air pollution caused by coal dust as well as the emission of GHGs during mining and combustion. During combustion, coal releases various types of gases, including carbon monoxide (CO), carbon dioxide (C_2O) and sulphur dioxide (S_2O), which are hazardous to life and the environment, and contribute to global warming. However, nearly all coal dust generated from the coal mines is sold to local cement manufacturing plants or exported to neighbouring countries, especially to the cement manufacturing company in Mbeya, Tanzania. The other renewable energy sources are many, and include solar and wind energy, which are being promoted in Malawi, though with little success. However, for African countries, which have yet to develop their infrastructure and basic industries, the need for centralized energy systems will continue for some time, although it may co-exist with advances in solar installations. Malawi is no exception to this.

Future vulnerability of the Energy Sector. The overall impact of climate change on the Energy Sector is difficult to ascertain without providing an analysis of the other major sectors that contribute to the energy demand and supply equation, such as the Water Resources Sector and the Forestry and Other Land-Use Sector. Nonetheless, this study used the LEAP model to project energy demand and production using urban populations of the four main cities of Lilongwe, Blantyre, Mzuzu and Zomba. However, future studies will need to include energy demand and consumption patterns for all townships in the country, including rural growth centres and communities in rural areas. Future projected total energy demand and risks for urban populations. These energy projections are evaluated within the context of: (i) total energy demand for urban populations, and (ii) total energy production as influenced by climate change. The total energy demand for urban populations for the cities of Lilongwe and Mzuzu mostly depend on biomass energy compared with other sources of energy ((Figs 4.23 and 4.25) In Zomba City, six times the amount of wood energy is used when compared with the energy from charcoal (Fig 4.26). In Blantyre City, however, the amount of energy derived from charcoal is just the same as that derived from wood-fuel (Fig 4.24). In general, urban households in Lilongwe, Blantyre and Zomba use four times the amount of energy derived from electricity compared with that derived from paraffin (kerosene). In Mzuzu City, households use almost equal quantities of energy derived from electricity and paraffin (kerosene).

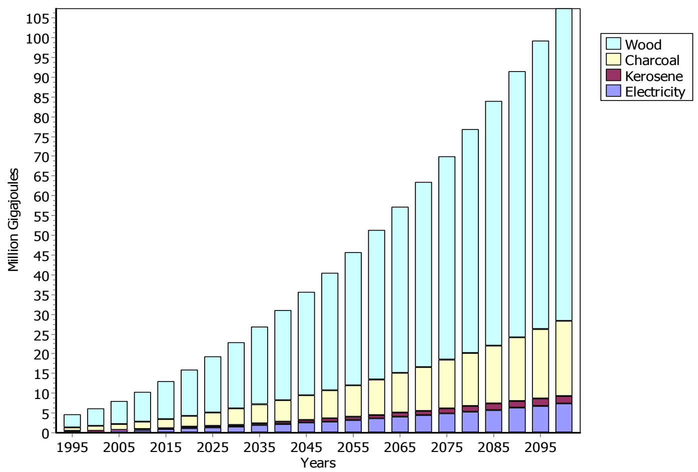


Fig 4.23: Projected total energy demand for Lilongwe City

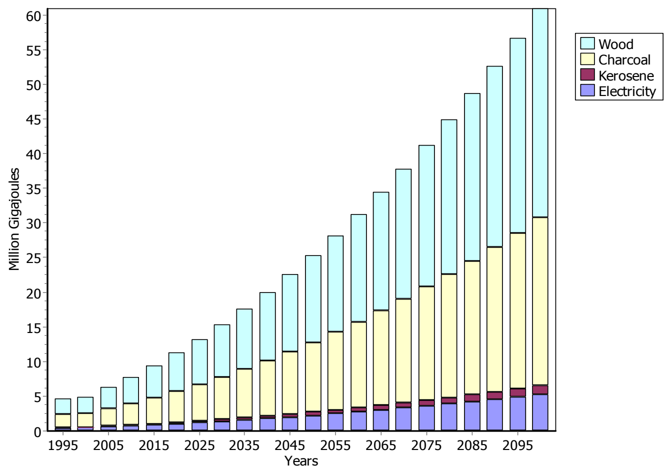


Fig 4.24: Projected total energy demand for Blantyre City

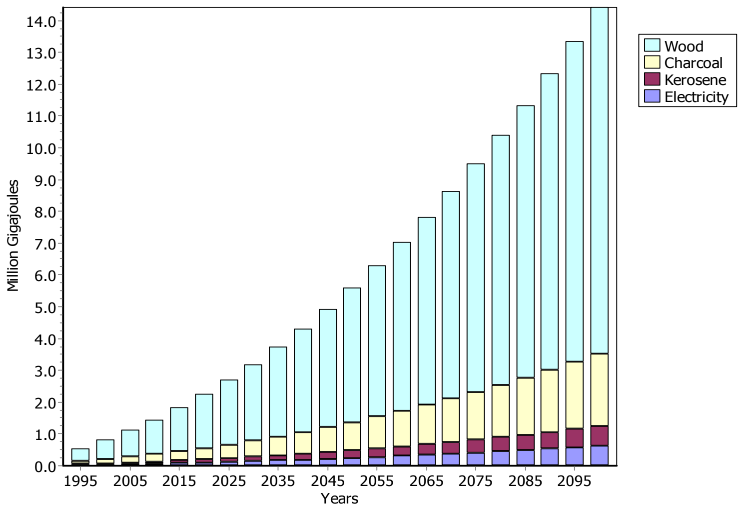


Fig 4.25: Projected total energy demand for Mzuzu City

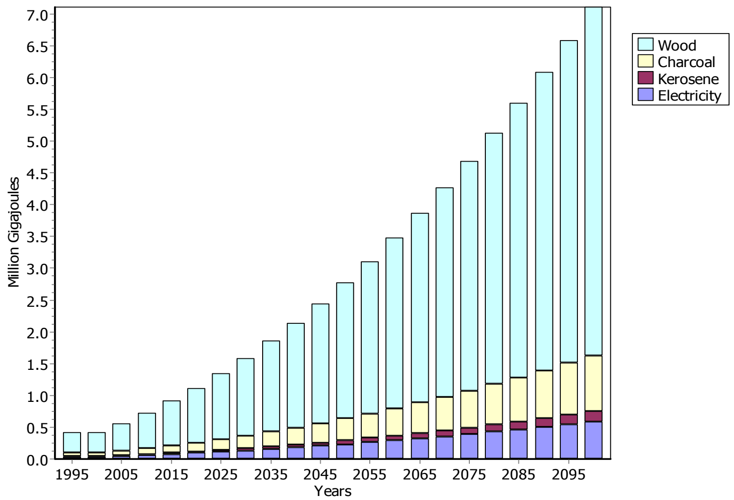


Fig 4.26: Projected total energy demand for Zomba City

Table 4.3 depicts the projected total **wood energy demand** for Lilongwe City, and **wood energy production demands under different climate change scenarios** for fuel-wood derived from Dzalanyama Forest Reserve in Lilongwe district up to the year 2100. There is an increasing demand for total energy with time in response to an increasing human population. However, the wood energy production under different climate change scenarios exhibits a declining trend in wood energy production with increasing time (Table 4.3).

Table 4.3: Projected wood energy demand for Lilongwe City, Lilongwe, 1995-2100

Year	Total energy demand (GJ)	Total wood energy production (GJ) under low, moderate and extreme climate change (CC) scenarios			
		Current climate	Low climate change scenario	Moderate climate change scenario	Extreme climate change scenario
1995	3,318,958	2,177,537	2,177,537	2,177,537	2,177,537
2000	4,414,891	2,177,537	2,177,537	2,177,537	2,064,305
2005	5,878,924	2,177,537	2,177,537	2,177,537	1,951,073
2010	7,582,144	2,177,537	2,177,537	2,177,537	1,837,842
2015	9,524,551	2,177,537	2,177,537	2,177,537	1,724,610
2020	11,706,146	2,177,537	2,177,537	2,177,537	1,611,378
2025	14,126,928	2,177,537	2,175,558	2,157,742	1,601,480
2030	16,786,897	2,177,537	2,173,578	2,137,946	1,591,582
2035	19,686,054	2,177,537	2,171,599	2,118,150	1,581,684
2040	22,824,398	2,177,537	2,169,619	2,098,354	1,571,786
2045	26,201,929	2,177,537	2,167,639	2,078,558	1,561,888
2050	29,818,647	2,177,537	2,165,660	2,058,763	1,551,990
2055	33,674,552	2,177,537	2,163,680	2,038,967	1,542,092
2060	37,769,645	2,177,537	2,161,701	2,019,171	1,532,194
2065	42,103,925	2,177,537	2,159,721	1,999,375	1,522,297
2070	46,677,392	2,177,537	2,157,742	1,979,579	1,512,399
2075	51,490,047	2,177,537	2,155,762	1,959,784	1,502,501
2080	56,541,888	2,177,537	2,116,566	1,890,102	1,476,370
2085	61,832,917	2,177,537	2,077,371	1,820,421	1,450,240
2090	67,363,133	2,177,537	2,038,175	1,750,740	1,424,109
2095	73,132,537	2,177,537	1,998,979	1,681,059	1,397,979
2100	79,141,128	2,177,537	1,959,784	1,611,378	1,371,849

The projected fuel-wood deficits under various climate change scenarios for the City of Lilongwe is depicted in Table 4.4. These data indicate that the current supply of wood energy from Dzalanyama Forest Reserve falls short of supply by more than 60%, assuming that the forest reserve is the main source of wood-fuel supply at a constant energy mix. The trend for wood energy deficit is similar for the low and moderate climate change scenarios for 2020, 2075 and 2100 at 81%, 96% and 98%, respectively. For the same years (2020, 2075 and 2100) the projected trends for the extreme climate change scenario is 86%, 97% and 98%, respectively. Thus, the biomass energy supply will fall short of the total energy requirements for the urban population of Lilongwe City under climate change in the future.

Table 4.4 Projected wood energy deficit under climate change in Lilongwe City, 1995-2000

Year	Wood energy deficit (%)			
	Current climate	Low climate change scenario	Moderate climate change scenario	Extreme climate change scenario
1995	34	34	34	34
2000	51	51	51	53
2005	63	63	63	67
2010	71	71	71	76
2015	77	77	77	82
2020	81	81	81	86
2025	85	85	85	89
2030	87	87	87	91
2035	89	89	89	92
2040	90	90	91	93
2045	92	92	92	94
2050	93	93	93	95
2055	94	94	94	95
2060	94	94	95	96
2065	95	95	95	96
2070	95	95	96	97
2075	96	96	96	97
2080	96	96	97	97
2085	96	97	97	98
2090	97	97	97	98
2095	97	97	98	98
2100	97	98	98	98

4.3.5 Water Resources Sector

The Water Resources Sector forms one of the key pillars of the socio-economic growth and development strategy under the current Malawi's Growth and Development Strategy (MDGS) of 2006 .The development of Malawi's water resources has provided improved water supply and sanitation to about 73% and 61% of the population, respectively.

Malawi's water resources are derived from a network of streams, rivers, underground aquifers and the five lakes of Malawi, Chilwa, Malombe, Chiuta and Kazuni. Lake Malawi dominates as the largest water body with an annual mean live storage of some 101 km^3 of water. The Shire River is the second dominant water body with an average flow rate of some 400 $m^3 s^{-1}$ as it leaves Lake Malawi, passing an annual average of some 18 km^3 of water out of the country as it enters into the Zambezi River. The importance of these available water resources to national socio-economic development of the country cannot be overemphasized, especially as the country depends on rain-fed agriculture.

Further, the country's water resources are important in the generation of hydro-electric power. Some 280 MW of hydro-power are generated from hydro-power generating plants on the Shire River. In addition, the lake levels support navigation, the fishing industry, tourism and wildlife resources. Lake transport is the only means of public transport for some areas along the Lakeshore Plain, such as Usisya, and also provides the cheapest means of cargo transportation. However, Lake Malawi and its tributaries, Songwe, North Rukuru, South Rukuru, Dwangwa, Lilongwe, Linthipe and Bua rivers, its outlet, the Shire River and its tributaries, Ruo and Mwanza, are vulnerable to the adverse effects of climate change, especially droughts and floods. Hence the need for vulnerability and adaptation assessment studies of the water resources of Malawi is required urgently.

Methodology. The assessment of water resources vulnerability is based on baseline data collected from the Ministry of Irrigation and Water Development (MoIWD), the Ministry of Agriculture and Food Security (MoAFS), the Department of Meteorological Services (DoMS) and information and data gathered during field visits to different study areas. Although historical data and information are adequate to develop scenarios of hydrological regimes that can be generated with climate change, they are inadequate and insufficient for carrying out intervention analyses of climate change to predict hydrological regime changes resulting from climate change. The assessment considers activities on: (i) the vulnerability of river run-off, and (ii) and assessment of the vulnerability of Lake Malawi.

The **assessment of the vulnerability of river run-off** is based on a baseline characterization of the mean river annual flows, maximum and minimum flows and recessions. The river mean monthly and annual run-off data were used in the baseline scenario, whereas the run-off and rainfall relationship was used to project run-off and rainfall scenarios. The rainfall scenario data were calculated using mean annual rainfall increases or decreases of 50%, 25% and 10%. These percentages were arrived at by assessing possible generated rainfall scenarios.

The **assessment of the vulnerability of Lake Malawi** water resources is based on a data base developed by Kidd (1983) under the United Nations Development Programme (UNDP) Project entitled "Advancement of Hydrological Services in Malawi –MW/77/012". The vulnerability of Lake Malawi's water resources was assessed using vulnerability scenarios based on the water balance equation. The water balance equation is based on the principles of mass conservation and the equation of continuity as follows:

Change in lake storage = (Inflow from catchment + rainfall over the lake) – [(Shire River flow + evaporation from the lake + change in ground water storage] ……………………………...…. [4.1].

Equation 4.1 can be shortened as follows:

$\varphi_{\Delta s} = \varphi_{if} + \varphi_{dr} - [\varphi_{of} + \varphi_{ep} + \varphi_{gs}]$ ………………………….……… ……. ………………….….[4.2]

Where:
$\varphi_{\Delta s}$ = change in water storage in Lake Malawi or Lake Malawi water levels
φ_{if} = inflow into Lake Malawi from rivers and streams draining into it
φ_{dr} = direct rainfall falling over Lake Malawi
φ_{of} = outflow into the Shire River
φ_{ep} = evaporation from Lake Malawi
φ_{gs} = groundwater storage (or flow into groundwater aquifers) around Lake Malawi

For the period 1954/55-1979/80, Kidd (1983) estimated these water balance components as follows:

$\varphi_{\Delta s}$	=	112 mm;	φ_{of}	=	- 418 mm;
φ_{if}	=	1,000 mm;	φ_{ep}	=	- 2,264 mm;
φ_{dr}	=	1,414 mm;	φ_{gs}	=	380 mm.

However, the above annual water balance equation can be disaggregated into monthly water balance equations as follows:

$\varphi_{\Delta s,j} = \varphi_{if,j} + \varphi_{dr,j} - [\varphi_{of,\,j} + \varphi_{ep,\,j} + \varphi_{gs,\,j}]$ ……………………………………………………… [4.3]

Where:
$\varphi_{\Delta s,\,j}$ = change in water storage in Lake Malawi or Lake Malawi water levels in month j
$\varphi_{if,\,j}$ = inflow into Lake Malawi from rivers and streams draining into it in month j
$\varphi_{dr,\,j}$ = the direct rainfall falling on Lake Malawi in month j
$\varphi_{of,\,j}$ = the outflow into the Shire River in month j
$\varphi_{ep,\,j}$ = evaporation from Lake Malawi in month j
$\varphi_{gs,\,j}$ = groundwater storage (or flow into groundwater aquifers) around Lake Malawi in month j

Future vulnerability of the Water Resources Sector. The future vulnerability of the Water Resources Sector focussed on **the vulnerability of**: (i) river basins, and (ii) Lake Malawi and Shire River **water resources.** The baseline data for various **rivers and river basins** is presented in Table 4.5. For example, from field inspections carried out in March 2008, the Mwanza River channel near its confluence with the Shire River had silted-up more than 2.0 m as observed from the Mwanza Bridge. It is actually very shallow and its bank shoulders are about 0.5 m high (Fig 4.27.), so that when it floods the water spreads several metres on both sides of the river banks.

Table 4.5: Baseline data for river run-off for selected rivers in Malawi

Name of River		Mean monthly and annual run-off (cubic metres per second)												
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.	Sep.	Oct.	Annual
North Rukuru	Mean	2.7	10.8	22.6	35.3	36.1	26.0	12.5	7.3	5.2	3.7	2.5	2.0	13.9
	Std Dev	1.8	13.3	15.0	28.8	17.4	15.6	10.0	4.0	2.8	1.5	0.9	0.8	9.3
South Rukuru	Mean	5.7	17.8	54.1	80.5	108.8	74.0	31.2	18.5	14.1	10.9	7.7	5.2	53.7
	Std Dev	4.0	10.8	32.6	37.3	46.3	37.2	14.8	7.2	5.1	3.7	2.5	1.8	16.9
Dwangwa	Mean	1.8	12.7	41.9	53.8	53.4	23.1	10.4	5.9	3.9	2.5	1.4	0.8	17.6
	Std Dev	2.0	11.4	24.4	28.7	29.5	19.2	8.4	7.3	4.6	3.3	2.2	1.7	11.9
Lilongwe	Mean	5.8	17.5	43.5	60.1	62.6	19.7	11.7	7.6	6.1	4.8	3.1	2.4	20.4
	Std Dev	9.6	11.6	34.8	72.6	100.7	11.4	18.9	16.8	15.7	14.4	9.1	6.5	26.8
Linthipe	Mean	1.8	16.0	33.7	38.5	41.3	19.2	7.1	4.1	2.7	2.2	1.4	1.0	14.1
	Std Dev	2.1	15.6	19.4	18.3	30.1	12.8	4.8	2.6	1.7	1.5	1.4	2.1	9.4
Bua	Mean	2.0	18.9	48.2	105.5	112.8	62.8	20.5	8.4	5.1	3.6	2.3	1.1	32.6
	Std Dev	3.7	38.8	44.9	72.4	66.3	42.0	17.2	6.8	3.9	2.7	2.0	1.2	25.2
Shire – Liwonde	Mean	298	307	346	389	422	450	461	437	404	365	337	313	376
	Std Dev	158	165	180	190	214	234	236	226	210	193	181	171	184
Shire- Matope	Mean	332	353	410	492	525	556	560	534	481	422	383	347	450
	Std Dev	180	187	192	201	221	234	230	228	208	199	194	187	205
Shire- Chikwawa	Mean	412	443	522	591	657	619	628	610	508	466	449	415	521
	Std Dev	169	199	186	244	311	289	289	253	242	211	184	174	212
Shire-Chiromo	Mean	302	413	563	648	657	601	582	534	488	417	353	311	480
	Std Dev	157	252	246	199	243	220	288	279	256	229	174	162	247
Mwanza	Mean	0.0	1.3	7.7	14.4	12.4	5.0	2.2	1.1	0.8	0.4	0.1	0.0	3.5
	Std Dev	0.0	2.5	10.7	18.3	16.0	6.9	2.6	1.4	1.1	0.6	0.2	0.0	3.0
Ruo River	Mean	19.2	65.1	113.0	136.0	134.0	78.5	36.9	29.3	26.1	17.7	12.6	11.3	53.7
	Std Dev	12.2	36.5	94.5	80.4	77.9	38.6	16.4	13.1	12.9	8.9	5.9	5.7	18.0

Fig 4.27: Silting-up of the Mwanza River channel bed, southern Malawi

From Table 4.5, the updated means and standard deviations presented here are slightly different from those presented in the National Water Resources Master Plan (NWRMP), except for those on the Shire River where the differences are negligible. The data sets used have been extended for a period of between 10 to 15 years, although there are large gaps due to poor hydrological data collection and processing. The Shire River mean flows, however, have large conflicting differences between the flows recorded at Matope, Chikwawa and Chiromo. The difference is further compounded by the backwater effects at the Chiromo gauge, which makes the recorded flows unreliable. There is a general laxity and neglect in the collection of hydrological data by the Department of Water Resources (DoWR), which needs to be urgently addressed if good quality data are to be collected and used as inputs into the water balance equation, and other water resources computer simulation models.

A rapid assessment of the hydrological regimes of the different rivers is shown in Table 4.6, which shows river run-off using climate change scenarios with rainfall decreases of 10%, 25% and 50%. The results indicate that the South Rukuru, Dwangwa, Lilongwe and Mwanza rivers would dry up when rainfall decreases by about half of baseline means of 436, 428, 516 and 451 mm per year, respectively).

Table 4.6: Mean river run-off reductions as affected by baseline rainfall for some rivers in Malawi

River		Mean monthly flows (cubic metres per second)												Annual averages		
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Flow in m^3/s	Runoff in mm	Rainfall in mm
N. Rukuru	Baseline	2.7	10.8	22.6	35.3	36.1	26.0	12.5	7.3	5.2	3.7	2.5	2.0	13.9	236	970
	-10%	2.1	8.5	17.8	27.8	28.4	20.4	9.9	5.7	4.1	2.9	2.0	1.6	10.9	187	873
	-25%	1.7	6.7	14.1	22.1	22.6	16.3	7.8	4.5	3.3	2.3	1.6	1.2	8.7	149	728
	-50%	1.0	3.9	8.1	12.6	12.9	9.3	4.5	2.6	1.9	1.3	0.9	0.7	5.0	85	485
S. Rukuru	Baseline	5.7	17.8	54.1	80.5	108.8	74.0	31.2	18.5	14.1	10.9	7.7	5.2	35.7	96	873
	-10%	4.3	13.5	41.1	61.1	82.7	56.2	23.7	14.0	10.7	8.3	5.9	3.9	27.1	67	786
	-25%	2.5	7.8	23.7	35.2	47.6	32.4	13.6	8.1	6.2	4.8	3.4	2.3	15.6	38	655
	-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	436
Dwangwa	Baseline	1.8	12.7	41.9	53.8	53.4	23.1	10.4	5.9	3.9	2.5	1.4	0.8	17.6	73	902
	-10%	1.5	10.7	35.3	45.2	44.9	19.5	8.7	4.9	3.3	2.1	1.2	0.6	14.8	61	812
	-25%	0.9	6.7	22.0	28.2	28.0	12.1	5.5	3.1	2.1	1.3	0.7	0.4	9.3	38	677
	-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	451
Lilongwe	Baseline	5.8	17.5	43.5	60.1	62.6	19.7	11.7	7.6	6.1	4.8	3.1	2.4	20.4	130	856
	-10%	1.6	4.9	12.3	17.0	17.7	5.6	3.3	2.2	1.7	1.4	0.9	0.7	5.8	98	770
	-25%	0.7	2.3	5.6	7.8	8.1	2.5	1.5	1.0	0.8	0.6	0.4	0.3	2.6	45	642
	-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	428
Linthipe	Baseline	1.8	16.0	33.7	38.5	41.3	19.2	7.1	4.1	2.7	2.2	1.4	1.0	14.1	152	964
	-10%	0.8	7.3	15.4	17.6	18.9	8.8	3.3	1.9	1.3	1.0	0.6	0.5	6.4	109	868
	-25%	0.5	4.8	10.1	11.5	12.4	5.8	2.1	1.2	0.8	0.6	0.4	0.3	4.2	72	723
	-50%	0.1	0.6	1.2	1.4	1.5	0.7	0.3	0.1	0.1	0.1	0.0	0.0	0.5	9	482
Bua	Baseline	2.0	18.9	48.2	105.5	112.8	62.8	20.5	8.4	5.1	3.6	2.3	1.1	32.6	97	1032
	-10%	0.2	1.7	4.4	9.7	10.4	5.8	1.9	0.8	0.5	0.3	0.2	0.1	3.0	51	929
	-25%	0.0	0.2	0.5	1.0	1.1	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.3	5	774
	-50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	516
Mwanza	Baseline	0.0	1.3	7.7	14.4	12.4	5.0	2.2	1.1	0.8	0.4	0.1	0.0	3.5	67	902
	-10%	0.0	1.2	7.2	13.5	11.6	4.6	2.1	1.0	0.7	0.4	0.1	0.0	3.3	56	812
	-25%	0.0	0.8	4.7	8.8	7.6	3.0	1.4	0.7	0.5	0.3	0.1	0.0	2.2	37	677
	-50%	0.0	0.1	0.6	1.1	0.9	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.3	5	451

Ruo River	Baseline	19.2	65.1	113.0	136.0	134.0	78.5	36.9	29.3	26.1	17.7	12.6	11.3	53.7	365	1373
	-10%	19.5	66.2	114.9	138.3	136.3	79.8	37.5	29.8	26.5	18.0	12.8	11.5	54.6	371	1236
	-25%	15.0	50.7	88.1	106.0	104.5	61.2	28.8	22.8	20.3	13.8	9.8	8.8	41.9	285	1030
	-50%	7.4	25.0	43.3	52.2	51.4	30.1	14.2	11.2	10.0	6.8	4.8	4.3	20.6	140	687

On the other hand, the monthly flows under the projected climate change scenarios, where the catchments have mean annual rainfall (not annual total) increased by 10, 25 and 50% give very high monthly and annual average flows. These mean monthly average flows will most likely result into large peak floods compared with those under the baseline scenario. Thus, these results predict high and frequent floods for North Rukuru around Karonga Boma, Dwangwa River around Dwangwa Sugar Estate, Linthipe around Salima Boma, Mwanza, and the Ruo River around their confluences with the Shire River in Chikwawa and Nsanje districts. The Ruo River, whose catchment area includes the Mulanje Mountain Massif (Fig 4.28), will cause more frequent and extensive flooding around its confluence with the Shire River than at the present moment. The Bua and Lilongwe rivers would experience very low river flows and severe water shortages if the annual rainfall were decreased by 25%.

Table 4.7: Mean and increased run-off due to increases in baseline mean rainfall

River		Mean monthly flows (cubic metres per second)												Annual Averages		
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Flow in m^3/s	Runoff mm	Rainfall mm
North Rukuru	Base	2.7	10.8	22.6	35.3	36.1	26.0	12.5	7.3	5.2	3.7	2.5	2.0	13.9	236	970
	+10%	2.7	10.9	22.8	35.7	36.4	26.2	12.7	7.3	5.2	3.8	2.5	2.0	14.0	238	1067
	+25%	3.2	12.7	26.6	41.6	42.4	30.6	14.8	8.5	6.1	4.4	3.0	2.3	16.3	278	1217
	+50%	3.9	15.6	32.6	50.9	52.0	37.5	18.1	10.5	7.5	5.4	3.6	2.8	20.0	340	1455
South Rukuru	Base	5.7	17.8	54.1	80.5	108.8	74.0	31.2	18.5	14.1	10.9	7.7	5.2	35.7	96	873
	+10%	6.2	19.4	58.8	87.5	118.3	80.5	33.9	20.1	15.4	11.9	8.4	5.6	38.8	104	960
	+25%	7.9	24.6	74.8	111.2	150.4	102.3	43.1	25.5	19.5	15.1	10.7	7.2	49.4	133	1091
	+50%	10.7	33.4	101.4	150.7	203.8	138.6	58.4	34.6	26.5	20.4	14.5	9.7	66.9	180	1310
Dwangwa	Base	1.8	12.7	41.9	53.8	53.4	23.1	10.4	5.9	3.9	2.5	1.4	0.8	17.6	73	902
	+10%	2.3	16.1	53.0	67.9	67.4	29.2	13.1	7.4	5.0	3.2	1.8	1.0	22.3	92	992
	+25%	2.9	20.1	66.2	84.9	84.3	36.5	16.4	9.3	6.2	3.9	2.2	1.2	27.8	116	1128
	+50%	3.8	26.8	88.3	113.3	112.5	48.7	21.9	12.3	8.3	5.3	2.9	1.6	37.1	154	1353
Lilongwe	Base	5.8	17.5	43.5	60.1	62.6	19.7	11.7	7.6	6.1	4.8	3.1	2.4	20.4	130	856
	+10%	2.8	8.5	21.2	29.2	30.5	9.6	5.7	3.7	3.0	2.3	1.5	1.2	9.9	169	942
	+25%	3.7	11.2	27.9	38.4	40.0	12.6	7.5	4.9	3.9	3.1	2.0	1.5	13.1	222	1070
	+50%	5.1	15.7	39.0	53.8	56.0	17.7	10.5	6.8	5.5	4.3	2.8	2.1	18.3	311	1284
Linthipe	Base	1.8	16.0	33.7	38.5	41.3	19.2	7.1	4.1	2.7	2.2	1.4	1.0	14.1	152	964
	+10%	1.2	10.7	22.5	25.7	27.6	12.8	4.8	2.7	1.8	1.4	0.9	0.7	9.4	160	1060
	+25%	1.5	13.2	27.8	31.8	34.1	15.9	5.9	3.3	2.3	1.8	1.1	0.8	11.6	198	1205
	+50%	2.0	17.4	36.7	41.9	45.0	20.9	7.8	4.4	3.0	2.4	1.5	1.1	15.3	260	1446
Bua	Base	2.0	18.9	48.2	105.5	112.8	62.8	20.5	8.4	5.1	3.6	2.3	1.1	32.6	97	1032
	+10%	0.4	3.8	9.7	21.3	22.8	12.7	4.1	1.7	1.0	0.7	0.5	0.2	6.6	112	1135
	+25%	0.6	5.4	13.7	30.0	32.1	17.9	5.8	2.4	1.5	1.0	0.7	0.3	9.3	158	1290
	+50%	0.8	8.0	20.3	44.5	47.6	26.5	8.6	3.5	2.2	1.5	1.0	0.5	13.7	234	1548
Mwanza	Base	0.0	1.3	7.7	14.4	12.4	5.0	2.2	1.1	0.8	0.4	0.1	0.0	3.5	67	902
	+10%	0.0	1.8	10.4	19.6	16.9	6.8	3.0	1.5	1.1	0.6	0.2	0.0	4.8	81	992
	+25%	0.0	2.2	12.9	24.3	20.9	8.4	3.7	1.9	1.3	0.7	0.2	0.0	5.9	101	1128
	+50%	0.0	2.9	17.0	32.0	27.6	11.1	4.9	2.4	1.8	0.9	0.3	0.0	7.8	133	1353

Ruo River	Base	19.2	65.1	113.0	136.0	134.0	78.5	36.9	29.3	26.1	17.7	12.6	11.3	53.7	365	1373
	+10%	25.6	86.8	150.7	181.4	178.7	104.7	49.2	39.1	34.8	23.6	16.8	15.1	71.6	487	1510
	+25%	30.2	102.3	177.6	213.7	210.6	123.4	58.0	46.0	41.0	27.8	19.8	17.8	84.4	574	1716
	+50%	37.8	128.1	222.3	267.5	263.6	154.4	72.6	57.6	51.3	34.8	24.8	22.2	105.6	718	2060

Note: Base – Baseline scenario

Fig 4.28: Flowing streams falling-off the cliffs of the Mulanje Mountain Massif

The South Rukuru and Bua Rivers would also be prone to high river flows, although field observations revealed that these have confined channels that will make the overflowing of floods an ununlikely event (Fig 4.29). However, these high flows would also mean water flowing at high velocities that are capable of scouring the river bed, but carrying a lot of sediment loads and depositing them in the lower reaches of the river. The sedimentation of the estuaries and confluences of the North Rukuru, Dwangwa, Linthipe, Mwanza and Ruo rivers would exacerbate flooding under the climate change scenarios of increased rainfall in these areas. .

Fig 4.29: Bua River channel near Lake Malawi in Nkhota Kota district

Lake Malawi and Shire River. Free Lake Malawi water levels and the Shire River water flows were developed using the water balance Equation 4.2 for the period 1954/55-1979/80. This is the period for which the water balance equation parameters were not influenced by: (i) the blocking of the Shire River in 1956 and 1957 for hydrological studies, (ii) blocking of the Shire River in 1965-66 during the construction of the Kamuzu Barrage, and (iii) manual regulation of the barrage to regulate water flows in the 1970s, 1980s and early 1990s. A regression equation was used in the study, with a priori assumption that there is negligible change in area of the lake with changes in lake levels. Figs 4.30 and 4.31 compare naturalised and controlled Shire River flows and Lake Malawi levels, respectively.

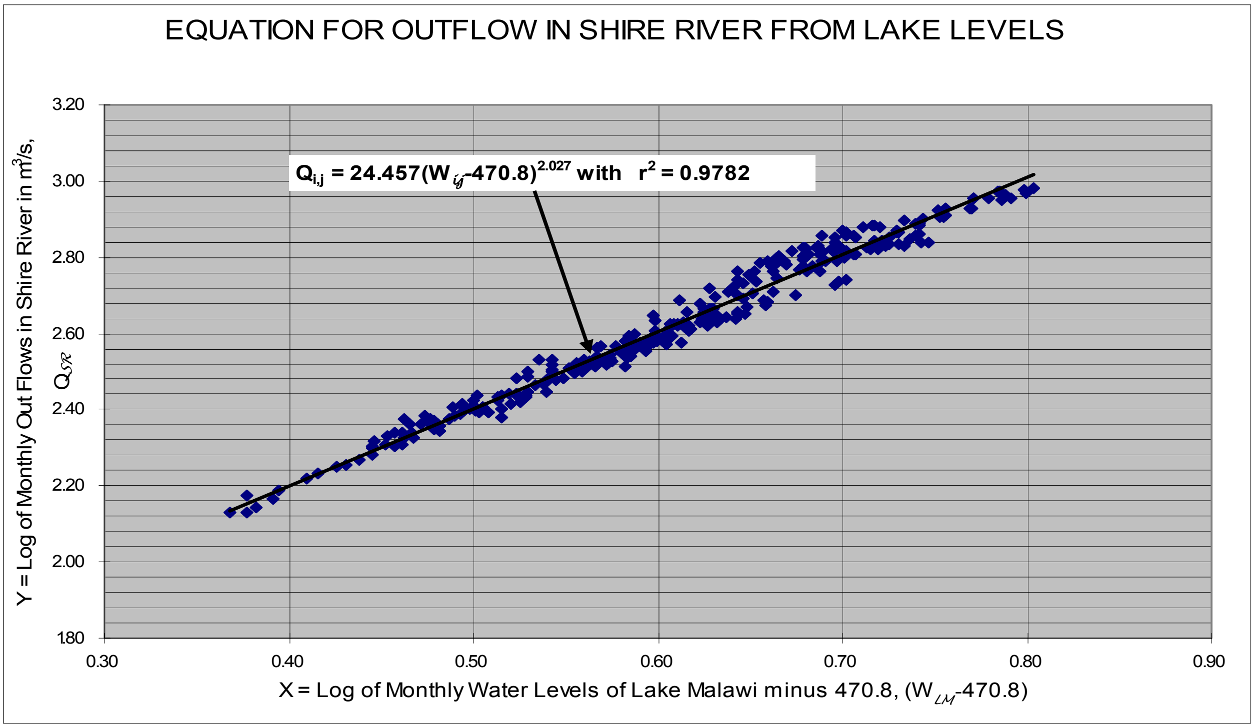


Fig 4.30: Relationship between monthly Shire River flows and Lake Malawi water levels

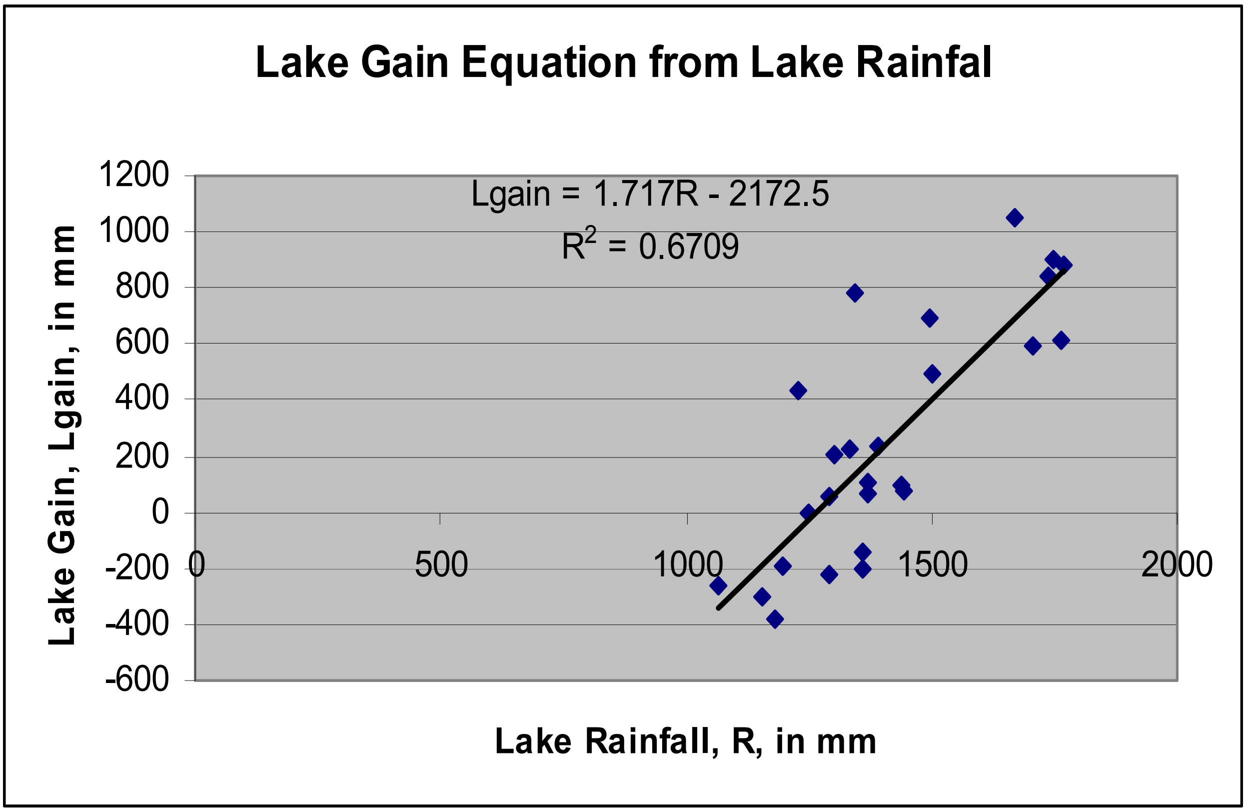


Fig 4.31: Relationship between Lake Malawi water gains and Lake Malawi rainfall

The monthly means of naturalised Lake levels ($Mean^{ntr}$) were calculated and compared with those used in the 1954/55-1979/80 water balance equation ($Mean^{wbe}$) used by Kidd (1983) (Table 4.8). The difference between these is about 0.45 m, which is the gain in lake water levels from blocking and regulating the Shire River flows. The generated natural lake levels were used to assess the vulnerability of lake gains (water level rises or falls). This was carried out by examining the relationship between direct rainfall over the lake and lake gains each water year (from November to October the following year). The lake gains are most sensitive to direct rainfall as evidenced by the water balance equation. This relationship is given in Fig 4.30.

Table 4.8 Monthly means of naturalised Lake levels ($Mean^{ntr}$):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
$Mean^{ntr}$	473.99	473.99	474.16	474.40	474.69	474.96	475.03	474.89	474.68	474.50	474.35	474.21
$Stdev^{ntr}$	0.52	0.54	0.56	0.54	0.54	0.59	0.59	0.58	0.57	0.56	0.56	0.56
$Mean^{wbe}$	474.45	474.48	474.65	474.88	475.17	475.42	475.47	475.32	475.12	474.94	474.79	474.66

Source: Kidd, 1983.

From Fig 4.31, it is clear that a direct annual lake rainfall of less than 1,265 mm drops the lake water level, whereas any annual lake rainfall that is higher than 1265 mm raises the lake water levels. The application of the climate change scenarios on rainfall reduction or increase presented in Section 2.2.1 generate lake gains shown in Table 4.9.

Table 4.9: Lake rise and/or fall scenarios as influenced by climate change in Malawi

Annual lake gains (mm)	Annual lake rainfall (mm)	Comments
1469	2121	50% above baseline
862	1768	25% above baseline
498	1555	10% above baseline
255	1414	Baseline, actual rise is 246 mm
13	1273	10% below baseline
-352	1061	25% below baseline
-959	707	25% below baseline

Hence, the lake gains are similar to the changes in storage of the water balance equation, but at the same time these determine whether the lake rises or falls over the years without increasing or decreasing the amount of rainfall. When the lake rainfall increases by 50% or drops to 10 % due to climate change, the lake level would show an upward trend. This upward trend is greatest when lake rainfall increases above 50%. The implication of this is that the mean annual lake levels can increase by more than 1.47 m between October and October the following year. It is likely that such increases can take place when the lake is already high, say above 476 m above mean sea level (amsl), pushing the maximum lake levels in April or May to as high as 480 m amsl within two to three years.

A reduction in lake rainfall by 25% and 50% would result in 0.35 and 0.96 m annual lake level drops, respectively. The significance of these scenarios is that the lake water levels can drop to below 470.8 m amsl within 4-6 years, resulting in no outflows into the Shire River. The lake level scenarios presented above would greatly influence the outflow in the Shire River, as demonstrated in the past (Fig 4.31). Already the lake levels have shown great vulnerability to drought conditions as demonstrated from the experiences at the turn of the century (Fig 4.1) and also to flooding as demonstrated in the late 1970s and early 1980s, which would have happened even without regulating the Shire River flows (Fig 4.31). The vulnerability assessment presented here shows that lake levels would easily rise to 478, 479 and 480 m amsl. within two to three years. These levels correspond to the Shire River outflows of 1,340, 1,740 and 2,200 $m^3 s^{-1}$, respectively, which are quite high, when compared with the Zambezi River with a 1,378,713 km^2 catchment area with an annual mean flow rate at the sea of some 3,300 $m^3 s^{-1}$.). The observed and naturalised water flows of the Shire River at Liwonde presented in Figure 4.32 show that the flows of 2,000 $m^3 s^{-1}$ would indeed be extremely high. Such flows, combined with the flooding scenarios from the Ruo and Mwanza Rivers, can cause devastating floods in the Shire Valley. On the other hand, low lake levels that would be caused by reduced rainfall of 25 or 50%, would reduce the Shire River flows to zero in the upper reaches of the river, and the lower reaches of the river may only flow during the wet season.

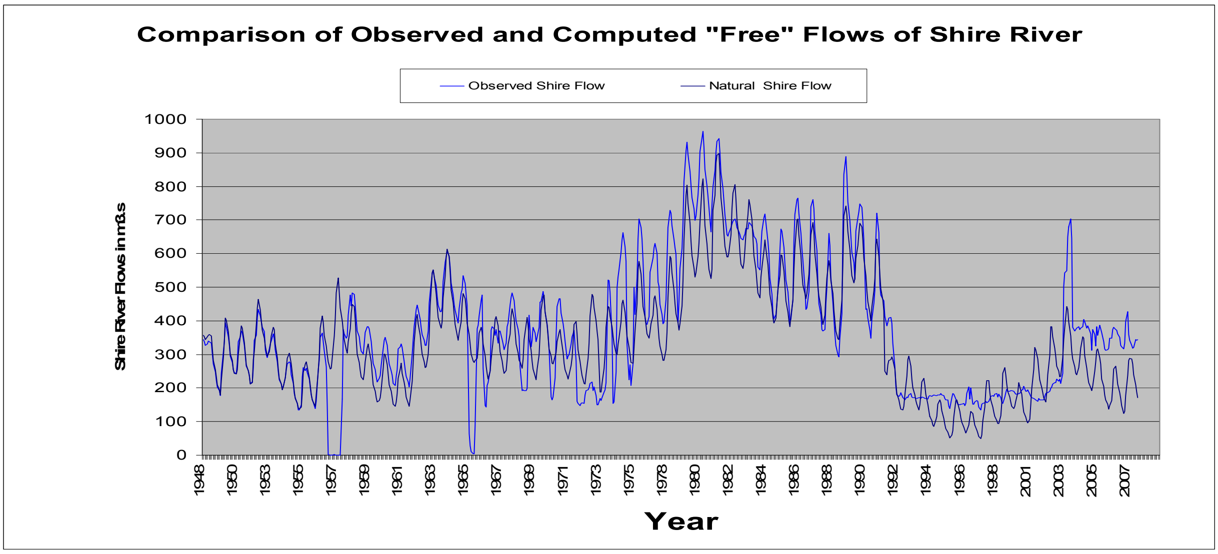


Fig 4.32: Comparison of observed and naturalized Shire River flows at Liwonde

Fig 4.33: Mwanza River silted-up channel bed, southern Malawi

Impact of the Water Resources Sector on the vulnerability of other sectors. The impact of the Water Resources Sector was assessed on the following: (i) environment, (ii) agriculture production, (iii) water and sanitation, (iv) energy, (v) transport, and (vi) other relevant sectors.

The **environment** is highly vulnerable to any changes that may occur to the hydrological regime that would ensue from the impacts of climate change. High or low water levels would negatively alter the environment around the lake, which would change habitat and biological diversity for the people living along and around the lake. There would be widespread flooding resulting into loss of life and destruction of coastal villages, holiday resorts and roads.. During periods of reduced rainfall, or droughts, the low water levels would affect the beachline by lowering the water levels, which would also result in aquatic habitat changes. The environment along the Shire River would equally be affected by high and/or low lake water levels, which would result in high or low Shire River flows. The zero outflows from the lake would completely change the environment along the Shire River, with the Elephant and Ndindi Marshes along the Shire River and other wetlands possibly disappearing. High flows would flood the Shire Valley on a year-round-basis and turn the wetlands into permanent water bodies. These environmental changes would also apply to the rivers and their riverine environments. There would be a general failure of the rivers and the lake to provide environmental flow requirements required to maintain ecological equilibrium. The effects of these changes on the environment, and the associated socio-economic impacts on the sectors of economic growth and vulnerable communities, require examination and analysis by environmentalists, natural resources management experts, agriculturists and policymakers. .

The Agriculture Sector comprises the crops and livestock sub-sectors. It is the Agriculture Sector that is the largest consumer of the water resources in the country. While flooding would result in the loss of fertile agricultural land, especially in the Shire Valley and along other river valleys, and crop losses or damages, the droughts and low water flows would reduce water availability for irrigation, dry season dimba cultivation, and the profitable production of livestock and fisheries. The scenarios presented above have serious implications on agricultural productivity and food security, which depends on rain-fed agriculture. However, there is a possibility that other parts of the country would get drier, whereas others might get wetter, thereby providing optimum conditions for crop and livestock production. It is, therefore, highly recommended that climate change forecasts should be improved so as to better predict spatial and temporal rainfall distribution across the country, especially in low-lying marginal rainfall areas. This will also lead to the full exploitation of country’s irrigation potential.

The **Water supply and sanitation** would largely be affected by hydrological changes as manifested through the recurrent droughts and reduced river flows. The low river flows, or hydrological drought conditions, as presented in the above scenarios, makes water supply and sanitation sub-sector highly vulnerable to climate change. The situation would be more precarious and desperate in urban areas with large water supply schemes, such as the cities of Blantyre, Lilongwe, Mzuzu and Zomba that also depend on run-of-river schemes, hence dependent on natural rainfall. Although these schemes have dams as sources of water supply, their reservoirs are not large enough to store enough water to last over one year after a severe drought, such as the one experienced in the 1991/92 crop growing season. The water supply insecurity would also affect the sanitation services in these cities, since wastewater treatment and safe wastewater disposal depends on run-off in the receiving waters or rivers. The water supply systems of smaller towns and rural communities would also be at risk, although most of these depend on groundwater resources. However, under low rainfall conditions, the groundwater resources would also be severely reduced, resulting into lowered groundwater tables and reduced water extraction from the boreholes. It should also be noted that boreholes for rural water supply are drilled to a depth of 45 m, so that these would quickly dry-up during severe droughts when the watertable sinks lower than this depth, as the case was in 1992 after the severe drought of the 1991/92 crop growing season. However, adequate data and information are not available to quantitatively analyse the vulnerability of groundwater resources to the adverse effects of climate change. There is need, therefore, to improve the collection and archiving of groundwater data, so as to better characterize the groundwater water resources of the country. .

Energy. The main source of Malawi's energy is the Shire River. Hence, energy supply is adversely affected by water deficits or shortages as a result of either reduced water flows or decreased rainfall. More than 99% of the country's electricity requirements is hydro-power generated on the Shire River, so that low water levels or low water flows would affect electricity generation up to a point where there would be no hydro-power generation. The low availability of water in other rivers, such as the Bua, South Rukuru, and North Rukuru among others, would also affect hydro-power generation.

The waters of Lake Malawi and the Shire River provide cheap and reliable **water transport** for the majority of the people living along the lakeshore areas. However, lake transport would be adversely affected by extremes hydrological regimes or events as a result of climate change and climate variability, especially as manifested through droughts and floods. The high or rising lake water levels would destroy beaches and buildings as experienced in the late 1970s when the lake level rose more than one meter above the normal operating levels. On the other hand, low lake water levels would reduce the water depth on the ports, making it difficult for ships to dock, as experienced in 1996 to 1997 when ships were unable to dock at Chipoka in Salima district. The Department of Marine (DoM) had to spent large sums of money to dredge the berths and approach channels to ensure access to port facilities at Chpoka. The lake water rise and the associated river flows would also affect the vulnerability of navigation services on the Shire River. This needs special attention as Malawi is planning to develop the Shire-Zambezi Waterway (SZW) and the construction of a port at Nsanje Boma.

Finally, there are many other sectors that depend on water resources that would be adversely affected by water level fluctuations on the Lake Malawi and the Shire River. These include national parks, wildlife, tourism, trade and industry. Wildlife would be affected by increased water flows in the Shire River, since a large portion of the Liwonde National Park would be significantly flooded. On the other hand, a reduction or cessation of the base water flow from Lake Malawi into the Shire River, just as it had happened at the turn of the century, would create acute water shortages for wild animals in the national park and other forest reserves, and would adversely affect hydro-power generation and the fisheries resources. Animal feed, which includes grasses and tree vegetation, would also be in short supply because of the prevailing dry conditions.

4.3.6 Wildlife Sector

Malawi has a wide variety of wildlife that is of ecologic and socio-economic importance. The majority of the wildlife is in protected areas (about 22% of the total land area of over 94,000 km^2), which also help to conserve catchments. Socio-economically, communities neighbouring protected areas, such as Kasungu National Park, and Vwaza Marsh Wildlife Reserve, are permitted to harvest some forest resources, such as firewood, grass, and medicinal plants, among others. However, the wildlife and their habitats, are threatened by changes in climate change and variability. Severe drought incidents that have so far afflicted wildlife in southern Africa, including Malawi, have illustrated that although the impacts of increased temperatures and rainfall deficits could be variable, but they are certainly harmful. For example, during the severe droughts of the 1979/80 and 1991/92 rainy seasons, high mortality of Nyala (*Tragelaphus angasi* G), which is the key species in the Lengwe National Park, was one of the observed impacts, besides overcrowding at water holes, poor regeneration of vegetation and over browsing and grazing.

Methodology. The primary approach recommended by the US Country Studies Program (US Country Studies Program, 1994) for conducting vulnerability and adaptation assessment for the Wildlife Sector was adopted in this study. The documents produced for the Initial National Communication (INC) of Malawi and the National Adaptations Programmes of Action (NAPA) for the Wildlife Sector were also reviewed to identify gaps in socio-economic impacts, current and future vulnerability of the Wildlife Sector to climate change, and adaptation assessments and policy recommendations. In this study, the vulnerability and adaptation measures for the African Elephant (*Loxodonta africana*) in Kasungu and Liwonde National Parks was investigated and evaluated. Kasungu National Park (Fig 4.34) is located in Kasungu district, central Malawi and is largely dominated by *Brachystegia* woodland species that are dissected by dambo vegetation.

The Liwonde National Park is located in Machinga district, southern Malawi and is largely characterized by M*opane* woodland. The Shire River is an important feature of this park. The Habitat Suitability Index (HSI) was used to evaluate the potential impacts of climate change. The HSI is defined as a numerical index that represents the capacity of a given habitat to support a selected fish or wildlife species (USFWS, 1991). The index has been defined as the ratio of a value of interest divided by a standard of comparison as indicated in Equation 4.4:

Index Value = (Value of interest)/(Standard comparison) ………………………………..….… [4.4]

The HSI has a minimum of 0.0 which represents totally unsuitable habitat and a maximum value of 1.0 which represents optimum habitat. The use of existing habitat models has the advantage of shortening the time required to develop outputs to an HSI model. Numerous animal-habitat models are available in the literature and were used to convert their existing outputs to an HSI. In this assessment, a literature search was conducted on the critical environmental factors affecting elephant populations in the savannas, and the models developed by different researchers were used to determine the HSI. The elephants in Kasungu and Liwonde National Parks have been monitored for management purposes for a long time. The Wildlife Research Unit (WRU)of the Department of National Parks and Wildlife (DoNPW) and various individuals have carried out studies on numbers, population dynamics and the relationships of the elephants with their habitats. These were collated in order to relate them to the influences of climate change. The HIS was calculated from all the variables to get a geometric mean [i.e., $HIS = (HS_1 \times HS_2 \times \ldots HS_n)^{1/n}$].

The HSI model, however, has some limitations. Although it is a very flexible model, its sub-models are a description of complex relationships. However, the interactions among habitat variables and dynamic responses to climate change are excluded. The utility of the sub-models in predicting species-habitat relationships are thus seriously compromised, and perhaps as a result of this, the sub-models are rarely tested and refined. From a climate change perspective, the HSI models suffer an additional drawback. The variation in climate may directly affect animal abundance, but in many cases, the influence is indirect, through its effect on other habitat parameters.

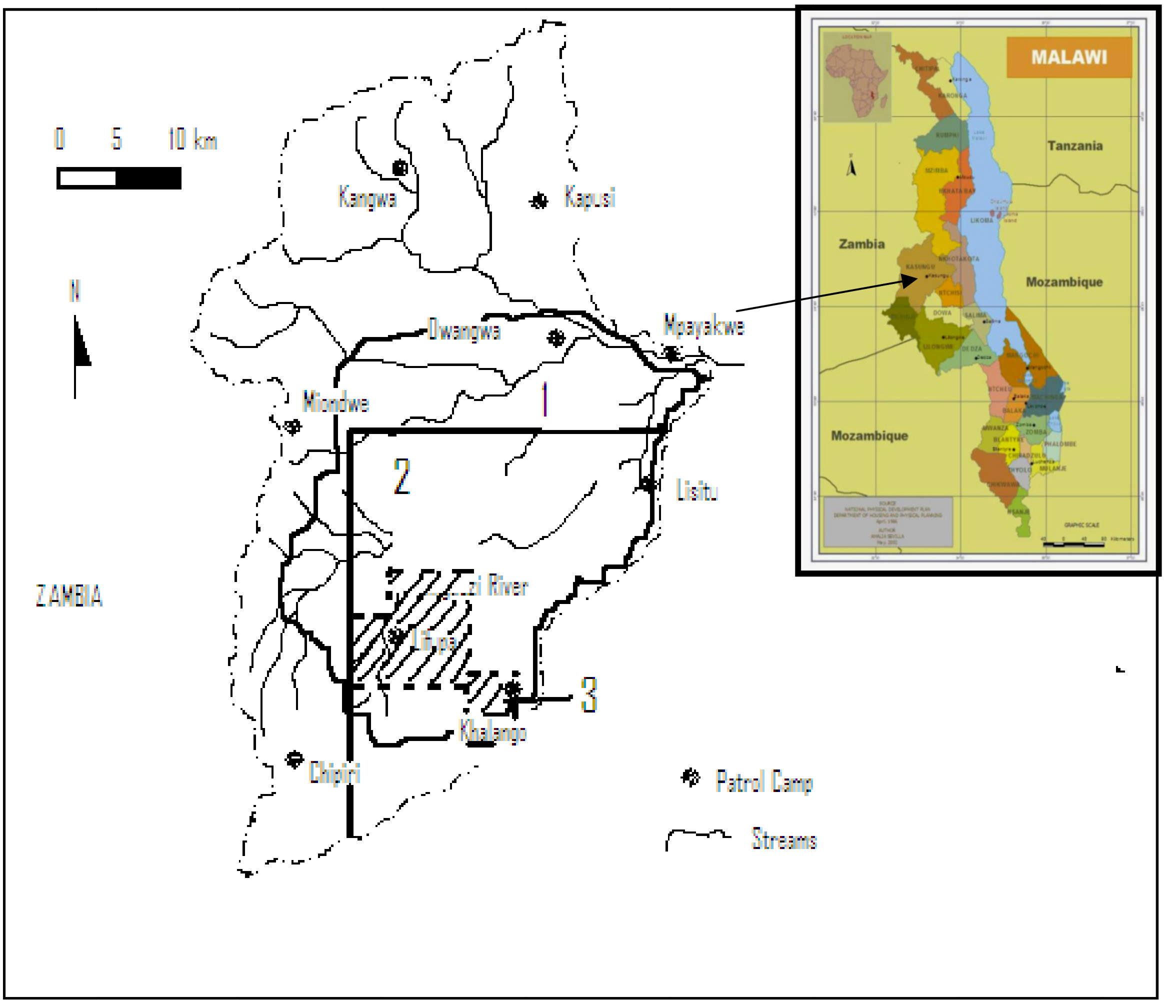


Fig 4.34: Areas of elephant spatial distribution in the 1970s (1), 2003 (2) and 2005/06 (3), Kasungu National Park, Kasungu, central Malawi

Current vulnerability to climate change. The recurrent and frequent droughts experienced over the last four decades, has led to the early drying-up of rivers and streams. Thus, water is available in large pools along big rivers only, where elephants congregate for watering, and hence become vulnerable to poachers. In addition, the vegetation dries up early in the dry season, resulting in reduced nutrient content in the grass and fodder. Dry conditions also promote forest fires, which is one of the major threats to wildlife in the country. The vulnerability of the elephants was evaluated through the use of critical environmental, biophysical and socio-economic variable that affect elephant populations in the savannas, which include: (i) nutrients, (ii) soil moisture (or soil-water), (iii) forest fire, and (iv) herbivores. Human-elephant conflicts (HEC) and poaching are additional underlying environmental drivers that directly impact on the elephant's performance.

Lindsay (1991) noted that at any given time of the year, habitats (or food types within habitats) can be marked according to potential **nutrient** intake rate. He confirmed in broad terms that the observed seasonal shift of elephants from woodlands to swamps was based on nutrient availability and intake. Nutrient quantity is enhanced by materials within 1-3 m on height. This is ideal feeding height for elephants (Owen-Smith, 2006). Wyatt and

Eltringham (1974) estimated that about 75% of the elephants' total time spent on feeding, and about 75% of the feeding activity, consisted of grazing or feeding at ground level with three feeding peaks: one in the morning, another in the afternoon, and the third around midnight. In this study, various observations on plant height and canopy coverage were used as indicators of nutrient quantity.

In Kasungu National Park, mapping elephant distributions was used as an indication of green areas. Images from radio tracking of three collared elephants from September 2004 to September 2006 showed that the elephants had very similar home ranges that were overlapping each other. From January to March, they were spread out along the Lingadzi River with a major area of concentration in the middle of the park.

In April and May, they spread out to the south-eastern boundary where they went out of the park, presumably to feed on green maize. In September 2006, they began to concentrate at the centre of the park on the Lingadzi River and spread a little southward to the Lifupa Dam. Both in October 2005 and October 2006, they all seemed to concentrate in the centre of the park, between Lingadzi and Lifupa Dam. This is probably the area with most suitable nutrients for the elephants in the park.

In Liwonde National Park, three major studies have recently been concluded describing habitat characteristics of various animal types. Harrison et al. (2007) described canopy cover (%), shrub cover (%), grass cover (%) and grass height (cm) at different distances from the water edge of the Shire River south of the Chinguni Hill, and at 100 m in front of the Hill between 2002 and 2003. Little canopy, shrubs and short grass, were dominant close to the floodplain. This is probably a sign of overgrazing of the floodplain by the different grazers, such as elephants, hippos, buffalos and waterbucks.

Another study by Dudley (2007) on the *Albizia harveyi* woodland association within the greater *Colophospermum* species in the Liwonde National Park showed that the woodland is being depleted, and that it is obvious that elephants are breaking down the woodlands in search of nutritious browse, which appears to be the primary cause of the observed decline in the species. The Mopane trees were generally unchanged, although they showed unexpected rates of radial growth and percentage canopy cover change.

In the Liwonde Rhino Sanctuary, Dudley (2006) established three woodland monitoring plots. The sanctuary is a fenced area of 49 km^2 that is a breeding ground for the introduced black rhino and other small antelopes. The elephants sometimes enter the sanctuary by walking over the fence. The plots were established to monitor the growth of vegetation in the absence of frequent elephant activity and illegal forest fires. In all the plots, all the canopy layers exhibited small canopy cover increases from 1993 to 2004. The sub-canopy and ground layers which are within the browsing heights of the elephants, had a little canopy cover that was mostly less than 10% as shown in Table 4.10.

Table 4.10: A comparison of mean values by species and layers, 1993-2004

Plot 1	Total per 500 m²			Mean per 500 m²							Mean per 100 m²	
	N	BA	%C*	HT	BA (cm²)	%C	Form	Browse B1	Browse B2	Browse B3	N	BA
Upper canopy layer (10.0<HT≤18.0 m)												
1993	6	43231	36.9	13.3	7205	6.2	0.0	0.3	0.5	0.2	1.2	8646
2004	6	48447	39.1	13.9	8074	6.5	0.0	0.5	0.0	0.0	1.2	9689
% C	0	+12.07	+6.00	+2.30	+12.1	+4.84	0	+66.67	-100	-100	0	+12.06
Sub-canopy layer (1.0<HT≤10.0 m)												
1993	42	5287	15.8	2.1	221	0.4	1.4	2.2	3.4	0.7	8.4	1057
2004	72	7765	34.1	2.9	108	0.5	1.0	1.9	1.1	0.3	14.4	1553
% C	+71.43	+46.87	+115.82	+33.33	-51.13	+25.00	-21.43	-13.64	-67.65	-57.14	+71.43	+46.93
Ground layer (HT≤1.0 m)												
1993	228	4278	3.72	0.5	19	0.02	-	-	-	-	45.6	856
2004	258	7818	5.98	0.5	30	0.02	-	-	-	-	52	1564
% C	+13.16	+82.75	+60.75	0.00	+57.89	0.00	-	-	-	-	+14.04	+82.71

The other critical factor is **soil moisture or soil-water.** Generally, elephants survive in areas with less than 150 mm of rainfall per year, but appear to be more at home in areas that receive some 2,000 mm of rainfall per year (Viljoen, 1991). Seasonal variation in food availability and quality affect the ranging patterns and migration of elephants, modified by water availability, which is dictated by rainfall (Viljoen and Bothma, 1991, Bernard et al., 2007). According to Osborn (2003), most studies of elephant movements in northern and southern Africa report distinct seasonal variations in range size and use. Generally, in areas with annual rainfall under 1,000 mm, the pattern is that elephants move away from permanent water sources at the beginning of the rainy season as water becomes widely available. The elephants are able to move to less heavily used areas of their range to find seasonally ephemeral foods, such as fresh grass, forbs and climbers. As seasonally available water dries up, elephants again start to concentrate near permanent water points. Through these studies, Osborn (2003) observed an obvious relationship between elephant movements and the pattern of rainfall in the Sengwa Wildlife Research Area in Zimbabwe, southern Africa.

In Malawi, rainfall records from the Kasungu and Liwonde National Parks were used to determine habitat suitability in this respect. In the 2005/06 rainy season, Kasungu received 526 mm of rainfall. This was far below the annual mean of 780 mm. This may have particularly affected the availability of water and nutrients in the dry season. There are water pools on the Lingadzi River, but the presence of the Lifupa Dam is very important for the survival of the elephants. Liwonde National Park had a seasonal total rainfall of 883.9 mm in the 2003/04, 819.5 mm in 2004/05, 1122.5 mm in 2005/06 and 1260.5 mm in 2006/07. The National Park has a long time mean of 998 mm of rain per year, which is sufficient for the growth and performance of grass and fodder for use by elephants.

Dublin et al. (1990) observed that even under extreme conditions of elephant-related tree mortality, the elephants were not able to reduce recruitment rates below adult mortality, and hence, cause a decline in woodland vegetation. In contrast, **fire** by itself can hold recruitment rates well below mortality rates. This may be an impact under climate change scenarios, particularly in drier environments where forest fires could be intense. Fire, however, is also an important habitat management tool that is used in many protected areas to rotate grazing pressure. However, both Kasungu and Liwonde National Parks do not have fire management plans, so that fire observations have been recorded as sightings of fire incidents. Nonetheless, Liwonde National Park has fire breaks around the park and around the Rhino Sanctuary perimeter.

The **human-elephant conflict (HEC)** is a major conservation challenge in Africa because it is fuelling an increase in the killing of elephants and the loss of elephant range and habitat (Walpole et al., 2006). Crop fields (mostly maize) close to protected areas are prone to elephant attacks. In Liwonde and Kasungu National Parks, crop garden invasions begin when the maize is just beginning to mature towards the end of the rainy season in March until the crops are ready for harvesting in April. Elephants enjoy maize and other foods crops because of their high nutritional value and easy access on the ground. However, elephants in the two national parks are under threat from increasing human population around the parks, including an increasing number of poachers. To protect the elephants and other animals, buffer zones and the fencing of some parts of the parks has been done. For example, Kasungu National Park has a 10 km buffer strip and a 45 km line of fence. However, in 2002, the fence was broken, and therefore, not functional and effective (Chinguwo-Phiri, 2002). Thus, in 2003, out of 256 ha of maize (belonging to 153 families) around the park, some 104 ha (41%) were damaged by elephants between March and May 2008. In addition, three people were killed by elephants that had strayed outside of the park (Ndhlovu, 2003).

Finally, **poaching**, especially that by poachers that use harmful means, such as guns and wire snares, also affect the habitat suitability for the elephants. Serious poaching incidents, such as by armed gangs using fire arms, is a threat to elephant population sustainability. Mkanda (1996) categorized poaching activities as follows: (i) low, 30 incidents per year, (ii) medium, 31-60 incidents per year, and (iii) high incidents, with more than 60 incidents per year. Poaching incidents in the two protected areas were assessed to determine the threat to habitat suitability. From 2000-2006, there were many serious poaching incidents of snaring, guns and gunshots in Kasungu and Liwonde National Parks. In the process, numerous elephants were killed. This poaching may not have been directed at elephants, but snaring, which seems to be biggest threat, may most likely affect infants and sometimes older elephants.

Future climate risks of the Wildlife Sector. The future climate risks of the Wildlife Sector was evaluated **with regard to:** (i) habitat suitability, (ii) nutrient availability, (iii) land degradation, and (iv) elephant damage. The results of the MAGICC/SCENGEN Model for Kasungu and Liwonde National Parks indicated that the mean annual temperatures would rise by 2.2 ^{o}C (an increase of +2.7% for Kasungu National Park). The model predicted a decrease in annual rainfall and an increase in annual temperatures for Liwonde National Park. On the other hand, the HAD 295 Model, and indeed all the other climate models, predicted higher temperatures (1.0-6.0 ^{o}C) compared with the 1961-1990 baseline temperatures.

Further, the Initial National Communication (INC) of Malawi published in 2003 projected temperature increases of between 1.0-3.0 °C with the doubling of CO_2 concentration in the atmosphere, which was benchmarked to the year 2075. Thus, both sets of analyses project temperature increases. Based on these results, the habitat suitability variables were rated on a scale of 0.0-1.0 to arrive at the figures presented in Table 4.11. There were no significant differences in the Habitat Suitability Index (NSI) between the two national parks. Both national parks have similar problems as habitats for elephants. However, Kasungu has a slight advantage over Liwonde because of its larger size and its current smaller population size of elephants.

Table 4.11: Habitat suitability indices (HSI) for elephant in Kasungu and Liwonde National Parks

Habitat Suitability (HS) Variable	Habitat Suitability Index (HIS)	
	Kasungu National Park	Liwonde National Park
Elephant density (HS_1)	1.000	0.500
Nutrient (HS_2)	0.800	0.800
Rainfall (HS_3)	0.800	0.800
Fire (HS_4)	0.500	0.500
Poaching (HS_5)	0.400	0.400
Elephant-Human Conflict (HS_6)	0.500	0.500
Habitat Suitability Index (HIS)	0.644	0.561

The **availability of nutrients** is directly dependent on the soil moisture or soil-water availability, which is in turn dependent on the total amount of rainfall received. Projected increases in temperatures and decreases in rainfall due to climate change will have serious implications on the HSI variables that influence elephant populations in the two parks. Temperature increases would lead to an early drying-up of seasonal streams and water pools. The elephants would congregate in areas with available water as is the case in the Liwonde National Park along the Shire River floodplain. In the absence of water in the dry season, the elephants may migrate to areas where water is available. With decreasing rainfall, hence, drier a environment, the availability of nutrients for the elephants will also decrease. Some plants will shed off their leaves early in the dry season, reducing the amount of dry matter and nutrients in the leaves. Forest fires will be hotter and more intense with their increasing frequencies due to increased dry matter. The consequences of this would be the loss of wildlife and some plant species. The elephants would adjust their time spent in the floodplains and in the adjacent woodlands. The absence of strict fire management strategies, such as fire plans, would make it difficult to implement plans to control illegal forest fires leading to more habitat destruction in hotter and drier years. The need to implement fire control measures is more urgent now than at any other time in the past.

The impact of **land degradation**, mainly as a result of the recurrent droughts, will be reduced vegetation cover in the national parks. The elephants will be most affected because there will be less forage and fodder for them to browse. As the human population around the parks continue to increase, there will also be increasing pressure on the resources of the parks. Poaching will continue to increase because people will continue to subsist on natural products from the parks. Encroachment for settlements and farming activities will also increase, and so will be the incidences of forest fires started by poachers. Elephant congregating near water points will make these more vulnerable to poachers. The projected increases in human population will result in habitat degradation, whereas encroachment into protected areas will cause more conflict. Elephants will be more threatened, and in some cases, where the populations are already small and vulnerable, extinctions may occur.

Human-elephant conflicts (HEC) will increase as a result of increasing human population pressures. In drier conditions, winter-cropping near riverine areas, or along river valleys, which are some of the favourite elephant habitats, will be intensified to take advantage of the available residual soil moisture, which would attract elephants into these fields. This will require that communities neighbouring the parks step up crop protection and management activities, including fencing. Fencing, which is currently considered to be the most effective way of controlling and confining elephant in the parks, is also associated with many challenges, including high construction and maintenance costs. Further, the fence materials are used by the local people to make snares, thereby causing more harm than good to the conservation of wildlife resources in the national parks. .

4.3.7 Fisheries Sector

The Fisheries Sector is an important source of employment, cash income and food security. The sector contributes about 4% to the Gross Domestic Product (GDP) and provides 70% of the total animal protein un Malawi (Department of Fisheries, 1998; Blad and Donda, 1996). The sector provides employment opportunities to many people, either in fishing, processing or trading activities. Besides direct subsistence, small-scale fisheries provide the main source of livelihood to a large number of rural households throughout the country (ICLARM/GTZ, 1991). Over 250,000 people living along the major fishing areas of Mangochi, Salima, Nkhota Kota, Nkhata Bay, Likoma, Rumphi and Karonga districts depend on fish as a source of food (FRU, 2000). The main sources of fish are the five lakes and a network of rivers and streams. However recent figures show signs of stagnation and decline to total collapse of certain fishery sites in the country (NEAP, 2002).

Malawi's fresh water resources, covering about 20% of the total surface area, are inhabited by a large diversity of living aquatic organisms. Since the fresh water resource is found inland, human activities, including agriculture and industrial processes, pose a threat to this resource. The fresh water resource is also dependent on local climatic and weather conditions, especially rainfall. The inland fresh water rivers and lakes, surrounded by land, are legitimate sinks of runoff due to rainfall, which carry along with them sediments, nutrients and chemicals from the land. The fresh water resource is, therefore, contained in one of the most fragile habitats so that it is also vulnerable to climate change. The major fishing grounds, including Lakes Malawi, Malombe and Chilwa, and the Upper Shire River continue to develop poor characteristics owing to the adverse effects of weather extremes and climate change. For instance, Lake Chilwa dried up in 1990 due to drought, and the surrounding communities suffered a lot, including non-fishermen as the income flow chain was disrupted. The El Nino episodes around the same time also significantly affected fishing activities on the lake. The aquatic habitats were rendered unproductive, and fishing became almost impossible. Resource-poor fishing communities became more vulnerable as their income levels were significantly reduced, and the source of protein was removed. More recently, stocks of fish species, such as *Opsaridium microlepis* (Mpasa), Ntchila, and the more popular *Oreochromis* spp (Chambo) have dwindled greatly..

The extent of the effects of climate change on the fisheries of Malawi have not been studied in depth, neither have the coping strategies and adaptation measures of the communities been elucidated. An evaluation of the existing adaptation measures can provide an insight into the formulation of long-term strategies and activities that are sustainable and allow vulnerable groups to cope with future climate changes

Methodology. The Inter-governmental Panel on Climate Change (IPCC) outlines three methods for evaluating climate change on fisheries. However, these methods are not appropriate for Malawi, and therefore, other approaches were explored to provide a more holistic analysis of the system. The physical environment around the water bodies are highly influenced by climatic factors, such as radiation, wind speed and rainfall, and chemical properties (Msiska, 2001). Temperature is particularly useful because it affects the productivity, rate of growth, decomposition and life cycles of organisms. Therefore, attempts were made in this study to model and predict possible future scenarios using the findings of Eccles (1974), including new scenarios generated by the MAGICC/SCENGEN Model. The temperature-depth profiles for Nkhata Bay were used to make future predictions and projections.

Of the **physical parameters,** only water temperature changes at the surface and the bottom of the lake were estimated from the two reports of Eccles (1974) and Munthali (2008). For the bottom waters, water temperature changes showed a shift of 0.45^{O}C for a period of 25 years at a depth of 300 m. It is worth noting that temperatures in Lake Malawi range from 22.0–28.0 ^{o}C. For surface waters, estimated temperature values were obtained on the premise that if the thermal structure of the lake is known, changes could be estimated for the available thermal habitat. Other changes in physical habitat features included: (i) water flow rates, (ii) water levels, (iii) water quality, and (iv) wetland nursery areas. These affect fish migration, spawning times, species distribution, and the overall productivity of Lake Malawi fisheries.

The **ECOPATH II Model** was used to evaluate fish vulnerability to the adverse impacts of climate change. This model involves the application of a series of equations derived from the general relationships given by Christensen and Pauly (1993) as follows:

Production by (i) – all predation on (i) – non predation losses of (i) – export of (i) = 0, for all i … [4.5]
or
Production by (i) – all predation on (i) – non predation losses of (i) – catch of (i) = 0, for all i …. [4.6]
Where:
i = fish species or group of species

On the other hand, these equations can be formulated as follows:

P_i-$M2_i$-P_i (1-EE_i)-EX_i = 0 ……..…………………………………………..…………………. [4.7]
or
$B_i.PB_i$-$\Sigma B_j.QB_{ji}$-$PB_i.B_i$ (1-EE_i)-EX_i=0 …………. ……………………………...………………..[4.8]
or
$B_i.PB_i.EE_i$-$\Sigma_j B_j.QB_j.DC_{ji}$-$EX_i$ = 0 ……………………………………………..………………[4.9]
Where:
PB_i = the production/biomass ratio
QB_i = the consumption /biomass ratio
DCij = the fraction of prey (i) in the average diet of predator j
j = predator species

In these equations, P_i is the production of (i), $M2_i$ is the total predation mortality of (i), EE_i is the ecotrophic efficiency of (i) or the proportion of the production that is either exported or predated upon, (1-EE_i) is the "other mortality", and EX_i is the export of (i).

Hence, in the energy box, the following applies:

Consumption = production + respiration + un-assimilated food ………………………………… [4.10]

This relationship builds on the theory of conservation of matter; hence it has a plausible scientific basis. Polovina (1984) first introduced the holistic approach in the study of the French Frigate Shoals by simplifying Laevastu et al. (1981) biomass budget approach. The result was the development of the ECOPATH model, which was later modified by Christensen and Pauly (1993) to ECOPATH II. In ecosystem models, where exploitation of the fishery is critical, catches are considered as total withdrawals over a period of time for each of the group modelled. These catches are represented by landings or yields from aquaculture. Further, an empirical formula derived by Pauly (1980) that incorporates water temperature as given in the regression equation below was employed:

$$\ln M = -0.015 - 0.279 \ln L_{\infty} + 0.6543 \ln K \; 0.463 \ln T \quad [4.11]$$

Where:

M = total mortality per year

K = growth function per year

T = average annual temperature (^{O}C)

L_{∞} =

This equation was computed from 175 different fish stocks. To apply this equation, M, K and L_{∞} for each stock must be known and the time series surface water temperature data should be available. Further modifications to the mass balance equation provide a more user friendly set of equations to generate information on trophic level exploitation as follows (Pauly *et al*., 1998, Willemse and Pauly 2004):

$$TL_k = \sum Y_i k.TL / \sum Yi.k \quad [4.12]$$

Where:

Y = fish catches

i = species

K = year

TL = trophic level

This equation suits the Malawi ecosystem better because it demonstrates the tropic dynamics over the years, indicating if any major shifts might have occurred as has been the case in the major global fish stocks (Pauly et al. 1998). This provides a diagnostic tool on the health of stocks and renders a convenient entry point for specific and more in depth studies. The basic questions which need to be addressed are: (i) have there been a change in functional relationships in the system? (ii) what are the main causes of stock decline and shifts? (iii) are these due to environment or management (fishing)? and (iv) how resilient is the ecosystem? However, since the model uses secondary data, it is self evident that the errors incurred during the collection of data will also be reflected in model simulation outputs. This is mostly to do with the precision of the frame surveys that either underestimate or overestimate catches, especially where high migrations of fishermen are encountered. Further, confidence limits are not incorporated in the model, which is also a weakness that has been recognized by the authors as well.

Current vulnerability of fish stocks. Starting with the studies that were conducted from the early 1930s, there has been a general recognition that some fish species are more vulnerable than others (Lowe, 1952). Thus, initial regulations on the protection of fish stocks were directed at protecting *Labeo mesops,* especially the stock targeted by the ring-net fishing method. Despite this effort, this species have since been over-fished (Msiska, 1991). Once catches of *Labeo mesops* had declined to non-economic levels, attention shifted to "Chambo" or *Oreochromis* species until the recent declines, which has alerted the communities that the ring–net fishing method is unsustainable.

The results of mean **trophic fluctuation** levels for Lake Malawi indicate that there have been large variations but the general trend appears to be a succession in species occurrence. While fishing practices are the main driving factors, environmental forcing factors equally contribute to this and they need to be adequately investigated. The results of temperature-depth profiles were computed for the months of May and August using data obtained in 1939, 1955 and 1964 from the work of Beauchamp (1953), Jackson et al. (1963) and Eccles (1974). The Lake Malawi trophic level fluctuations are presented in Figs 4.35 and 4.36).

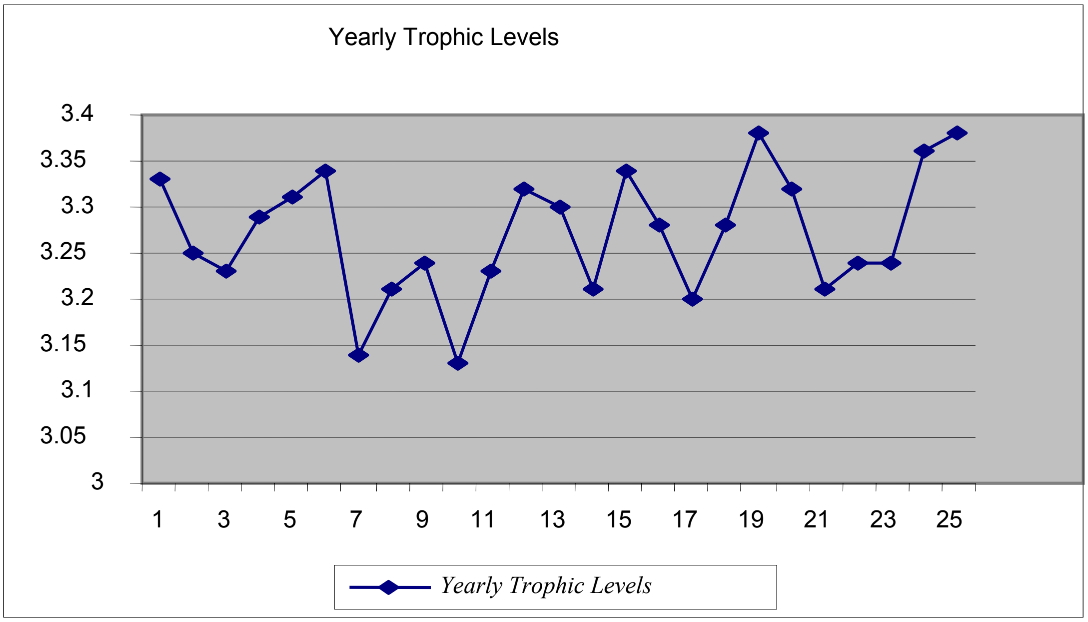


Fig 4:35: Mean annual trophic levels of fish catches from Lake Malawi.
Key: 1= 1976, 2=1977, ……, 24=2000, 25 = 2001

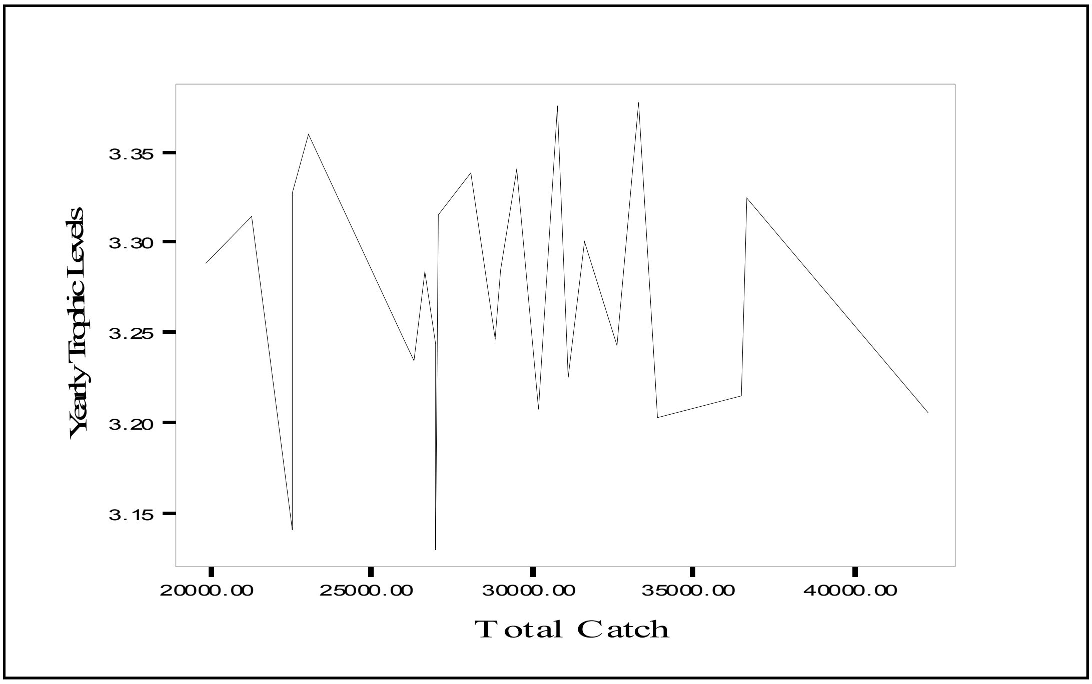


Fig 4.36: Amplitude of mean trophic levels of fish catches from Lake Malawi.

One of the most important points to note from fish catch data is that the phytoplankton feeding *Tilapias* have almost collapsed. In the absence of identifiable fish species to occupy the same niche, Usipa has become a prominent group. But the latter feeds on zooplankton, which is a higher trophic level, creating a rather unsustainable situation for lake fisheries. These findings coincide with a trend which has been recorded in Lake Victoria in East Africa (Witte *et al*. 2007).

Lake Malombe, which is connected to Lake Malawi through the Shire River, is another important source of fish in the country. However, the mean trophic levels for Lake Malombe exhibit an increasing trend. This may imply that the system is more ecologically unstable than that for Lake Malawi, and it can swing in any direction. The question to ask is: Is this system going to be dominated by piscivorous fish? According to the trends in fish catches, *Tilapia* species have virtually disappeared and are being replaced by zooplankton-feeding Kambuzi. Elsewhere in the World, the trend is to move away from the dominance of piscivorous fish to invertebrates and jellyfish (Pauly et al. 1998).

There are also **biophysical impacts**, such as **temperature-depth profiles,** which influence and affect fish stocks, One of the major findings of the early research work conducted on Lake Malawi is the existence of a thermocline due to a density-dependent stratification (Msiska 2001). In the early 1970s, Eccles (1974) raised the alarm that the lake may be warming-up at a depth of around 300 m. The current study extended the prediction to a more futurist time-scale, confirming the trend and observing that even surface temperatures are warming up. While early observations were confined to deep waters, current predictions are extending the phenomenon to surface waters. Furthermore, it has been observed that in the deeper waters, temperature profiles are closer together compared with the surface water medium. Generally, this raises the fears of more frequent and intense overturns.

Future vulnerability of fish stocks. The Lake Malawi fish catches fluctuate between 26,000 and 31,000 t per year, whereas the overall biomass varies between 120, 000 and 200,000 t per year (Snoeks, 2004). Lake Malombe catches are more difficult to predict because of the major trophic shift from phytoplankton to zooplankton grazers. However, the general trend is downward. Hilborn and Walters (2001) showed that the effects of management and environment are statistically confounded, making predictions difficult unless the relative contributions are quantified. Climate change will also have a profound impact on fish stocks. Fish studies on Lake Victoria in East Africa (Witte et al. (2007) have shown that climate change may lead to the following: (i) increased eutrophication, which in turn causes algae blooms and lowers dissolved oxygen, and (ii) morphological adaptations, including increased gill surface area, altered retina structure and feeding apparatus. Studies in Malawi have characterized temperature profiles and dissolved oxygen trends, with special focus on Chambo and Usipa.

Lake Malawi has enjoyed many years of research with respect to surface and deep water **temperature profiles**. Because of the density related factors, it has long been established that temperature profiles decrease with depth. However, given new data of surface warming, mainly caused by changes in climate, the projected temperature profiles suggest serious implications for the survival of flora and fauna in the lake ecosystem. Further, there is a causal relationship between water temperature and dissolved oxygen, which is related to the gaseous dissolving capacity of the water. The reduction of the holding capacity of water for dissolved oxygen is well documented. For water temperature at 20 ^{o}C more than 10 mg per liter of oxygen is dissolved in water, whereas at 27 ^{o}C only 7.86 mg per liter of oxygen is held by pure water (Boyd 1982). Therefore, for fish which are adapted to high oxygen contents, temperature increases would induce oxygen stress. Preliminary studies have shown that Chambo are indeed sensitive to low dissolved oxygen content and show signs of stress at dissolved oxygen levels lower than 5 mg per liter (Msiska 2005). However, while most *Tilapias* adapt well to low dissolved oxygen, it has been observed that *Oreochromis karongae* does not. Below 5 mg per liter of dissolved oxygen, this species undergoes oxykinetic reactions. Is this due to the fact that this fish species possess an unusual chromosome number of 2n = 38 instead of the normal 2n= 44 for other *Tilapias*? (Harvey et al. 2002). This requires further investigations as it might explain and lead to the development of long-tern and sustainable daptation measures and strategies for warmer water temperatures induced by climate change.

The continuing decline of **Chambo** catches is clear and obvious from a review presented in this report. However, the underlying question is how adaptable are the fish species to the fishing pressure and environmental changes, where, adaptation is considered as a process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented? The genetic robustness of a species to local events, including over-fishing and climate change, could be determined through genetic factors, such as F_{st}. In this study, reference is made to studies conducted by Sodsuk et al. (1995) and Kafumbata and Ambali (2005) (Table 4.12).

Table 4.12: Genetic studies of Chambo over the past 10 years.

Year	Genetic parameter, F_{st}	Method	Source
1992	0.208, 0.188, 0.125	DNA-PCR	Kafumbata and Ambali, 2005.
2005	0.50-0.67, 0.52-0.64, 0.47-0.67,	Allozyme	Sodsuk et al., 1995.

On the other hand, the overall catches of **Usipa** are characterized by high fluctuations indicating an intrinsic ability to quickly rebound after being fished-down. This is due to a high turnover rate (Maguza-Tembo et al. 2006), hence this species could be most amenable to studies of environmental effects. To a large extent, this species masks over-exploitation of other fish species. In contrast to *Tilapias*, there is no regulation to control the fishing of Usipa in the waters of Malawi.

4.3.8 Human Health Sector

The health status of Malawians continues to be poor, whereas the progress on basic health indicators is mixed. Life expectancy declined from 48 to 37 years between 1990 and 2000, mainly as a result of the HIV and AIDS epidemic. The under-five mortality rate (per 1,000 live births) has improved from 258 in the 1980s to 133 in 2004, and the infant mortality rate has declined from 138 per 1,000 live births in the late 1980s to 76 in 2004. Malawi's maternal mortality rate (per 100,000 live births) has come down from 1,120 in 2000 to 984 in 2004, but remains alarmingly high (DHS, 2000; DHS, 2004). The HIV and AIDS adult prevalence rate was 14.1% in 2005 (NAC, 2005), and appears to have stabilized around this figure. Malaria incidence has declined from the extremely high rate of 812 cases per 1,000 in 1992 to around 282 per 1,000 in 2005 (HMIS, 2006), but continues to be a major problem, especially among women and children (World Bank, 2007).

Malnutrition is common in Malawi. One in every two children under the age 5 years is chronically malnourished. Forty eight percent (48%) of Malawian children less than 5 years of age are stunted, 30% are underweight, and 7% have severe malnutrition (UNICEF, 2003). Further, an examination of the trends in health indicators from the three demographic health surveys conducted in 1992, 2000 and 2004 shows that there has been little to no progress in combating malnutrition since 1992. Stunting, the best indicator for chronic malnutrition, has hovered around 48-49% for the last 14 years for children under five years of age. Underweight and wasting have improved a little bit during the same period. These data are broadly consistent with those from the National Micronutrient Survey for 2001, according to which 53% of children under the age of 3 years suffer from stunting, 31% are underweight, and 4.7% suffer from wasting (World Bank, 2007). The reasons for childhood malnutrition are many, and include illiteracy of the mothers, poverty and lack of child spacing (Madise, 2001). However, in times of extreme climate fluctuations, the level of malnutrition may go above the prevailing baseline.

Recent studies indicate that 3.2 m people in Malawi required supplemental feeding between 1991 and 1992 when there was drought. The World Food Programme (WFP) estimated at the same time that the admission to Nutritional Rehabilitation Units (NRU), due to kwashiorkor, increased by between 69 and 100%. The link between climate change and malnutrition in a country like Malawi, given the heavy reliance on rain-fed agriculture with around 85% of the population being subsistence farmers, has serious implications on human health. Any fluctuations in climate leading to adverse weather conditions is likely to lead to significant malnutrition problems as less food is consumed.

While these health problems may not be entirely attributed to climate change, especially given that some degree of future climate change will occur regardless of future greenhouse gas emissions, climate change may have easily exacerbated the incidence of such health problems. Indirectly, the changes in climate can negatively affect agricultural productivity and impact on nutritional levels of many family households. Many children suffer from symptoms and signs that are related to malnutrition. These include stunted growth, wasting, and body swelling, a manifestation of severe malnutrition. This happens even in what are considered to be good years in terms of food production. With changing climatic conditions, the impact on these would be unimaginable. The impact of climate on other sectors, such as fisheries, forestry, energy and water resources, would therefore indirectly impact on human health as well.

Methodology. .The study principally employed secondary research methods and addressed questions in five main research areas: (i) current association between disease outcomes and climate change and climate variability, (ii) current strategies, policies, and measures designed to reduce the burden of climate-sensitive health determinants and outcomes, (iii) health implications of the potential impacts of climate change and climate variability on other sectors, (iv) the estimated qualitative future potential health impacts, and (v) additional adaptation policies and measures, including procedures for evaluation after implementation.

The first step in this study was to specify the health issues of concern today and of potential risk in the future, against a background of climate change dating to as far back as 1960. While efforts have been made to quantitatively assess the link between climate change and human health, data limitations have prevented the use of computer simulation models to assess current and future vulnerabilities, and necessitated the use of expert judgement to make qualitative assessments based on previous relevant work conducted in the country. Where gaps were identified in the literature, efforts were made to collect relevant data to fill the gaps. Through a desk study, and field observations, four diseases and one health problem that have a high likelihood of being induced and influenced by climate change were identified and selected for an in-depth analysis of climate change on these. These are: (i) malaria, (ii) cholera, (ii) diarrhoea, and (iv) malnutrition.

Current and future vulnerability. This section discusses the distribution and potential linkages between climate change and human health, and analyses each of the health problems: (i) malaria, (ii) cholera, (iii) diarrhoea, and (iv) malnutrition, in terms of current and future vulnerability due to climate change upon the sustainable livelihoods of family households.

Malaria. All people in Malawi are at risk of catching malaria, with 97% at endemic risk and 3% at epidemic risk (MG, 2007). Malaria is transmitted by the Anopheles mosquito which enables the malaria parasite to complete its growth cycle. Climate influences all the three components of the life cycle of the parasite. Rainfall creates water pools, which are breeding sites for the Anopheles mosquito where it deposits its eggs, and the larvae and pupae develop into adulthood within a period of 9-12 days under tropical conditions. Such breeding sites may dry up prematurely in the absence of further rainfall, or conversely, they could be flushed and destroyed by excessive rains. Thus, rainfall is a key determinant of the geographic distribution and seasonality of malaria (Centre for Disease Control (CDC), 2004). The World Health Report for 2003 highlighted climate and environmental changes as some of the factors that contribute to increasing malaria burden in Africa (EAD, 2006). Climate also determines human behaviours that may increase contact with the Anopheles mosquitoes between dawn and dusk, when they are most active. For example, hot weather may encourage people to sleep outdoors or discourage them from using bed nets, whereas during the harvesting season, agricultural workers might sleep in the fields or nearby locales, without protection against mosquito bites. However, the transmission of malaria does not normally occur at very high altitudes, such as the Nyika, Viphya and Mulanje Plateaus, which are cold places. But with increasing global warming due to temperatures raised by climate change, the story could be different in the future.
Fig 4.37 presents The correlation between malaria incidence and temperature for the period 1974-2006 shows that malaria is not directly influenced by temperature as shown by the linear equation Y = 0.3882x + 231.31 (where Y is malaria incidence and x is temperature), whose gradient is close to zero, and a small and insignificant coefficient of determination (R^2) of 0.0007 or 0.07%.

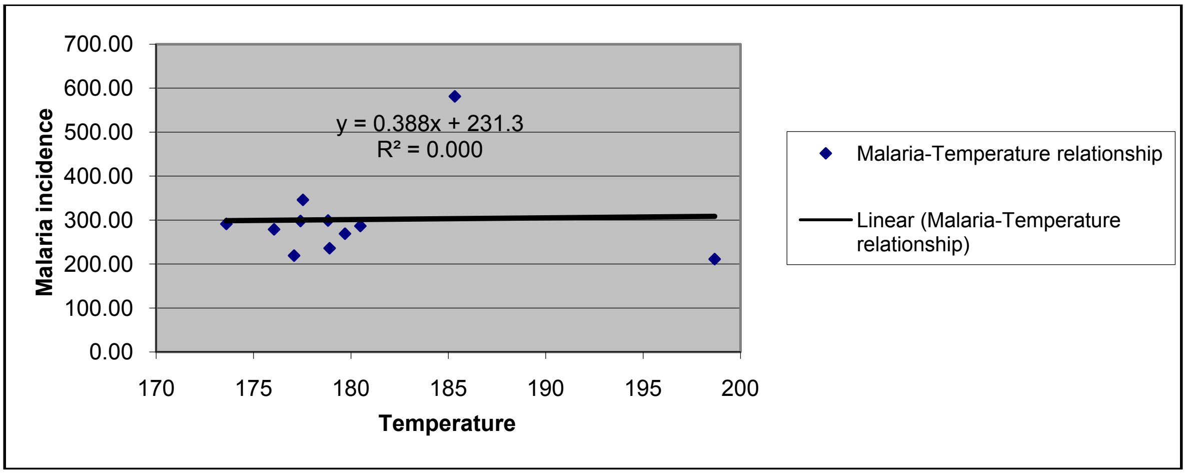


Fig 4.37: Relationship between malaria incidence and temperature (°C)
Source of data: DoMS, 2006; HIMS, 2006.

Thus, malaria incidences may not necessarily be directly attributed to temperature changes but rather to other factors that respond to temperature changes, such as human behaviour during hot times, e.g., lack of usage of protective gear, such as mosquito nets or the application of insecticides. However, if adequate data were available, other factors that influence malaria incidences could have been determined using the Malarial Epidemiological Model, which is stated as follows:

$$R = B_M \times S_H \times S_M \times L_M \times I_P \qquad [4.13]$$

Where

B_M = the rate at which infected mosquitoes bite humans
S_H = human susceptibility to infection
S_M = mosquito susceptibility to infection
L_M = infected mosquito longevity,
I_P = probability that plasmodia infecting mosquitoes will survive 1 day.

On the other hand, Fig 4.38 shows a negative relationship between malaria and rainfall, however, with rainfall explaining only 11% of the variation, which is low. However, what can be inferred from this is that a reduction of 1 mm in rainfall results into 2 incidences of malaria, which has serious implications for future climate change.

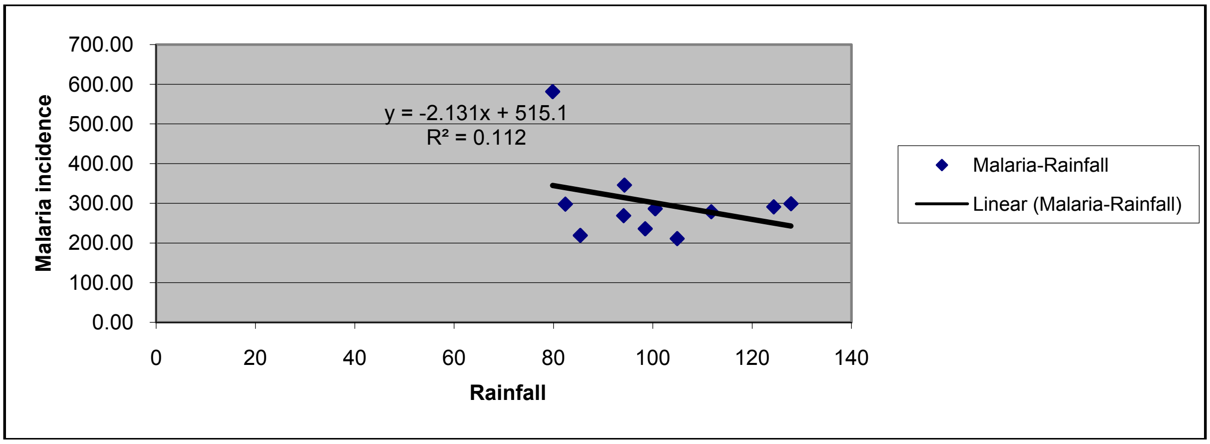


Fig 4.38: Relationship between malaria incidence and rainfall (mm)
Source: Metrological department (2006; HIMS; 2006).

Diarrhoea and cholera. Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms most of which are transmitted by contaminated water. It is more common when there is a shortage of clean water for drinking, cooking and cleaning. Basic hygiene is important in the prevention of this disease. **Cholera** and other diarrhoeal diseases have many predisposing factors. With an adult HIV prevalence of 15%, a large proportion of the 840,000 infected Malawians are likely to succumb to diarrhoea illnesses related to HIV infection. However, in times of climatic stress, the number and severity of diarrhoea in an already immune-compromised population would be unimaginable (MG, 2007). Reportedly, the cholera epidemic during the 2001.02 drought season was the worst in a long period of time. Over 1,000 people died, and another 33,211 were infected (Health Communication, 2004; Economic Report, 2002). In Nkhota Kota district, there was a case fatality rate of over 5%. Normally, when managed properly, cholera has a case fatality rate of less than 1%. Cholera outbreaks have been reported from time to time, and the above evidence suggests a linkage between climate change and water-borne diseases, such as cholera.

However, there are two possible scenarios that one can look at in terms of the effects of climate change on diarrhoea. First, if climate change brings increased rainfall and temperatures without the improvements in socio-economic factors, the prevalence of diarrhoea due to organisms that favour these conditions may increase and get worse. Cholera may become endemic in many parts of the country, and epidemics may be bigger and more difficult to manage. Second, if the major ecological zones become hotter and drier with time, then organisms that contaminate dwindling water supplies will become more prevalent. Diseases, such as dysentery caused by various species of *Shigella,* may become more common due to increasing contamination of the drying wells. The number of diarrhoea and cholera cases between 1982 and 1994 reflect, in part, the effects of rainfall on these diseases. Fig 39 shows the relationship between diarrhoea and temperature, which shows that temperature plays a role in determining the levels of diarrhoea incidences. Specifically, a unit increase in temperature that could arise from temperature change, could lead to as much as 34,397 incidences of diarrhoea. For example, the high temperatures experienced during the "mango season" from November to January, is accompanied by many houseflies that readily transmit diarrhoea germs, hence the spreading of the disease.

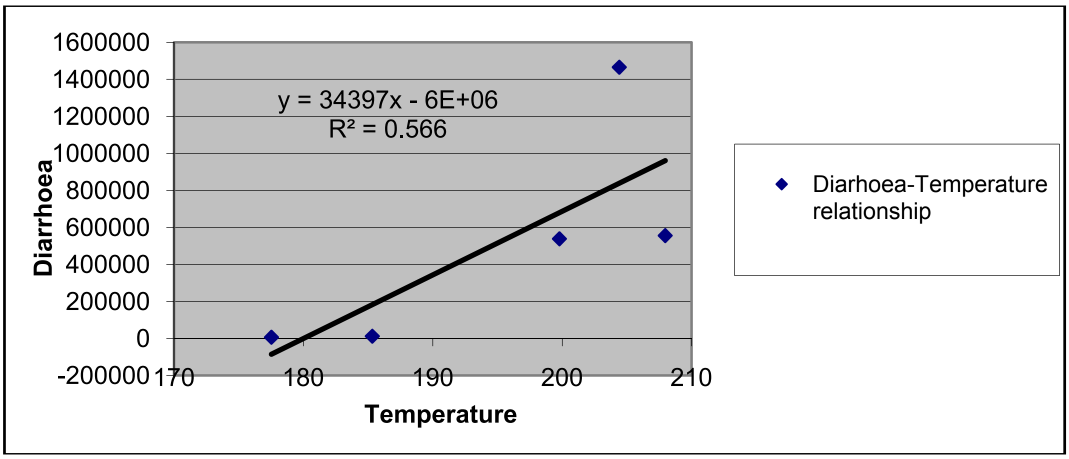


Fig 4.39: Relationship between diarrhoea and temperature **(°C)**
Source of data: DoMS, 2006; HIMS; 2006.

Similarly, there is a negative correlation between rainfall and diarrhoeal diseases (Fig 4.40). However, compared with temperature, rainfall is not a significant determinant of diarrhoeal disease incidences. However, in general, high temperatures are associated with reduced diarrhoeal incidences, with a unit increase in temperature leading to reduction in diarrhoea cases of over 75 people. The reduction in the incidence of diarrhoea can be attributed to reduced swimming activities during heavy rainfall periods because of the murkiness of the water, as well as over-flooding. Further, it may mean that the germs that cause diarrhoea are more influenced by other factors that are activated during the rainy season, other than rainfall itself.

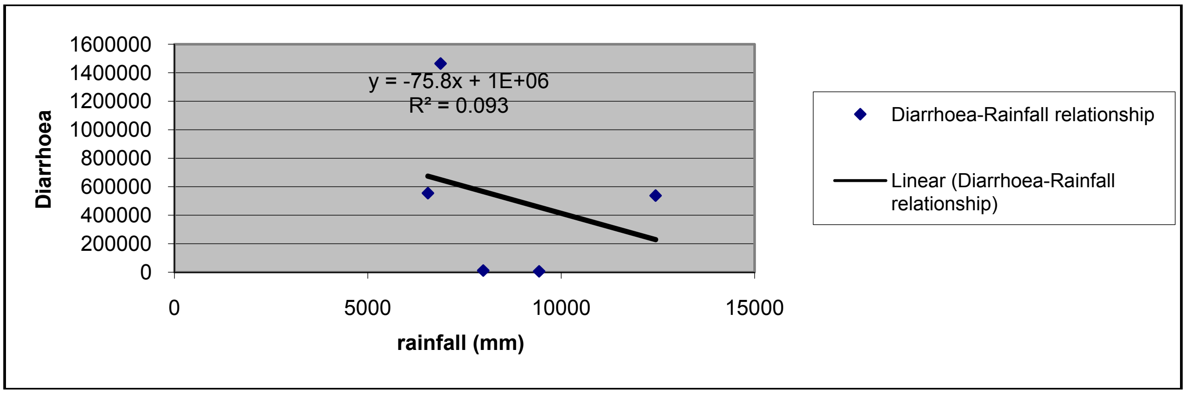


Fig 4.40: Relationship between diarrhoea incidence and rainfall (mm) in Malawi
Source of data: DoMS, 2006; HIMS; 2006.

The prevalence of diarrhoea (chorela) for the period 1998-2007 shows that there was a high incidence of cholera during the years that were relatively dry (Fig 4.41). During the years of drought, such as 1998, 2001 and 2005, the amounts of rainfall received was low, but the temperatures were also high.

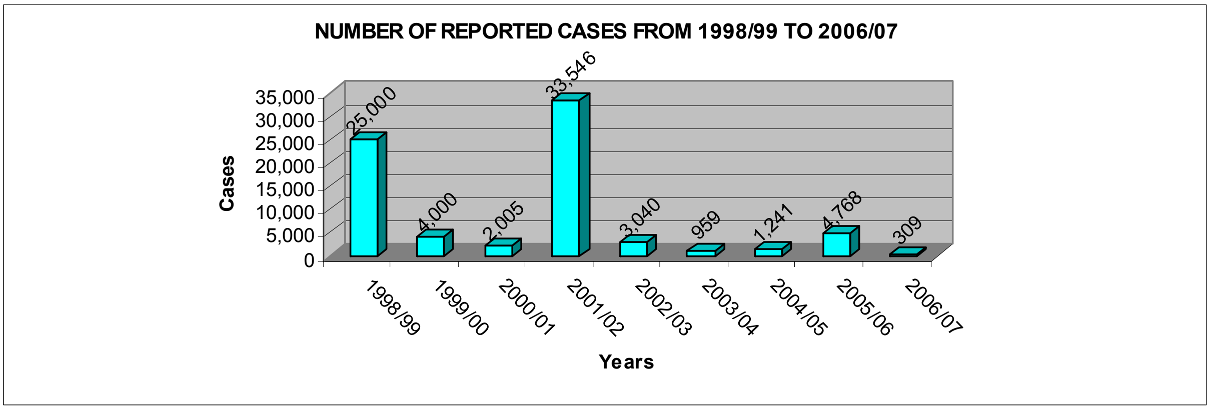


Fig 4.41: Number of reported cholera cases in Malawi, 1998-2007
Source of data: Anon., 2008.

The number of deaths under such drought conditions (low rainfall and high temperatures) was quite high. The number of reported deaths due to cholera since 1998 is given in Fig 4.42. Notably, more cholera deaths were reported in the drought years of 1998/99 and 2001/02 where major cholera outbreaks occurred with 850 and 953 deaths, respectively.

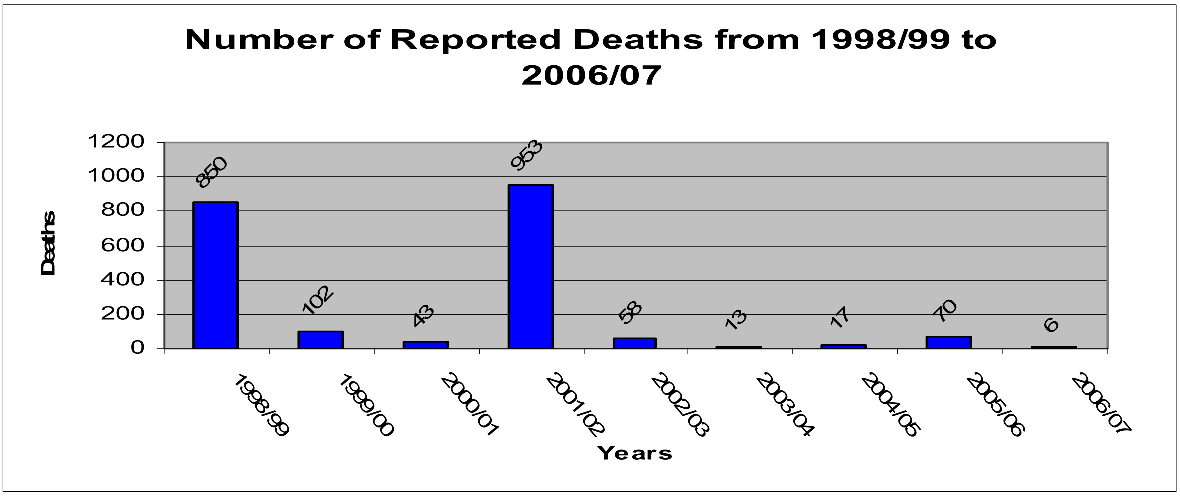


Fig 4.42: Number of cholera deaths in the 1998 and 2001 drought years
Source: Anon., 2008. (Epidemiology Quarterly Bulletin, 2008)

Malnutrition. According to the 2000 MDHS Survey, malnutrition is one of the most important health and welfare problems facing Malawi to day. Young children and women of the reproductive age group are especially vulnerable to nutritional deficits and micronutrient deficiency disorders. The effect that climate change may have on nutrition is perhaps self-evident because climate is directly linked to agricultural production. Malawi's agriculture is predominantly subsistence in nature and dependent on natural rainfall, so that the impact of climate change, as manifested through droughts and floods, is always very severe. This has already become evident in recent years with several incidences of droughts and erratic rainfall. There has been a number of significant droughts over the last five decades (1978-79, 1981-82, 1991-92, 1998-99, 2001-02, 2005-06), which negatively impacted on agricultural production and food security, hence food deficits and hunger, which led to malnutrition.

Fig 4.43 shows a significant and positive relationship between malnutrition incidences and increasing temperature levels. A unit change in temperature leads to as much as 7,599 incidences of malnutrition cases. This can perhaps be attributed to the indirect effects of the agricultural sector, since high temperatures, which are also associated with low rainfall, are likely to reduce crop yields. This would in turn compromise the quantity and quality of food to be consumed, leading to malnutrition.

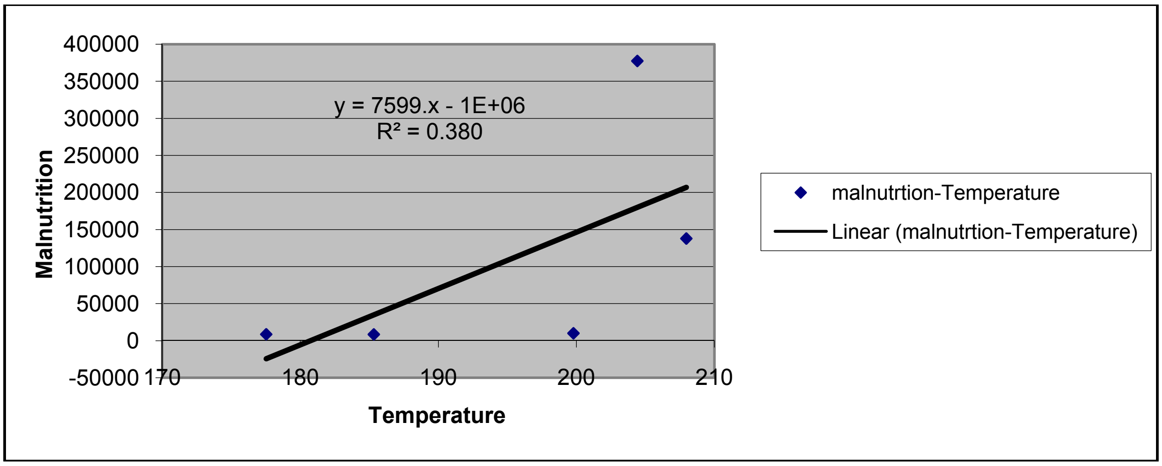


Fig 4.43. Relationship between malnutrition and temperature
Source: Metrological department (2006; HIMS; 2006).

On the other hand, malnutrition is negatively correlated with rainfall (Fig 4.44). The lower the amount of rainfall received, the higher the likelihood of malnutrition. Similarly, this reflects an indirect effect from other sectors, especially the Agriculture Sector (crops and livestock). .

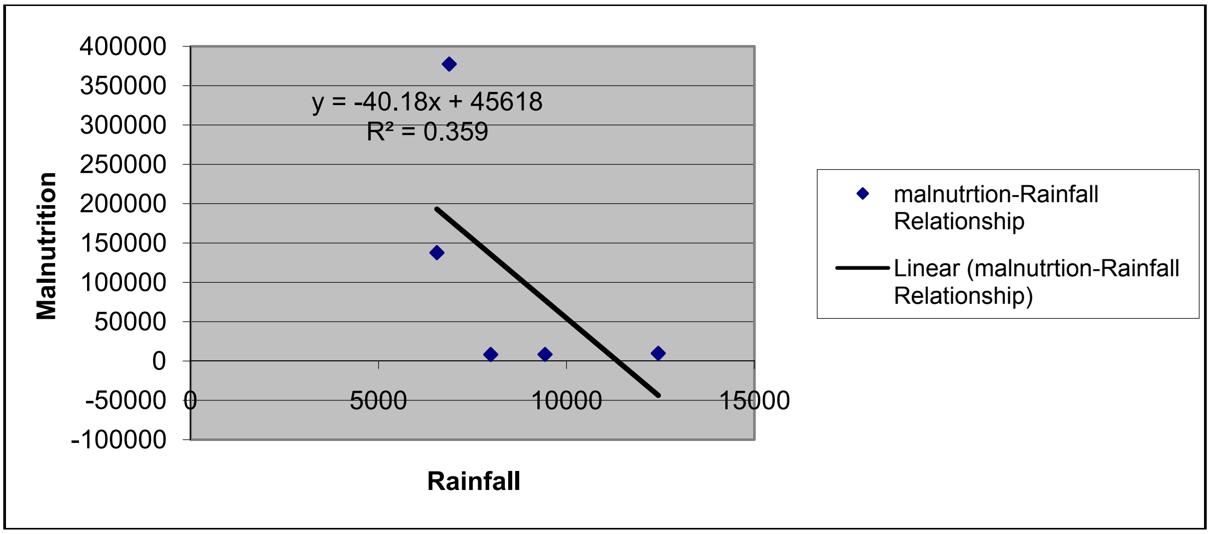


Fig 4.44: Relationship between malnutrition incidences and rainfall (mm)
Source: DoMS, 2006; HIMS; 2006.

Potential future health impacts. In the short-term, food security will continue to be a major problem as a result of a combination of factors, including small landholding sizes, increasing poverty, unreliable rainfall, poor soil and water management and conservation practices, poor agronomic and crop husbandry practices, uncontrolled inset pests and diseases, and lack of access to credit facilities. However, over the last three years (2005/06-2007/08) the situation on food security has improved considerably, since Malawi has been able to achieve food security at both national and household levels through the implementation of the Farm Input Subsidy Programme (FISP). Through the FISP, resource-poor small-scale farmers access fertilizers, seeds and crop production products at Government subsidized prices. Through this programme, Malawi has attained food security at both national and household levels. However, more efforts are required to further increase crop productivity through the implementation of various other strategies, including crop diversification and the development of crop cultivars that are drought and disease tolerant. Adaptation to climate change will, therefore, require the development of human capital, strengthening of institutional systems and sound management of public finances and natural resource.

The effects of climate change on human health are likely to be more evident within the coming few decades. Debates on climate change have focused on recent increases in malaria in the highlands of East Africa (Lindsay and Martens, 1996; Mouchet et al., 1998). In Malawi, malaria is increasingly being found in High Altitude Plateaus and hilly areas, which used to be malaria free soma four to five decades ago. For example, there were no recorded malaria incidences in the city of Mzuzu on the Viphya Plateau some forty years ago, The situation is completely different now, as Mzuzu is infested with mosquitoes, hence a lot of reported malaria cases. Besides warmer temperatures, the other factors that have significantly contributed to increased malaria distribution in recent years are the frequent movements of the people, increased deforestation, drug resistance and changes in vector control programmes.

Thus, if the number of diarrhoea cases will increase as a result of climate change, then Government will be forced to increase financial allocation for the control and treatment of this disease. In the recent past, when there was a cholera epidemic outbreak, Government was caught unawares as it run short of the necessary fluid replacement therapy drugs at the peak of the epidemic, resulting in the loss of life that would otherwise have been saved. Furthermore, diarrhoea episodes worsen the nutritional problems experienced by the most vulnerable groups in rural communities and the urban-poor, especially children and other vulnerable groups. Thus, there would be an increased incidence of childhood mortality as a result of diarrhoea and malnutrition. The adult population too would be affected, especially those who are already affected by the high prevalence of HIV-related diarrhoea episodes.

4.4 Key Adaptation Strategies

According to Burton (1992), adaptation to climate change is a process through which people reduce the adverse effects of climate on their health and well being and take advantage of opportunities that the climatic environment provides. Often, adaptation involves adjustment to enhance the viability of social and economic activities. Adaptation measures to climate change among communities have been considered with two broad areas of activities: (i) measures that reduce vulnerability, and (ii) measures that increase resilience through the utilisation of assets. Further, adaptation measures can be looked at from different levels and time span. At household and community level, it would be interesting to appreciate how families cope with situations of weather extremes. At national and institutional levels, there is need to look at how the policies, programmes and strategies support the efforts to overcome vulnerabilities in both the short- and long- term horizon.

4.4.1 Socio-Economic Scenarios and Trends

Vulnerability and adaptation to climate change is closely linked to the socio-economic growth and development of any country. First, the main driving forces of past and future anthropogenic GHG emissions include demographics, economics, technology and the policies. Second, vulnerability to climate change depends on the interactions between changing socio-economic conditions and climate hazards. Third, the feasibility of adaptation options requires socio-economic analyses of the underlying barriers and opportunities. Therefore, socio-economic conditions must be described in enough detail to evaluate the merit of adaptation of the policy options and strategies.

Economic, social, and technical systems, and their interactions, are complex entities and only a limited overview is provided here. A frequently used approach to organize discussion of the drivers of GHG emissions is through the so-called IPAT (Impact, Population, Affluence and Technology) identity equation [Equation 4.14].

Impact = Population × Affluence × Technology ………………………………………………… (4.14]

The IPAT identity equation states that environmental impacts (e.g., GHG emissions) are the product of the level of population times affluence (income per capita, i.e., Gross Domestic Product (GDP) divided by population) times the level of technology deployed (GHG emissions per unit of income).

The main purpose of using socio-economic scenarios is to explore alternative futures both qualitatively and (if possible) quantitatively, so that one can assess the implications of current decisions and long-range policy for vulnerability and adaptation to climate change (Malone et al., 2004). Scenarios are coherent, internally consistent and plausible descriptions of possible future status of the world. They can be considered as a convenient way of visualizing a range of possible futures, constructing worlds outside the normal time-spans and processes covering the public policy environment. A scenario differs from a forecast in that a scenario is a plausible future, whereas a forecast is the most likely future. However, scenarios and forecasts are similar in that both are internally consistent. Being only a plausible future, a scenario is ideally part of a set of scenarios, which together span the range of likely future developments.

Selected socio-economic scenarios. Many projections of climate change have made use of the IPCCC's IS92 scenarios (Pepper et al., 1992) and the IPCC's Reference SRES (Special Report on Emission Scenarios), which have no specific climate policy interventions (Nakicenovic et al., 2000).. The SRES Scenarios employ four storylines: (i) A1, (ii) A2, (iii) B1 and (iv) B2, to describe consistently the relationships between emission driving forces and their evolution, and add context for the scenario quantification (Nakicenovic et al., 2000). Each storyline represents different demographic, social, economic, technological, and environmental developments, which may be viewed positively by some people, and/or negatively by others.

For this study, the A1 and B1 storylines were selected for use because they were identified as being the most suitable for Malawi's local conditions because they approximate closely to what is articulated in Malawi's Vision 2020 and the Malawi Growth and Development Strategy (MGDS). The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system: (i) fossil intensive (A1FI), (ii) non fossil energy sources (A1T), and (iv) a balance across all sources (A1B).. The B1 storyline and scenario family describes a convergent world with the same global population, which peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material mortality and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

Socio-economic trends. The socio-economic trends are presented within the broader context of: (i) population growth, (ii) GDP growth, and (iii) food demand for an increasing human population. The **population** of Malawi grew from 737,000 in 1901 to 970,000 in 1911, 4.0 million in 1966, 8.0 million in 1987, 9.9 million in 1998, and is presently (2008) 13.1 million and growing at the rate of 2.8% per year (NSO, 2008). The dramatic rise in population, especially starting from 1964 at independence, is depicted in Fig 4.45.(NSO, 2008). The population density increased from 85 persons km^{-2} in 1987 to 105 persons km^{-2} in 1998, and is presently (2008) 139 persons km^{-2} (NSO, 2005; 2008)

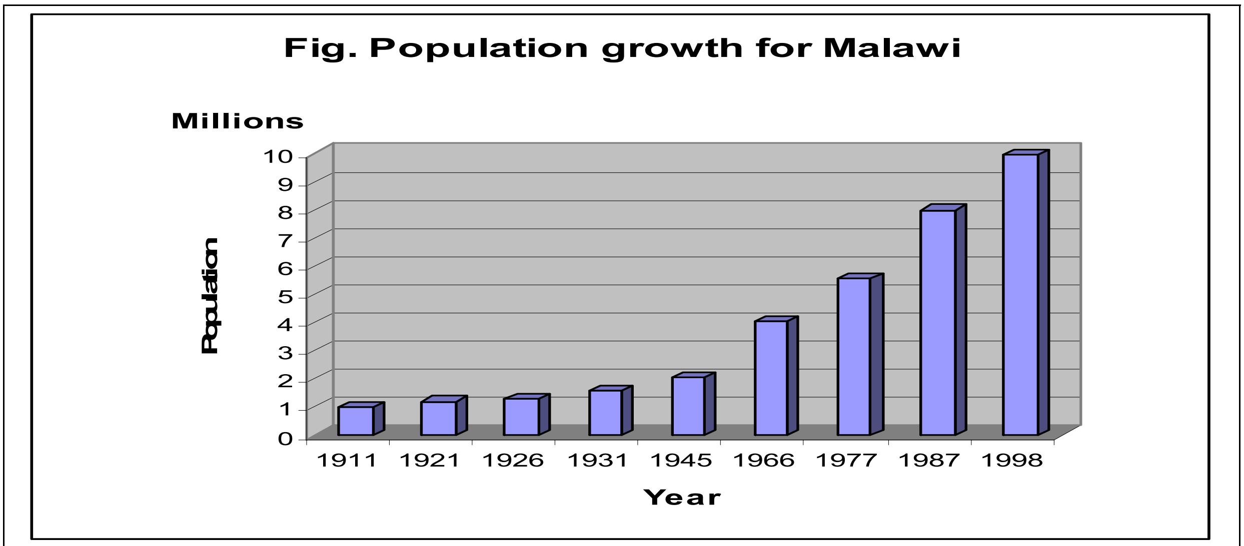


Fig 4.45: Population growth in Malawi, 1901–1998
Source: NSO, 2000

Based on these population trends, long-term population projections using SRES Scenarios A1 and B1 shows that Malawi's population will reach 17.3 million by the year 2030 (Fig. 4.46). This population

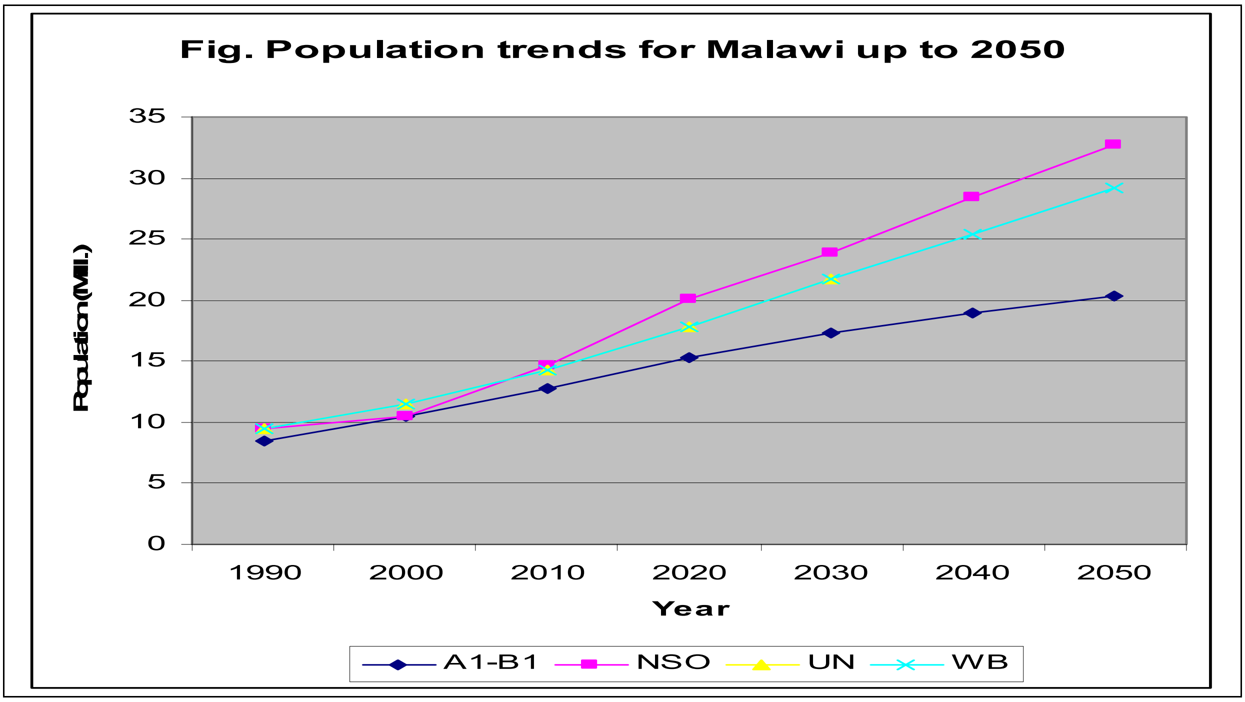


Fig 4.46: A comparison of population projections using different scenarios, 1990-2050

Projection is lower than the projections made by: (i) United Nations (UN) of 21.7 mi by the year 2030, (ii) World Bank (WB) of 21.6 m by the year 2030; and (iii) Malawi's National Statistical Office (NSO) of 20.1 million by the year 2020. The A1 and B1 scenarios, however, show a stabilisation and possible decline in population after 2050. Several factors arising from the implementation of the different policies and programmes may contribute to the observed population dynamics, such as: (i) the use of contraceptives, (ii) increased levels of education among women, especially girls, and (iii) an increase in employment opportunities, especially for women.

Malawi's macro-economic performance over the last two decades has been mediocre, mainly as a result of both adverse climatic conditions, or weather shocks, and weak public expenditure management. Hence, economic growth has been feeble and dismal, averaging 3% between 1996 and 2005, with the real **Gross Domestic Product (GDP)** averaging 1.5% per year. However, over the last five years, the Government has developed and put in place steps to improve the fiscal situation and pursue sustainable macro-economic policies, by enforcing strict fiscal discipline since the 2005/06 fiscal year. These measures are aimed at reducing inflation, increasing GDP growth, reducing domestic debt and increasing gross reserves. The projected GDP growth rate, inflation rate, net domestic debt and gross reserves for the period 2003-2011 are presented in Table 4.13. The inflation rate and net domestic debt are projected to decline, whereas GDP and gross revenue are projected to increase over the 5-year period. On the other hand, the GDP projections using the SRES Scenarios A1 and B1 indicate an increasing trend in GDP growth up to the year 2100 (Fig 4.47)..

Table 4.13: Macroeconomic medium-term indicators for Malawi

Indicator	Year								
	2003	2004	2005	2006	2007	2008	2009	2010	2011
Inflation rate	9.8	13.7	16.9	9.8	6.4	7.2	5.0	5.0	5.0
GDP growth	3.9	4.6	1.9	8.3	5.6	6.0	6.0	6.0	6.0
Net domestic debt	22.3	22.6	21.5	23.3	20.8	17.6	10	10	10
Fiscal balance	-0.9	-4.1	-1.3	-0.9	-0.7	-1.1	-1.0	-1.0	-1.0
Gross reserves	1.4	1.3	1.6	2.0	1.9	2.1	3.0	3.0	3.0

Source: MG, 2006.

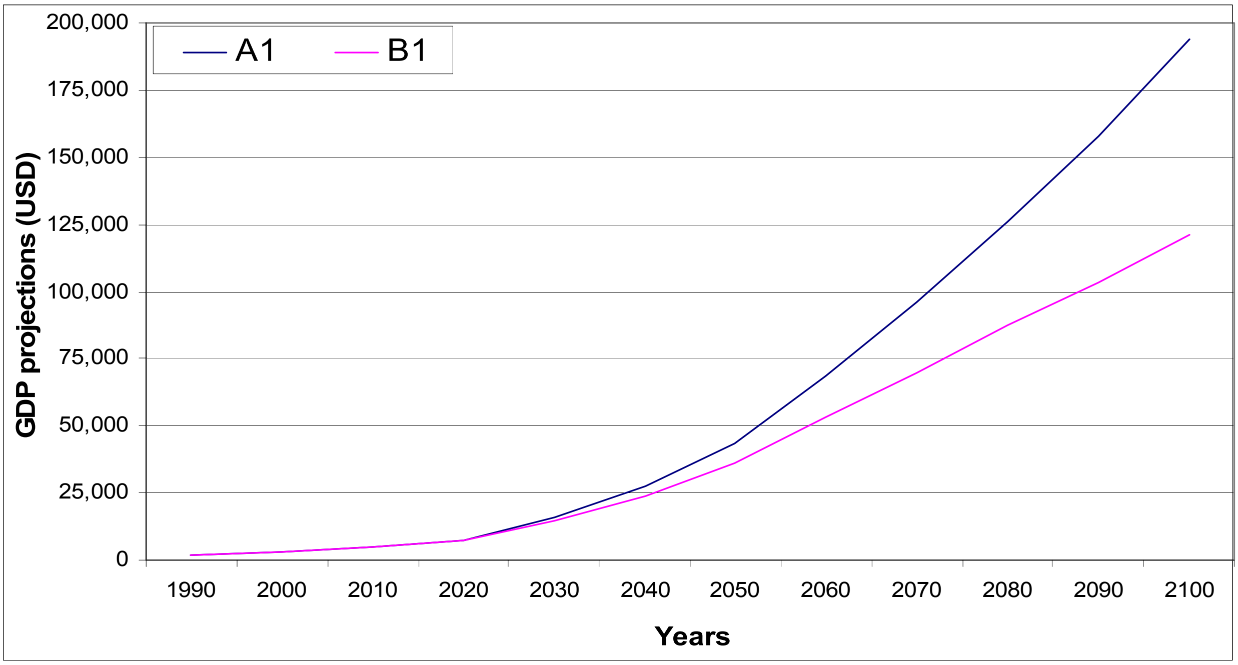


Fig 4.47: Gross domestic product projections for Malawi using the A1 and B1 scenarios, 1990-2100

During the last two decades, Malawi has experienced severe adverse weather conditions, ranging from the worst and severe drought of the 1991/92 crop season to extreme flooding and flush floods in the 2000/01 crop season. The socio-economic impact of these on the country's **food security**, **hunger**, **malnutrition** and **sustainable livelihoods** has been immense. For example, the country had to import the staple food crop maize to meet the shortfall during the 1991/92 drought season. Presently, Malawi's population of 13.1 m people will requires close to 3.0 m tons of maize to ensure food security (assuming each adult requires 320 kg of maize per year). Assuming that the population and GDP projections using the A1 and B1 scenarios cited above were realised, the scenario for food security would also be affected as shown in Table 4.14. The requirement for maize would increase from 3.5 m tons in 2000 to 5.5 m tons in 2100. Thus, the challenge for Malawi is to much population growth with food production so as to ensure food security.

Long-term policies, strategies and economic plans. Malawi has put in place a number of policies, strategies and economic plans to address the various socio-economic concerns. Most of the policies are, among other things, aimed at reducing poverty and the vulnerability of the population to various natural and man- made episodes or disasters, especially among the rural communities, fragile agro-ecosystems and vulnerable sectors of growth. These policies, strategies and programmes include (i) Vision 20:20, (ii) Malawi Poverty Reduction Strategy (MPRS), (iii) Malawi Economic Growth Strategy (MEGS), and (iv) Malawi Growth Development Strategy (MGDS), and the salient features of these is presented in Chapter 1. Presently, to operationalize the agriculture component of the MGDS, Government has prepared the Agriculture Development Programmes (ADP), which will be implemented over a period of five years (2006-2011), which coincides with the implementation period of the MGDS.

4.4.2 Agriculture Sector

Despite the fact that communities have adapted to climate change in the past, it is important to understand the nature of current and potential shocks at household, community, national and regional levels, where natural and human systems are likely to be most vulnerable (IPCC, 2001). While climate change is likely to present some opportunities for some sectors and regions, promoting programmes that will allow rural communities to adapt to these changes will be an ideal policy and livelihood option for Malawi. In this study, some communities, especially those around Ngabu in Chikwawa on the Shire Valley, southern Malawi, and along the Lakeshore Plain, are more vulnerable to the risks posed by climate change than other communities on the Medium to High Altitude Plateaus of Lilongwe in central Malawi, Mzuzu in northern Malawi, and Bvumbwe in southern Malawi. However, all communities need to enhance their adaptive capacity to face both the present and future climate change challenges outside their normal coping range. While the notion of climate change is embraced by all development partners and stakeholders, the challenge is to promote adaptive capacity in the context of competing sustainable development objectives. Community vulnerability is, therefore, a socially constructed phenomenon influenced by institutional and economic dynamics that must be understood by policymakers. The vulnerability of these communities to climate change has been discovered to be determined by its exposure, by its physical setting and sensitivity, and by its ability and opportunity to adapt to change.

Thus, the need for adaptation is based on the fact that the potential impacts of climate change on agricultural systems will depend not only on climate *per se*, but also on the internal dynamics of agricultural systems, including their ability to adapt to the changes (FAO, 2001). Success in adapting to climate change depends on how well agricultural systems adapt to the current and future changes in climate. At farm level, two broad adaptation options can be distinguished for both the crops and livestock sub-sectors: (i) changes in land use, and (ii) changes in crop and livestock management practices. Further, there is scope for mitigation or limiting greenhouse gas emissions from the agriculture, forestry, industrial processes, waste management and the energy sectors. Hence, responses to the impacts of climate change include those efforts that mitigate the impacts of climate change (i.e., limiting greenhouse gas emissions), and those that promote adaptation to the impacts of climate change while promoting a positive impact that is also cost-effective on the Malawi economy. These measures encompass both anticipatory adaptation, and institutional and regulatory adaptations. The selection of measures for adaptation are based on the basis that these are consistent with the government policy of poverty alleviation and food security,

Table 4.14: Estimated basic food demand for Malawi using SRES A1 and B1 Scenarios

Indicator	**Year**										
	1990	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2080**	**2090**	**2100**
Population (% change from 1990)	24	51	81	104	124	141	148	150	147	135	123
Estimated change in GNP/GDP (%change from 1990)	47	147	289	657	1147	1773	2636	3510	4405	5242	6152
Estimated change in total food consumption from 1990	24	51	81	104	124	141	148	150	147	135	123
Estimated total cereal needs (000's metric tons)*	2,896	3,527	4,227	4,764	5,231	5,629	5,792	5,839	5,769	5,488	5,208
Estimated import and food aid share (%)	8.5	8	7	7	6	5	5	4	4	3	3
Estimated in-country production (000's metric tons)*	2,650	3,244	3,931	4,431	4,918	5,347	5,502	5,605	5,538	5,324	5,052
Average cereal crop yields (kg/ha)*	1,634	2,001	2,424	2,732	3,032	3,297	3,393	3,456	3,415	3,283	3,115
Estimated percentage increase in crop yields from 1990**		22	48	67	86	102	108	112	109	101	91

Source: Adopted from Malone et al. (2004)

* The various data used in this table are derived from the WRI (2000) Report

** Cereal crop yields are estimated based on the required in-country production and assumes that planted area is constant and that these measures are already integrated into the proposed Agricultural and Livestock Development Strategy Plan (ALDSP) (MoALD, 1995), and the recently developed Agricultural Development Programme (ADP) (MG, 2008).. Further, it is envisaged that the measures are compatible with adaptation measures in other sectors, are addressing high priority areas and that the measures are affordable. In spite of the fact that Malawi faces acute poverty, educational and health problems, which are top priority on Governments' poverty alleviation programme, it is, however, envisaged that the proposed measures, whether passive, reactive or anticipatory, are cost-effective, achievable and will ameliorate the anticipated or actual adverse consequences associated with climate change.

4.4.2.1 Crops sub-sector.

Changes in land-use. The changes in land-use management are mainly in the context of: (i) changes in cultivated land area, (ii) changes in crop types, and (iii) changes in crop location. The **changes in cultivated land area** refers to both expansion and reduction in the amount of land under cultivation. Expansion in cropped land area may occur where temperature increases may reduce climatic constraints. An extension in cropped land area may be feasible on the High Altitude Plateaus (such as the Viphya, Nyika, Dedza and Mulanje Plateaus), where presently crop production is constrained by low temperatures and infertile soils (Lithosols). This expansion would also increase the area for range pastures to higher altitudes.

The **changes in crop types** would include: (i) growing crop cultivars, or varieties, which have higher thermal requirements or short season crops that are also tolerant to drought or are specifically adapted to harsh climatic conditions, and therefore, responsive to changed environmental and climatic conditions, (ii) genetic manipulation of traits to enhance adaptation to harsh or changing climatic conditions, (iii) introducing or switching to climate adapted crops, (iv) improving growth rates and water use-efficiency of crops at current and elevated CO_2 levels or short-duration maturity cultivars, (v) modelling cropping systems under climate change and climate variability to screen the best alternative cropping systems that are better adapted to changed climatic conditions, (vi) encouraging the use of contour farming, crop residue management, conservation farming, agro-forestry systems and practices, including improved fallows, (vii) crop diversification by promoting horticulture, livestock, fisheries, and other cereal crops besides maize, and (viii) implementing management strategies and policies for sustainable irrigated agriculture. Of particular significance would be the breeding of new crop varieties or crop cultivars that are more tolerant to soil-water stressing conditions during the vegetative and reproductive growth stages. This would also include growing climate adapted crops, such as native species that are more drought-resilient than hybrids. Further, crop diversification, or the use of alternative crops (e.g., cassava, sweetpotatoes, sorghum and millets) that are drought tolerant and adaptable to diverse local climatic conditions is an alternative adaptation measure. Country-wide adoption of sorghum would be of particular interest. Sorghum was the cereal crop grown in all parts of Africa before maize was introduced some three to four centuries ago from central America by the Portuguese explorers.

The changes in the growing of different types of crops to adapt to climate change implies

changes in the allocation of land to different uses based on the specific requirements of each crop based on regional climate and local micro-climate. Apart from climate change, the potential adjustment to land-use for a given crop will depend on the importance of the crop in meeting food security requirements and/or cash incomes of the communities. Thus, increasing temperatures that cause warming in the High Altitude Plateaus would imply shifting the growing of many crops to higher altitudes, as the lower altitudes (e.g., the Shire Valley and some areas along the Lakeshore Plain) become drier and less favourable for arable cropping without irrigation water.

Changes in crop management practices. The other major and important changes would occur in the following areas: (i) use of irrigation water and integrated soil fertility management (mineral plus organic fertilizers), (ii) judicious control of insect pests, weeds, parasites and diseases, (iii) soil drainage and the control of erosion, (iv) changes in farm infrastructure, and (v) changes in crop husbandry and agronomic practices. Under increased temperature conditions, there will be need for changes in **irrigation management practices** to counter the effects of soil-water stress due to increased evapo-transpiration. The increased evapo-transpiration would also lead to reduced groundwater supplies, hence increased need for irrigation water. This scenario is especially important for the Shire Valley, and some rain shadow areas (such as the Phalombe Plain), where crop production is currently constrained by limited and poorly distributed rainfall, other than soil fertility, which is the major constraint to crop production in the country. .

There are many **crop varieties that are high yielding and tolerant to drought and diseases,** which are available on the market to day. For example, research has defined crop variety suitability based on agro-ecological zones. Thus, the maize hybrids MH18 and NSCM 41 are suitable for low altitude zones (e.g., Lakeshore Plain), whereas MH 12 or NSCM 51 are suitable high altitude area (e.g., Medium Altitude Plateau). On the other hand, SC 403 and NSCM 41 are early maturing and short-duration varieties and suitable for marginal rainfall areas (on the lake Shore Plain and Shire Valley), whereas SC 717 or PAN 77 are long-duration maturity varieties suitable for upland areas (on the medium to High Altitude Plateaus). Among the legumes, there are high yielding varieties of groundnuts (Chalimbana, Manipintar, Mawanga, Nsinjiro and CG7), pigeonpea (ICP 9145), cowpea (Sudan 1) and common bean (Nasaka, Napilira, Sapatsika, Maluwa and Kholophethe). It is important to note that bananas are drought tolerant, and the areas where this is a staple food, such some parts of Karonga, food insecurity is particularly not an issue. It is districts tat are located on the Medium Altitude Plateau, such as Mzimba, Kasungu and Lilongwe, which depend on maize as the staple food, that are often food insecure, especially when drought strikes. The strategies for **controlling insect pests, weeds and diseases in crops and livestock** will also be substantially affected by climate change. An increase in these, especially the parasitic weed *Striga asiatica* in maize, will lead to increased costs in maize production, and where uncontrolled, greatly reduce crop yields of grain and dry matter. Control measures will be required for these, and so will be the requirement for improving long range forecasts for insect pests, parasites, diseases and other climate-related calamities.

In the event that total rainfall increases (and with possible increases in intensity as well), there will be need to **control soil erosion and/or improve soil drainage.** Soil erosion and surface run-of may lead to reduced soil fertility (owing to nutrient leaching, increased plant nutrient uptake and poor agronomic practices, especially poor weeding), whereas restricted drainage would lead to increased salinity, so that the beneficial effects of a possible warmer climate may be offset by increased costs of soil erosion control, requirements for draining off excess water and making better use of climate and weather data and weather forecasts. This may ultimately lead to reduced yields and higher production costs. There will be need to improve soil management and conservation practices to reduce surface run-off and arrest soil erosion and land degradation. The envisaged changes in the shifts of agricultural production, especially into areas that are currently classified as marginal areas, such as High Altitude Plateaus and fragile wetlands, will require **changes in farm infrastructure**, especially farm layouts and agricultural support services, such as marketing and the provision of long-term or short-term credit. These changes in infrastructure will need to be accompanied by pragmatic changes in Government policy to ensure that they are properly implemented and benefit rural communities.

If the above changes are likely to occur, there will be need for changes in the way the crops are managed, i.e., **changes in crop husbandry and agronomic practices**. This will include: (i) changes in agronomic and crop husbandry practices, such as tillage, ploughing, harvesting, fertilizer types and amounts, control measures for insect pests, disease and parasites, soil and water conservation, time of planting, and plant density, (ii) crop diversification, (iii) altering planting dates, (iv) changing crop varieties to those that are adaptable to adverse climatic conditions, especially drought under low rainfall conditions, (v) changing cropping patterns and/or planting systems, (vi) changing fertilizer application regimes, and (viii) applying supplementary irrigation water..

4.4.2.2 Livestock sub-sector

The main driving factors, or indicators, that need to be addressed in the livestock sub-sector include: (i) young stock mortality, (ii) reproductive efficiency, and (iii) animal weight at weaning. Table 4.15 shows the indicator variables and the adaptation strategies and measures to address the negative effects of climate change on livestock, as dictated by current policy.

Table 4.15: Indicator variables and adaptation strategies for the Livestock sub-Sector

Indicator variable	Adaptation strategies and/or policy decision
Young stock mortalities in livestock (cattle)	• Breed for resistant or tolerance to parasites and heat stresses • Relocate animals to less vulnerable (high ground) grazing areas • Graze together with other species of livestock, e.g., sheep (grazers and browsers) • Use of frequent broad spectrum antihelmintics • Emergency preparedness plans for emerging diseases, such as the Rift Valley Fever (RVF) • Change in location of watering points.
Reproductive efficiency (conception rates in cattle)	• Relocation to better quality forage areas • Shift to more prolific species of livestock, e.g.,. goats or rabbits

Animal weight at weaning (growth rates in cattle)	• Supplement crop residues with other forages during extreme weather conditions, i.e., use of feed conservation techniques • Shift to heat tolerant breeds • Improve local livestock breeding system • Reduce stocking densities by culling all infertile cows to relieve grazing pressure • Shift to fast growing low input cattle, or other species of livestock, e.g., goats, pigs and chickens • Shift to heat tolerant breeds • Supplement with crop residues • Extend weaning age of young animals • Shift to drought resistant and/or tolerant crops

The key adaptation measures are related to changes in feeds and feeding systems. Table 4.13 gives a general guideline on the possible grass and legume species that may be adapted in the two agro-ecological zones at Ngabu on the Shire Valley, and Likasi on the medium Altitude Plateau on the Lilongwe Plain during periods of extreme climatic events, especially the recurrent and devastating droughts as the one experienced during the 1991/92 crop season. A good number of the pasture species are either drought resistant or drought tolerant, and qualify as strong candidates in the adaptation strategy aimed at reducing the adverse effects of climate change. The temperature and rainfall scenarios for 2010, 2020, 2050 and 2075 point to a decreasing rainfall pattern, but an increasing temperature trend for both Ngabu and Likasi, a future situation which will be instrumental in driving policymakers into choosing appropriate adaptation measures and policy decisions.

The pasture species shown in Table 4.13, most of which are drought tolerant will be an appropriate resource base for adaptation in the two agro-ecological zones to mitigate the negative effects of future predicted extreme climatic or weather conditions. The reduced availability of forage for cattle will put extreme pressure on the communal grazing production systems to shift to heat tolerant, small-framed breeds of cattle, such as Brahman crosses, and the smaller Malawi Zebu cattle which have notable merits for both heat tolerance and less demand on nutritional requirements.

In conclusion, this analysis has hinted on the extreme vulnerability and poor adaptive response of to extreme weather events, such as droughts and floods. Policymakers should explore adaptation measures outlined in this study, and depending on availability of human and financial resources, shift to more practical, managed adaptation strategies that will complement mitigation options. It is proposed that for the drought and flood-prone Shire Valley, adaptation policies that are more anticipatory in response and cost-effective should be adopted. Best-bet adaptation measures, such as planned culling of cattle to reduce grazing pressure and close contact with wildlife should seriously be considered for the Shire Valley agro-ecology. For both the Shire Valley and the Lilongwe Plain, diversification of the production system by shifting to fast growing, low input cattle and short-cycle intensive meat production systems, might be a viable adaptation measure to address the adverse impacts of extreme weather events and climate change.

Table 4.16: Adaptability of improved pasture and legume species in central and southern Malawi

Species	Lilongwe Plain	Shire Valley	Remarks
Grasses			**Environmental characteristics**
Buffel	A	A	• Drought resistant, grows well in areas with 300-800 mm/year
Bushman mine	A	A	• Drought tolerant and some tolerance to water logging
Forage sorghum	A	A	• Drought tolerant and does well in low altitude areas, but not as efficient in utilizing soil nitrogen as pearl millet
Guinea	A	A	• Grows best in areas receiving more than 890 mm of rainfall, drought and shade resistance but frost sensitive
Kikuyu	N	N	• Adapted to highland areas with > 890 mm of rain e.g., Nyika Plateau
Love	A	_	• High rainfall area grass, good drought tolerance, does not tolerate water logging, but has low palatability
Napier	A	A	• Does well under warm and moist conditions. Best suited for areas receiving more than 1,016 mm of rainfall per year. It is also drought tolerant but susceptible to frost
Pearl millet	A	A	• Grows in areas receiving 400-1,000 mm of rainfall, highly drought resistant, can grow in areas receiving as little as 200 mm of rainfall per year, and does best in areas characterized by high temperatures, such as the Shire Valley
Rhodes grass	A	A	• Thrives best in areas receiving more than 760 mm of rainfall
Setaria	P	N	• Adapted to areas receiving more than 760 mm rainfall, but is unfortunately not well adapted to Malawi conditions
Star grass	A	A	• Suitable for drier climates, does well in areas receiving more than 760 mm of rainfall, and does not tolerate water logging
Tanner	A	_	• Thrives under moist conditions and even floats on water
Torpedo	A	_	• Thrives best under moist conditions but does not tolerate extreme water logging
Legumes			**Environmental characteristics**
Axillaris	A	_	• Sensitive to water logging, best in areas receiving more than 1000 mm of rainfall
Caribbean stylo	N	A	• Adapted to hot summer rainfall areas, e.g., Shire Valley and along the Lakeshore Plain districts
Centro	N	N	• Requires more than 1,270 mm of rainfall, tolerant to acidity, drought and water logging
Glycine	A	P	• High rainfall legume, sensitive to frost, does not tolerate water logging or extreme acidity
Greenleaf	A	N	• Requires more than 890 mm of rainfall, and is not very drought tolerant
Joint vetch	A	_	• Tolerates water logging
Kenyan white	N	_	• Adapted to tropical highland areas receiving more than

clover			890 mm of rainfall, and is drought tolerant.
Leucaena	A	A	• Thrives best in hot and wet conditions, extremely drought tolerant and retains green leaf throughout the dry season in most areas. Performs well at low altitudes, e.g., Shire Valley
Lotononis	A	_	• Grows well in dambos, sandy soils in areas receiving more than 890 mm of rainfall, and is tolerant to extreme acidity
Silverleaf	A	N	• Best suited to areas receiving more than 890 mm of rainfall, tolerates acidity and partial water logging
Siratro	A	A	• Very drought resistant, performs very well on the Lakeshore Plain and in the Shire Valley
Stylo (cook)	A	N	• Tolerates acidity and water logging, but not heavy shading
Townsville	N	N	• Not suitable for Malawi, similar to Caribbean Stylo, does not compete well with weeds

Key: A=Adapted; P=Possibly adapted; N=Not adapted; - =Insufficient information.
Source: Adopted and modified from Hodges et al., 1983.

The adoption of these adaptation measures with the full agreement and cooperation of key stakeholders in the Livestock sub-Sector will improve the resilience of livestock communities in the two agro-ecological zones to cope with extreme effects of climate change. This will lead to favourable socio-economic impacts and sustainable livelihoods derived from the livestock. It should be emphasized that this study has presented adaptation measures for consideration by policymakers, and is in no way intended to be a panacea to all the future climatic risks to be faced by livestock. The Government of Malawi will have to critically analyze the priority constraints that limit the ability of livestock communities to adapt to extreme weather events and climate change, some of which are cultural, technical, financial, social and economical.

4.4.3 Forestry and Other Land-Use Sector

The vulnerability and adaptation assessment results of the Forestry and Other Land Use Sector (FOLU) have shown that the sector is highly vulnerable to adverse impacts of climate change. Specifically, the Medium Altitude Plateau and the Shire Valley will become drier, whereas the High Altitude Plateaus and other upland areas will remain wetter. The Gap Model has shown that forests would change to drier types under moderate to extreme climatic conditions, and that wood productivity will decline from 0% to 37% per ha. Hence, there is need for the implementation of adaptation strategies and measures that address these projected climate change impacts by local communities, District Assemblies (DAs), the Department of Forestry (DoF), and other stakeholders, including Non-Governmental Organizations (NGOs) and Civil Society Urganizations (CSOs). The proposed adaptation measures include: (i) development of seed banks for raising drought tolerant tree species, (ii) breeding and screening drought tolerant tree species, and (iii) proper management of forest resources. However, it should also be emphasized that mitigation options, which include tree planting (aforestation and reforestation) that will be covered in Chapter 5, are also important adaptation measures and strategies.

Development of seed banks for the raising of drought-tolerant tree species. Seeds of drought-tolerant tree species that are already adapted to existing harsh environments in Malawi, such as the Lakeshore Plain areas and the Shire Valley that have been identified need to be collected, assembled and stored for future use in the projected harsh environment. These harsh environments are characterized by low altitudes (less than 200 m asl), low rainfall (less than 700 mm of rainfall per year) and long periods of soil-water stressing condtions (more than 36 weeks). The indigenous tree species adapted to such environments include: *Cordyl Africana, Sclerocarya birrea, Steculia appendiculate, Albizzia harveyi, Bosca salicifolia, Dalbergia melanoxylon, Tamarindes indica, Loncocarpus capassa, Adansonia digitat, Acacia negrescens, Acacia tortilis, Combretum imberde, Ficus spp, Ziziphus mauritania, Dodonea viscose, Pterocarpus angolensis, Strychnis potatorum, Acacia nilotica.* In addition, there are other tree species that have been evaluated and recommended by the DoF. These include: *Senna spectabilis, Senna siamea, Burttdauva nyasica, Khaya nyasica, Acacia karro, Azadrichta indica, Eucalyptus camadulensis, E. teretoconis, Gliricidia sepium, Sesbania sesban, Tephrosia vogelii, Acacia polycantha, Burkea Africana, Moringa olifera.*

Breeding and screening of drought tolerant tree species. There is need for a coordinated research approach to tree breeding and/or screening programme aimed at developing and identifying high yielding, and drought and disease tolerant tree species that would be suitable for the predicted warmer and drier environments in the future. These will be a new generation of tree species suitable for harsh and dry environments of Malawi. The breeding materials would include local tree species already adapted to low and marginal rainfall conditions in the country, and tree species from other parts of the world, which are drier than Malawi, such as the Sahel region.

Proper management of existing forest resources. This adaptation measure aims at increasing the ability of the existing forests to adapt to climate change by adopting forest management systems and practices that reduce the impact of climate change on tree growth and development. These include tree planting programmes, protection of existing forests from forest fires, raising public awareness through seminars, drama, print and mass media, improving the composition of forest tree species, and strengthening legislation through the incorporation of climate change related issues into national policies and strategies.

4.4.4 Energy Sector

Given the long time scale for climate to change, the key question to ask is: how would the resource, economic and social systems respond to energy deficits and increasing demands? While the literature on the impacts of climate change on energy demand and supply has expanded dramatically, little work has systematically been conducted to assessed the potential to ameliorate the predicted impacts. First, the ability to adapt and cope with weather hazards depends on economic resources, infrastructure, technology, and social safety nets (IPCC, 1995). Developing countries often do not have the resources for these, and thus, are ill-prepared in terms of early warning and disaster response systems, and victim relief and recovery assistance (GEF, 2000). Second, for many countries, climate change is only one of the many environmental problems they confront. Many are already under pressure from population growth, rapid urbanization and resource depletion, making them vulnerable to the further challenges thrown up by climate change. (IPCC, 2001; Jepma and Munashinghe, 1996).

Malawi is in need of urgent and effective development actions, which, by definition, are resilient to current and increasing climate variability impacting its various sources of energy. It is necessary to strengthen systems for coping with climate variability and reducing vulnerability, and to integrate these into energy planning. Strengthened systems for coping with current climate variability will enable Malawi to address the longer-term impacts of climate change. Both adaptation and mitigation do not occur as discrete activities, but oftentimes arise as part of on-going activities. The incremental benefits of adaptation are often not as clear as they are for mitigation projects, with many activities simply requiring better development planning.

It is within this context that Malawi developed its National Adaptation Programmes of Action (NAPA) by evaluating the impacts of adverse climatic conditions on eight sectors of economic growth, and ranked the identified activities using multi-criteria analysis to arrive at a list of fifteen urgent and immediate priority needs for adaptation (MG, 2006). These including: (i) targeting afforestation and re-afforestation programmes to control siltation and the provision of fuel-wood, and for their benefits, such as sources of alternative cash income, (ii) improving energy access and security in rural areas (e.g., through extension of the Rural Electrification Programme, use of energy-efficient stoves and development of ethanol-based stoves), (iii) developing and implementing strategies for drought preparedness, flood zoning and mitigation works, (iv) developing technologies to mitigate climate change, and (v) providing standby power generation facilities.

Proposed adaptation measures. However, many other experts have used other methods for identifying adaptation measures. Four broad categories described by Downing (1992) can be distinguished as follows: (i) accommodation, (ii) planned resiliency, (iii) purposeful adjustment, and (iv) crisis response. This study has used this typology to group current and future climate change adaptation strategies for the Energy Sector.

Accommodation. Socio-economic systems can gradually adapt to small changes in climate and climate variability. This level of adaptation is at no cost, since the changes are below a threshold of noticeable economic impact and occur on a time scale that coincides with changes in socioeconomic systems. The additional impetus of gradual and low magnitude climate change may not be noticeable. The focus on this is on: (i) energy efficiency improvements, and (ii) energy conservation. The e**nergy efficiency improvements,** which will have to be autonomous in most cases, offer a significant response option. For example, people and enterprises most likely substitute capital for energy to the extent that energy is valued more than capital, and energy for capital to the extent that capital is valued more than energy. Substitution of capital for energy is likely to take place in warmer climates, where people will have to invest more to remain comfortable. Substitution of energy for capital will take place in cooler climates, where people can invest less, and remain as comfortable. Malawi's centralized energy systems, hydro-power and other systems, will need to benefit from cleaner and more efficient energy conversion technologies. This transition will be based on autonomous efficiency improvements in the short- to medium-term, but Malawi, like other developing countries in Africa, will not be in a position to drive trends toward such improvements in the short-term, due to economic and technical trends. Further, there is an urgent need for **energy conservation.** Energy wastage in Africa is quite high; in some cases, savings of up to 40% can be achieved. In the electricity sub-sector, total system losses sometimes exceed 30% in situations where universal standards are below 8%, including some systems in Africa (Davidson, 1992). Reducing these inefficiencies will provide a demand side option for electricity supply. The potential for energy saving through demand side management is very high, as households have realized that they can conserve energy by switching-off bulbs in the house or by efficient utilisation of cooking appliances. However, most of the industries in the country do not practice demand side management strategies because of the cost implications of changing their boiler systems and replacing them with inefficient electric motors. Demand side management options, thus, need strong support programmes to overcome a number of implementation barriers.

Planned resiliency. A set of adjustments can be envisioned for any economic sector that provides for greater resiliency to climatic variations, regardless of the eventual climate change. In many cases, these adjustments will be beneficial for other reasons, and have a net benefit given the current range of climatic variations, and include: (i) inter-country electricity connectivity and micro-grids, (ii) aforestation projects (iii) promoting the use of efficient and affordable stoves, and (iv) biomass briquette initiatives. Malawi has an installed capacity of 284 MW. Ninety-eight percent (98%) of this is run-of-river (ROR) hydro-power on the Shire River, making Malawi's power supply highly vulnerable to droughts and floods. It may be worth pointing out that over the period 1915-1935, the Shire River was not able to get outflow from Lake Malawi because the lake levels has receded below the 474 m above sea level mark. The Electricity Supply Corporation no Malawi (ESCOM) is currently implementing the load-shedding strategy because electricity demand exceeds demand. To meet capacity and energy requirements in the medium-term, imports via **inter-country connectivity,** or domestic expansion and rehabilitation, have been proposed. ESCOM conducted an international competitive process to identify a supply source for electricity imports via a proposed inter-connector. This resulted in agreement between ESCOM and Hidroelectrica Cabora Bassa (HCB) of Mozambique, where HCB will sell 50 MW of firm energy to ESCOM. The interconnection will also facilitate the modernisation of the Tedzani I and II, Nkula A and B Power Stations in Malawi.

The Malawi-Mozambique interconnectivity was made possible through the Southern Africa Power Pool (SAPP) ratified in August 1995 by the Southern African Development Community (SADC) member countries under an Inter-governmental Memorandum of Understanding (IGMOU) and related agreements which together govern the operation of the power pool. SAPP was initiated in recognition of the fact that southern Africa exhibits substantial variations in energy resource endowments, degrees of industrial development, levels and patterns of power consumption and power costs. These differences present opportunities for coordinated development of the regional power sector to (i) generate savings through aggregation of loads with different load profiles, (ii) achieve efficient use of energy resources by exploiting large scale power generation schemes that are viable only on the basis of large multi-country markets, (iii) manage the risks of climate-related power shortages in hydro-dependent countries. Further, Malawi has several rivers and streams that have the potential for **mini- and micro-hydro power generation plants** in the country. Most of the sites have been identified, but not studied in full detail. Currently, only one mini-hydro power station on the Wovwe River in Karonga district, Northern Region, has been established and is now operational. The installed capacity is 4.5 MW and currently the plant supplies power to Karonga, Rumphi, Mzuzu and Mzimba on Malawi, and the neighbouring towns of Lundazi and Chama in the Eastern Province of Zambia. Thus, technology is available for micro-hydro power generation. This generation unit comprises a complete self-contained unit for isolated operation, equipped with an automatic controller to maintain a virtually constant frequency with reference to varying load demands. Thus, this facility allows electricity to be generated in most parts of the country, where presently transmission lines are too costly to erect.

Indigenous miombo and other woodlands in sub-Saharan Africa contribute significantly to the firewood supply for use and conversion to charcoal. Although natural stocks of wood may be high, wood resources available to the majority of the rural people are very low, especially when viewed against a backdrop of increasing human population, and the increased magnitude and frequency of droughts and forest fires. It is for this reason that the Environmental Affairs Department (EAD) is supporting the implementation of **aforestation projects [Community Environmental Micro Projects (CEMPs)]** in all District Assemblies (DAs). CEMPs are a set of small-scale activities initiated and implemented by community groups in urban or rural areas who wish to actively participate in environment and natural resource management. These CEMPs are supported through the Environmental Fund, which EAD manages, as provided for in the Environmental Management Act pf 1996. The Fund was approved by Cabinet in 2003 to provide a sustainable financing mechanism for environment and natural resources management. These CEMPs conduct a lot of activities besides aforestation projects, such as the installation of solar power, guinea foul rearing as well as capacity building for District Environmental Sub-Committees.

The Malawi Government and its development partners have embarked on public- private sector partnerships in seeking alternative sources of energy, especially where the country's energy mix is heavily dominated by firewood, paraffin and charcoal. This aims at **promoting the use of efficient and affordable stoves.** The first among such programmes is the "Programme for Basic Energy and Conservation in Southern Africa (ProBEC)", which is supported by SADC and GTZ. The programme is focussing on the following seven activities: (i) the promotion of the use of efficient and affordable firewood clay stoves in rural households. (ii) the promotion of highly efficient firewood stoves (Rocket stoves) in urban and peri-urban households, (iii) the promotion of the sale of improved institutional Rocket stoves to social infrastructure institutions, (iv) promotion of energy for productive use and income generation, targeting worker canteens, staff houses and worker compounds, and (v) promotion of the employer and contractor pre-financing approach

Future developments will include the use of household Rocket stoves for firewood, and household Rocket stoves suitable for dual-fuel (firewood and/or charcoal), and an aggressive training programme for building contractor companies on the construction of improved fixed household firewood burning cooking stoves. Further, ProBEC has investigated the use of firewood for agro-processing, food production and water heating (such as water geysers in guesthouses, bakery ovens, and tobacco curing devices), for small- and medium-sized enterprises. Thus far, Rocket stoves for restaurants and geysers for guesthouses as well as chip fryers have been marketed, and there is good potential for the "rocket-based tobacco curing technology" that has so far been developed and is still currently under testing. There is already a high demand from industry, and once the technology has been proven, dissemination to small scale farmers will be expected as well.

Finally, the **biomass briquette production initiative** has been implemented by various stakeholders for the last two decades. A good example is the Ndirande Nkhuni Biomass Briquette Programme (UNDP, 2001), which involved training women's groups to produce briquettes from waste materials for use and sale as an alternative fuel source. Women were involved in the design of the wooden briquette-making machines, which are inexpensive and easy to maintain. Spare parts are easy to get and local artisans have been trained by the project to make new machines when necessary. The training focused on women because they are the main users of household energy. The women's groups also received training in maintenance skills, entrepreneurship, and business management. Some women went on to train others for a small fee.

Purposeful adjustment. Specific practices that are designed primarily to cope with expected climate change, that are adopted as forecasts of climate change become more certain, and are not justified by other social and economic benefits, can be termed purposeful adjustments. They entail a higher cost than those in the previous level of response and a higher risk of failure if the climatic changes are different from expected. These mainly encompass **renewable energy sources**. In 2001, Malawi, with support from the United Nations Development Programme/Global Environment Facility (UNDP/GEF) under the project entitled: "Barrier Removal to Renewable Energy (BARREM)", adopted a strategy aimed at priming the market for solar photo-voltaic (PV) as a measure for reducing greenhouse gases that cause global warming. Specifically, the strategy aimed at: (i) assisting local stakeholders in building local capacity to promote, install and service solar PV applications, (ii) assisting to develop favourable regulatory frameworks for solar PVs, (iii) facilitating the development of viable financing mechanisms for solar PVs; (iv) demonstrating the viability of investments in solar PV technologies, and (v) promotion of widespread replication. Popular opinion is that solar energy should be harnessed to the fullest to fill the supply gaps in the national energy market. As such, it may be desirable that most solar energy applications be targeted to meet the energy needs of those consumers whose access to conventional energy, particularly electricity, is limited either due to low disposable income or remote geographical locations relative to the national grid. With this background, the most suitable applications for solar systems in Malawi include: (i) portable lanterns, (ii) household lighting systems, (iii) institutional lighting and power generation, (iv) rural refrigeration, (v) pumping for community water supply, (vi) pumping for irrigation, (vii) electric fencing, and (viii) remote communication systems. Thermal solar energy is used for heating water and air. Most of the solar water heaters have been installed in private houses, but more so in public institutions, such as boarding schools and hospitals.

Crisis response. The domain of climate change marked by crisis response indicates the failure of adjustments adopted earlier to address the adverse impacts of climate change. It is observed that there is less certainty about the relationship between climate change and the occurrence of natural disasters (McGuigan et al., 2002). The changes anticipated will contribute to the increasing severity of natural hazards, storm surges and flooding. Malawi, like other developing countries, is also more vulnerable to extreme weather events, such as floods and droughts. The location, lack of services and infrastructure, and poor building structures all increase the vulnerability to flooding, storm surges, cyclonic winds and high intensity rainfall which may put out of commission centrally planned energy grids or prevent access to other forms of energy. Adaptation activities for climate-related energy crisis can be capital-intensive, and the benefits highly localized and immediate. Apart from funds, tiered national and regional insurance schemes have been proposed. They form part of an approach that emphasizes managing and spreading the risk to the country of climate effects, such as extreme weather events and aiding recovery efforts.

Adaptation policy framework. Unlike mitigation, adaptation will in most cases provide local benefits, realized without long lead times. Therefore, some adaptation will occur autonomously, as individuals respond to market or environmental changes. There are also some aspects of adaptation that require public goods delivering global benefits, including improved information on climate systems and climate-resilient technologies. Hence, this explains why the National Adaptation Programmes of Action (NAPA) for Malawi adopted a project framework approach for the implementation of the identified adaptation measures. This study suggests that the method used herein, to define courses of adaptation action, allows different players at individual, household, community and national levels to implement certain tenets of the adaptation to energy changes resulting directly or indirectly from climate change.

Indeed, governments have a role in providing a policy framework to guide effective adaptation by individuals and firms in the medium- and the long-term horizon. The following key areas are amongst several issues that can be highlighted: (i) high-quality climate information and tools for risk management will help to drive efficient energy markets, so that improved regional climate predictions will be critical, particularly for rainfall and storm patterns,. (ii) land-use planning and performance standards should encourage both private and public sector investment in buildings and other long-lived infrastructure to take into account the vulnerability of different elements to climate change in the Energy Sector, (iii) Government can contribute through long-term polices for climate-sensitive public goods, including natural resources protection and management that yield various forms of energy and emergency preparedness, and (iv) a financial safety net may be required for the poorest in society, who are likely to be the most vulnerable to the impacts and least able to afford protection from any energy deficits. Hence, adaptation actions should be integrated into development policy and planning at every level. This study argues that donors, development partners and Government should invest in projects that assist countries to prepare national communications, research projects and national strategies. Whilst these play an important role in preparing developing countries for the impending problems of climate change, there is very little emphasis on capacity strengthening for technocrats in their ability to assemble, generate, manipulate and interpret data bases to inform climate change adaptations. Furthermore, for adaptation to be effective, capacity building and training is required at all levels, including local communities.

4.4.5 Water Resources Sector

The adaptation to climate change and climate variability in the Water Resources Sector requires measures that would address the adverse impacts of climate change, especially floods and droughts. The proposed water conservation strategies and development programmes with **water demand management (WDM)** activities should be the main strategies for the development and implementation of adaptation measures and strategies for climate change and climate variability. This should include improved water supply, particularly to rural communities through reservoir storage, gravity piped water supply systems and innovative deep borehole constructions that provide security of water supply systems during drought years. The borehole water supply improvement initiative should include improved positioning of pumps into the aquifer with overhead storage to allow water to be reticulated to the village communities wherever practicable.

The advancement of **small to large scale water resources** infrastructure development should lead to the implementation of adaptation of appropriate measures and strategies. Multi-purpose dam sites were already identified in the National Water Resources master Plan (NWRMP) on the North Rukuru, South Rukuru, Bua and Lilongwe/Linthipe Rivers for which feasibility and design studies are required before construction can commence. Among the dams already identified are: (i) the Rumphi (Njakwa), Henga Valley (Phwezi) and Fufu dams on South Rukuru, (ii) the Mbongozi, Malenga and Chasomba dams on Bua River, and (iii) the Kholombizo (Matope) dam and Kamuzu Barrage upgrade on Shire River.

There are also several sites that need to be examined for possible dams on other rivers and streams throughout the country, with a view of constructing these dams as part of the water resources development programme aimed at creating water security for the people of Malawi. This is important because Malawi is relatively more vulnerable in the region, and is far behind in the development of flood protection, and drought relief adaptation infrastructures.

The strategy should also include adaptation measures that improve water resources management, particularly in fostering floods and drought monitoring, forecasting and warning systems. The sustainability, appropriateness and effectiveness of such systems should be the guiding principle in their planning, design and implementation. So far, the Department of Meteorological Services (DoMS) is capable of providing data and information for such services. The other strategy is WDM, which will ensure that the available water resources are not wasted, such as through poor and ineffective irrigation methods and/or water leakages through broken pipes. The WDM measures should also include pollution control and water recycling, water demand regulatory pricing and incentives to reduce water wastage. There is also need to have institutional capacity development for the operating and maintenance of infrastructure, especially dams and barrages on the Shire River.

However, the proposed water resources development strategies have two main inherent risks: (i) lack of technical and financial resources, and (ii) poor land-use and management practices that lead to siltation of water reservoirs, including rivers and streams. The **water resources conservation structures** required include: (i) small reservoirs and rain harvesting structures, and (ii) large dams with the capacity to generate electricity and irrigate enough land for adaptation to climate change, especially droughts, This requires financial resources and trained manpower to design, build and manage the structures, which may not be altogether readily available. The problems of poor land-use are due to poor soil and water conservation and management practises, especially under smallholder farm conditions. However, this requires intensification of land husbandry efforts so that communities learn and adopt soil and water conservation practises that significantly reduce soil erosion and siltation in the rivers and streams.

The financial risks of implementing adaptation measures and strategies requires the construction of simple but effective **water resources structures**, such as small dams and rainwater harvesting structures in the most vulnerable areas. A deliberate policy could be put in place in the water and environmental sector to target medium and large scale multi-purpose dams for investment and development by Local Government, Water Boards, and other private non-state actors. Large multi-purpose dams identified in the NWRMP can be constructed for flood protection and climate change adaptation measures, whereas the Kholombizo dam on the Shire River can be used for navigation..

The proposed water resources management programmes are mainly aimed at improving flood and drought monitoring and management systems through forecasting and early warnings. It is also important for managing the water resources conservation infrastructures. The main risk is the lack of Government resources for the design, implementation and management of such monitoring systems. However, the increased socio-economic developments in flood and drought warning systems should justify the economic need for such systems, and thereby enable the Government and private sector investment in water resources monitoring for floods and droughts.

Thus, the water resources conservation infrastructure developments mentioned above should spur and support such economic developments that can justify investments in the water resources management initiatives, which should also include catchment protection and rehabilitation works to promote soil and water conservations in the catchments with dams. Complacency is perhaps one of the biggest risks of WDM. This is because of the false assertion that there is always enough water, or that there are no problems of water scarcity, especially during times of excess water supply through rainfall. This negates strategies of WDM aimed at conserving and utilising what has already been developed for use. However, when WDM awareness campaigns and extension is part and parcel of the water resources development programmes, this risk may be reduced considerably.

4.4.6 Wildlife Sector

Wildlife plays an important role in the development of the tourism industry in the country. The elephant is an iconic species because it is the largest land mammal, it is one of the "big five" mammal species and it is classified as endangered by the International Union for the Conservation of Nature (IUCN), and is in Appendix I of the Convention of International Trade of Endangered Species (CITES). It is used as a marketing tool for tourism in areas where it occurs. Its presence is used to catalyze the establishment of partnerships for development and also facilitates ecosystem management, and it is for this reason that the elephant has been used as an 'indicator animal species".

The response of the elephant to climate change will equally apply to other types of wild animals. A well articulated wildlife management policy and an elephant management plan in particular will, therefore, contribute to the development of the tourism industry in the country. To achieve this, there are several climate change adaptation strategies that can be implemented, including: (i) establishment of elephant movement corridors, (ii) implementation of a management action palm, (iii) reducing human-elephant conflicts, and (iv) implementation of other adaptation responses to reduce vulnerability.

Elephant movement corridors. The elephant habitat will be decreasing and the range will be shifting as a result of extreme weather conditions and climate change. The elephants may begin moving long distances in search of food. The ecosystem approach to conservation in the two national parks will need to be considered as an important management strategy. There is urgent need to finalize the Malawi-Zambia Trans-Frontier Conservation Area (TFCA) Agreement for the proposed Kasungu-Lukusuzi area corridor. For the Liwonde National Park, the corridor to the Mangochi Forest Reserve must be maintained and the drafted management plan for the two areas seriously considered for implementation.

Implementation of a habitat management action plan. The habitat management action plan must be considered as an important aspect of wildlife management. This must be implemented to the letter regarding research, fire management and the creation of drinking water holes in the parks.

Reducing human-elephant conflicts. The increasing incidents of human-elephant conflicts need to be addressed by working together with farming communities living around the parks to reduce the growing of crops around the parks as much as possible. These farming communities must support the efforts put up by the Department of National Parks and Wildlife (DoNPW) of planting only low risk crops around the boundaries of national parks.

Other responses to reduce vulnerability. The other responses to reduce vulnerability include: (i) funding for the translocating of elephants from areas where there are too many to those areas where there are fewer numbers, (ii) monitoring elephant movement in order to quantify the factors that drive their behaviour, (iii) formation and implementation of the Majete Wildlife Reserve Public-Private Partnership, (iv) curbing encroachment and reducing poaching from an increasing human population through the enforcement of current regulations and the strengthening of public-private partnerships.

Barriers and opportunities. Despite the availability of the proposed adaptation measures, the Wildlife Sector is faced with a lot of problems that constrain the implementation of these. The management of wildlife is a complex science that is based on several natural and social sciences. The successful management of wildlife will increasingly depend on the knowledge of the roles of different actors in maintaining ecosystem integrity. Climate change is one such field, and although it has not been identified as an area for regular monitoring, it can easily be done. Through adaptive management procedures, the impacts of climate change on wildlife can be tested to formulate appropriate management decisions.

However, the DoNPW is constrained by many factors, including limited material, human and financial resources. This, therefore, makes the implementation of its programmes difficult. The Department has been unable to systematically implement the adaptive management strategic plan upon which most of the wildlife management strategies are based due to limited resources. Its current implementation is mostly ad hoc in nature, responding to calls for assistance with decisions usually based on researched findings, by expert judgement. Further, compiling information for this study has not been easy because there are no monitoring studies and reports on the ecology of protected areas. The Kasungu National Park has more information gaps compared with Liwonde National Park. In addition, there is pressure in all national; parks from high and increasing human population pressures. Many people living adjacent to these parks are resource-poor, living below the poverty line and primarily depend on the natural resources derived from these parks for their upkeep and sustainable livelihoods. Land is getting scarce around the parks, enhancing the conflict between people and wildlife resources in the parks. Policing of protected areas is difficult and there is an anti-agonistic attitude between the people and the DoNPW. Further, one other major barrier is that wildlife management in Malawi is not considered as a priority sector of Government. Currently, it takes a lot of effort to get response from Government to support wildlife management efforts, yet the Department is pivotal to the much taunted tourism that is high on the agenda of the Malawi Growth and Development Strategy (MGDS).

Nonetheless, there are some opportunities that the DoNPW can exploit to improve the management of wildlife resources in the parks and to reduce human-animal conflicts. First, there is the National Committee on Climate Change (NCCC), which is the Government's voice regarding climate change policy activities and provides an important forum for various stakeholders to share information on climate change. The DoNPW is represented on this committee and therefore, fully participates in climate change initiatives organized by the Secretariat. Further, the DoNPW is a member and a signatory of a number of international conventions, such as the Conservation of Biodiversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Ramsar Convention on Wetlands and the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Convention. All these aim at conserving biodiversity and have many strong synergies. One of the major areas of focus in most of these conventions is climate change. Thus, it is clear that an elephant management strategic plan must be developed and approved for implementation as soon as possible. In this strategy, research on the implications on climate change must be prioritized. Land-use planning around protected areas must be encouraged in order to reduce the levels of human-wildlife conflicts, but enhance tourism.

4.4.7 Fisheries Sector

The vulnerability of the fish stocks in the water bodies of Malawi requires that appropriate measures and strategies are put in place to address the identified problems. Various adaptation measures are available, including those aimed at re-stocking and protecting the depleted fish stocks. At **individual species level,** scientific evidence indicates that once temperature increases, fish will tend to develop heat shock proteins. The synthesis of these proteins is induced when temperature rises between 5 and 15 ^{0}C above normal environmental requirements (Jobling, 1995). These are also produced in response to other stressors, such as heavy metals and xenobiotics or radiation, hence they are not specific. Obviously, the history of a particular fish species is important such that those exposed to higher temperatures will be more heat tolerant. Some species are, therefore, more eurythermal than others; with the latter being described as sternothermic. Generally, there is inadequate understanding of the issues underpinning response to climate change. However, the people expected to conduct these studies are not properly and well-trained. In particular, the adoption of suitable models, such as the Pressure-State-Response Model, or the driver-pressure-state-impact response, would be helpful.

The second adaptation strategy is the **protection of vulnerable stocks** to changes in **c**limate. Climate change and over-fishing are closely-linked. The starting point is formulating implementable regulations for the most vulnerable fish stocks. However, the formulation of these started a long time ago, but observance and adherence by local communities has fallen short of expectations. The current thinking is that the involvement of local communities in what is termed a 'bottom-up approach' would be the most appropriate adaptation strategy.

The third is the **re-stocking of vulnerable stocks.** The hatchery-bred stocks could be used in re-stocking programmes, but there must be an assured means of protecting fish in the wild. Techniques for breeding in captivity are many and available, but the will to implement them on a wide-scale basis is lacking. The Presidential Initiative on Aquaculture (PIA) launched in 2005 is meant to have provided the necessary impetus for these studies, but so far, this has not happened. Without the involvement of local communities, this is likely to remain a pipe dream.

The fourth is to protect **protected areas**. Since the establishment of Lake Malawi National Park in 1982, no other lake has been subjected to such restrictions. The value for adopting such areas has become more apparent and urgent over time. Consideration should be given to include up to 10% of the lake area to be under protection, which is supported by scientific evidence from recent global studies (Sumaila et al., 2001). Elsewhere in the world, the fisheries resources have benefited from such restoration programmes, and the establishment of protected areas or parks has become a common practice. In Malawi, little progress has been made to utilize these tools for restoring fisheries through habitat changes. This hinges on relevant policy issues that are not being given serious consideration. Further, the protection and proper management of fish resources should include pond fish farming and cage aquaculture.

Aquaculture (**pond fish farming)** in Malawi has generally been on the increase, although its focus on the small-scale sector has limited its growth. From 1995 to 2002, the annual production has been estimated to have risen from 200 to 800 t, and future prospects also look promising. Subsequent future projections show tremendous. The **cage aquaculture** is another recent major undertaking operated by MALDECO as one way of protecting and increasing fish production.

Constraints to adaptation. There are many problems that constrain the adoption of the recommended adaptation measures, including: (i) lack of alternative protein sources, (ii) expensive animal feeds, (iii) non-adoption of a regional approach, (iv) limited scientific information on aquatic resources, and (v) human perceptions. Where there is need to protect fish by imposing a ban on the catching of fish, alternative sources of protein must be identified. Encouraging people to catch more Usipa only provides a short-term solution. The raising of small stock, such as goats, rabbits and chickens, among others, can provide relief. Animal feeds, especially concentrates, are **expensive** and usually beyond the purchasing power of most small-scale farmers. Hence, the adoption of intensive livestock farming activities along the Lakeshore Plain remains limited and restrictive. There is also a **lack of a coordinated regional approach** to the management of fish among Malawi, Mozambique and Tanzania. Mozambique and Tanzania are the two crucial riparian states with joint management programmes with Malawi of the Lake Malawi aquatic ecosystem. There have been joint Lake Malawi research programs, so that a framework for collaboration exists through the existing Southern African Development Community (SADC) protocols. However, if these states do not adopt the same conservation measures as Malawi, then the regional approach will not yield any benefits at all. Further, there is **limited scientific information on aquatic resources.** Without the necessary knowledge about the aquatic resources, successful management cannot be assured. Sustainable means of funding research needs to be explored and implemented, including a "pollution fee" and other conservation considerations. Finally, there is the **human perception** factor. Although most Malawians understand the challenges posed by climate change, few are convinced that something could be done to adapt to climate change, and are resigned to the fate of reduced productivity. Many people are sceptical and do not appreciate the new technological innovations (Kaunda et al., 2004). .

Policy recommendations. To effectively manage the available fishery resources, there is need to implement the Fisheries Act to the letter. First, the Fisheries Act should be amended to come up with a more clear statement on alien introductions as this only compounds climate change issues. However, the displacement of species from their habitat is especially relevant to sternothermic species. Second, conservation policies should be adopted through the involvement of communities to avoid past management failures that relied to "top-down" approaches. District Assemblies (DAs) of the Lakeshore districts should be fully involved in the policing of protected areas that have been established to hedge against species extinction and to act as refugia. Third, environmental research should incorporate an economic assessment of the fish resources to demonstrate future benefits that can be generated from conservation. New generation discount approaches that have been developed elsewhere (Ainsworth and Sumaila, 2005), need to be adapted and adopted for Malawi waters. Fourth, fishing of threatened species, such as Chambo, Ntchila, Mpasa and others, should be banned for a specific period in specific areas to test their ability to recover based on natural recruitment. Finally, the widely acclaimed Malawi principle on conservation should be enforced. Internationally, this is a respected blue print, but its proponent, Malawi, has so far failed to implement it as well.

4.4.8 Human Health Sector

This possible strategies and measures to adapt to the adverse effects and impacts of climate change in the Human Health Sector mainly address the issues of malaria, diarrhoeal diseases and malnutrition, which are a major problem in the country.

Malaria.. Malaria is the commonest and one of the main killer diseases. Hence, besides HIV and AIDs, malaria prevention and curative strategies are receiving high priority at both local and national levels as articulated in the Malawi Growth and Development Strategy (MGDS). At **household and community level**, there is anecdotal evidence that Malawian use fumes from burning leaves of high-scented plants, such as *Eucalyptus* trees or cow dung, to act as repellents of the vectors that carry the malaria parasite. The effectiveness of such indigenous technologies has not been documented. Further, some rural family households have developed capacity to use presumptive diagnosis of malaria, such as the signs of fever, and have often provided their own treatment using drugs from retail outlets, or herbal remedies from traditional healers. At **national and institutional levels**, the Ministry of Health and Population Services (MoHPS) is the Government ministry responsible for health services in the country. In 1984, Government established the National Malaria Control Programme (NMCP) under the Preventive Health Services Unit (PHSU) within the MoHPS located at the Community Health Sciences Unit (CHSU). Further, the National Malaria Technical Committee (NMTC) was established to provide advisory role to NMCP. The NMTC is: (i) a channel for creating an avenue for MoHPS and partners to network and share information on malaria prevention, control, and research activities, (ii) provide advice on coordination and collaboration activities for the NMCP, and (iii) support the Roll Back Malaria Strategy and Plan for Malawi by advising on national malaria policies, prevention, control strategies and research priorities.

Presently, Government, through the MoHPS, has put in place a number of strategies and measures to address the problems of malaria, which include: (i) prevention and control mechanism for malaria, and (ii) promotion of insecticide-treated mosquito nets (ITMNs). Prior to 1992, in an effort to **prevent and control malaria**, chloroquine was the first-line treatment drug for all forms of malaria in the country. However, it was later discovered that pregnant women were reluctant to take this prophylaxis treatment due to its bitter taste, and after all, it had also because resistant to some strains of malaria. Because of these limitations, Government abandoned the treatment of malaria using chloroquine. Since 1995, the NMCP has been **promoting the use of insect-treated mosquito nets (ITMN)** as a means of vector control, especially for vulnerable groups, such as children under 5 years of age and pregnant women. The use of the ITMN has resulted in a substantial reduction of infant mortality of approximately 25%. The ITMN programme was scaled-up through antenatal and under-5 clinics in December 2002, and in late 2003, approximately one million subsidized ITMNs distribution kits were provided nationally through community venues, such as village health committees and community-based organizations (CBOs), as well as through antenatal and under-5 clinics. The MoHPS plans to conduct this campaign once a year just before the rainy season begins (EAD, 2006). The measure, however, is not as effective because it only targets expectant mothers and children under the age of 5 years. This means that only very few men, women and children over five years old, who can afford to buy these, can benefit from this intervention. This study, therefore, recommends that Government should subsidize the ITMNs even further to enable the poor of the poorest, and other equally vulnerable groups, to access this timely intervention.

Diarrhoea. The most serious aspect of diarrhoea is the dehydration that usually accompanies the condition. Parents and healthcare workers' access to, and the knowledge of how to use oral dehydration therapy, have usually constrained the efficacy of this treatment. Generally, to reduce the burden of diarrhoea on human health, a number of measures are recommended for implemented at both household and national levels. At **household level**, both preventive and curative measures are used. The preventive measures include: (i) boiling drinking water, (ii) filtration and chlorination of drinking water, and (iii) improvement in personal hygiene, whereas the curative measures include the use of: (i) oral rehydration salts, (ii) home made sugar and salt solution, and (iii) cereal based solutions, such as rice water. At national level, both preventive and curative measures are also used. The preventive measures include: (i) public awareness on hygiene and sanitation, (ii) provision of potable water sources, (iii) provision of subsidized chlorination tablets, (v) improvements in garbage and waste collection and disposal in urban centres, and (v) immediate burial of cholera victims, whereas the curative measures include: (i) oral rehydration salts, (ii) intravenous fluids, (iii) antibiotic treatment, and (iv) isolation wards in case of diarrhoeal disease outbreaks. However, these measures are not 100% effective. For example, the provision of potable water sources or points is not effective because not all the people have access to this resource. Hence, this cannot be assumed to be effective until the whole population access portable water. As such, it is proposed that Government should improve the provision of portable water to rural communities.

Malnutrition. Many households tend to adopt a low-risk and low-yield production pattern. On the other hand, it often pays much higher returns if one takes greater risks, which would allow the build-up of capital. In Malawi, risk avoidance is a typical behaviour, just as is the case with most people in unstable environments, where the frequency of natural disasters makes it difficult to invest in sustainable adaptation measures and longer-term planning strategies. Many households resort to reducing the number of meals per day in order to try to make the available food resources last longer (FEWS, 2002). This inadequate food intake, however, oftentimes results into malnutrition and make individuals succumb to various kinds of diseases. In particular, children are the most affected by malnutrition because they just want to maintain their body weights, but also need energy to grow. Specifically, some of the current adaptation measures include: (i) crop and diet diversification: through the cultivation of roots and tubers (cassava, sweet potatoes) and other drought tolerant crop cultivars, and (ii) winter cropping systems using small-scale irrigation technologies, such as treadle pumps, drip irrigation and stream diversion. The implementation of irrigation farming during the winter months will be enhanced through the implementation of the proposed Greenbelt Initiative (GBI), which aims at irrigating maize in a belt from Chitipa to Nsanje. This initiative has received international acclaim, and the Flemish Government has recently taken the lead by granting Malawi financial resources to commence the implementation of this initiative in the winter months of 2009.

Additional adaptation policies and measures. Most of the coping and adaptation measures presented above, focus on treatment measures other than prevention measures. However, even more important than treatment of human health problems arising from climate change, the prevention through adoption of climate-friendly industrial and farming techniques, as well as the practicing of hygiene and ensuring availability and use of safe water and sanitation, would offer lasting solutions to climate-induced health problems. Further, cross-cutting sectoral strategies would be worth targeting given their indirect effects on human health. These include: (i) improvement in socio-economic factors, such as improving food security and reducing poverty, (ii) improvements in the availability and access to clean portable water for drinking and sanitation purposes, and (iii) improved agricultural research and extension delivery services to increase agricultural productivity. Given the agrarian nature of Malawi's economy, any food supply constraints against a backdrop of adverse impacts of climate change, especially floods and droughts, will lead to greatly reduced crop production, hence hunger and malnutrition.

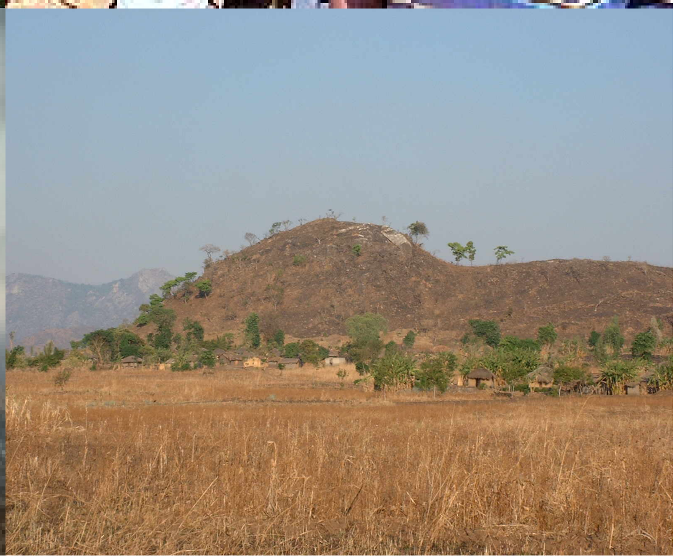
4.5 Summary

This Chapter has discussed in detail how the various sectors of economic growth, fragile agro-ecosystems and poor communities and vulnerable to climate change. Although Malawi is not a large emitter of greenhouse gases, as a nation that is dependent on rain-fed agriculture against a backdrop of increasing poverty, is highly vulnerable to the adverse impacts of climate change and climate variability. Hence, measures for adapting to climate change are urgently required in Malawi, especially in the wake of the increasing frequency and magnitude of floods and droughts over the last five decades.

Thus, adaptation measures and strategies have been proposed for implementation in all the sectors of economic growth: (i) Agriculture, (ii) Forestry and Other Land Use, (iii) Energy, (iv) Water Resources, (v) Fisheries, (vi) Wildlife, and .(vii) Human Health. Malawi needs to implement the proposed adaptation measures with the urgency that they deserve to ensure sustainable livelihoods for the majority of resource-poor family households.

Chapter 5
Programmes Containing Measures to Mitigate Climate Change



5.1 Background

Climate change is mainly caused by global warming, which results from human-induced greenhouse gas (GHG) emissions. Climate change negatively impacts on food security, water, fisheries, wildlife and forest sources; hydro-power generation, human health and sustainable livelihoods of family households. Based on the results of 2000 GHG Inventory (Chapter 3), the following sectors were identified as the major contributors to the observed GHG emissions in Malawi: (i) Agriculture, (ii) Forestry and Other Land-Use, (iii) Energy, (iv) Industrial Processes and Product Use, and (v) Waste Management. The challenge facing Malawi to day is how to reduce these GHG emissions from these important sectors of economic growth without compromising her development agenda as articulated in the Malawi Growth and Development Strategy (MGDS). Hence, concerted efforts are required to reduce the emissions of GHGs in these sectors through the use of appropriate, user-friendly and affordable mitigation measures and strategies or options, while at the same time increasing Malawi's mining and industrial manufacturing capacity. This chapter presents results of the identified mitigation options that should be implemented in Malawi to reduce GHG emissions without compromising Malawi's industrial development endevours.

5.1.1 Findings from the 1990 and 1994 GHG Inventories

Based on the GHG Inventories for 1990 and 1994, the main source category for carbon dioxide (CO_2) emissions were the Land-Use Change and Forestry Sector, followed by the Energy Sector, and distantly followed by the Agriculture Sector (Tables 5.1 and 5.2).

Table 5.1 Total greenhouse gas (GHG) emissions (Gg) for 1990

Greenhouse gas sources and sink categories	Greenhouse gas emissions and removals					
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_X	CO
Energy (Reference Approach)	619.13	0.00	276.23	0.72	27.12	895.95
Industrial Processes	50.12	0.00	4.02	0.00	0.00	0.00
Agriculture	0.00	0.00	50.83	0.36	1.58	30.78
Land Use Change and Forestry	21200.30	-1320.81	0.86	0.01	0.21	7.50
Waste Management	0.00	0.00	4.33	0.00	0.00	0.00
Total emissions and removals	21869.54	-1320.81	336.26	1.09	28.92	934.23

Source: EAD, 1999

Table 5.2: Total greenhouse gas (GHG) emissions (Gg) for 1994

Greenhouse gas source and sink categories	Greenhouse gas emissions and removals					
	CO_2 emissions	CO_2 removals	CH_4	NO_2	NO_x	CO
Energy (Reference Approach)	660.88	0.00	135.09	0.71	24.03	879.58
Industrial Processes	58.38	0.00	0.00	0.00	0.00	0.00
Agriculture	0.00	0.00	48.50	7.05	2.24	72.20
Land-Use Change and Forestry	18528.02	-1016.00	0.02	0.01	0.04	0.02
Waste Management	0.00	0.00	4.29	0.00	0.00	0.00
Total emissions and removals	19247.28	-1016.00	187.90	7.77	26.31	951.80

Source: EAD, 2003

Further, the inventories indicate that CO_2 contributed the largest amount of GHG emissions, followed by CH_4, whereas the sectors that emitted the most GHGs were: (i) Forestry and Land-Use Change, (ii) Energy, and (iii) Agriculture. The overall findings from these studies are that Malawi is a **net emitter of CO_2**. (Tables 5.1 and 5.2), a finding that was mostly attributed to the socio-economic development activities in agricultural production, deforestation and the conversion of prime forestry land into agricultural land. It is against this background that mitigation analyses reported in the Initial National Communication (INC) of Malawi were conducted in the following five sectors: (i) Energy, (ii) Industrial Processes, (iii) Agriculture, (iv) Land Use Change and Forestry, and (v) Waste management (Tables 5.1 and 5.2). .

5.1.2 Findings from the 2000 GHG Inventory

Total GHGs emitted by different sectors of economic from 1995-2000 are given in Table 3.1 (Chapter 3). For the year 2000, a total of 23,294.502 Gg of CO_2 equivalent were emitted from the following sectors: (i) Energy, (ii) Industrial Processes and Other Product Use (IPPU), (iii) Agriculture, Forestry and Other Land-Use (AFOLU), and (iv) Waste Management. The relative sectoral contributions were in the order: (i) Agriculture, Forestry and Other Land-Use Sector (22,033.952 Gg), (ii) Energy Sector (871.5 Gg), (iii) Waste Management (332.97 Gg), and (iv) Industrial Processes and Product Use (56.08 Gg). The 2000 GHG Inventory follows a similar trend to the 1990 and 1994 GHG Inventories, so that Malawi remains a **net emitter** of CO_2, with the main contributors as the Agriculture, Forestry and Other Land-Use Sectors. Although GHG emissions from the Energy and Industrial Processes and Product Use Sectors are smaller, the opening up of limestone processing plants in Balaka district, cement manufacturing in Kasungu and Mangochi districts, and uranium mining at Kayerekera in Karonga district, and the prospects of opening a bauxite mine on Mount Mulanje, will significantly increase GHG emissions in these sectors over the coming ten years. Thus, these findings provided sufficient information for the identification of sectors which should be targeted for the reduction of GHGs. Thus, mitigation options for reducing GHGs were developed and evaluated for the following five sectors: (i) Energy, (ii) Industrial Processes and Product Use (IPPU), (iii) Forestry and Other Land-Use, (iv) Agriculture, and (v) Waste Management. However, when reporting the final GHG Inventory results, the Agriculture and Forestry and Other Land-Use sectors are combined into one sector: Agriculture, Forestry and Other Land-Use.

5.2 Energy Sector

Malawi is endowed with abundant energy resources: (i) biomass, (ii) coal, (ii) perennial rivers for hydro-power generation, (iii) solar energy for heat and the generation of electricity, (iv) wind energy for water pumping and other minor applications, (v) hot springs for geothermal power generation, and (vi) uranium deposits for nuclear power generation, whereas all petroleum products are exclusively imported into the country (MEP, 2002). The Department of Energy Affairs (DoEA) categorizes these energy resources into five sub-sectors: (i) biomass (firewood, charcoal, crop and industrial residues), (ii) electricity (hydro and thermal), (iii) liquid fuel and gas (petrol, diesel, paraffin, ethanol, gel-fuel, avgas, JetA1, liquid petroleum gas (LPG), (iv) coal and peat, and (v) other renewable energy resources (solar, wind, biogas, mini and micro-hydros).

However, Malawi's main source of energy is biomass, accounting for 93% of total energy used, and forests are the major source of this bio-energy. Petroleum products account for 3.5%, hydro-electricity constitutes 2.3%, whereas coal accounts for 1.0% of the total energy consumed. The remaining 0.2% comes from renewable energy sources (REIAMA, 2006; MEP, 2006). Thus, Malawi’s energy balance is dominated by biomass, and the bulk of this biomass is used in its primary form as firewood (52%) residues (7%) and the remaining 41% is converted into charcoal. It is the use of biomass that accounts for the bulk of the GHG emissions. To reduce the emissions of these GHGs, some renewable energy technologies (RETs) have been introduced into the country, which include: (i) solar home systems, (ii) biogas, (iii) wind energy systems, and (iv) min- or micro-hydro systems. Solar home systems, especially photovoltaic systems, dominate the RET industry. However, the uptake and adoption of these is dismally low, which is largely attributed to the relatively high initial costs, the absence of appropriate institutional delivery mechanisms and a poor track record on the maintenance of these. Presently, there is a large number of RETs systems that are not operating due to lack of maintenance and back-up activities (MEP, 2002). On the other hand, the cost of conventional energy sources, such as petroleum products, grid electricity connection and coal, is unaffordable by the majority of Malawians who are resource-poor. It is because of these constraints that make most people totally depend on fuel-wood, which is relatively easier to obtain from various sources, but then is the biomass that significantly contribute to the enhanced GHG emissions that are responsible for global warming.

5.2.1 Methodology

The mitigation options were assessed using the Long-Range Energy Alternatives Planning (LEAP) Model. The assessments were based on the potential impacts of GHG emissions on various sectors of economic growth, cost benefit ratio (direct and indirect), consistency with national environmental goals and objectives, ease of implementation, long-term sustainability, consistency with national development goals, and the availability of data for the evaluation of the identified mitigation option..

Description of the LEAP Model. Briefly, the LEAP Model is a bottom-up scenario-based energy-environment modeling tool, which is based on a comprehensive accounting of how energy is consumed, converted and produced in a given region, or economic sector, under a range of alternative assumptions on the population, economic development, technology and price levels, among many other factors. With its flexible data structures, LEAP allows for the analysis of technological specifications and end-use details as the user chooses, and one can go beyond simple accounting, such as building simulations and assembling data bases. However, unlike macro-economic models, the LEAP Model does not attempt to estimate the impact of energy policies on employment or Growth Domestic Product (GDP). Similarly, it

does not automatically generate optimum or market-equilibrium scenarios, although it can be used to identify least-cost scenarios. The advantage of the LEAP Model is its flexibility and ease-of-use, which allows moving rapidly from policy ideas to policy analysis without having to resort to more complex models and calculations.

Further, the LEAP Model serves several purposes, including (i) providing a comprehensive data base system for maintaining energy and environment information, (ii) forecasting or projecting future energy supply and demand, as well as GHG emissions over a long-term planning horizon, and (iii) examining a wide range of projects, programs, technologies, and strategies that best address environmental and energy problems. Most of the energy end-use devices, such as feedstock fuels, auxiliary fuels and output fuels are potential sources of environmental loadings. The environmental loadings for a given technology are specified by creating a link to one of the library of technologies known as the Technology and Environmental Database (TED). TED contains emission factors for hundreds of energy consuming and energy producing technologies, including default emission factors proposed by the Inter-governmental Panel on Climate Change (IPCC) for use in climate change mitigation analyses. The default emission factors in TED are all direct emission factors, and not lifecycle. Since the LEAP Model is a bottom-up energy and environment modeling tool, it requires a lot of activity input data, which are unfortunately not readily available for local Malawi conditions, and greatly constrained the model evaluation and verification processes. However, where such local emission factors were not available, default values were used.

Baseline scenarios and mitigation options: Mitigation assessments must take into account the importance of the assumptions and scenario definitions as recommended by the United Nations Framework Convention on Climate Change (UNFCCC). The mitigation assessments in this study considered two scenarios: (i) the baseline scenario, and (ii) the mitigation scenario. The baseline scenario, also known as the reference scenario, depicts the future emission trends in which there are no policies or measures put in place designed to reduce greenhouse gas (GHG) emissions. The mitigation scenario reflects a future in which policies and measures are adapted to reduce GHG sources, or enhance GHG sinks. According to UNFCCC, a mitigation scenario should not simply reflect the current plan, but should also assess what would be hypothetically achieved based on the goals of the scenario.

Assessment criteria: Within the context of UNFCCC, a mitigation assessment is a national-level analysis of the various technologies and practices that have the capacity to reduce GHG emissions. Within the Energy Sector, there are a number of GHG emitting sources, which can be potentially analyzed and mitigated upon. However, in this study, each option was selected based on the important characteristics that included: (i) potential for large impact on GHG emissions, (ii) cost-benefit-ratio (direct and indirect), (iii) consistency with national environment goals, (iv) ease of implementation, (v) long-term sustainability, (vi) consistency with national development goals, and (vii) data availability for model verification and evaluation.

Mitigation options: Several mitigation options were identified, and categorized into policy and technology based options. The technologies with the highest potential were selected using expert judgment for more detailed analysis and evaluation. Basically, technological potential mitigation options used were based on switching from a high carbon content fuels to low carbon content (or no carbon at all) ones, and adopting those technologies that have higher energy conversion efficiencies. The selected mitigation options included: (i) cooking using grid electricity, (ii) efficient lighting technologies, (iii) efficient firewood cooking stoves, (iv) increasing the efficiency in ESCOM's capacity and energy balances, (v) increasing the ethanol to petrol blending ratio, and (vi) switching from paraffin (kerosene) lamps to PV lamps. The **use of grid electricity for cooking** involves improving access to affordable and modern energy sources. This can be done through: (i) rural electrification (to reach at least 30% in 2020) at an annual electrification rate of 7% (UN, 2005), (iii) reduction in biomass use (from 93% in 2000 to 75% in 2010 and 50% in 2020), and (iii) increasing publicity campaigns on the value of switching from firewood to grid electricity in rural and peri-urban areas.

The use of **efficient lighting technologies (e.g., switching from paraffin (kerosene) to PV lamps** includes the following strategies (i) reducing the use of paraffin (kerosene) lamps for lighting by 50% (both in rural and urban households), (ii) increasing the use of PV solar systems for lighting by 5%, (ii) encouraging all electrified households to use electricity for lighting and cooking. The **efficient use of firewood cooking stoves** mitigation option involves the use of technologies that promote the use of Clay and Rocket firewood stoves instead of the 3-stone open fire cooking stoves that is currently used by most family households. This involves engaging Non-Governmental Organizations (NGOs), Community Based Organizations (CBOs) and other private sector entrepreneurs to produce and expand the marketing of the Clay and Rocket firewood stoves. **Increasing the efficiency of ESCOM's capacity and energy balances** mitigation option can be done by: (i) reducing load shedding (when peak capacity exceeds peak load), (ii) pursuing the electricity import strategy through the interconnection and the development of new power generating plants, (iii) introducing gas-turbine at peak hours, and (iv) rehabilitating the Kapichira II and Tedzani I and II hydro-power generating stations

The **promotion of efficient demand side management** mitigation option can be done through: (i) increasing customer connections by 1,000 per year, (ii) promoting the use of the 3-high efficiency compact fluorescent lamps, (iii) introducing a time-of–use tariff approach as an incentive for medium and low voltage industrial customers, and (iv) increasing the use of prepaid meter connections. Finally, **increasing the ethanol to petrol blending ratios option** can be done by simply increasing the ethanol to petrol blending ratio to 20% ethanol and 80% petrol. This would further require increasing public awareness and engaging the transport sector on the advantages of utilizing this type of fuel.

Running the LEAP Model: All these technology options were assessed and evaluated using the LEAP Model by clearly stating the baseline scenario and mitigation option. The activity data for the base year 2000 are known as current account data. The end year of the mitigation analysis was 2040, which is a timeframe that within the range of 30-40 years as recommended by UNFCCC.

5.2.2 Results and Findings

The results and findings are presented for each mitigation option as follows: (i) cooking using grid electricity, (ii) increasing efficiency in ESCOM's capacity and energy balances, (iii) efficient use of firewood cooking stoves, (iv) efficient use of lighting technologies, and (v) increasing the ethanol to petrol blending ratio.

Cooking using grid electricity: The Malawi Government (MG), through the Department of Energy Affairs (DoEA), has initiated a public awareness campaign to sensitize Malawians on the benefits of switching from firewood to grid electricity for cooking, with the aim of reducing GHG emissions from the use of biomass energy. It is expected that by the year 2040, 50% (up from 2.1% in 2000) of the households will be using grid electricity for cooking, and that this switch will be at the expense of reducing firewood and charcoal for cooking and heating. The results of analysis for the baseline scenario and the mitigation option are compared in Fig 5.1. In 2000, the GHG emissions resulting from urban household cooking was 37.7 Gg (CO_2 equivalent). In 2040, the baseline scenario shows that 226 Gg of GHG will be emitted, whereas the mitigation scenario will emit 169 Gg, which indicates that the use of grid electricity will result in a GHG emission reduction of 57 Gg (CO_2 equivalent).

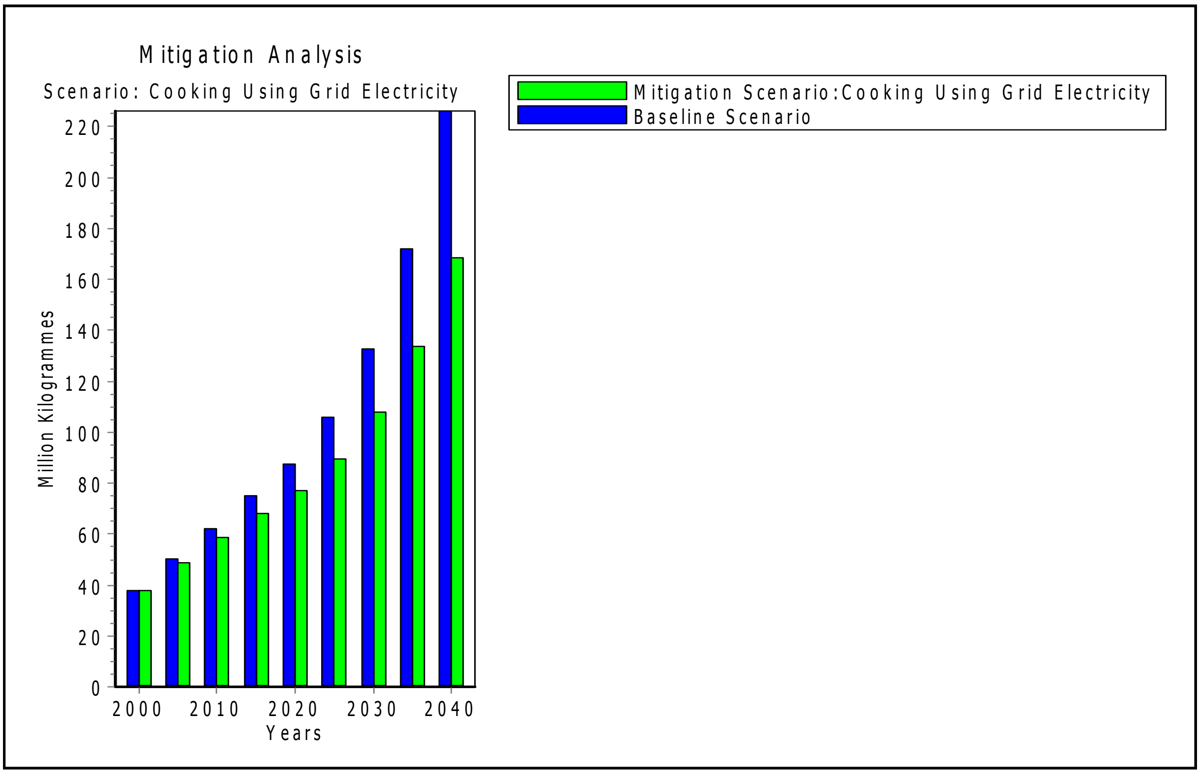


Fig 5.1: A comparison of GHG emissions between the baseline scenario and cooking with grid electricity

Increasing the efficiency of ESCOM's capacity and energy balances: Expanding electricity connections, and reducing load shading and outages, will result into all day electricity availability to all family households and the industrial sector, which will lead to reduced dependence on wood-fuel. This will correspondingly reduce GHG emissions over time as depicted in Table 5.3.

Table 5.3: Demand side management (DSM) of national electricity in Malawi

Capacity balance (MW)	2008	2009	2010	2011	2012	2013	2014	2015
Real capacity	283	303	303	343	373	397	397	517
Net peak load	286	302	323	346	364	387	410	435
Reserve margin	26	28	28	32	30	32	32	44
Difference	(28)	(27)	(48)	(35)	(21)	(22)	(46)	(38)
Additional connections	16,000	17000	18000	19000	20000	21000	22000	23000
Step loads (MW)	5	10	15	20	25	30	35	40
DSM 1: CFL program	0	6	10	12	14	15	17	18
DSM 2: Time-of-use tariffs	0	3	5	7	10	10	10	10

Use of efficient firewood cooking stoves: Cooking using firewood at household level is mostly done on a three-stone open fire cooking system, whose efficiency is around 10% (MEP, 2002). Efficient cooking stoves, such as the Clay and Rocket firewood stoves are being promoted with the aim of conserving energy and forests by reducing the amount of firewood required for cooking the same amount of food, thus contributing to GHG reductions in the atmosphere. According to ProBEC (2007), some 3,481 Rocket firewood stoves, with an average capacity of 100 litres, are being used in schools under the Malawi

School Feeding Programme. The data on the use of Clay stoves are scanty, but there are presently about 89 CBO groups that produce Clay stoves. Each producer group has some 10 to 20 members who have been trained by ProBEC in conjunction with the DoEA. Presently, ProBEC is on a publicity campaign to encourage CBOs to aggressively promote the use of Clay and Rocket firewood stoves, so that by 2040, some 10% and 5% of the urban and rural households, respectively, shall be able to use these efficient stoves. Malawi's energy mix projections indicate that by the year 2010, biomass will contribute 75%, which will be reduced to 50% by the year 2020 (DoEA, 2002). Thus, based on the combined effort of switching from three-stone open fire stoves to efficient firewood cooking stoves, a target of 40% of households using efficient firewood stoves by the year 2040 will be achieved.

The baseline scenario and mitigation option are compared in Fig 5.2, which shows that the total baseline GHG emissions emanating from households in 2000 was about 770 Gg. However, the baseline scenario indicates that by the year 2040, 2190 Gg of GHGs will be emitted, whereas under the mitigation option some 1450 Gg will be emitted, a reduction of 740 Gg. Thus, by switching from the three-stone open fire cooking system to the energy efficient firewood stoves would result in a reduction of 740 Gg (CO_2 equivalent).

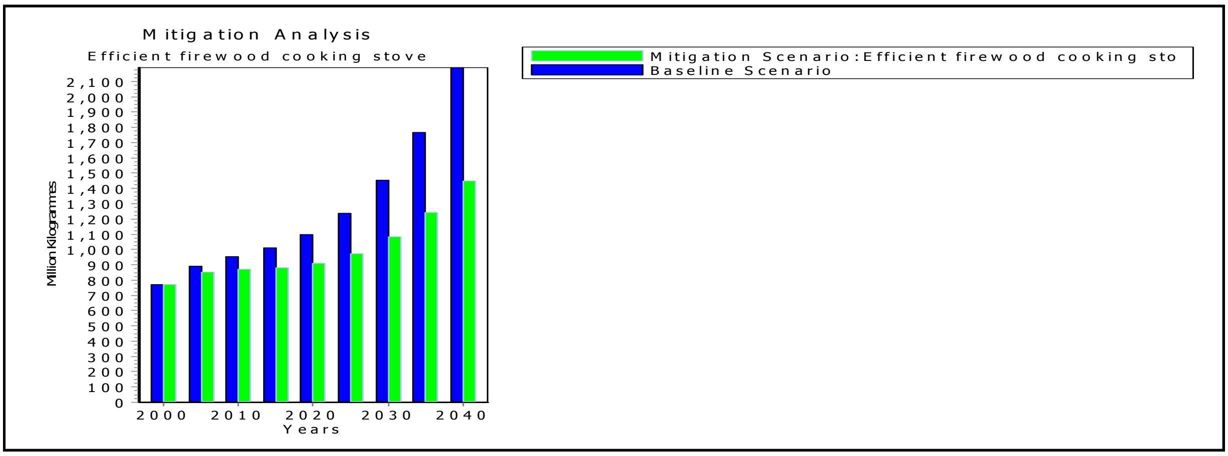


Fig 5.2: A comparison of GHG emissions between the baseline scenario and efficient firewood stoves

Use of efficient lighting technologies: The majority of rural households in Malawi use paraffin (kerosene) lamps for lighting. On average, each rural household uses 1 litre of paraffin per month for lighting, whereas urban households use about 1.5 litres per month. However, it is now strongly recommended that family households should switch from the use of paraffin lamps to solar PV and grid electricity lighting. However, this switch can only be done if the alternatives to firewood are accessible at affordable prices to the majority of the people in the country, which is not the case. Thus, in 2000, the renewable energy sources accounted for only 0.2 % of the energy mix. In 2005, solar PV for lighting accounted for 37.4% of the total renewable energy sources (Milner, 2005), and only 4% of the households were electrified in 2000. It is assumed that 90% of the non-electrified urban households used paraffin, compared with 10% of rural households that used paraffin. On the other hand, rural households used 1.0% PV solar for lighting, whereas only 0.5% of the urban households used PV solar lighting, with the remainder of the people using biomass energy for lighting. However, Government would like to increase the renewable energy contribution to the energy mix from 0.2% in 2000 to 5.5% in 2010, 7.7% in 2020, and 10% in

2050 (DoEA, 2002). Presently, it is assumed that PV solar will increase by the same proportion and that by 2040; solar PV lighting will increase by 10%. The electrification rate per year is estimated to increase at the rate 7% and 1% for urban and rural households, respectively (UNDP, 2005). Further, it is assumed that a typical household in Malawi uses 50 Watts electric bulbs for lighting, which have an average energy intensity of 110 kW-hr per year, which is assumed to decrease by 1% due to technological advancement. In this study, a mitigation target was set in such a way that by the year 2040, the use of paraffin lamps for lighting would be reduced by 50% (both in rural and urban households) and that 50% of the people would use PV solar for lighting and that all electrified households would use electricity only for lighting. The results of the baseline scenario and the mitigation option are compared in Fig 5.3.

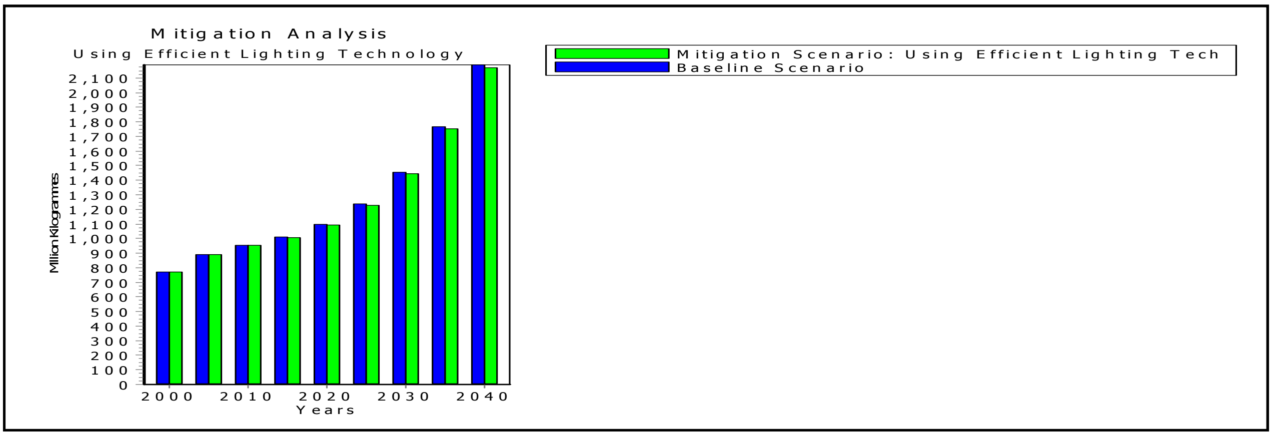


Fig 5.3: A comparison of emissions between the baseline and efficient lighting technologies

The total baseline scenario GHG emissions emanating from family households in 2000 was 770 Gg. However, the baseline scenario indicates that in 2040, 2190 Gg will be emitted, whereas the mitigation option will emit 2170 Gg. Thus, in 2040, the use of efficient lighting technologies will reduce GHG emissions by 20 Gg. .

Increasing ethanol to petrol blending ratio. One of the main objectives of Malawi's National Strategy for Sustainable Development (NSSD), which was developed in response to the World Summit on Sustainable Development (WSSD) that was held in Johannesburg in 2002, is to reduce petroleum imports and conserve the environment by blending petrol with ethanol. Currently, the blend ratio is 90% petrol to 10% ethanol (MEP, 2002), which needs to be reduced as the number of cars is increasing on the roads of Malawi. Presently, Malawi's transport infrastructure includes about 14 594 km of roads, 810 km of railway track, 4 major lake harbours and 4 commercial airports. About 47,000 cars (50% of the registered vehicles) are petrol-engine propelled, whereas the average passenger-km per person is 250 (RTD, 2007). It is assumed that on average, each passenger car carries 4 people, with an average fuel consumption of 12 km per litre, and that the number of passenger cars is growing at the rate of 3% per year. This means that a lot of petrol is imported and used in the country, which contributes greatly to GHG emissions, as reported in Chapter 3. Thus, any effort geared at reducing petroleum products is a welcome initiative. Hence, Government is currently planning to increase the amount of ethanol in the current petrol to ethanol blend ratio of 90:10 to 80:20 (MEP, 2002). If this plan materializes, then by the year 2040, 50% of the passenger cars will be using blended fuel of the new formulation (80% petrol: 20% ethanol).

Fig 5.4 compares GHG emissions between the baseline scenario and the mitigation option where the ethanol ratio is increased. In 2000, the baseline scenario shows that 100 Gg was emitted and this increased to 660 Gg in 2040. However, the mitigation option indicates that 570 Gg of GHG emissions were emitted in 2000, which was reduced to 480 Gg in 2040, as reduction of 80 Gg.

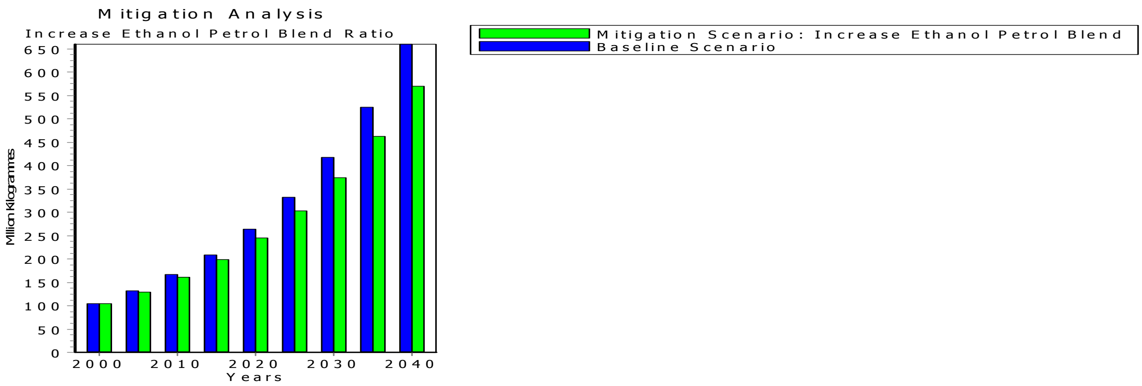


Fig 5.4: A comparison of GHG emissions between the baseline scenario and the petrol: ethanol blend ratio option

Implementation of the mitigation options: Thus, it is incumbent upon public and private sector organizations, including rural communities, to implement renewable energy technologies to reduce GHGs emissions arising from the Energy Sector, especially from the increasing number of cars on Malawi roads. This can conveniently be done by: (i) aggressively promoting the use of efficient cooking stoves instead of the traditional three-stone open fire cooking system, (ii) enhancing Government-NGO-CBO partnerships to create public awareness on the availability of efficient Clay and Rocket cooking stoves, (iii) promoting the use of solar and energy efficient technologies in public and private sector organizations, (iv) enforcing vehicle emission standards, (v) managing transport and demand side management, and (vi) promoting and introducing demand side management measures by ESCOM, including time-of–day tariffs and efficient lighting systems, and (vii) undertaking research into the value and safety of higher ethanol-petrol blends, and engaging the transport and motor industry in the development of these.

5.2.3 Summary

The Malawi energy mix is heavily dominated by biomass. Some 96% of the biomass come from firewood and charcoal, which are primarily used for cooking and heating by the majority of family households. Based on the four mitigation options which were identified and evaluated using the LEAP Model, the use of cooking stoves is more efficient than the traditional three-stone open fire cooking system. The reductions in GHGs can be achieved by implementing all the identified mitigation options. Further there is need for capacity building and training, and research to determine activity data for use in the models. Thus, it is recommended that during the preparation of future national communications, Malawi should: (i) mobilize human and financial resources for collecting the relevant energy data, (ii) enhance the capability of the local experts in the use of the LEAP Model through on-the-job or short course training, (iii) implement the proposed mitigation options to realize the projected emission reduction potentials, and (iv) consider and evaluate other mitigation options, including: (a) building a code of conduct for the commercial sector, such as mandatory introduction of solar home systems, (b) imposing energy efficiency standards on a wider range of equipments on the procurement of new equipment (such as variable speed diversity of equipment, drives, motors, compressors, HVAC systems) to increase industrial efficiency, (c) labeling and mandatory energy performance standards, and (d) enforcing vehicle emission standards, transport management, and demand side management.

5.3 Industrial Processes and Product Use Sector

The Industrial Processes and Product Use (IPPU) Sector was not included in the Initial National Communication (NC) of Malawi, yet its associated emissions are very important and significant in warming the atmosphere. Globally, industrial emissions accounted for 43% of carbon (C) released in 1995 (IPCC, 2007). CO_2 emissions in this sector grew at a rate of 1.5% per year between 1971 and 1995, slowing to 0.4% per year from 1990. Globally, 50% of the energy used in industries is from iron, steel, cement, pulp, paper and chemical manufacturing, and the refining of petroleum products (IPCC, 2007). In Malawi, most of the industrial GHGs are due to cement, lime, ethanol, beverage, and fertilizer production, beside bio-digesters, and the paint, and wood industries (Muyila, 2007).

For example, the total CO_2 emissions from various industries for the years 1993-2004 for Malawi were estimated as depicted in Table 5.4 (Muyila, 2007). It is due to these significant emissions that the Industrial Processes and Product use Sector was included for an in-depth analysis of mitigation options in the Second National Communication (SNC) of Malawi document. The identified mitigation options for reducing GHGs include: (i) industries that use carbon capture and storage, (ii) technologies that blend cement with rice husks, (iii) industries that use CO_2 as a raw material, and (iv) the Solvay process for adding value to lime.

The effective removal of barriers is expected to significantly contribute to the increased technology adoption, hence greater reductions in industrial GHG by up to 40% by 2040. Worldwide, governments are encouraged to work through five types of instruments for shaping the environmental behavior of industry. These include (Evans and Stevenson, 2000): (i) regulation (issue of a permit to a firm to operate to depend on meeting environmental standards, and failure to do so incurs financial or criminal penalties); (ii) voluntary programmes (regulators are engaged in an interactive dialogue with firms with an emphasis on sharing and disseminating information and expertise); (iii) market-based instruments (administration of taxes, tariffs, subsidies and other such methods to shift the financial calculations of firms toward environmentally beneficial decisions); (iv) transparency (public awareness of the dangers of pollutants plus ready access to the required reporting by firms on their discharges), and (v) information and education (public education that creates awareness of the risks to human health from pollutants).

Table 5.4: Greenhouse gas (GHG) emissions from the IPPU Sector, 1993-2004

Year	Industrial CO_2 (Gg)				
	Lime	Cement	Molasses	Ethanol	Total
1993	10.354		13.26	10.354	34.0
1994	10.71	60.9	14.07	10.710	96.4
1995	9.915	59.0	12.92	9.915	91.8
1996	10.352	46.5	15.1	10.352	82.3
1997	11.65	37.4	12.21	11.650	72.9
1998	8.96	47.3	12.59	8.960	77.8
1999	9.208	55.7	13.06	9.208	87.2
2000	8.99	56.1	-	8.990	74.1
2001	-	55.6	-	-	55.6
2002	-	54.5	-	-	54.5
2003	-	80.3	-	-	80.3
2004	-	59.6	-	-	59.6

Source: EAD, 2007

5.3.1 Methodology

The APINA Model (Draft Version 4) was used to assess and evaluate different mitigation options in the Industrial Processes and Product Use Sector. The analysis and evaluation involved comparing model outputs from the baseline scenario (business as usual) with the proposed mitigation options. Aimed at reducing GHG emissions

Model description: The APINA Model is fully described elsewhere (Anon., 1995). In brie, the model uses Equation 5.1 to evaluate the proposed mitigation options.

Quantity of GHG Emission = [Process Output] x [Emission Factor] ……………………… [1]

The model input data were obtained from different industrial processing and agro-processing companies in Malawi (Muyila, 2007), whereas the emission factors were obtained from the IPCC Guidelines (IPCC, 2006). These emission factors are tabulated in Table 5.5.

Table 5.5: Emission factors used in Industrial Processes and Product Use Sector

Sources	Process responsible	Emission factor (ton CO_2/ton Product)
Cement production	Clinker production/ calcinations	0.4985
Lime production	Lime (quick-lime) production	0.507
Ethanol production	Fermentation of molasses	0.28

Source: EAD, 2007

Mitigation options. The proposed mitigation options reducing GHG emissions were categorized into: (i) industrial options, (ii) technical options, and (iii) other options. The **industrial options for reducing GHG emissions** include: (i) provision of regulation: permits to firms to operate depending on meeting environmental standards, so that failure to do so, results into financial or criminal penalties; (ii) voluntary engagement of programme regulators with firms so as to share and disseminate information and expertise interactively; (iii) use of market-based instruments, such as the administration of taxes, tariffs and subsidies so as to shift the financial calculations of firms toward environmentally beneficial decisions; (iv) transparency: in public awareness campaigns on the dangers of pollutants and the reporting by firms of the pollutant discharges from their firms, and (v) information, education and public awareness campaigns on the risks of pollutants on human health and the environment. The main **technical options** include the promotion of: (i) industries that use carbon capture and storage, (ii) technologies that blend cement with rice husks, (iii) industries that use CO_2 as a raw material, and (iv) industries that add value to lime via the Solvay process

The **use carbon capture and storage (CCS)** is an approach that is used to reduce (or mitigate) global warming by capturing CO_2 from large point sources, such as fossil fuel power plants and storing this, instead of releasing it into the atmosphere. The technology for large scale capture of CO_2 is already commercially available and fairly well developed. This is premised on the following assumptions: (i) CO_2 may be recovered from the calcination (lime and cement production) and fermentation (ethanol production) processes by incorporating absorption plants, gas scrubbers, dehydration drums and other unit operations, (ii) CO_2 from fermentation is usually purer (>98%) than that from the calcination process (Shreve, 1977), so that CO_2 capture directly reduce the amount of CO_2 emitted from industrial processes, and (iii) costs of C capture and storage are higher because they require energy to separate and purify CO_2 from the gases. Studies carried out for CCS from power plants indicate that some US$ 15.00/ton CO_2, US$ 53.00/ton CO_2, US$ 41.00/ton CO_2 and US$ 23.00/ton CO_2 are net costs of capture for the hydrogen, PC, NGCC, and IGCC processes, respectively. The mean of these costs (US$ 33.00/ton CO_2) has been used for computations in this report.

Rice milling generates a by-product know as rice husk. This **rice husk can be blended with cement** to form an equally good cement product (Allen, 2005). During the milling of paddy, about 78% of its weight is received as rice, broken rice and bran .The remaining 22% is received as husk. This husk can be used as fuel in the rice mills to generate steam for the parboiling process. The husk contains 75% organic volatile matter with the remaining 25% as rice husk ash (RHA). This RHA contains about 85-90% amorphous silica, which can be blended with cement to produce a product that can be made into a good cement product. The assessments using the APINA Model workbook showed that a benefit of US$ 14.7/ton CO_2 can be achieved by blending 40% cement with 30% RHA. Another important mitigation option is the **use of CO_2 as a raw material** in industrial processes as an alternative approach of reducing GHG emissions. This mitigation option is applicable to such processes as: (i) carbonated beverage production, (ii) the manufacturing of fire extinguishers, and (iii(the production of methanol and salicylic acid. By creating demand for CO_2, other industries are encouraged to apply CCS in their operations.

Lime production has been identified as one of the three industries that are leading in the emissions of GHGs in the country. However, the **value addition of lime via the Solvay process** uses CO_2 to produce soda ash (sodium carbonate), thereby reducing CO_2 emissions. In addition, the by-product produced during the process is calcium chloride ($CaCl_2$), which is a solid, unlike in the calcination process where the by-product is CO_2. Further, $CaCl_2$ is used in many other activities, such as food processing and road maintenance. Studies by Shreve (1977) and Wesnæs and Weidema (2006) have shown a benefit of US$ 9.5/ton as a result of a reduction in CO_2 arising from the Solvay process in cement production. Finally, there are other options that can be used to reduce GHG emissions in the processing and manufacturing industries. However, since it is difficult to quantitatively measure their contribution to the GHG emissions, these have been analyzed qualitatively. These options include: (i) research and extension activities that demonstrate new technologies and processes that reduce or avoid GHG emissions, (ii) tax incentives for the use of energy efficient appliances and fuel switching to reduce GHG emissions, (iii) emission and efficiency standards that would discourage the use of non-efficient equipment and processes, (iv) voluntary agreements among industries to use technologies that are GHG emission-free, and (v) process modification in the manufacturing industries to be done periodically.

Baseline scenario. The baseline scenario is the "business as usual" option. Under the baseline scenario, the GHG emissions are predicted by a trend from past data with a discount rate of 5%. In this study, only technical options were used in the evaluations.

5.3.2 Results and Findings

The results and findings are presented by mitigation option as follows: (i) promoting industries that use carbon capture and storage techniques, (ii) promoting technologies that blend cement with rice husks, (iii) promoting industries that use CO_2 as a raw material, and (iv) value addition of lime via the Solvay process. The analyses of the capacity and cost of the four mitigation options, using an annual discount rate of 5%, and an annual industrial growth rate of 0.5%, are presented in Table 5.6.

Promoting industries that use carbon capture and storage: The carbon capture and storage mitigation option directly reduces the amount of CO_2 emitted from industrial processes by 23.7 Gg per year (Table 5.6). This is a cost-intensive technology that uses up a lot of energy to separate and purify CO_2 from flue gases, estimated at US$ 33.00/ton CO_2 reduction (Table 5.6). The total cost of the mitigation option by 2040 is pegged at US $ 758.4.

Table 5.6: Cost and capacity of mitigation options in the IPPU Sector

Option	Cost/ton CO_2 reduced	Average annual CO_2 reduction (Gg/year)	Total mitigation cost by 2040	Total cost by 2040
Carbon capture and storage	33	23.7	105600	758.4
Rice husk cement production	-14.7	4.8	-470400	153.6
Processes using C as raw material	N/a	N/a	-	-
Solvay processing of lime	-9.5	0.7	-304000	22.4
Total	8.8	29.2		934.4

Promoting technologies that blend cement with rice husks: Rice husk ash (RHA), which contains around 85-90% amorphous silica, can be blended with Portland cement to produce an alternative high quality cement product. A benefit of \$14.7/ton CO_2 is achieved by blending 40% of current cement production with 30% w/w rice husk ash. About 4.8 Gg CO_2 per year is reduced (Table 5.8).

Promoting industries that use CO_2 as a raw material: Promoting and encouraging processes that use CO_2 as a raw material constitutes an alternative approach to reducing GHG emissions. The development of chemical and pharmaceutical industries that use CO_2 as reagents would literally create new C sinks. Once established, such industries would catalyze the development of more extensive manufacturing enterprises, and be used to synthesize health products, such as anti-malarial agents. Malawi Carlsberg Brewery and the Coca Coal Company would play a leading role in the use of this mitigation option. However, owing to lack of data, no simulation runs could be done in this study.

Promoting technologies that blend cement with rice husks: Lime production is one of the three industries that emit a lot of GHG by Malawi standards. Value addition of lime by the Solvay process to produce soda ash reduces CO_2 emissions into the atmosphere at the rate 0.7 Gg/year. This is because the oxide is used up in the calcinations process. A net benefit of US \$9.5/ton due to reduced CO_2 can be realized by incorporating the Solvay process in cement production (Table 5.6).

Implementation of mitigation options: Government and private sector organizations need to put in place mechanisms that ensure the uptake and adoption of the mitigation options, including compliance with current legislation. Some of the strategies that can be used to do this include: (i) providing incentives to make it easier to acquire the necessary machinery, (ii) enhancing the capacity of City and Town Assemblies in using the different mitigation options, (iii) increasing public awareness campaigns on the use of the various mitigation options, (iv) creating an enabling environment that allows free participation of all stakeholders in the application of the available mitigation options, (v) promoting effective information and technology transfer mechanisms for the recommended mitigation options, (vi) enhancing human capacity development and training, and (vii) promoting participatory extension approaches to enhance technology uptake and utilization.

Barriers to the adoption of mitigation options: There are several barriers or factors that constrain mitigation technology adoption, including: (i) inadequate capital, (ii) lack of operational funds, (iii) non-availability of information, and (iv) poor networking among stakeholders. All these affect the diffusion process of the mitigation option technologies.

Further, these problems are exacerbated by other constraints, such as: (i) slow decision-making processes inherent in organizations, especially when the mitigation option may be perceived to be of low priority or is expensive, (ii) lack of technical information on the performance of the technology, (iii) lack of skilled and trained manpower, and (v) difficulty in demonstrating energy efficiency, quantifying the impacts, non-inclusion of external costs, and slow diffusion of innovative technologies into markets.

5.3.3 Summary

Industrial processes and manufacturing are responsible for large quantities of GHG emissions, contributing some 43% of global CO_2 released in 1995. In Malawi, most industrial GHGs are due to cement and lime production. The mitigation options identified for reducing GHGs in the sector are: (i) carbon capture and storage, (ii) cement blending with rice husks, (iii) use of CO_2 as a raw material, and (iv) value addition of lime via the Solvay process. However, the utilization of these mitigation options will depend on the effective removal of barriers that constrain the adoption of the mitigation option technologies.

5.4 Agriculture Sector

At a global level, agriculture contributes 20% of the total anthropogenic GHGs emissions, 50% of CH_4 emissions from enteric formation and paddy rice cultivation, and 70% of N_2O emissions from artificial fertilizer applications. At regional level, Malawi has the least emissions of GHGs compared with the neighbouring countries of Tanzania, South Africa and Zimbabwe (Table 5.7).

Table 5.7: Agricultural greenhouse gas (GHG) emissions in the southern Africa region

Country	GHG emissions (Gg)
Malawi	3,750.00
Tanzania	33,284.00
South Africa	21,683.00
Zimbabwe	5,876.00
Global	36,300,000.00

Source: CEEST, 1999.

At a national level, agriculture contributes 26% of the total CH_4, 91% of the total N_2O, 9% of the total NOx, and 8% of the total CO emissions, so that as a whole, the sector contributes some 12.4% of the total CO_2 equivalent of the GHGs (Figs 5.8 and 5.9). The total CO_2 emissions were 60.22 Gg in 2000, which is about half for that of 1990.

Livestock was responsible for 31.64 Gg of the CH_4 emissions in 2000; enteric fermentation and manure management accounted for 94.7% and 5.3%, respectively. Enteric fermentation from livestock was responsible for 94.7 Gg of the CH_4 emissions, but the contribution from manure management was very small.

The total N_2O from agricultural soils was the third highest at 8.45 Gg (Table 5.9). The contribution from manure management was negligible. Rice production was responsible for 5.10 Gg of the CH_4 emissions in 2000 from intermittently flooded rice (80%) and continuously flooded rice (20%). The GHG emissions from the Agriculture Sector in 2000 shows that the field burning of agricultural residues and livestock and manure management are the main emitters of GHGs (Table 5.9). Clearly, mitigation strategies to reduce these emissions are required in the sector.

Table 5.8: Greenhouse gas (GHG) emissions (Gg) from the Agriculture Sector, 1990, 1994, 2000

Year	Greenhouse gas (Gg)					
	N_2O	CH_4	CO	NOx	CO_2	Total GHG
1990	114	1244	91	60	0	1509
1994	1887	1201	217	90	0	3394
2000	3446	944	181	66	0	4637

Source: Sibale and Chiwatakwenda, 2007.

Table 5.9: Greenhouse gas (GHG) emissions (Gg) from the Agriculture Sector, 990, 1994, 2000

Sub-sector	Greenhouse gas	Year		
		1990	1994	2000
Livestock and manure management	CH_4	35.78	31.95	31.64
	N_2O	Unknown	0.17	0.75
Rice cultivation	CH_4	13.64	14.89	5.13
Burning of savannah	CH_4	0.13	0.42	Unknown
	CO	4.34	11.06	Unknown
	N_2O	0.0023	0.01	Unknown
	NOx	0.0025	0.19	Unknown
Field burning of agricultural residues	CH_4	1.24	1.75	1.77
	CO	25.94	61.14	60.22
	N_2O	0.04	0.06	1.57
	NOx	1.50	2.05	1.64
Agricultural soils	N_2O	0.31	5.66	8.45

Source: EAD, 2008

5.4.1 Methodology

The identified mitigation options were evaluated using the Century Model (Version 4). The assessment was based on the total cost of the mitigation option and total GHG reduction that would arise from each mitigation option.

Description of the model: The Century Model (Version 4.0) is an agro-ecosystem model that was developed to deal with a wide range of cropping systems for the analysis of the effects of management practices on the productivity and sustainability of agro-ecosystems. The model integrates the effects of climate, soil driving variables and agricultural management practices to simulate: (i) carbon (C), nitrogen (N) and water dynamics in the soil-plant system, (ii) complex agricultural management systems, such as crop rotations, tillage practices, fertilization, irrigation, grazing, and harvest methods, and (iii) dynamics of grassland systems, agricultural cropping systems, forest systems, and savannah systems. The grassland, crop and forest systems have different plant production sub-models, which are linked to a common soil organic matter sub-model. The savannah model uses the grassland, crop and forest subsystems and allows for the two subsystems to interact through the shading effects and N competition. The soil organic matter sub-model simulates the flow of C, N, P, and S through plant litter and different inorganic and organic pools in the soil, using monthly time steps. The input model data were obtained from the literature in the Departments of Agricultural Research Services (DARS), Agricultural Extension Services (DAES), Animal Health and Livestock Development (DoAHLD) and the Department of Forestry (DoF).

Mitigation options: The mitigation options identified in Initial National Communication (INC) of Malawi are still valid for this assessment. The mitigation options identified for the Second National Communication (SNC) of Malawi include the following: (i) improved rice cultivation practices, (ii) improved animal husbandry practices, (iii) improved manure management practices, (iv) improved fertilizer management practices, (v) application of zero tillage or conservation farming, and (vi) application of agro-forestry practices, which include crop rotations, mixed cropping and intercropping systems. The Century Model was used to evaluate the identified mitigation options. The results of the simulations were then used to prepare a cost curve that depicts the cost and total abated emissions for each mitigation option (Fig 5.5). The cost of implementing the mitigation options has been prepared using an interest discount rate of 5%.

Screening the mitigation options: The mitigation options were screened using a criteria that included: (i) total cost of mitigation, and (ii) total GHG reduction due to the mitigation option. Table 5.10 presents information on the cost and the GHG savings for each mitigation option. The use of these data sets has resulted in the generation of the cost curve depicted in Fig 5.5.

Table 5.10: Potential savings that can be made from applying various mitigation options

Option	Option potential	Cumulative mitigation	Cost of saved CO_2	Total mitigation cost
	Million Tons CO_2	Million Tons CO_2	$/Ton CO_2	($ million)
Baseline	-	-		
Fertiliser application	1.16	1.16	-$12.28	(14)
Manure management	0.03	1.19	-$8.71	(0)
Improved rice cultivation	0.17	1.36	$0.00	-
Agro-forestry	0.55	1.91	$1.36	1
Improved cultivation methods	0.56	2.47	$2.05	1
Total	2.47	-	-	(12.59)

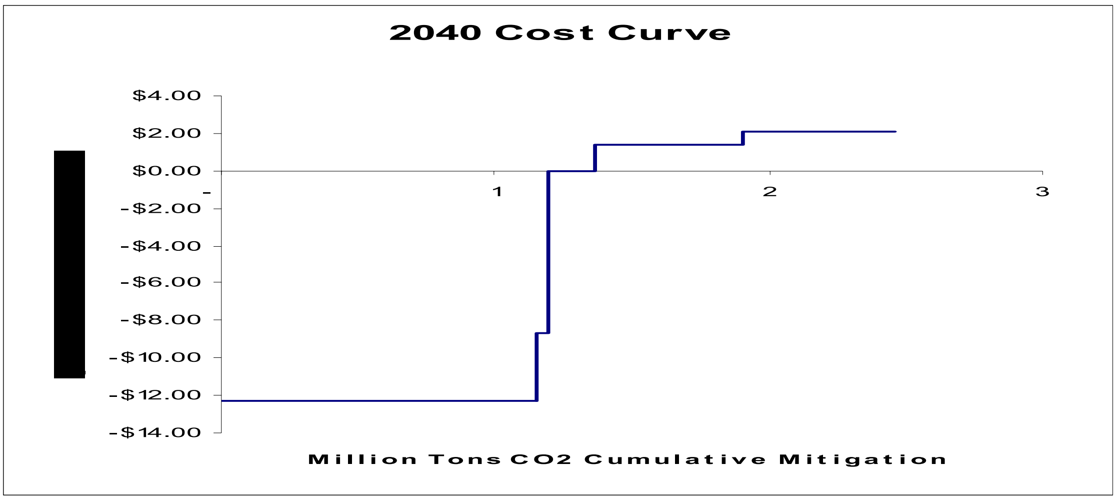


Fig 5.5: Cost curve for mitigation options

Note: The east expensive option is drawn first, and then the most expensive is drawn last.

The cost curve was obtained on the assumption that 2.0 m ha are under of crop production in the country, and that 95% of this is dedicated to maize production. A mitigation option screening matrix was developed that ranked the six mitigation options by assigning a value of 1 for the best ranking criteria and a value of 6 for the worst. The sum of the rankings is shown at the bottom of Table 5.11. The option with the lowest sum of the rankings is the best mitigation option. From Table 5.11, the improved animal husbandry option was the least desirable option, whereas the fertilizer application option is the most desirable option.

Baseline scenario: The baseline scenario, in the context of this study, was the prediction of what would be the situation if no mitigation options are adopted. Thus, the baseline scenario took into account the expected effects of climate related policies that are already in place, and the expected growth of the Agriculture Sector. However, due to the stochastic nature of social, economic and socio-political performances of developing countries, including Malawi, it is difficult to make reliable long-term predictions of GHG emissions. The baseline scenario assumes that the emissions will increase at a rate of 0.5% annually starting from the year 2000 up to the tear 2075.

Table 5.11: Criteria and rankings of different mitigation options

Criteria	Rice cultivation	Animal husbandry	Manure management	Fertiliser application	Zero Tillage	Agro-forestry
Mitigation Potential (m tons CO_2e)	0.2	-	0.0	1.2	0.6	0.6
Direct Unit Costs (benefits) $/ton CO_2e	0.0	0.0	(8.7)	-12.3	2.0	1.4
Direct Total Costs (million $)	$0	$0	$0	-$14	$1	$1
Overall Cost Ranking	3	6	2	1	5	4
Indirect Costs						
- Increase in domestic employment	5	2	1	6	3	4
- Decrease in import payments	4	3	6	1	5	2
Consistency with Development Goals						
- Potential for wealth generation	1	2	3	4	4	4
- Consistency MGDS & MDGs	6	5	3	1	2	4
Consistency with Environmental Goals						
-Potential for reducing air, water pollution	4	6	2	3	1	5
Feasibility: technical; political; social	4	6	3	2	1	5
Overall ranking	27	30	20	18	21	28

Figure 2.7: Scenarios for application different mitigation options towards reduction of CO_2

5.4.4 Results and Findings

Improved cultivation methods through the use of zero-tillage or conservation farming: The amounts of the C in the passive organic pool were simulated and results for the baseline were compared with those of the mitigation option (Fig 5.6), which shows that 160 g (carbon)/m^2) were sequestered using the zero tillage cultivation technique. Thus, improved cultivation through zero tillage, or conservation agriculture, increased the carbon pool, rising to 170 g/m^2 in from 2025 to 2075.

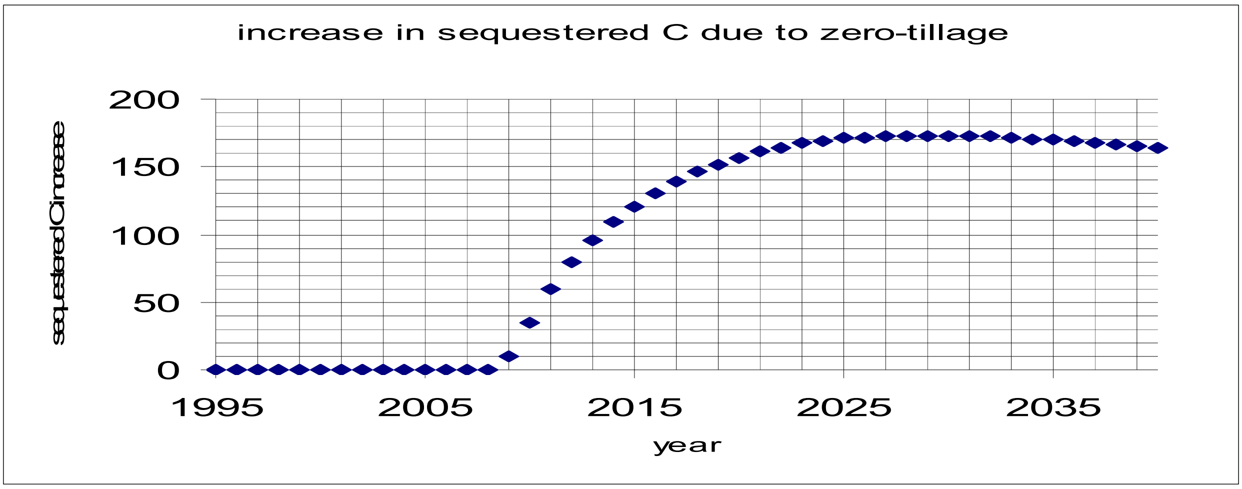


Fig 5.6: Increase in sequestered carbon due to zero-tillage

Improved fertiliser management: The mitigation option of applying just enough fertilizer to meet the crops' demand and reduce losses was investigated by simulating the amount of fertilizer N that would be lost through volatilization. The results of the baseline scenario and the mitigation option are compared in Fig 5.7. The data shows that there would be a 0.56 g m^{-2} reduction in N–loss from the use of the improved fertilizer management strategy. The N-loss was defined as the product of total N losses and the fraction of volatilised nitrogen (Fig 5.7).

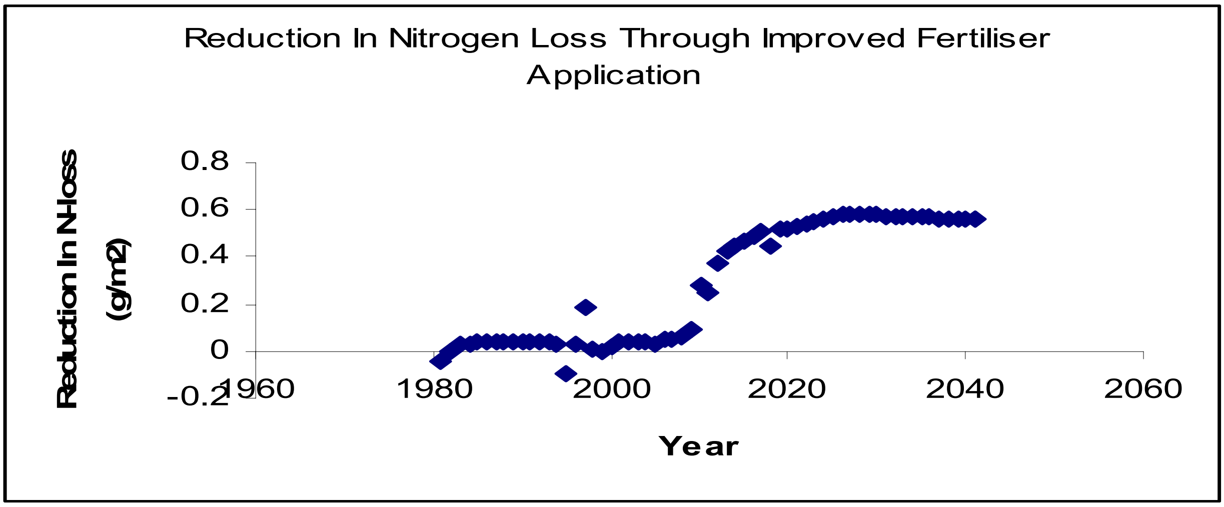
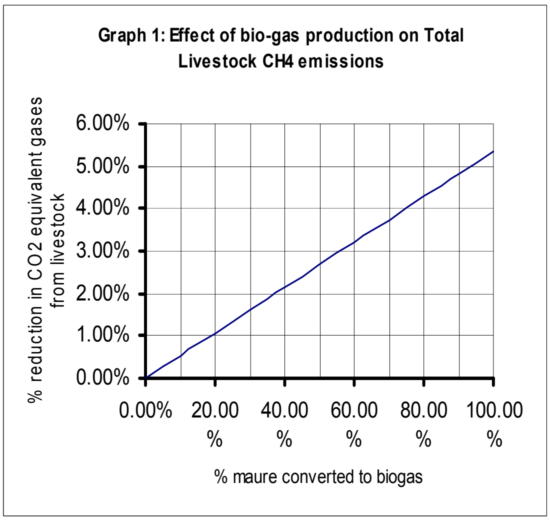


Fig 5.7: Reduction in nitrogen loss through improved fertiliser N management

Improved management of manure: The efficient management of livestock manure results in a 5.4% reduction in CO_2 emissions, giving saving of about US$ 8.71 per ton of CO_2. For example, if 1.0% of manure is used for biogas production, then a total reduction of 80% in total CO_2 emissions is expected (Fig 5.8). The expected savings in CO_2 emissions, through the performance of such an option, is given in Fig 5.8. However, since CO_2 has a lower Global Warming Potential (GWP) than CH_4, its use for fuel results in lower gas emissions. Further, the use of firewood (hence deforestation) is avoided because of the biogas production. Hence, the total GHG reduction may by calculated as follows:

GHG reduction = (Amount of firewood CO_2) + (23 – 44/16) (Amount of methane from manure)…... [2]
Where:
23 is the GWP of methane, and
44/16 is the molar mass ratio of CO_2 to CH_4.



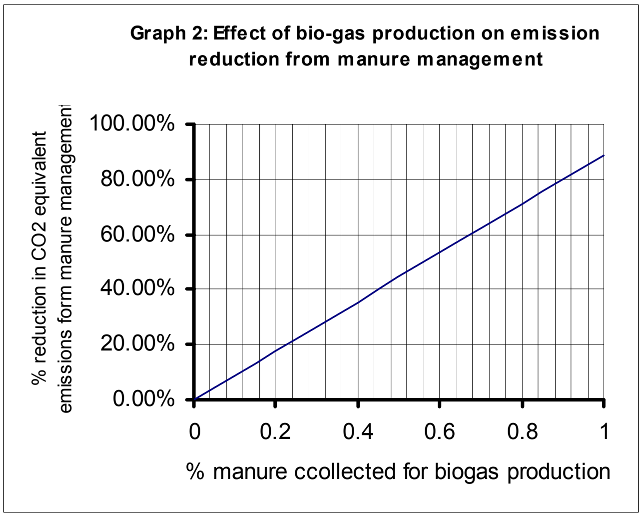


Fig 5.8: Effect of biogas production through improved livestock manure management

Fig 5.9 shows the jaws chart, which depicts the effect of any given mitigation option on total GHG emissions. The baseline scenario shows the highest levels of GHG emissions because no effort was put in place to abate or reduce the emissions. Each mitigation option results in a further reduction of GHG emissions, and unlike in the cost curve (Fig 5.5) that uses one year data only, the emissions resulting from mitigation options are for all the years up to 2040. However, the main limitation of the jaws chart is that it does not depict the cost of a mitigation option, unlike the cost curve.

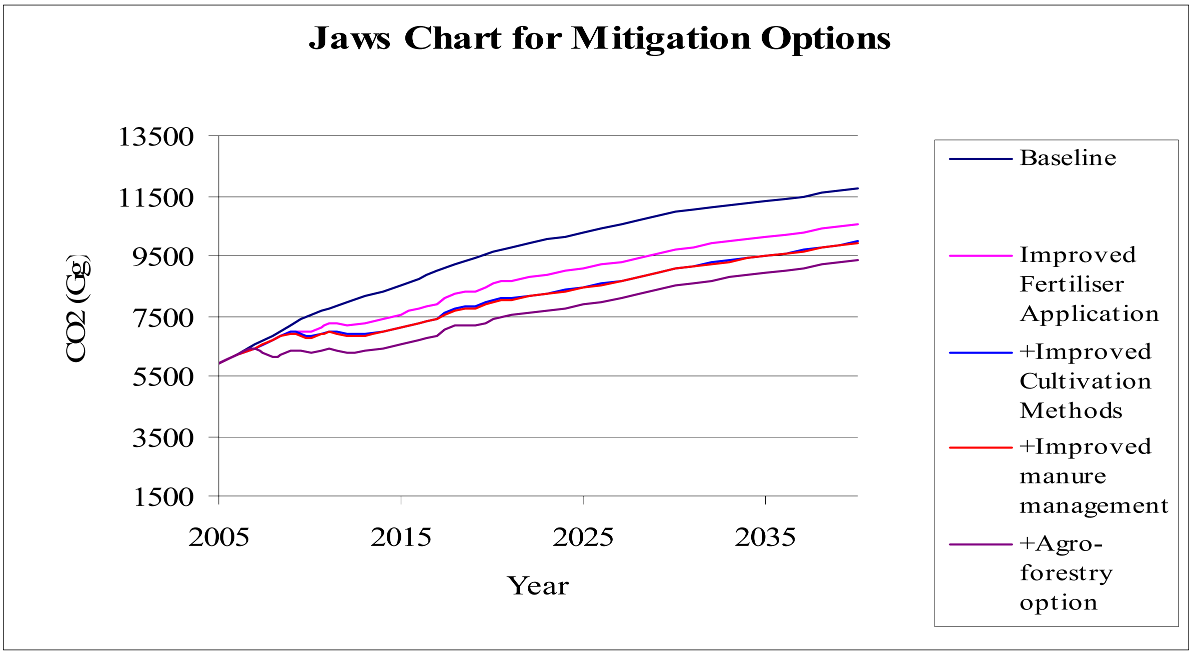


Fig 5.9: Effect of different mitigation options on CO_2 emissions reduction, 2005-2035

The cost and savings from the use of different mitigation options is presented in Table 5.12, using a net present value (NPV) that is set at a 5% annual discount rate. This shows that the improved fertilizer management option is the most superior in saving CO_2 compared with the other options.

Table 5.12: Performance of the various mitigation options

Mitigation option	Cost \$/ton CO_2	Gg CO_2 saved	% Total area option is to be applied	Area affected
Improved fertiliser application	(\$12.28)	1157	10%	200000
Improved cultivation methods	\$2.05	557	5%	100000
Improved rice cultivation	0	169	25%	12500
Improved manure management	-0.24	33	-	-
Use of agro-forestry practices	\$1.36	550	5%	6000

Note: % Total area is given as % of 2 million hectares, except for rice cultivation which is 50, 00 ha (the baseline year rice area)

Implementation of the mitigation options: To achieve the desired reduced GHG emissions in the Agriculture Sector, there is need to: (i) enhance the capacity and skills of farmers in managing various cropping, cultivation, harvesting and fertilizer management practices, (ii) reduce the high costs required to develop and formulate animal feeds, (iii) expand the area under improved fertiliser management practices, (iv) increase public awareness and education on climate change related information, especially that relating to mitigation options, (v) expand and promote rights to property, such as land tenure, (vi) improve fertiliser use-efficiency by reducing losses, and the use of integrated soil fertility management strategies, (vii) improve soil and water management practices, as well as the storage of carbon in the soil, (viii) promote the use of agricultural crop residues to improve soil fertility and reduce the open burning of crop residues, (ix) promote the growing and management of trees species that are carbon sinks, purifiers and useful in carbon sequestration programmes, (x) reduce savannah burning as a land clearing practice, (xi) promote rain-fed production of rice with intermittent irrigation, (xii) expand upland rice production systems, (xiii) expand the proportion of total land area under the improved fertilizer mitigation option (>200 000 ha) and agro-forestry systems (>6000 ha).

Barriers and opportunities: However, there are barriers that constrain the adoption and application of these mitigation options. Some of these include the lack of: (i) technical capacity and skills (ii) public awareness on climate change related information and the availability of mitigation options aimed at reducing GHGs, and (iii) rights to property, such as secure land tenure systems that encourage long-term investment. To address these barriers, Malawi needs to (i) use participatory approaches to engage all actors and stakeholders, (ii) improve early warning systems, (iii) develop institutional linkages with other organizations at international, regional, national and local levels, especially on technology transfer initiatives, and (iv) rationalise input and output prices of agricultural commodities to ensure profitability.

5.4.3 Summary

This chapter has highlighted several mitigation options for reducing GHG emissions in the Agriculture Sector. This is the most important sector for Malawi's economic growth. Nearly all agricultural activities contribute to GHG emissions, but the burning of agricultural residues, the application of inorganic fertilizer materials and enteric fermentation from manure management, are the main emitters of GHGs. Therefore, concerted efforts are required to implement all the available mitigation options to reduce GHG emissions, especially methane and nitrous oxide.

5.5 Forestry and Other Land-Use Sector

Forests in Malawi play an important role in the socio-economic growth and development of the country. Forests supply about 93% of the country's energy needs, provide timber and poles for construction and industrial use, supply non-timber forest products for food security and income, support wildlife and biodiversity, and provide recreational and environmental services. Among the environmental services provided by forests, is carbon sequestration. Carbon sequestration is the uptake and storage of carbon on land which reduces atmospheric accumulation, and thus, delays its impact on global climate. However, despite the important role that forests play in Malawi, the forest resources are under threat from agricultural expansion, high population growth, increased wood-fuel demands, and forest fires.

The destruction of forests through burning and the decaying of woody biomass results directly into significant contribution of CO_2 to the atmosphere. However, the expansion of forests and the maintenance of existing stands can capture a lot of CO_2 from the atmosphere and maintain it on land over decades. During 2000, the GHG emissions from the forestry and land-use sector totaled 17,512 Gg CO_2. equivalent, mainly through changes in forest and woody biomass, forest conversion and soil out-gassing. The burning and decaying of woody biomass also directly contributes to CO_2 emissions. Thus, it is important for Malawi to identify mitigation options in the Forestry and Other Land-Use Sector that would reduce the atmospheric accumulation of CO_2, thereby reducing its impact on global climate change. The major objective of this assessment was to analyze the costs, benefits and impact of mitigation options. In particular, the study aimed at identifying a mix of options that are likely to provide the desired forestry products and services at the least cost and minimum negative environmental and social impacts.

5.5.1 Methodology

There are many methods and models that are currently available for use in conducting mitigation and abatement analysis in the Forestry and Other Land-Use (FOLU) Sector. However, for this study, the bottom-up Comprehensive Mitigation Analysis Process (COMAP) was selected because it meets the objectives of this assessment. and was also used in the previous study when preparing the Initial National Communication (INC).of Malawi. This will also make it easier to compare the results from the two studies.

Model description. COMAP is a model that guides an analyst to undertake a comprehensive assessment of the role of the Forestry and Land-use Sector in a country's climate change mitigation effort (Sathaye and Meyers, 1995). It aims at finding the least expensive way of providing forest products and services while reducing the amount of CO_2

emitted (Makundi and Sathaye, 1999). In using the COMAP Model, the following specific steps were followed: (i) identifying mitigation options appropriate for carbon sequestration, (ii) assessment of the current and future land area available for the mitigation options, (iii) assessment of the current and future wood-product demands, (iv) determination of the land area and wood production scenarios by mitigation options, (v) estimation of the carbon sequestration per unit area for major available land classes, by mitigation option, (vi) estimation of the unit costs and benefits, (vii) evaluation of cost-effectiveness indicators, (viii) development of future carbon sequestration and cost scenarios, (ix) exploration of the policies, institutional arrangements and incentives necessary for the implementation option, and (x) estimation of the national macro-economic effects of these scenarios.

The steps taken in conducting the analysis include identifying and categorizing the mitigation options that are suitable for implementation, and determining the forest and agricultural land area that might be available to meet current and future domestic and foreign demands for wood (e.g., fuel-wood, industrial wood products and construction timber) products, and for land (e.g., used for carbon sequestration and environmental purposes). The mitigation options were then matched with the types of future wood-products that would be demanded and with the type of land that would be available. This matching requires iterating between satisfying the demand for wood products and land availability considerations. Based on this information, the potential for carbon sequestration and costs and benefits per hectare of each mitigation option were determined. This information was used to establish the cost effectiveness of each option and its ranking among other options. Furthermore, this information, in combination with land use scenarios, was used to estimate the total and average cost of carbon sequestration or emission reductions. Finally, an assessment of the macro-economic effects of each scenario, on employment, balance of payments, Gross Domestic Product (GDP), and capital investment may be carried out using formal economic models or assessment methods used by the country. However, for completeness of the mitigation assessments, an exploration of the policies, incentives and institutions necessary to implement each option, as well as the barriers that must be overcome need to be undertaken.

COMAP modules: The COMAP framework that uses an Excel spreadsheet and has four main modules: (i) forestation, (ii) protection, (iii) bio-energy, and (iv) biomass. With the exception of the biomass module, the rest correspond to the main types of mitigation options in the Forestry and Other Land-Use Sector. Each module has a set of sub-modules, which are used to analyze specific mitigation options. The **forestation module** includes all projects and policies intended to re-plant an area, ranging from natural reforestation, enhanced natural reforestation, afforestation, short rotation forestry, agro-forestry, and community and urban forestry, among many others. Where non-forest tree plantations, such as rubber, are not included under the Agriculture Sector mitigation assessment, then they can be analyzed under this module as an afforestation or reforestation option. All the modules are run for both the baseline scenario and the mitigation option. The forestation module then calculates the annual changes in carbon stocks and the cost-effectiveness indicators associated with the scenarios.

Some of the low cost and most effective mitigation options involve **protecting the forests** from being depleted and/or degraded, leading to CO_2 emissions. There are a number of options which call for halting deforestation of a given forest in a region, or conversion of a threatened forest into a protected area. The forest protection module estimates the associated annual and cumulative changes in carbon stocks and the cost effectiveness indicators for the mitigation policy. This is done for both baseline and mitigation scenarios so as to obtain net reduction in CO_2 emissions. The **bio-energy module** analyses the substitution of GHG-intensive products, such as the use of grown biomass (bio-fuel) to substitute for fossil fuels. This may delay the release of carbon from the fossil fuels for as long as the fossil fuels remain unused. Other examples include the use of efficient stoves and charcoal kilns, wood-derived from renewable energy sources when used as a substitute for wood obtained from depleted natural forests, and the use of biomass products to replace emission-intensive products, such as concrete, steel, and plastics.

The **biomass module** is actually a biomass balance module aimed at tracking demand and supply of forest products in the sector. This is important since one of the main roles of the Forestry and Product Use Sector in any country is to meet the current and projected future biomass demands. When the demand on biomass exceeds the rate of growth, a decline in the size of the forest estate (deforestation) or degradation of the biomass density becomes evident. Thus, mitigation options cannot be implemented without arrangements for meeting biomass demands, including imports to cover biomass deficits. Because of the increasing demands on forests, it is necessary to analyze the current and projected changes in land-use patterns and the resulting changes in biomass supply, with the ultimate goal of matching it with the demand on biomass. The biomass module is used to track the dynamics of land-use patterns over time, including changes in biomass pools, product supply and demand.

Baseline scenario: The baseline scenario describes the key assumptions that were made in the development of likely trends and the nature of input data used. It gives the current trends of land-use in Malawi and describes the existing land-use distribution among and within sectors, the rate at which land is being converted from one use to another, and identifies the factors that lead to such land conversions. This sets the background for the identification of mitigation options.

Model input data: The data used in the study was sourced from: (i) Department of Forestry (DoF) in the Ministry of Lands and Natural Resources (MoLNR), especially under the Malawi Forest Resources Mapping and Biomass Assessment Project, and (ii) Food and Agriculture Organisation (FAO) of the United Nations (UN), especially from the State of the World's Forest Reports (FAO, 2003; 2005a; 2007), Global Forest Assessment Reports (FAO, 2001; 2006), and the Malawi Country Report (FAO, 2005b). To run the model, the following data inputs were used: (i) land area (ha), (ii) soil carbon density, (iii) biomass density, (iv) rates of growth of biomass, (v) carbon stocks, (vi) carbon sequestration rates, and (vii) costs and benefits. All the modules were run for both baseline and mitigation scenarios. The model then calculated the annual changes in carbon stocks and the cost-effectiveness indicators associated with each scenario.

Mitigation options: The proposed mitigation options can be classified into two basic types: (i) expanding the stand of trees and the pool of carbon in wood products, and (ii) maintaining the existing stands of the trees and the proportion of forest products currently in use. Tree captures CO_2 from the atmosphere and maintains it on land. Maintaining existing tree stands can be achieved through reduced deforestation, forest protection, or more efficient conversion and use of forest products. It, therefore, keeps the avoided CO_2 emissions from entering the atmosphere for the duration of the pool maintenance. An alternative way of reducing carbon emissions include the use of wood obtained from renewable energy sources (e.g., forest plantations) or the use of a substitute for non-renewable emission sources, such as fossil fuel. This substitution delays the release of CO_2 from the fossil fuel for as long as one continues to use wood from a renewable energy source instead of the fossil fuel. In this same way, wood derived from sustainable sources, can be used as a substitute for wood-fuel derived from depletable natural forests. This also delays CO_2 release from the unsustainable sources (Sathaye and Meyers, 1995).

Based on the baseline scenario outlined above, it is clear that Malawi requires the two interventions in order to check forest depletion and degradation, i.e., (i) forest protection and conservation, and (ii) reforestation and afforestation. **Afforestation** is the planting of forests on bare land, whereas **reforestation** is the replanting or natural regeneration of deforested land. The difference between the two terms depends on the period of time that land has remained bare. The **forestation** option is considered as part of the **afforestation** and **reforestation**. In this study, agro-forestry (trees on-farm) and bio-energy are considered under the Agriculture and Energy Sectors, respectively. Hence, it is only the forest protection and conservation, and the reforestation and afforestation options that will be considered in this study.

From the baseline scenario, it has been established that Malawi is losing an average of 33,000 ha of forest land every year, and an average of 39,600 ha of primary forest land is lost every year due to human encroachment. Thus, based on these observations, Government needs to protect its existing primary forests. Hence, in the mitigation scenario, it is assumed that adequate steps are taken to ensure that the area is protected and that 3,336,000 ha of forest land proposed for protection in 2007 remains protected until 2040. In particular, it is assumed that improved forest protection can be attained by providing adequate financial resources to the DoF that is involved in forest protection and management. With adequate financial resources, the DoF will be able to improve its capacity for fire control measures, law enforcement activities, such as confiscating illegal forest products (e.g., charcoal, firewood and timber), and arresting people who encroach on forest land. Thus, the DoF will be able to effectively reduce forest fires, illegal cutting down of trees, charcoal burning, encroachment for agricultural expansion, and other practices that degrade natural forests. In this way, protection will reduce CO_2 emissions from the sector.

The reforestation and afforestation mitigation option depends on the availability of suitable land for the planting of trees. However, the question that is often raised is whether Malawi has enough and sufficient land for climate change mitigation activities. On the surface, the high population densities and low agricultural productivity may suggest that there is enough land to be used for forestation programmes. However, when an assessment of degraded land (this is land that either originally contained forests or that has been left fallow and agriculture is no longer practiced for various social and economic reasons) is undertaken in a country, the results usually show large amounts of degraded land available for forestation (Makundi and Satahye; 2004; Sathaye et al., 2001; Nijnik, 2005). An assessment of this type of land may also provide information on the tree species that are suitable for land under a particular silvicultural (forestry) zone, and on estimated costs and benefits of afforestation for each spatial unit of the forest classification (Nijnik, 2005). Malawi is yet to carry out such a comprehensive assessment of degraded land that is available for tree planting, defined across silvicultural zones.

Nonetheless, this mitigation option has been incorporated to account for the Tree Planting for Carbon Sequestration and Other Ecosystem Services Programmes initiated by Government in 2007. These initiatives aim at increasing the area under forest cover in order to enhance carbon sequestration and other ecosystem services that contribute to the reduction of GHGs, in particular CO_2. The programme promotes tree planting and forest management by family households and institutions. This programme will enable Malawi contribute to the attainment of the objective of the UNFCCC, which aims at promoting the stabilization of the emissions of man-made greenhouse gases into the atmosphere. This programme is implemented in all the 193 constituencies of the country, involving individuals and farm families who are provided with inputs and training in how to raise tree nurseries and tree planting. The participants are required to devote some land for tree planting and management for periods ranging from 15 to 30 years depending on the tree species planted. Fast growing indigenous tree species are being promoted. Each constituency has an allocation of 5 farmers growing 3 to 5 ha of trees, thereby creating a nation-wide maximum of 4,825 ha of plantation annually, and a total of 24,125 ha in the initial five years. The estimated cost for the initial 5 years is estimated at MK 2.0 billion (approximately US$ 14.6 million (using an exchange rate of US $ 1.00= MK 137.00).

Data collection and analysis: The data collected were used to run the various sub-modules, whereas the model outputs were used to calculate the amounts of carbon sequestered and accumulated, costs and benefits. For the forest protection and conservation, the carbon density in living biomass was obtained by multiplying the biomass density with the carbon ratio for each scenario. The carbon ratio varies between 0.45 and 0.55, but for this analysis, we assumed that the carbon ratio is 0.5 and that it is the same for both the baseline scenario and the mitigation option. The carbon pool (t C) for each year was obtained by multiplying the total carbon density (t C/ha) with total land area (ha) under each scenario, whereas the total costs and benefits were determined by aggregating the costs and benefits for the baseline scenario and mitigation options. For the afforestation and reforestation option, the total amount of stored C was calculated as the sum of C in vegetation, soil, decomposing matter and wood (forest) products. The C density of 9 t C/ha per year was determined by multiplying the biomass density with the carbon ratio, whereas the total pool of C (t C) for each year was obtained by multiplying the total C density (t C/ha) with the land area (ha) under each scenario. The net benefit of the reforestation programme per year is obtained by subtracting the sum of the annual cost of wasteland and the cumulative cost of converted land from the sum of the annual benefits from wasteland and the cumulative benefit from converted land. Hence, the value of the gross product of natural forests can be estimated by multiplying the net price of the product by its actual harvested volume.

5.5.2 Results and Findings

The forest protection and conservation mitigation option: As alluded to earlier, this mitigation option assumes that adequate steps are taken to ensure that 3,336,000 ha of forest land projected for 2007 remain protected until 2040. The baseline scenario assumed a biomass density of 95 t ha^{-1} for the year 2005 (FAO, 2007), and that the biomass density declines at the rate of 2% per year under the baseline scenario but that it increases at a rate of 2% per year under the mitigation option. Thus, under the baseline scenario, biomass density declines to 47 t ha^{-1} in 2040 while under the mitigation option it rises to 175 t ha^{-1}. What follows is a brief description of the carbon sequestered, monetary costs and benefits, and cost effectiveness.

In the baseline scenario for the **carbon changes**, the biomass C declines from 52 t C ha^{-1} in 2000 to 23t C ha^{-1} in 2040, but it increases to 88 t C ha^{-1} under the mitigation option. Further, it was assumed that the soil C density remained unchanged at 100 t C ha^{-1} in the baseline scenario, but that it increased at the rate of 1% per year in the mitigation option, thereby reaching a level of 139 t C ha^{-1} in 2040. Adding the biomass and soil C density gives the total C density for each year under each scenario. The total C density decreased from 152 t C ha^{-1} in 2000 to 123 t C ha^{-1} in 2040 for the baseline scenario, but increased to 227 t C ha^{-1} in the mitigation option. Since both C density and land area decline in the baseline scenario, the C pool also declines from 544 million t C in 2000 to 277 million t C in 2040. In the mitigation option, the carbon pool increases to 756 million t C by 2040 (Fig 5.10).

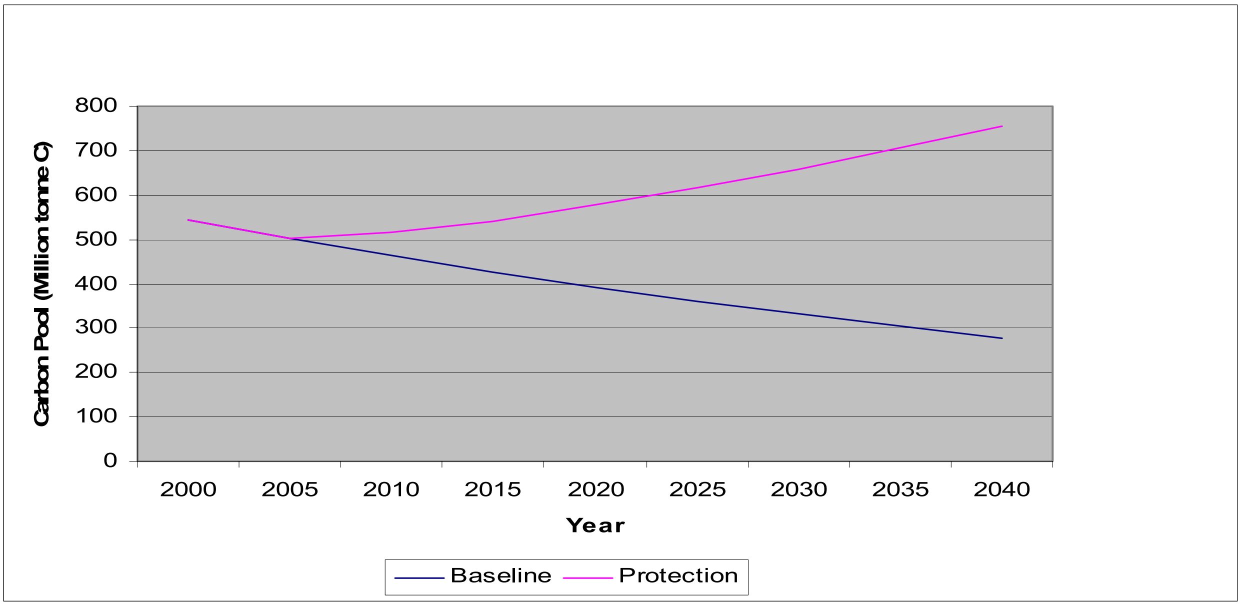


Fig 5.10: Carbon pool changes under the forest protection mitigation option, 2000-2040

In the baseline scenario, in evaluating **monetary costs and benefits**, the cost of forest protection is set to be US$ 1.5 ha^{-1} year^{-1}. This has been estimated based on the actual budget expenditure of the Viphya Plantations (DoF, 2002). This has been used on the assumption that forest areas in Malawi are poorly protected due to insufficient funds actually spent on forest protection and management. In the mitigation option, the cost of forest protection increases to US$ 5.00 ha^{-1} year^{-1}. This is based on the approved budget estimates for the Viphya Plantations (DoF, 2002), which if actually disbursed, would provide adequate protection to the plantation. An average figure of US$ 50.00 ha^{-1} year^{-1} has been used in the baseline scenario as the opportunity cost of land or the benefit from land conversion. This is based on the assumption that some of the land is converted to commercial farming, such as tobacco growing, whilst some is used for subsistence farming. Thus, the land that is used for commercial farming will have conversion benefits that are larger than US$ 50.00 ha^{-1} year^{-1}, whereas those used for subsistence farming will have conversion benefits which will be less than US$ 50.00 ha^{-1} year^{-1}. There is no opportunity cost of land under the mitigation option since no land conversion occurs under the forest protection option.

For the benefits of forest protection, a default value of US$ 2.00 ha^{-1} year^{-1} was used in the baseline scenario, but was increased to US$ 15.00 ha^{-1} year^{-1} because mitigation reduces land and vegetation degradation in protected areas. Thus, the net benefit for the baseline scenario for each year is obtained by subtracting the total cost of protection from the sum of all benefits of land conversion and the benefits from forests. The net benefits for the baseline scenario decline from US$ 3,417,000.00 in 2001 to US$ 2,773,500.00 by 2040. The net benefit

for the mitigation option for each year is obtained by subtracting the sum of all costs of forest protection, including the opportunity cost of land from the total benefits of protection. The net benefit of forest protection for each year is US$ 31,557,089.00. The present value of the stream of costs and benefits are computed using a discount rate of 10%. Although there is no agreement on the right discount rate to use, higher (commercial) rates are recommended for private investment projects, whereas lower rates are recommended for social projects. In general, reducing the discount rate, say to 5%, makes the project more favourable, whereas increasing the discount rate, say to 15%, makes it less favourable.
Finally, the COMAP Model generates a number of **cost-effectiveness indicators**, which help to compare and select from different mitigation options. These indicators include: (i) net present value (NPV) of benefits ha^{-1} and per t^{-1} of carbon, initial cost of forest protection ha^{-1} and per t^{-1} of carbon, present value costs (endowment cost) ha^{-1} and per t^{-1} of carbon, and the benefits of reduced atmospheric carbon (BRAC). The NPV of benefits provide the net direct benefits to be obtained from a project or a mitigation option. In this mitigation option, the NPV of benefits is US$ 0.29 t^{-1} C or US$ 39.00 ha^{-1}. It must be noted that the protection option includes indirect benefits of forest protection. The initial cost of protection does not include future discounted investment costs needed during the implementation of the option. This indicator simply provides information on the amount of resources required to establish the project.

The initial cost of protection is US$ 0.04 t^{-1} C or US$ 500 ha^{-1}. The present value of costs is the sum of establishment costs and the discounted value of all future investment and recurring costs during the lifetime of the project. This indicator is useful because it provides the endowment necessary to maintain the project for its duration. The endowment requirement for the protection option is US$ 0.35 t^{-1} C or US$ 47.00 ha_{-1}. The BRAC indicator expresses the net present value of a project in terms of the amount of atmospheric CO_2 reduced, taking into account the timing of emission reductions and atmospheric residence of the emitted CO_2. Thus, it estimates the benefit of reducing atmospheric CO_2 instead of reducing the net emissions. The BRAC for the protection option is US$ 0.022 t^{-1} $year^{-1}$ of C.

The reforestation and afforestation mitigation option: Under this mitigation option, 4,825 ha of land are to be reforested each year starting from 2007 to 2011, bringing in a total of 24,125 ha of additional forest land. The C gains, costs and benefits and the cost-effectiveness indicators of this project are evaluated and assessed. In the baseline scenario, it is assumed that the biomass density remains fixed at 20 t ha^{-1} until 2040, and a C ratio of 45%, since land was assumed to be degraded. The soil C density was assumed to be 70 t C ha^{-1}, assuming that the land is degraded and there is a lot of human disturbances, such as cultivation. Thus, in the baseline scenario, the carbon pool is estimated at 79 t C ha^{-1}.

Reforestation has the potential to increase C density through increased C in vegetation, soil, decomposing matter and woody products. For vegetation C, it was assumed that the planted species have a rotation period of 15 years, a yield (mean annual increment) of 12 t of biomass ha^{-1} $year^{-1}$, and a C ratio of 0.5 (since this is under forestry). Further, it was assumed that soil C increased by 2 t C ha^{-1} over the rotation period of 15 years, and then remains fixed in the soil in perpetuity. Decomposition is equivalent to storing C. Thus, the decomposition of biomass on land also creates a stock of C. In this study, we have assumed a decomposition period is 6 years, and that the amount of decomposing C left behind is 6 t C ha^{-1} year^{-1}. If the forest products were renewed continuously, they would store C over an infinite period. The amount of carbon stored in the form of products will depend on the product life. The longer the product life, the more C will be stored away. In this assessment, it was assumed that the average product life is 30 years and the amount of C in the product is 30 t C ha^{-1}. This amounts to 128 t C ha^{-1}. The pool of C for the reforestation scenario is the sum of carbon stored by the mitigation option and the baseline scenario soil C. This gives a pool of 198 t C ha^{-1}.

For the baseline scenario, this is fixed at 1,905,875 t C year^{-1}. However, for the mitigation option, this increases to 2, 477,638 t C in 2007, 4,192,925 t C in 2010, and stabilizes at 4,764,688 t C year^{-1} from 2011 to 2040 (Fig 5.11).

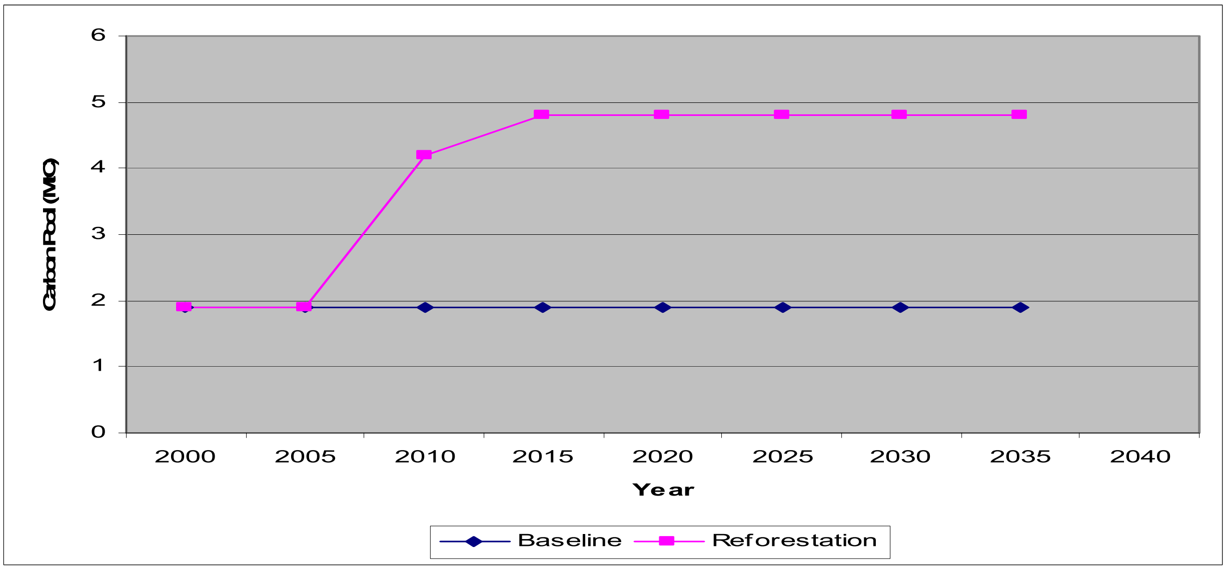


Fig 5.11: Carbon pool under the reforestation mitigation option, 2000-2040

In the baseline scenario, the **monetary costs and benefits** of reforestation was assumed to be US$ 5.00 ha^{-1} year^{-1}. In the mitigation option, reforestation incurs initial (establishment), recurrent, and monitoring costs. These costs have been estimated from the Tree Planting for Carbon Sequestration and Other Ecosystem Services Programme budget. According to this budget, the average establishment cost is estimated at US$ 616.00 ha^{-1}, recurrent cost is US $ 4.00 ha^{-1}, and monitoring cost is US $ 8 ha^{-1} (MG, 2006).

In the baseline scenario, the annual benefits obtained from working the degraded lands has been assumed to be US$ 10.00 ha^{-1} For the mitigation scenario, the benefits are derived from the sale and utilization of non-timber forest products, such as firewood, honey, mushrooms and orchids, management incentives, and C trade. Since it was assumed that there would be no timber production, a non-timber benefit of US$ 5.00 ha^{-1} was assumed for 2007, and this increases overtime to a modest maximum of US$ 15.00 ha^{-1} in 2015. Government is expected to provide incentives to the participants, which include a payment of US$ 234.00 ha^{-1} in the first and second years for successful planting, managing and protecting the trees, and US $ 117.00 ha^{-1} in years 3 to 5 for effective protection and management of the trees. It has been assumed that the sale of C would take place in the year 2012 after the establishment phase. A conservative price of US$ 6.00 of C t^{-1} C has been used.

The total costs and benefits of degraded land in the baseline scenario amount to US$ 120,625.00 and US$ 241,250.00 year^{-1}, respectively, giving a net benefit of US$ 120,625.00 year^{-1}. In the mitigation option, the present value of benefits is US$ 1,348 ha^{-1}, whilst the present value of costs is US$ 1,468.00 ha^{-1}, giving a net present value of benefits amounting to -US$ 120.00 ha^{-1} (the present values of stream of costs and benefits are computed using a discount rate of 10%)..The negative value of the net present value of benefits can be attributed to the huge initial costs incurred during the establishment phase and the modest values of the non-timber forest products used. Thus, the net benefit of the programme increases from – US$ 6,320,437 in 2007 to –US$ 25,643,624 in 2010, and stabilizes at -US$ 32,084,686 from 2011 to 2040.

The NPV of benefits provided by the reforestation programme is -US$ 50.54.00 t^{-1} C or -US$ 5,989.00 ha^{-1}. This is not surprising considering that the programme has very high establishment costs, averaging US$ 616.00 ha^{-1}. The average cost of establishing a forest plantation, excluding the opportunity cost of land, was estimated to range from US$ 230.00 to US$ 1,000.00 ha^{-1} with an average of US$ 400.00 ha^{-1} (Sathaye and Meyers, 1995). The initial cost of reforestation is US$ 5.10 t^{-1} C or US$ 601.00 ha^{-1}, which is higher than the protection option. The endowment requirements for the reforestation option is US$ 55.81.00 t^{-1} C or US$ 6613.00 ha^{-1}, and the benefit of reducing atmospheric C instead of reducing net emissions (BRAC) is - US$ 0.38/t C per year.

Socio-economic implications: One of the important macro-economic indicators of an economy is the GDP, which is a measure of economic activity within a year. The contribution of the forest sector to Malawi's GDP is not well known. This is because at the moment the country does not produce a separate forest account, but its account is included in the joint Agriculture, Forest and Fisheries Account. Hence, the level of detail is very low and based on rough estimates (Chulu, 1996). Because of this, the forest resources and their direct and indirect services benefits are not fully accounted for in the national accounts. Thus, there is no elaborate link between forest degradation on one hand and macroeconomic performance of the economy on the other. Lack of this important link has led to the design of inappropriate policies that ignore the impact of forest depletion on the economy. Further, the losses that are incurred to the society due to forest degradation and depletion, or the benefits that are gained by the society due to sustainable forest management, are underestimated or ignored. Correcting for this anomaly is an important step towards the proper management of the country's forest resource base, which is a key to sustainable livelihoods of the people and the economic growth and development of the country.

The Agriculture, Forestry and Fisheries Account comprise two major components: (i) estate agriculture, and (ii) smallholder agriculture. Estate agriculture is further divided into: (i) tobacco production, (ii) tea, tung oil and coffee production, and (iii) sugar, timber and commercial fishing. However, value added from natural forests is omitted. The value added to harvested natural forest products can be calculated as the difference between the price of the product and the costs of intermediate production (MK 800.00Hassan, 2002). This is often called the net price. The missing values of resources from natural forests need to be incorporated into the national accounts. For instance, when the GDP of MK 13,116.70 million for the year 2000 (MG, 2005) is adjusted for the missing values from primary forests, estimated at million, it increases by 6% to MK 13, 916.70 million (Kasulo and Luhanga, 2005). This is quite a substantial amount considering that the Forestry and Other Land-Use Sector as a whole is often believed to contribute between 3 and 5% of GDP. This shows that the projected decline in primary forests will eventually negatively affect the growth in GDP.

The major problem here is that while depreciation of produced capital, such as plant and machinery, is always taken into account in calculating GDP figures, the degradation of natural capital, such as forests, is not considered at all. It is impossible to continue enjoying growth in GDP when the natural capital is continuously being depleted. It is, therefore, recommended that Malawi should seriously think about developing environmental and natural resource accounts, since natural resources form the backbone of the economy and provide the basis for the social and economic development of the country.

Implementation of the mitigation options: There is need for policies to successfully implement the identified mitigation options. Malawi has a number of supportive policies that can help in the implementation of the suggested mitigation options. These policies can be divided into: (i) forestry policies, and (ii) non-forestry policies.

The **National Forestry Policy** of 1996 provides a framework for conservation, management, protection and utilization of forest resources in Malawi. The goal of the policy is to sustain the contribution of the forest resources for up-liftment of the quality of peoples' lives, particularly that of the rural people who are most disadvantaged. Because so many people are dependent on forests for their livelihoods, the policy favours rural communities. Villagers under the current forest policy have some regulated access to some forest reserves to collect indigenous fruits and other non-timber forest products without an official permit. This is possible through co-management programmes established with surrounding villages. The policy also promotes the participation of local communities and the private sector in the conservation and management of their own forests, by removing restrictions on sustainable harvesting of essential forest products (EAD, 2000). The **Forest Act** of 1997 backs up the National Forestry Policy. The Act provides for participatory forestry, forest management, forest research, forest education, forest industries, forest protection and the rehabilitation of environmentally fragile areas, and international cooperation in forestry. It is one thing to come up with a good policy, and a different thing to implement it. So to implement the National Forestry Policy, a National Forestry Programme was formulated and launched in 2001. The programme has 12 strategies which are being implemented by Government at national and local levels, private sector, civil society, and the international donor community.

There are a number of non-forestry policies that can also influence the implementation of these mitigation options. Of relevance among these is the Malawi National Land Policy of 2002. The goal of the Land Policy is to ensure tenure security and equitable access to land, so as to facilitate the attainment of social harmony and broad-based social and economic development through optimum and ecologically balanced use of land and land-based resources. The policy has a number of specific objectives that have to be satisfied in order to achieve the overall goal. The specific objectives include: (i) promoting tenure reforms that guarantee security and instill confidence and fairness in all land transactions, (ii) promoting decentralized and transparent land administration, (iv) extending land-use planning strategies to all urban and rural areas, (v) establishing a modern land registration system for delivering land services to all, (vi) enhancing conservation and community management of local resources, and (vii) promoting research and capacity building in land surveying and land management (MG, 2002). Of equal importance in the implementation of the mitigation options, are Government policies in the Agriculture Sector. The objective of the Agriculture Policy is to promote environmentally sound agricultural development by ensuring sustainable crop and livestock production through ecologically appropriate production and management techniques, and appropriate legal and institutional framework for sustainable environmental management. One of the guiding principles of the policy objective is ensuring that increased agricultural production is based on improved and appropriate farming systems and increased security of land tenure, on currently allocated land rather than on expansion of cropland. One of its strategies is to intensify agricultural production on most suitable lands to avoid expansion into marginal and/or fragile areas (GoM, 2004).

Barriers to mitigation option adoption: The policies described above, though supportive, may not easily be translated into successful implementation of the mitigation options due to the existence of some barriers. These barriers can be categorized into: (i) technical barriers, (ii) financial barriers, and (iii) institutional barriers. Technically, Malawi lacks adequate trained personnel to carry out mitigation projects and provide extension services necessary for their successful implementation. It is, therefore, recommended that these mitigation projects should always come with a training component to ensure that all the people involved in the projects are knowledgeable about forest management. Unfortunately, Government funding to forestry, national parks and game reserves has been very low in most years in the past although there are presently some improvements. However, reversing the current trend in forest degradation will require a lot of resources and new commitments from the Government, the private sector and NGOs. The mitigation options do not represent financially profitable projects, and as such, there may not be enough investment funds from the commercial sector. The Government needs to come up with incentives for the private sector to participate in long-term investment in forestry programmes.

Conflicts between institutions may prove to be the strongest hindrance in implementing these mitigation options, particularly where clear roles and responsibilities are not stipulated between and among institutions. For example, the programme on Tree Planting and Management for Carbon Sequestration and Other Ecosystem Services is said to be implemented by the DoF in the Project's profile, while in the Project document, the Environmental Affairs Department (EAD) is the lead agency in coordinating the implementation of the programme. In the implementation of the mitigation options, mandates, roles and responsibilities of all participating institutions should be clearly spelt-out to avoid duplication of efforts and conflict of interest.

5.5.3 Summary

Three mitigation options were identified. However, two of these: (i) forestry protection and conservation, and (ii) reforestation and afforestation, have the desired potential to significantly reduce GHG emissions through various tree planting programmes that enhance carbon storage, which increases carbon pool to 756 million t C by 2040.

5.6 Waste Management Sector

Waste treatment and disposal produce GHGs, which are emitted into the atmosphere and contribute to global warming (IPCC, 2006). The mitigation of GHGs aims at abating the effects of climate change. This can be achieved by reduction in generation of waste, recovery of GHGs, and adopting waste management practices that minimize the overall effect of GHGs (Ayalon et al., 2007).

The key GHGs emitted in the Waste Management Sector (WMS) include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). By 1977, CO_2, CH_4 and N_2O contributed 70%, 24% and 6%, respectively, of the enhanced global GHG effect (Houghton, 1994). These make up one tenth of the 1.0% of the total atmosphere (Phiri et al., 2003). Oxygen (O_2) and nitrogen (N_2) constitute 78% and 21% of the atmosphere, respectively. Other naturally occurring GHGs, include water (H_2O) and ozone (O_3). The manmade compounds, such as chlorofluorocarbons (CFSs), hydrofluorocarbons (HFCs) and perfluorinated carbons (PFCs) also act as GHGs. Carbon monoxide (CO), nitrogen oxides (NO_x), ammonia (NH_3) and non-methane volatile organic compounds (NMVOCs) contribute indirectly to the greenhouse effect (Phiri et al., 2003).

In the Waste Management Sector (WMS), GHG emissions considered are from the following source categories: (i) solid waste disposal, (ii) biological treatment of solid waste, (iii) incineration and open burning of waste, and (iv) wastewater treatment and discharge. The emissions for the period 1995 to 2000 are shown in Table 5.13.

Table 5.13: Greenhouse gas (GHG) emissions (Gg) from the Waste Management Sector, 1995-2000

Greenhouse gas	Year					
	1995	1996	1997	1998	1999	2000
Methane (CH_4)	6.7093	6.9949	7.2856	7.5877	7.8931	8.2482
Carbon dioxide (CO_2)	42.7052	44.5972	46.6669	48.5174	50.7593	54.0936
Nitrous oxide (N_2O)	0.1742	0.182	0.1901	0.1979	0.2068	0.2195

Source, EAD, 2008.

Solid waste is generated from many sources, including: (i) households, (ii) offices, (iii) shops, (iv) markets, (v) restaurants, (vi) public and private institutions, (vii) industrial installations, (viii) waterworks and sewage facilities, (ix) construction and demolition sites, and (x) agricultural production activities. In southern Africa, waste mainly consists of food waste (23%), paper and/or cardboard (25%) and wood (15%) (IPCC, 2006). In Malawi, solid waste, on average, mainly consists of: (i) organic matter (90%), (ii) plastic rubber (4%), (iii) paper (4%), (iv) metal (1%), (v) textile (0.5%), and (vi) glass (0.5%) (Chinyama and Mandhlopa, 1999). The food, beverage and tobacco industries are the major sources of food waste. Paper and cardboard are generally produced in offices, schools, and packaging industries. Thus, the critical solid waste components are: (i) organic matter; (ii) food waste, (iii) wood, and (iv) paper because they contain most of the degradable organic compounds (DOC) in municipal solid waste (MSW) (IPCC, 2006). On the other hand, the non-fossil carbon in rubber is hardly degradable under anaerobic conditions (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

5.6.1 Methodology

The Landfill Gas Emissions Model (LANDGEM), was used to assess the impact of implementing the mitigation options in the WMS. The analysis considered the quantities of emissions, waste reduced, environmental sustainability, cost implications, time and equipment requirements and other benefits.

Description of the Model: The Landfill Gas Emissions Model (LANDGEM) is based on the first order decay equation. The model assumes that CO_2 emissions are the same as CH_4 emissions and that total landfill gas emissions are twice the CH_4 emissions, and was used to estimate the impact of the implementation of the different mitigation options on GHG emissions. Default values recommended by IPCC were used because of the lack of local site-specific data. These emission factors data include: (i) CH_4 generation rate constant, k = 0.04 $year^{-1}$, and (ii) CH_4 generation potential, L_0 = 100 m^3 $(Mg)^{-1}$ (Pelt et al., 1998). The mitigation option assessment was based on the following assumptions: (i) emissions from open dumps and sanitary landfills are the same, (ii) landfills were opened in 1990, (iii) landfills were closed in 2010, (iv) the size of landfills is about 4.0 ha, (v) the depth of landfills is one metre, (vi) the landfills are co-disposal sites, (vii) the density of landfill waste is 700 kg m^{-3} (Vesilind et al., 2002), (viii) the diversion rate of landfills is 69% (IPCC, 2006), and (ix) landfill capacity is 7,608,418 tones.

Mitigation options. The proposed mitigation options selected for assessment include the following: (i) reduction in the generation of waste, (ii) composting, {iii) mechanical-biological treatment, (iv) disposal of waste in sanitary landfills, and (v) combustion. .

The **reduction of waste** at the point of generation can be achieved through the reduction of demand for raw materials. Four ways to reduce demand for raw materials can be distinguished: (i) increase the amount of scrap reprocessed (recycling), (ii) decrease the amount of manufactured goods by eliminating the need for the product, (iii) increase the life time of a product; and (iv) reduce the amount of material used per product. Alternative actions that result in the reduction of the amounts of municipal solid waste (MSW) include: (i) refusing bags at departmental stores, (ii) using laundry detergent refills instead of purchasing new bottles or containers, (iii) bringing one's own bags to grocery stores, and (iv) using cloth diapers (Lober, 1996). At household level, waste can be reduced nearly by 30% (Vesilind et al., 2002). Food preservation, recycling of paper and economic use of food and papers all contribute to the reduction in GHG emissions. Furthermore, the use of biomass substances, instead of substances of fossil fuel origin, should be explored. For example, plastics can be replaced by paper packaging.

The **composting** option involves the conversion and separation of solid waste into humus by microorganisms, largely through aerobic decomposition of organic matter. Degradable organic compounds (DOC) in the waste material are converted into CO_2 (IPCC, 2006). The CO_2 emitted so far is reabsorbed by plants for photosynthesis. The CH_4 formed in the anaerobic sections of compost heap is to a large extent oxidized in the aerobic sections to form CO_2. The methane released into the atmosphere is about 1% of the initial C content in the material (Beck-Friis, 2001; Detzel et al., 2003; Arnold, 2005). Composting can also produce N_2O from 0.5% to 5% of the initial N content of the material (Peterson et al., 1998; Vesterinen, 1996). The effect of N_2O and CO_2 emissions are 0.04% of the same mass of CH_4.

Composting on a municipal scale requires that shredded and/or screened refuse, or organic matter, should be separated at source. The material is laid in piles of 1.2 to 2 m high, which need to be aerated by turning or using PVC pipes. Composting has low capital cost and allows for the use of wastewater sludge, but the operating cost can be high. Other limitations are bad odour and small reduction in the volume of waste requiring disposal (Vesilind et al., 2002). An investment of less than US$ 10.00 in composting reduces GHG emissions of one ton CO_2 equivalent per year (Ayalon et al., 2007). Further, CH_4 emissions in composting are low. On the other hand, household waste can be composted within six months and at a much lower cost, and the resultant compost has significant environmental and cash value (Vesilind et al., 2002). Composting undertaken at household level reduces wastes at solid waste disposal sites (SWDS), and compost from kitchen and garden waste is used as a soil conditioner and for improving soil fertility.

The mechanical-biological (MB) treatment of waste is aimed at reducing the volume of waste for disposal and subsequent gas emissions from final disposal of the waste (IPCC, 2006). Mechanical operations separate the material into: (i) fractions for composting, (ii) anaerobic treatment, (iii) combustion, and (iv) recycling. They include the processes of separation, crushing and shredding. The MB treatment reduces the amount of organic material by 40-60% (Kaartinen, 2004), and on average, MB treated waste produces up to 95% less CH_4 gas than untreated waste when deposited in the SWDS (Binner, 2002). The sanitary landfill mitigation option is an engineered method for the disposal of solid and hazardous waste in a manner that protects the environment (Vesilind et al., 2002). Sanitary landfill facilitates gas recovery, thus reducing emissions to the atmosphere. The gas yield is based on waste deposits, waste composition and moisture content. Biological decomposition of municipal solid waste (MSW) produces 442.0 $m^3\ t^{-1}$ of waste containing up to 55% CH_4. The range of CH_4 yield is 60.0 to 120.0 $m^3\ t^{-1}$, averaging 100 $m^3\ t^{-1}$ of waste on dry matter basis, over a period of 10 to 40 years. Typical gas constituents are CH_4, 45-60%, CO_2, 40-60%, N, 2-5%, O_2, 0.1-1%, NH_3, 0.1-1% and H, 0-0.2% (Tchobanoglous et al., 1993). Many of the NMVOC landfill gases are toxic and/or odorous. Landfill gas can be used for power and heat generation, steam, vehicle fuel or methanol production (Vesilind et al., 2002), and the recovered fraction for energy use is between 50 and 90% (Augenstein and Pacey, 1992) Sanitary landfill involves compaction and covering of deposited waste by a layer of soil at the end of each day's operation. The movement, placement and compaction of waste in landfills require large machines, including tractors, loaders, compactors, motor graders, hydraulic excavators, water trucks and service vehicles. The major design components of a landfill include: (i) a liner, (ii) leachate collection and management system, (iii) gas management facilities, (iv) storm water management, and (v) the final cap. However, a composite liner can be expensive, costing as much as US$ 250,000 to cover 0.5 ha of land (Vesilind et al., 2002). Much of the municipal solid waste (MSW) can be burned in **combustors as a waste treatment and gas recovery measure.** Up to 15% of the solid waste can be processed for energy. Combustion of refuse produced by a community is sufficient to provide about 20% of the electrical power needs for that community (Vesilind et al., 2002). Combustors generally comprise: (i) a storage pit for storing and sorting incoming refuse, (ii) a crane for charging the combustion box, (iii) a combustion chamber or furnace, (iv) a heat recovery system, (v) an ash handling system, and (vi) an air pollution system. Waste may be pre-processed to remove non-combustible items, reduce size of the combustible fraction and minimize the cost of emission controls. Gas emissions of concern from combustion are sulphur dioxide (SO_2), sulphur trioxide (SO_3) and CO_2. Since CH_4 is 17 times more potent as a GHG than CO_2, it can be argued that the production of CO_2 in combustion is better than the production of CH_4 in landfills (Vesilind et al., 2002).

Screening mitigation options: The mitigation options were assessed based on the quantities of emissions or waste reduced, environmental sustainability, cost implications, time and equipment requirements, and other benefits or disadvantages. The technologies were screened based on several criteria as show in Table 5.14. The scores for the variables ranged from zero (0), regarded as least favourable, to four (4), regarded as the most favorable. The limitations and benefits of each score were either negative (-1) or positive (+1), and the mitigation options were screened and ranked based on total scores (Table 5.15).

Table 5.14: Parameters used for screening mitigation options in the Waste Management Sector

Parameter	Variables				Score
Emissions/waste reduced	0-25%				1
	26- 50%				2
	51- 75%				3
	76-100%				4
Time requirement (years)	0- 2				4
	3-10				3
	11- 50				2
	51-200				1
Equipment requirement	Heavy				1
	Medium				2
	Light				3
	Simple tools				4
Sustainability	Environ acceptable	(yes)	1	(no)	0
	Health concerns	(yes)	0	(no)	1
	Aesthetically acceptable	(yes)	1	(no)	0
	Odorous effect	(yes)	0	(no)	1
Cost implications	Handling/ storing	(yes)	0	(no)	1
	Labour	(yes)	0	(no)	1
	Collection & transport	(yes)	0	(no)	1
	Preprocessing	(yes)	0	(no)	1
Other/ additional	Benefits				1
Other / additional	Limitations				-1

Table 5.15: Screening matrix for the mitigation options in the Waste Management Sector

Mitigation options	Target emissions	Target waste	Waste/emission reduced	Sustainability	Time	Equipment	Costs	Other benefits/limitations	Rank	Remarks
Waste reduction	CH_4, CO_2	Paper, plastics	2	4	4	4	4	1	16	30% waste reduced, sustainable, no special time or machinery, no cost & saves non replenishable raw materials.
Composting	CH_4	Organic, sludge	4	3	4	1	0	1	13	95% CH_4 effect reduced, odorous, requires heavy machinery, high operation costs, stabilizes soil
Mechanical - biological treatment	CH_4	Organic, plastics, metals	4	4	4	1	0	0	13	95% CH_4 effect & 60% CO_2 reduced, sustainable, requires heavy machinery & high operation costs
Sanitary landfills	CH_4, CO_2 & N_2O	Organic matter	4	3	2	1	0	2	12	Reduces 95% of gas, requires heavy machinery & high operation costs, takes long time of continued GHG yield, produces leachate, fuel & methanol.
Combustion/ incineration	CH_4	Combustibles	4	0	4	1	0	1	10	Reduces 90% of GHG effect, requires heavy machinery & high operation costs, produces H_2SO_4, ash, & O_3, generates energy

5.6.2 Results and Findings

The four mitigation options were assessed for their ability to reduce GHG emissions. The baseline GHG emissions exhibited an increasing trend for CH_4 and CO_2 until the year of the closure of the landfill in the year 2010, when these started declining (Fig 4.12). The NMOC emissions were of insignificant consequence. The CO_2 was the GHG emitted in the largest emissions compared with CH_4 and NMVOC (Fig 5.12). These baseline scenario emissions were estimated with a waste diversion fraction of 31% as recommended by IPCC (2006).

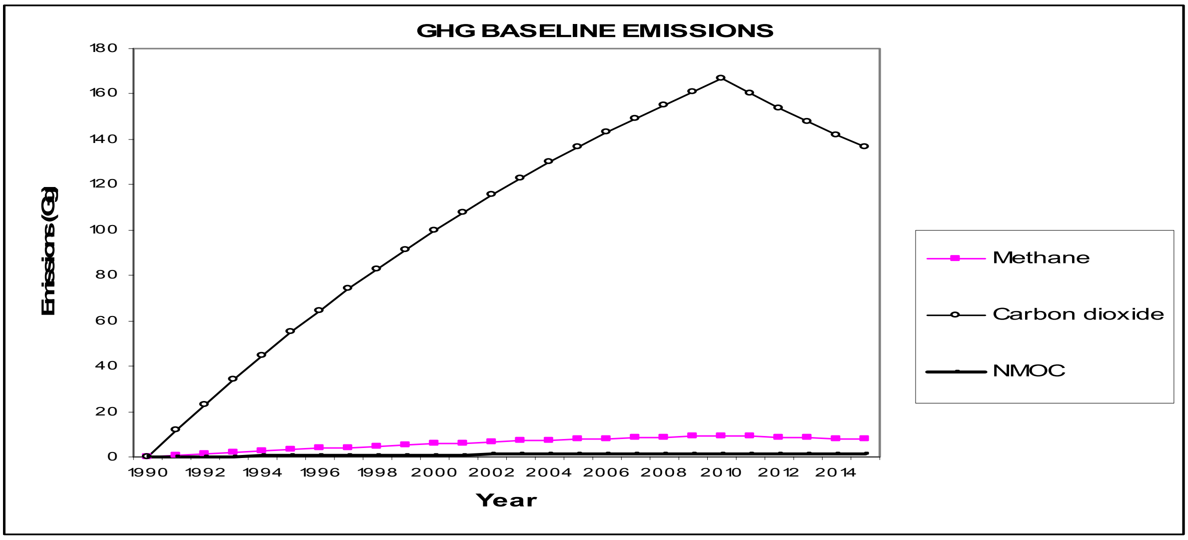


Fig 5.12: GHG baseline scenario emissions

The four mitigation options are compared in Fig 5.13. This is based on a reduction of waste disposal at the landfills by 30%. All the four mitigation options exhibit an increasing trend up to the year of closure, and thereafter declined. All the four migration options significantly reduced GHG emissions compared with the baseline scenario. However, it is the waste reduction option that is the most preferred mitigation option because it has no cost implications. While composting and mechanical biological treatment achieve the same results, they have different mitigation effects. The former is advantageous since no cost is accrued and it is feasible and applicable at household level.

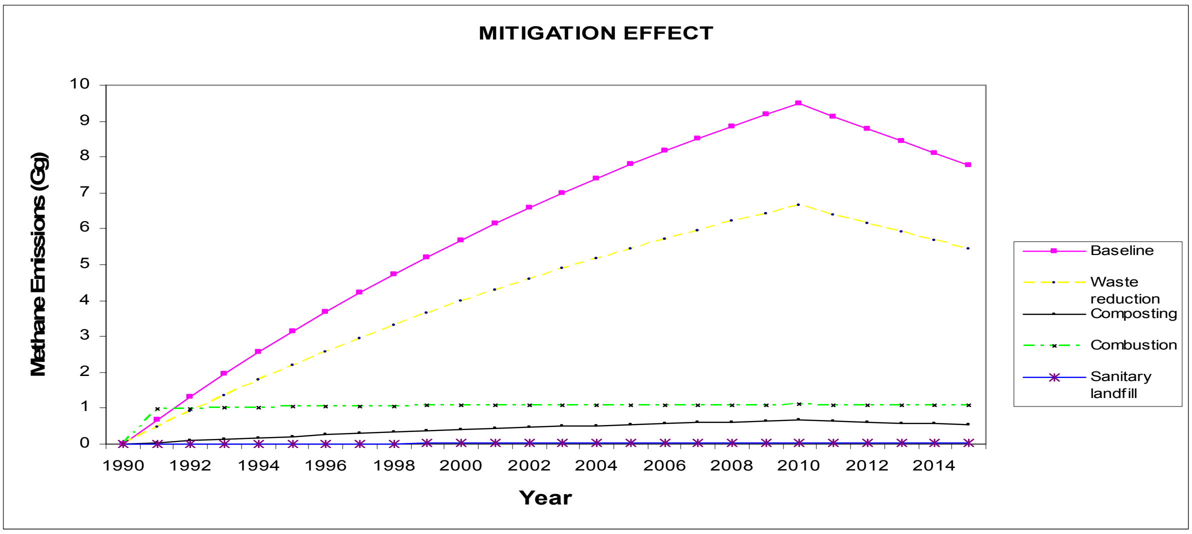


Fig 5.13: Effect of four mitigation options on methane emissions

5.6.3 **Summary**

Waste treatment and disposal contribute to the production of GHGs, which contribute to global warming. The reduction of GHG emissions from this sector can be achieved by reducing the generation of waste, recovery of GHGs, and adopting waste management practices that minimize the overall effect of GHG emissions into the atmosphere. Important mitigation options for GHG emissions under this sector include: (i) reduction in generation of waste; (ii) composting; (iii) mechanical-biological treatment; (iv) disposal of waste in sanitary landfills, and (v) combustion.

Sanitary landfills are the most effective option for the mitigation of CH_4, composting is the second best, whereas the incineration option is the least effective mitigation option. Reduction of waste generation has the least mitigation effect on the national GHG emissions. However, reduction of waste generation is the most economically and environmentally viable option in mitigating GHGs. It is recommended that the reduction of waste be adopted as the mitigation option of choice. The waste that is generated can be treated using mechanical-biological treatment, depending on availability of resources. Otherwise, the degradable waste can be composted or disposed at sanitary landfills that have GHG recovery systems. The remaining waste can be combusted or incinerated. However, there are some key barriers that constrain the adoption and implementation of these mitigation options that will need to be eliminated all together to realize the benefits of these mitigation options. The important ones include: (i) high capital investment, operational and maintenance costs, (ii) adverse environmental effects, (iii) limited institutional capacity for the city and town assemblies, and (iv) limited government priority setting.

5.7 Summary and Recommendations

5.7.1 Summary

Energy Sector: In the Energy Sector, three options (i) efficient technologies for cooking, (ii) fuel switch for lighting in the household sector, and (iii) increasing the petrol to ethanol blend ratio in the transport sector offered better and promising results. The use of efficient cooking stoves instead of the traditional three-stone open fire cooking system is the most important mitigation option; about 650 Gg of GHG emissions (CO_2 equivalent) in 2040 in the household sector are reduced. Increasing the blend ratio from 90% petrol: 10% ethanol to 80% petrol: 20% ethanol would mitigate about 90 Gg of total GHG emissions (CO_2 equivalent) in 2040 in the transport sector. The utilization of efficient lighting technology mitigates about 20 Gg of GHG emissions (CO_2 equivalent) in the same year.

Industrial Processes and Product Use (IPPU) Sector: In the Industrial Processes and Product Use Sector, the production of lime, cement, molasses and ethanol are important contributors to GHG emissions. Carbon capture and storage, value addition of lime, rice husk cement production and the use of CO_2 as a raw material, are the best options that may reduce GHG emissions from the sector. The effective removal of barriers is expected to contribute to greater reduction of industrial GHG emissions by up to 40% in 2040.

Agriculture Sector: In the Agriculture Sector, at an interest rate of 5%, the best option is the growing of upland rice, which results in 9.0 million tons of GHG emissions (as equivalent to CO_2) being avoided by using a combination of the mitigation options. These are improved fertilizer application, improved cultivation methods, improved manure management and agro-forestry practices.

Forestry and Other Land-Use (FOLU) Sector: In the Forestry and Other Land-Use Sector, two options (i) forestry protection and conservation, and (ii) reforestation and afforestation, have the desired potential to significantly reduce GHG emissions by increasing the various tree planting programmes that enhance carbon storage. In the mitigation option, the carbon pool increases to 756 million t C by 2040.

Waste Management Sector: Sanitary landfills is the most efficient option in reducing CH_4 emissions, while composting and combustion or incineration are the next best for waste management. Although the reduction of waste generation has the least mitigation effect at national level, it is the most economically and environmentally viable option.

5.7.2 Recommendations

The various mitigation options reported in this study have enormous potential to reduce total GHG emissions in the various sectors of the economy. However, in order to achieve the national developmental goals and objectives, it is recommended that Government should aggressively:

- Involve all partners and practitioners, using participatory approaches under the current decentralization policy, in the use and implementation GHG mitigations options,
- Promote the use of affordable and user-friendly alternative renewable energy technologies (RETs),
- Reduce dependence on biomass energy through capital subsidies, tax breaks, and technical, financial and institutional support
- Strengthen tree planting programmes throughout the country;
- Strengthen the implementation modalities of the current policies and legal instruments that increase access to affordable, user-friendly RETs at both household and institutional levels
- Enhance capacity building and training programmes for communities and professionals, especially in the selection of appropriate RETs, systems analysis and computer simulation modelling, including the training in climatology, meteorology, and atmospheric sciences within local universities and other institutions, and
- Provide funding for the proposed climate change projects, starting with the proposals in the National Adaptation Programmes of Action (NAPA) and Second National Communication (SNC) of Malawi.

Chapter 6
Other Information Considered Relevant to the Achievement of the Objectives of the Convention

6.1 Background

In accordance with Article 4, Paragraph 1(f) of the United Nations Framework Convention on Climate Change (UNFCCC), Malawi is obliged to report on the steps that it is taking to integrate climate change issues into relevant social, economical and environmental policies, strategies and programmes in various sectors of the economy. Nine sectors have been identified as follows: (i) Agriculture, (ii) Water Resources, (iii) Energy, (iv) Forestry and Other Land-Use (FOLU), (v) Fisheries, (vi) Wildlife, (vii) Human Health, (viii) Industrial Processes and Product Use (IPPU), and (ix) Waste Management.

Presently, Malawi has conducted several studies aimed at fulfilling her obligations under the Convention. These have included the preparation and submission of Malawi's Initial National Communication (INC) to the Conference of Parties (COP) of the UNFCCC in December 2003, and the preparation of several other climate change related documents, including: (i) Research and Systematic Observation (EAD, 2005), (ii) Technology Transfer and Needs Assessment (EAD, 2003), (iii) National Adaptation Programmes of Action (NAPA) (EAD, 2006), and (iv) National Capacity Self- Assessment (EAD, 2006). Based on the results of these findings, several issues have been highlighted that need to be addressed with the urgency that they deserve as follows: (i) integrating climate change into national socio-economic and environmental policies, strategies and programmes, (ii) enhancing climate change and systematic observation by the Departments of Meteorological Services (DoMS), Department of Water Resources (DOWRY), Department of Agricultural Research Services (DARS), Department of Forestry (DoF), Department of Fisheries (DoF) and the universities of Malawi and Mzuzu, among other research institutions, such as the Agricultural Research and Extension Trust (ARÊTE), Tea Research Foundation of Central Africa (TRF), and Non-Government Organizations (NGOs), such as Total LandCare Malawi. (iii) initiating research on climate change and climate variability related topics, and the determination of capacity and emission factors, activity data and minimum data sets for model calibration, validation, testing and experimentation, and the development of various measures and strategies for adapting and coping with climate change, and mitigating climate change, (iv) initiating programmes on information dissemination and utilization on climate change and climate change related issues; and conducting education, training and public awareness campaigns to communities, (v) making available information on capacity building at the national, regional and sub-regional levels, and (vi) enhancing efforts to promote information sharing and networking.

What follows is an outline of the efforts that have been taken by Malawi to integrate climate change concerns into policies and programmes of different sectors at local and national levels considering medium- and long-term development strategic plans, poverty reduction strategies, Agenda 21, Millennium Development Goals, national environmental action plans, and any other relevant documents.

6.1.1 Rationale

The Malawi Government considers environmental management and the address of climate change as an integral component of the economy in particular food security and poverty alleviation programmes. As central pillars of the national development policies and strategies, the Government adopted Vision 2020 in 2000, the Malawi Poverty Reduction

Strategy (MPRSP) in 2003, and the Malawi Growth and Development Strategy (MGDS) in 2006. Further, these documents recognize the importance of cross-cutting issues, such as climate change, gender and HIV and AIDS, and science and technology as important components of an over-arching and sustainable development strategy. Hence, to address the current pressing climate change issues, Malawi needs data and information to manage the environment and climate change in particular as manifested in the form of floods and droughts. The rationale is to ensure that all government policies integrate climate change issues which will enable address any climate change programmes.

6.1.2 Initial National Communication of Malawi

Malawi submitted its Initial National Communication (INC) to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (NECK) in December 2003. Some of the main challenges observed in the INC of Malawi include:-

(i) Lack of research conducted in climate change issues: There has been no Government institution that has conducted climate change research, despite the fact that the Department of Agricultural Research Services (DARS) is the main public sector institution mandated to conduct agricultural research and related disciplines, such as climate related to agriculture. First, work conducted on climate change has been limited to the collection and recording of climate variables (rainfall, temperature, solar radiation, wind sped and relative humidity) at several weather recording sites coordinated by the Department of Meteorological Services (DoMS) in collaboration with the Ministry of Agriculture and Food Security (MoAFS) and the Department of Water Resources (DoWR) are the only activities performed.

(ii) Inadequate specialized training in climate change and climate change-related disciplines at individual and institutional levels,
(ii)Inadequate funding of the proposed climate change projects prioritized in the document;
(iii) Inadequate technical capacity to run computer simulation models and decision support systems;
(iv)Lack of local institutions to host short-term training courses on systems analysis and computer simulation modeling,
(vi) lack of activity data, emission factors and minimum data sets for model verification;
(vii) lack of public awareness to fully appreciate environmental issues, although policy statements on the environment are clear in national policy documents, such as Vision 2020, MPRSP and MGDS and (viii) poverty, as Malawi is ranked as a Least Developed Country (LDC) with about 65% of its population living below the poverty line. Economically depressed populations frequently experience life-threatening difficulties in adapting to the adverse impacts of climate change.

6.1.3 Second National Communication of Malawi

Malawi initiated the preparation of the Second National Communication (SNC) of Malawi to fulfill her commitment and obligations of periodically reporting to the COP of the UNFCCC greenhouse gas emissions (GHGs) by source and removals by sinks, programmes containing measures to mitigate, and to facilitate adequate adaptation to climate change, and any other information considered relevant to the achievement of the objective of the Convention.

6.1.4 Other Information Considered Relevant to the Achievement of the Convention

Since the preparation of the INC in 2003, a lot of work has been conducted in response to changing socio-economic circumstances, including Government policies, strategies and programmes, and the increasing frequency of floods and drought. Specifically, this chapter presents information on:

(i) Steps taken to integrate climate change into relevant socio-economic and environmental policies and strategies,
(ii) transfer of technologies,
(iii) climate change systematic observation,
(iv) research programmes containing measures to mitigate, and to facilitate adequate adaptation to climate change,
(v) education, training and public awareness on climate change,
(vi) capacity building, and integrating climate change adaptation measures into medium- and long-term planning strategies,
(vii) information sharing and networking, and
(viii) National Adaptation Programmes of Action (NAPA).

6.2 Steps Taken to Integrate Climate Change into Relevant Socio-Economic and Environmental Policies and Strategies

There are several steps that have been taken to integrate environmental issues into relevant sectoral and national policies, strategies and programmes. Unfortunately, most of these do not specifically mention climate change, but these are part of issues presented under Environment at both national and local levels.

6.2.1 National Context and Vision

Vision 2020. The Malawi Vision 2020 is the national long-term development perspective for Malawi that provides a framework for national development goals, policies and strategies. It emphasizes sustainable development and recognizes the importance of monitoring GHGs, adoption of ozone-friendly technologies and the promotion of public awareness on climate change issues.

Malawi Poverty Reduction Strategy (MPRSP). **In May 2002, the Malawi Government launched the Malawi Poverty Reduction Strategy (MPRSP) for poverty reduction through socio-economic and political empowerment of the poor.** To achieve this, Government incorporated the poverty alleviation programme (PAP) which was launched in 1994 to address chronic poverty in the country. Programmes and projects undertaken under PAP include the Safety Net Programmes and the Malawi Social Action Fund (MASAF). The **safety net programmes** aim at alleviating poverty and target vulnerable groups and communities, such as the poor, elderly, infirm, physically challenged, and resource- poor female-headed households. Safety Net Programmes include the Public Works Programme, (PWP), Targeted Inputs Programme (TIP), Targeted Nutrition Programme (TNP), Direct Voucher Transfers (DVT) to disadvantaged groups and Farm Inputs Subsidy Programme that targets resource [poor families in the country. The **Malawi Social Action Fund**

(MASAF), which is jointly funded by the Malawi Government (MG) and the World Bank (WB), is a key programme under PAP. MASAF provides, *inter alia,* infrastructure for provision of social services, such as school blocks, clinics, water supply, roads, bridges and other social infrastructures.

In both the Poverty Alleviation Programme and the Malawi Poverty Reduction Strategy, an environment component was included to ensure that the strategic programmes were environmental friendly and achieve sustainable development as enshrined in the Agenda 21.

Malawi Economic Growth Strategy (MEGS). In July 2004, Malawi developed MEGS in close cooperation with the private sector in an effort to respond to some of the concerns raised by stakeholders, especially the shortfalls observed in the MPRSP under Pillar 1: "Sustainable Pro-poor Growth"

Malawi Growth and Development Strategy (MGDS). The Malawi Government prepared the Malawi Growth and Development Strategy (2006-2011) in 2006, which underscores the importance of agriculture, environment and climate change, which is placed under Theme One that is dealing with sustainable economic growth, and under Sub-theme Four, which deals with the conservation of Malawi's natural resources base. Government deliberately prepared an addendum of climate change to the MGDS to incorporate and strengthen climate change issues coverage in the MGDS.

Thus, these national policies and strategies recognize the importance of the environment, hence climate change, as important pillars for sustainable socio-economic growth and development, poverty alleviation, food security, and environmental protection.

6.2.2 Environmental Policies and Strategies

National Environmental Action Plan (NEAP). Following Malawi's participation at the United Nations Conference on Environment and Development (UNCED in Rio de Janeiro in 1992, the National Environmental Action Plan (NEAP) was prepared and launched in 1994. The NEAP is an operational tool for the implementation of Agenda 21, and has identified several key environmental concerns, including air pollution and climate change.

National Environment Policy (NEP). The Malawi Government adopted the National Environment Policy (NEP) in 1996, and revised it in 2004. The policy provides for an overall framework through which sectoral policies are reviewed to assess their consistency with the principles of sound environmental management. The Policy also emphasizes on the empowering of local communities in the management of their natural resources to promote social equity, minimize the adverse impacts of climate change, and reduce air pollution and GHG emissions.

National Strategy for Sustainable Development (NSSD): This was adopted by the Malawi Government in 2004 to respond to the call by the World Summit on Sustainable Development (WSSD) held in Johannesburg, Republic of South Africa in 2002. Through the NSSD, Government committed itself to intensify its role in the implementation of the UNFCCC activities and programmes. The installation of satellite data receiving equipment, publicity of climate change issues and the preparation of the different country studies including this Second National Communication are some of the activities which have been implemented in accordance with the NSSD.

6.2.3 Legal Framework and Compliance

Legal framework: The Government has put in place a series of legislative frameworks to promote and consolidate climate change and other socio-economic growth and development activities in the country. These include: (i) the Forestry Act (1997), (ii) Fisheries Conservation Act (1998), (iii) Occupational Safety and Health Welfare Act (1997), and (iv) Pesticides Act (2000), among many other policies and acts. The Environment Management Act of, 1996 is the legal instrument for implementing and enforcing compliance with the various regulatory frameworks for the protection and preservation of the environment. It also provides for the protection of the ozone layer by regulating substances, activities and practices that deplete or are likely to deplete the stratospheric ozone layer or other components of the stratosphere.

There is the National Council on the Environment (NCE), which is supported by the Technical Committee for the Environment (TCE), which deals with all environmental issues. Further, there is the National Climate Change Committee (NCCC) with the responsibility of reviewing policies and programmes on climate change, which is chaired by the DoMS with its Secretariat in EAD.

Legal compliance: Environmental Impact Assessments (EIAs) have been instituted and promoted as an environmental management tools to ensure that development activities are implemented in a sustainable and environmentally-friendly manner. Many public and private sector organizations are now undertaking EIAs before they commence implementing their projects. Industrial development projects that emit carbon dioxide are also appraised under Environmental Impact Assessment; however, the enforcement of compliance is limited because of capacity bottlenecks with respect to equipment to monitor carbon dioxide emitted from the industries such as the Uranium Mine at Kayelekera in Karonga district. However, climate change is not directly incorporated in all EIAs.

6.2.4 Sectoral Policies and Strategies

The sectors of economic growth for which sectoral policies, strategies programmes and projects have been developed include: Agriculture (food and nutrition, land resources, irrigation, extension and research), Water Resources, Forestry, Energy, Human health, Fisheries, and Wildlife.

6.2.5 Sectoral Programmes and Projects

In an effort to implement the various policies and strategies, several programmes and projects have been developed and have been, and continue to be, implemented by various public and private sector organizations, including Non-Governmental Organizations (NGOs). These are efforts aimed at achieving sustainable development through the reduction of poverty and the implementation of measures that ensure environmental sustainability. Some of these programmes or projects are on renewable energy and biomass energy sources.

Renewable energy programmes. Malawi has put in place the National Sustainable and Renewable Energy Programme (NSREP) supported by the Global Environment Facility (GEF), the Danish International Development Agency (DANIDA) and the Southern African Development Community (SADC), which aims at promoting the use and development of Renewable Energy Technologies (RETs). The Department of Energy is the coordinating and implementing agency of the programme.

Biomass energy projects: Biomass energy is the major source of energy in Malawi, and is also one of the main causes of deforestation and GHGs emissions. There are a number of national programmes, which are being implemented to promote efficient use of biomass energy, as well as looking at alternatives to firewood and charcoal. Some of the programmes and/or projects include the following: (i) SADC Regional Programme on Biomass Energy Conservation (ProBEC) funded by Deutsche Gescllschaft fur Technische Zusammenarbeit/European Union (GTZ/EU), (ii) Briquetting using sawdust under the NSREP Programme, (iii) Biogas dissemination project under NSREP; and (iv) Dissemination of improved ceramic firewood and charcoal stoves by various NGOs.

6.2.6 Decentralization Policy of 1998 and the Local Government Act of 1998. The Decentralization Policy and Act have devolved administrative and political authority to the district and local level structures. This is intended to promote good governance, transparency and accountability. The decentralization policy also fosters the empowerment of local communities to demand services from those most able to provide them. The decentralized Environmental Action Plans (EAP) and the Micro-Projects have been developed according to the rules and regulations as recommended in the Policy and Act. Besides Government, there are other institutions that also promote good governance, transparency and accountability, such as the Finance and Audit Committee of Parliament, the Anti-Corruption Bureau, National Initiative for Civic Education (NICE), Centre for Environmental Policy and Advocacy (CEPA), among many others. .

6.2.7 Sectors Subjected to Climate Change Adaptation and Mitigation Assessments

The main thematic areas of focus that have been identified for adaptation and mitigation analysis are: (i) Programmes containing measures to facilitate adequate adaptation to climate change (Vulnerability and Adaptation (V&A) Assessments), and (ii) Programmes containing measures to mitigate climate change (Mitigation Analysis). Within the V&A Assessments thematic area, studies have been performed in following seven sectors: (i) Agriculture, (ii) Forestry and Other Land-Use, (iii) Water Resources, (iv) Fisheries, (v) Wildlife, (vi) Energy, and (vii) Human Health, whereas mitigation analysis studies have been conducted in the following four sectors: (i) Energy, (ii) Agriculture, (iii) Forestry and Other Land-Use, (iv) Industrial Processes and product Use, and (v) Waste Management. These are the sectors that emit more GHGs and/or are adversely affected by the impacts of climate change, especially as manifested through the increasing frequency and magnitudes of floods and droughts over the last four decades.

6.2.8 Consultation Process with Stakeholders

There are many stakeholders in various public and private sector organizations, committees and organizations that are dealing with climate change issues in Malawi. These include stakeholders from the following organizations and institutions: (i) Agriculture (Research, Extension and Livestock), (ii) Water, (iii) Fisheries, (iv) Meteorological Services, (v) Wildlife, (vi) Forestry, (vii) Energy, (viii) Gender and Child Development, (ix) Education, and (x) Community Services. The other institutions include: (i) NGOs (e.g. Wildlife and Environmental Society of Malawi (WESM), Coordination Unit for the Rehabilitation of the Environment (CURE), World Vision, Action Aid (Malawi) and National Herbarium and Botanical Gardens of Malawi), (ii) academic institutions (Universities of Malawi and Mzuzu), (iii) Cabinet Committee on the Environment (CCE), and (iv) National Climate Change Committee (NCCC). The stakeholders in these sectors, committees and organizations were consulted through high-level consultative and participatory meetings that included senior Government officials and development partners.

6.2.9 Linking Mitigation and Adaptation Measures to National Programmes

There are no specific provisions on climate change issues in the various policy and strategy documents, especially at national level. In most cases, climate change is just mentioned as part of the environmental issues. However, the preparation of the Second National Communication (SNC) will promote public awareness on climate change issues so that the proposed climate change adaptation and mitigation measures will find a place in any new policy documents. Further, the vision of the policy and strategy documents in the future will have to seriously consider climate change as one of the main over-arching issues to ensure sustainable economic growth and development under changing climatic conditions, land degradation and increasing poverty.

6.2.10 Linking Climate Change Concerns to National Priority Issues

Similarly, few efforts have been made to specifically link climate change issues to national priority issues. However, the National Environment Action Plan (NEAP) clearly identified climate change as a major issue impacting on Malawi's economic development pathway. In addition, various sectoral policies and strategies, especially in agriculture, water, forestry and fisheries, have included aspects of climate change in their policy and strategy documents merely as a cross-cutting issue. This is because these sectors are greatly impacted upon by climate change and climate variability. This lack of integration also perhaps highlights the fact that it is only recently that climate change has taken centre stage in development circles.

6.2.11 National Policies Adopted by Government

Two principle statures designed to address the environment, and indirectly climate change, have been adopted by the Malawi Government: (i) National Environment Policy of 1996 (revised in 2004), and (ii) Environment Management Act of 1996. Both the Policy and Act are in the Environmental Affairs Department (EAD), which is the UNFCCC Focal Point for Malawi. EAD is also responsible for promoting sustainable utilization and management of the environment and the natural resource base.

6.3 Transfer of Technologies

There are many technologies that have been identified and introduced in various economic growth sectors, such as: (i) energy, (ii) agriculture, (iii) irrigation, (iv) water development, (v) meteorology, (vi) industrial processes and waste management, (viii) health, and (ix) education. The available technologies can be categorized as follows: (i) technologies in power generation (solar photovoltaic, wind, mini and/or micro hydro, biomass and solar fired thermal), (ii) solar thermal (solar water heaters and solar dryers for crops, fish and tobacco), (iii) biomass (improved and efficient cooking stoves, improved charcoal production and liquid bio-fuels (gel fuel), (iv) demand side management (industrial efficiency and retrofits), and (v) waste technologies (biomass wastes (sawdust stoves, briquettes and co-generation), animal and human waste (biogas) and crop residues).

6.3.1 National Policies and Legal Framework for the Implementation of Decision 4/CP7

Malawi has put in place institutional arrangements to engage various stakeholders in the technology transfer and needs assessment process. The DoEA is the lead technical institution on energy matters, which is assisted by the Technology Steering Committee (TCC) that is coordinated by the Environmental Affairs Department (EAD). The National Sustainable and Renewable Energy Programme (NSREP) developed in 1997, has highlighted the legal and institutional framework, barriers to technology transfer, adoption and utilization, information sharing and dissemination, and various means and pathways for disseminating climate change technologies. The other policies on technology transfer may be inferred from the Technology Policy of the National Commission of Science and Technology, the Education Policy in the Ministry of Education, Science and Technology, and the policies developed by the Universities of Malawi and Mzuzu.

Technology needs and assessment. The technology needs assessment has greatly benefited from the activities that are being undertaken in other countries in the southern Africa region with technical assistance from the Climate Technology Initiative (CTI). The appropriate technologies were identified based on the following criteria: (i) development benefits (employment creation potential, capacity building, health and quality of life improvement, human and material resource mobilization), (ii) market potential (affordability, cost, finance, investment, barriers, durability and availability), and (iii) climate change (reduction in GHG emissions, enhancement of sinks and effects on the environment).

Barriers to technology transfer. Although many technologies have been identified and introduced in Malawi, the uptake and use of these is slow and very low indeed. There are many barriers to the uptake of these, including: poverty, lack of materials and appropriate technical skills, retrogressive cultural briefs, high initial investment costs and lack of public awareness.

6.3.2 Activities Related Capacity Building, Investment and Technology Assessments

The implementation and institutionalization of climate change in different sectors of the economy is still in its infancy, despite the glaring adverse impacts of climate change that have been experienced over the last four decade. There is need for: (i) training and education on climate change, (ii) public awareness campaigns on the adverse impacts of climate change on vulnerable communities, sectors of economic growth and fragile agro-systems, (iii) institutionalization of climate change in relevant Government Ministries and/or Departments, Civil Society Organizations (CSO) and NGOs, and (iv) introduction of climate change issues in primary, secondary and higher learning institutions, and capacity building at various levels of technology development, implementation and utilization (such as (a) train local communities in the use and implementation of the technologies, (b) train local artisans in the manufacture or fabrication of the available technologies, and (c) provide civic education to communities on the importance and use of renewable energy technologies.

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For the technology transfer, dissemination, uptake and utilization process to occur, an enabling environment needs to be created by Government for all stakeholders. This requires good and conducive Government policies and good governance. The current Government Farm Inputs Subsidy Programmme, which provides farm inputs (fertilizers, seeds and crop protection products) at reduced or subsidized prices, has resulted in an unprecedented upsurge in the uptake of these technologies, with spill-over of surplus food production, hence impacting directly food security, hunger, poverty and sustainable livelihoods of family households. Similarly, to ensure technology uptake and utilization on renewable energy sources, efforts should be put in place to link these to the Farm Inputs Subsidy Programme, including granting duty free status on imported technologies. This will ensure that investments in the technologies that reduce GHG emissions are utilized by communities.

6.3.3 Process, Key Outcomes and Funding of Technology Needs Assessment

In 2003, Malawi prepared the Technology Transfer and Needs Assessment (TTNA) Report pursuant to Decision 4/CP.7, its annex, and the implementation of Article 4, Paragraph 5, of the Convention. Technical guidance was received from the Climate Technology Initiative (CTI) of the United Sates of America (USA). During stakeholder consultations, a Technology Taskforce Team, with a Chairperson, was formed to lead the formulation of the technology transfer and needs assessment process. Through this participatory consultative process, institutional arrangements were agreed upon as follows: (i) Climate Change Technology Steering Committee (with a Chairperson), (ii) Secretariat: Environmental Affairs Department (EAD), (iii) Technical lead institution: Department of Energy Affairs (DoEA), (iv) Five technology sub-teams as follows: (a) PV-Systems, (b) Biomass, (c) Biogas, (d) Wind, and (e) Other Renewable Energy Sources. The Taskforce Team identified a list of stakeholders that included public and private sector organizations, such as NGOs, the academia, Faith-Based Organizations (FBOs), and multi-lateral and bi-lateral donor agencies.

Criteria for prioritizing technologies. The following three basic globally accepted criteria were used to prioritize the technologies: (i) development benefits, (ii) implementation potential, and (ii) contribution to climate change response measures and goals. The three basic criteria were sub-divided for depth and completeness taking national circumstances into consideration as depicted in Table 6.1.

Table 6.1: Sub-division of the criteria for depth and completeness of the technologies

Development benefits	Market potential	Climate change
• **Employment creation potential.** • **Capacity building** • **Health and quality of life improvement** • **Resource mobilization (human and materials)**	• Affordability • Cost • Finance • Investment • Barriers • Durability and availability	• Reduction of GHG emissions • Enhancement of sinks • Effects on the environment

Priority sectors. During the consultative workshop, stakeholders identified and prioritized sectors as follows: (i) Energy, (ii) Agriculture, (iii) Irrigation, (iv) Water Development, (v) Meteorology, (vi) Industrial Processes and Product Use, (vii) Human Health, and (viii) Education.

Pilot programmes and technologies introduced in the country. Various technologies have been introduced and tested in the country, despite the fact that the country has a small industrial base. These technologies are mainly on renewable energy sources, and include: (i) technologies for power generation (solar photovoltaic, wind, mini and/or micro hydro and biomass, (ii) solar thermal (solar water heaters (SWH) and solar drying (crops and fish and tobacco curing), (iii) biomass (non-power) (improved and efficient cooking stoves, improved charcoal production, liquid bio-fuel (gel-fuel and blu-wave), (iv) demand side management (DSM) (industrial efficiency, retrofits), (v) waste technologies (biomass waste (sawdust stoves, briquettes and co-generation), animal and human waste, biogas, crop residues), and (vi) other technologies, which include rocket stoves, waste management, and ground satellite stations that receive data from Meteo-Sat.

Pilot programmes on technology transfer that have been researched upon. The technology transfer programmes have mainly been carried out by the Industrial Research and Technology Development Centre (MIRTDC). These include: (i) improved biomass stoves, which have been reported to save up to 55% of the energy, (ii) micro hydro-power plants in the northern region for supplying up to 10 kW of power to a youth centre, (iii) briquettes pressing machines, and (iv) bee keeping technology strategy for sustainable livelihoods in Mulanje. Unfortunately, the uptake and utilization of these technologies is rather slow and low.

6.3.4 Technology Transfer Programmes Supported by International Organizations

Several programmes and/or projects related to climate change that are supported by the international donor community are currently under implementation in some parts of the country. These include technologies on: (i) renewable energy sources, and (ii) research and development initiatives.

Renewable energy technologies. These include: (i) solar and thermal PVs in donor-supported government clinics and Community Day Secondary Schools. These have been supported by the United Nations Children's Fund (UNICEF), Japanese International Cooperation Agency (JICA), Global Environment Facility(GEF) (the BARREM Project), and the Christian Health Association in Malawi (CHAM), among many others, and (ii) biogas under the Women in Development Project supported by the World Bank (WB).

Research and development initiatives. These include the following: (i) wind technology for water pumping, (ii) rocket stoves, ceramic charcoal stoves, ceramic wood stoves and institutional stoves supported by a number of donors including GTZ under the PROBEC Programme, and has partly been implemented by Bunda College and The Polytechnic, (iii) the MIRTDC proposal to build a local model for mitigation scenarios on energy, (iv) use of energy efficient stoves, solar photovoltaic and other cost effective, non-pollutant technologies, and (v) use of ethanol-based fuels, such as gel-fuel for cooking and heating. .

6.3.5 Role of Various Stakeholders in the Technology Transfer Process

There are many stakeholders in public and private sector organizations, including NGOs, the universities and CSOs that are involved in the technology transfer process to various end-users.

Universities of Malawi and Mzuzu. The Universities of Malawi and Mzuzu are currently running some short courses and conducting some research related to the environment and climate change issues. These include: (i) The Malawi Polytechnic: teaching and research in atmospheric physics; design, manufacture, and testing of ethanol stoves; design of solar thermal systems, i.e., driers and cookers; development of a wind generator for rural water supply; development of an improved charcoal kiln; development of a portable model biogas plant; and development of a solar refrigerator, (ii) Chancellor College: (a) Department of Geography and Earth Sciences: courses on climatology, hydrology, and meteorology; (b) Natural Resources Environment Centre (NAREC): research on "Strengthening Local Agricultural Innovation Systems in Less Favoured and High Potential Areas of Tanzania and Malawi to Adapt to the Challenges and Opportunities Arising from Climate Change and Variability" from Contrasting Sites Selected from Mzimba, Mulanje, Karonga, Chikwawa and Nsanje, (iii) Bunda College of Agriculture: (a) Centre for Agricultural Research Development (CARD) in conjunction with Christian Aid-Malawi, research project on "Mainstreaming Climate Change Adaptation and Mitigation in Sectoral and National Development Plans and Strategies in Malawi", which is a review of sectoral and national development policies and strategies, and (iv) Mzuzu University has established a faculty dealing with renewable energy sources. As a teaching institution, it will also be involved in conducting research and the transfer of technologies to all stakeholders, including local communities.

Private sector and parastatal organizations. The Electricity Supply Corporation of Malawi (ESCOM) is promoting the use of energy-saver bulbs, whereas the Ethanol Company (ETHCO) of Malawi has introduced an ethanol stove. Efforts by the private sector to invest in gel-fuel production has met a challenge of low uptake of the technology because it is competing with paraffin, which is still relatively cheaper at the present moment.

Non-governmental organizations (NGOs). NGOs and other private sector institutions, such as the Renewable Industries Association in Malawi (RIAM) and International Power Control Systems (IPCS) have been involved in the promotion and dissemination of renewable energy technologies, such as solar photovoltaic. Other NGOs, such as OXFAM, Action Aid and the Evangelical Lutheran Development Programme (ELDP), have also been disseminating energy-efficient technologies, such as cooking stoves.

6.3.6 Successes, Failures and Lessons Learnt from Technology Transfer Initiatives

A lot of experience has been gained working with and using renewable energy sources in Malawi. Many lessons have been learnt on the performance of the technologies, slow and low uptake and utilization by communities of the technologies. Both successes and failures have been recorded, especially in the following technologies: (i) biogas technology, (ii) wind resource and wind energy technologies, (iii) energy efficiency technologies, (iv) small hydro-power technologies, and (v) solar photovoltaic technologies. Generally, the uptake and utilization of these technologies is low owing to various barriers and constraints, including: (i) poor animal husbandry practices, (ii) non-involvement of stakeholders in project design, (iii) lack of appropriate technical skills at all levels, (iv) cultural beliefs, (v) lack of public awareness, and (vi) high initial investment costs.

6.3.7 Technologies Identified in the National Adaptation Programmes of Action

The National Adaptations Programmes of Action (NAPA) has identified a number of short- and long-term priority adaptation strategies, which if implemented, would facilitate adequate adaptation to climate change. The short-term adaptation strategies include crop diversification; adjusting timing of farm operations; changes in tillage practices; crop storage and food reserves; irrigation, and efficient use of water, whereas long-term options, include early warning systems. The long-term strategies include: (i) rehabilitating and upgrading observation network; (ii) improving telecommunications to ensure reliable collection and exchange of data and information; (iii) creating an efficient data acquisition and management system, (iv) developing an adequate and well-trained human resource base, (v) enhancing capacity in the DoMS to produce, interpret and disseminate weather information and other products, (vi) improving interaction between the DoMS and the user community so as to maximize the benefits of applying weather forecasting products and information in decision making, and (vii) increasing capacity of users, planners and decision makers in applying meteorological information and products in various socio-economic sectors.

6.3.8 Linking Technology Transfer Activities to the National Planning Process

If policies, legislative and institutional frameworks can be strengthened; and the capacity of key Government and NGOs responsible for planning and supporting the implementation of mitigation, adaptation, risk reduction management and climate proofing interventions increased; then more people would adopt the available renewable energy technologies, thereby reducing GHGs emissions into the atmosphere. This would be a significant step, especially considering that the Initial National Communication (INC) of 2003 further confirmed that Malawi is a net emitter of CO_2. Presently, Malawi has developed policies and strategies to stimulate economic growth and development through poverty reduction to ensure food and water security, empower vulnerable rural communities, ensure sustainable utilization of Malawi's natural resources, and protecting the environment, as articulated in

Malawi's Vision 2020, Malawi Poverty Reduction Strategy (MPRSP), Malawi Growth and Development Strategy (MGDS), and the National Environmental Action Plan (NEAP).

6.4 Climate Change Research and Systematic Observation

Research and systematic observation are encouraged under the UNFCCC through Article 4.1(g) and Article 5 as related to the climate system atmosphere, hydrosphere, biosphere and geosphere and their interactions. Malawi has collected some data in these fields but their period of recording varies greatly. The earliest rainfall data are from 1890 while that of air temperature goes back to 1901. However, systematic observations started only after the First World War in 1918. In the other sectors, such as hydrology and agriculture, systematic observation have been recently introduced and maintained. The UNFCCC Reporting Guidelines on National Observing Systems, as adopted by the Conference of Parties (COP), has been used to guide in the preparation of systematic observation.

6.4.1 National and/or Regional Programmes for Research and Systematic Observation

The 2005 Research and Systematic Observation Report outlines achievements of Malawi in contributing to the activities and programmes, as appropriate, of national, regional and global research networks and observation systems. The report further contributes to the Global Climate Observing System (GCOS) Programme that aims at assuring that systematic observation and information are available to policymakers, planners and other potential users.

6.4.2 Institutions Involved in Climate Change Research and Systematic Observation

There is no institution in Malawi that is specifically mandated to conduct climate change research. However, there are some institutions that are involved in coordinating research (National Commission for Science and Technology), and conducting research in other fields that are related to climate change (e.g., Department of Agricultural Research Services (DARS)), whereas climate change systematic observation is mainly carried out by DoMS, and supported by Ministry of Agriculture and Food Security (MoAFS) and the Department of Water Resources (DoWR).

National Commission for Science and Technology (NCST). The NCST, which is an umbrella organization responsible for coordinating and overseeing all types of research in the country, was established in 1974 with the aim of providing national direction on Science and Technology (S&T), promoting and coordinating the development and application of S&T for maximum economic and social benefits to all Malawians. The NCST has the following programmes and activities: (i) development of a national science and technology policy for Malawi; (ii) development of a national research strategy and master plan; (iii) management of contract research programmes; (iv) development of linkages on research and development, (v) development of databases and inventories; (vi) awarding of S&T awards; and (vii) coordination of the Sustainable Development Network Programme (SDNP).

Department of Agricultural Research Services (DARS). DARS is the only Government Department whose mandate is to conduct agricultural research in Malawi. Since the Agriculture Sector is highly vulnerable to climate change, some research on climate change-related topics have been conducted, including: (i) crop response and performance under drought and soil-water stress conditions, (ii) breeding crop varieties and cultivars that are tolerant to drought and low soil fertility (especially nitrogen) conditions, and (iii) soil and water conservation measures and practices to control soil erosion, hence the siltation of rivers. The need to conduct climate change research by DARS within the Soil Physics Unit, which has in the past conducted some research on climate-related topics, and has been a repository of climate data from various agricultural sites in the country, is more urgent now that any other time in the past.

Department of Meteorological Services (DoMS). Malawi is a member of the World Meteorological Organisation (WMO) and follows the WMO standards and procedures for observations for its twenty-six stations for both the surface and upper air observations. However, upper air observations have been discontinued because of the breakdown of infrastructures, lack of materials and limited financial resources. Hence, upper air observations have not been continuous resulting into unsystematic observation. Surface observational structures are still in place to maintain systematic observations but lack of financial resources will affect the future ability to maintain these systematic observations. The Department is mandated to make, collect, process, store and disseminate meteorological data, information and products to all users. It provides efficient weather and climate services to all socio-economic sectors at local, national and regional levels.

6.4.3 Nature and Level of Participation in Global Research and Observations

Systematic observation related to climate change are conducted and recorded by some public and some private sector organizations, including: (i) Department of Meteorological Services (DoMS), (ii) Ministry of Agriculture and Food Security (MoAFS), (iii) Department of Water Resources (DoWR), (iv) District Assemblies (DAs), (v) Universities of Malawi and Mzuzu, and (vi) Non-Government Organizations (NGOs).

Department of Meteorological Services (DoMS). Malawi participates in the Global Climate Observing System (GCOS) through the provision of meteorological observations from two main stations at Chileka and Lilongwe Airports through the GTS as part of international data exchange programme (Table 6.2).

Table 6.2: Participation in the global atmospheric observing systems by Malawi.

Key question	Observing system			
	GSN	GUAN	GAW	Other
How many stations are the responsibility of the…?	3	1	1	21
How many stations are operating now ?	3	Nil	Nil	21
How many of those are operating to GCOS standards now ?	2	Nil	Nil	Nil
How many are expected to be operating in 2005 ?	3	1	1	24
How many are providing data to international data centre now ?	2	Nil	Nil	Nil

Key: GAW- Global Atmospheric Watch; GSN- Global Surface Network, GUAN: Global Upper Air Network

Malawi also participates in the provision of meteorological data to the World Data Centres (WDC) and archiving initiatives with other institutions. The DoMS is mandated to quality control all atmospheric observations in the country according to WMO standards and procedures, and archive them. A brief overview of some of the observations made by the DoMS are given below.

Oceanographic observations. Malawi is an inland country, does not record oceanographic observations. However, it has the third largest lake in Africa, Lake Malawi, which so far has limited meteorological and hydrological data, such as surface water temperatures, wind speed, lake rainfall, radiation and relative humidity.

Terrestrial observations. Malawi does not have a Global Terrestrial Network (GTN). However, there are some institutions that monitor land-use, land cover, land-use change, forestry and fire distribution.

Space-based observing programme. Malawi has no national space-based observing programmes. However, the country has ground-based systems to receive data and information from the METEOSAT series of satellites.

Other observations. The DoMS has in the past operated monitoring and early warning systems in collaboration with other Government Departments. These systems were on: (i) Flood forecasting and early warning system for the Lower Shire in collaboration with the Department of Water Resources (DoWR), (ii) Early warning system for food security, in collaboration with the MoAFS, (iii) Tropical cyclone monitoring and early warning system in collaboration with the Department for Disaster Management Affairs,(DDMA), and (iv) Drought monitoring and early warning system done in collaboration with the SADC Drought Monitoring Centre in Harare, Zimbabwe. Presently, it is only the tropical cyclone and drought monitoring system that is still operational, although on a low level.

Ministry of Agriculture and Food Security (MoAFS). The MoAFS carries out seasonal systematic observations, such as phonological observations, crop statistics, agricultural inputs, labour and marketing information. The Ministry also maintains a large number of rain gauges for recording rainfall data throughout the country. These rainfall data are quality controlled by the DoMS and kept in its data bank and archives.

Department of Water Resources (D0WR). The DoWR comprises the two sections of: (i) Hydrogeology, and (ii) Hydrology. The Department maintains systematic observations of stream flows, rainfall, evaporation, water quality, water quantity and Lake Malawi levels, among other parameters. However, it is only the rainfall and evaporation data are quality controlled by the DoMS.

City and District Assemblies. City and District Assemblies, such as Blantyre City Assembly, are engaged in the implementation of both mitigation and adaptation activities, which include tree planting and the burning of waste on dumping sites to capture methane.

University of Malawi (UNIMA). UNIMA collects and stores topographical and meteorological data under the auspices of its constituent colleges. At Bunda College of Agriculture, the Centre for Agricultural Research and Development (CARD), in conjunction with Christian Aid-Malawi is conducting a research programme on "Mainstreaming Climate Change Adaptation and Mitigation in Sectoral and National Development Plans and Strategies in Malawi", whereas at Chancellor College, the Natural Resources Environment Centre (NAREC) has initiated research on "Strengthening local agricultural innovation systems in less favoured and high potential areas of Tanzania and Malawi to adapt to the challenges and opportunities arising from climate change and variability". In both projects, weather data, such as rainfall and temperature, are recorded.

University of Mzuzu. The new University of Mzuzu records some weather data, including rainfall, air temperature, wind speed, solar radiation and relative humidity at its local weather station in Mzuzu City. It is also poised to commence some climate-related studies, especially because it already offering a course on renewable energy sources.

Private sector and parastatal organizations. These include the National Herbarium and Botanic Gardens of Malawi (NHBG), Tea Research Foundation of Central Africa (TRF), the Sugar Corporation of Malawi (SUCOMA) and Agricultural Research Extension Trust (ARET). Some weather data have been recorded through the projects funded by the Malawi Environment Endowment Trust (MEET). These projects are on climate change-related topics and land degradation.

Public-private partnership in climate change adaptation and mitigation: The public-private partnership has been defined as any collaborative effort between public and private sector in which each sector contributes to the planning, resources and mutual objectives. The partnership in this context, articulates the building of public-private partnerships for addressing climate change issues in Malawi. For example, one public-private partnership in the area of climate change mitigation is when Mark O Ltd worked on the Blue-wave technology using ethanol. Other joint initiatives are envisaged under some programmes and projects, including: (i) forestation, (ii) reforestation, (iii) construction of water harvesting technologies (e.g., dykes and small scale community dams), and (iv) diversification of crops and livestock. The organizations that have already started doing this work, include parastatal organizations (e.g., ESCOM, Action Aid, Care Malawi, Evangelical Lutheran Development Programme of Malawi, Coordination Unit for the Rehabilitation of the Environment (CURE), Wildlife and Environmental Society of Malawi (WESM), Livingstonia Synod of the Church of Central African Presbyterian (CCAP) and Eagles Relief of the Living Waters Church, among many others.

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6.4.4 Barriers and Constraints in Systematic Observation

Generally, the rates of technology uptake and utilization of the various technologies is low. This is because there are many problems and barriers that constrain the adoption rate of the renewable energy technologies. The **barriers to technology and data exchange** nationally, regionally and globally under the World Meteorological Organization (WMO) Guidelines are mainly due to inconsistent availability of systematic data, ageing telecommunication systems, lack of financial resources, and inadequate capacity. These barriers need to be addressed urgently.

Cooperation in systematic observation studies: Cooperation between various institutions working on issues related to climate risk is currently limited. As a result of the adverse impacts of climate change, and climate variability, especially over the forty years soon after the Phalombe disaster in 1991, the Malawi Government created the Department of Disaster Management Affairs (DDMA) as its commitment to specifically deal with natural disasters and climate-related calamities, especially droughts, floods, landslides, mudslides and insect pests outbreaks (such as red locusts).

6.4.5 Gaps in Meteorological Research and Observation

There is a need to enhance research capacity in Government Research Stations and the Universities of Malawi and Mzuzu to tackle the many challenges posed by climate change and climate variability. The absence of adequate research and systematic observation activities in meteorological, atmospheric and oceanographic research and observation is a barrier to instituting timely monitoring and warning systems against the adverse effects of extreme weather events. Improvements in research and systematic observation activities will reduce the effects of climate change on vulnerable communities and fragile agro-ecosystems.

6.4.6 Needs and Priorities for Climate Change Research and Systematic Observation

Climate change research and systematic observation have been constrained by many factors, which include: (i) weak institutional capacity in most sectors, (ii) limited financial resources, (iii) inadequate professional staff, (iv) lack of central co-ordination, so that each sector is carrying out its own research and systematic observation studies independently, (v) lack of mechanisms for sharing information among sectors, either horizontally or vertically, and (vi) current structures for coordinating climate change initiatives are not functional for various reasons, but perhaps most importantly inadequate financial resources.

Thus, as a nation that is dependent on agriculture, Malawi needs to urgently address the aforementioned problems, including: (i) enhancing research capacity in public and private sector organizations, especially Department of Meteorology, DARS and the Universities of Malawi and Mzuzu, (ii) building capacity at both individual and institutional levels, (iii) developing a comprehensive system of data storage, management, quality control and accessibility, (iv) establishing an elaborate national and global network of systematic observation stations for effective and efficient exchange of data and information at all levels, and (v) installing automatic weather stations in the country, including an upper air monitoring equipment.

6.5 Research Programmes Containing Measures to Mitigate and Adapt to Climate Change

As alluded to earlier, there is limited research on climate change issues that is being conducted in the country. However, some institutions are involved in climate change related research and extension activities. Some of these research initiatives are briefly presented below.

6.5.1 Climate Change Research Programmes and Systematic Observation

Malawi is involved in conducting some research on climate change-related issues and systematic observation through its participation in the activities of the following international organizations: (i) the United Nations Framework Convention on Climate Change (UNFCCC); (ii) World Climate Programme (WCP) of the WMO; (iii) IPCC; and (iv) United Nations Environmental Programme (UNEP). Some of the initiatives under implemented by public and private sector organizations, including NGOs, are briefly described below.

Ministry of Agriculture and Food Security: (MoAFS) The Department of Agricultural Research Services (DARS) in the MOAFS carries out seasonal systematic observations on parameters such as phonological observations, crop statistics, agricultural inputs, labour and agricultural marketing. It also maintains a large number of rain gauges for the recording of rainfall data at various research and extension services sites throughout the country. These rainfall and air temperature data are quality controlled by DoMS that also stores the data in its archives.

Parastatal organizations: The most relevant parastatal organizations include: (i) the University of Malawi [(a) Bunda College of Agriculture: Centre for Agricultural Research and Development (CARD), (b) Chancellor College: Centre for Social Research (CSR), Centre for Educational Research and Training (CERT), Natural Resources and Environment Centre (NAREC), Molecular Biology and Ecology Research Unit (MBERU), Consultancy and Industrial Research Unit, (c) College of Medicine, and (d) The Polytechnic], (ii) University of Mzuzu, and (iii) Malawi Industrial Research and Technology Research Centre (MIRTDC).

6.5.2 Specific Needs to Strengthen Research on GHGs, Mitigation and Adaptation

Many activities have been, and continue to be, implemented as follows: (i) Chancellor College has been engaged in a number of activities including: (a) the introduction and support of higher degree programmes (M.Sc. and Ph.D. in environment and climate change-related disciplines and B.Sc. in atmospheric science), (b) concretization of the establishment of a Climate Change Research Unit within NAREC, (c) short to medium level training courses on climate change modeling, and (d) strong networking with regional and international organizations, (ii) the Department of Energy Affairs (DoEA) is involved in: (a) building codes of conduct to promote the use of RET, especially solar thermal and solar PV, (b) installation of wind generated electricity, (c) setting up proper marketing systems for alternative energy sources, and (d) introduction of nuclear reactors to provide alternative energy to bio-energy, (iii) the Ministry of Agriculture and Food Security (MoAFS) is involved in: (a) the introduction of biogas digesters using manure, (b) the production of fertilizer from manure to supplement inorganic fertilizers, and (c) introduction of Bio-fuel crops (e.g. Jatropha) on commercial basis. To better implement these activities in all institutions, there is need for capacity building at individual and institutional levels, training of professional staff in all aspects of climate change-related research and extension activities.

6.5.3 Need for Advanced Training for National Experts

Advanced training is required in all institutions involved in climate change studies. The training should be for university degrees in climate change related disciplines, such as climatology and meteorology, and specialist training in diverse fields such as computer simulation modeling, participatory research and extension methodologies, statistical and socio-economic analysis, management and leadership skills, the research methodology, and communication skills. Our experience with the preparation of the Second National Communication has clearly shown that inadequate training in the use of computer models greatly limited some of studies to subjective expert judgments treatment as compared to objective judgments that would be derived from model simulation outputs. Hence, it is highly recommended that in the preparation of future national communications, all national experts should undergo a two or three week intensive training course on the use and application of models in climate change models, the research methodology, and the use of participatory approaches in the collection of data and information.

Constraints and needs: However, climate change research in the country has been constrained by weak institutional capacity in most sectors coupled with limited financial resources as outlined in Section 6.4.6. Further, the other major constraint is lack central point for data management, storage and retrieval. However, the establishment of the Malawi Geographical Information Coordinating Council (MGICC) may play an important role in coordinating and managing a large database required for the preparation of national communications. Thus, there is a need to: (i) enhance research capacity in public and private sector research institutions such as the Universities of Malawi and Mzuzu, (ii) build capacity in managing national data banks and archives for systematic observation in all sectors involved in climate change issues, and (iii) develop a comprehensive system of data storage, a mechanism for quality control, and an easily accessible user-friendly retrievable electronic system, and establish an elaborate national and global network of systematic observation stations for effective and efficient exchange of data and information at all levels. Further, despite the availability or the recording of some climate variables, some of these are not systematic because they are not recorded continuously over a period of 24 hours.

6.6 Education, Training and Public Awareness on Climate Change

Articles 4.1 (i) of the Convention urges Parties to promote and encourage the development and implementation of educational and public awareness programmes on climate change and its impacts. In response to this call, Malawi prepared the National Environmental Action Plan (NEAP) of 1994 and revised it in 2002, which has articulated the need for the provision of environmental education and public information as necessary actions to address environmental issues, such as climate change and air pollution. However, illiteracy and poverty continue to constrain education and training initiatives in Malawi. Nonetheless, some professionals have been exposed to climate change studies during conferences, workshops, meetings and study tours organized by international organizations, such as the United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO).

Thus, training, education, public awareness, capacity building and information sharing will provide information on the steps that Malawi has taken to implement Article 6 of the UNFCCC, and part of the Buenos Aires Plan of Action. This information will comprise: (i) institutional framework for implementation of Article 6 of the UNFCCC, (ii) level of awareness, (iii) implemented and/or on-going activities for education, training and public awareness, (iv) public access to information, and (v) sub-regional, regional, and international cooperation to promote education, training, and public awareness. On capacity building, the following are highlighted: (i) status of the capacities built (ii) needs and options on capacity building and development, (iii) dissemination and sharing of information on capacity building activities, and (vi) status of activities and level of participation of other stakeholders in Malawi. Finally, information is provided on: (i) efforts made to promote information sharing, (ii) participation in and contribution to information networks, (iii) access to and use of information technologies.

6.6.1 Activities Undertaken to Implement Article 6 of the Convention

The importance of education, training and public awareness on climate change cannot be overemphasized. This is a service that should be provided by all institutions involved with the promotion of climate change adaptation and mitigation initiatives. These trainings and out-reach programmes are carried out in different institutions and by various interest groups as briefly described below.

Education and Outreach Unit of the Environmental Affairs Department: The Environmental Affairs Department (EAD) has an Education and Outreach Unit whose aim is "to ensure that all Malawians are environmentally aware and prepared to take appropriate action to ensure sustainable use of the environment". The formal and non-formal education establishments and the mass media are encouraged and supported to take responsibility in communicating environmental education as part of their tasks. Recent outreach activities include: (i) encouraging grassroots participation in environmental decision-making and management, (ii) facilitating the development of training materials, (iii) enhancing access to information on environmental issues, and (iv) increasing environmental awareness on climate change issues. EAD, in its capacity as UNFCCC Focal Point, disseminates information using mass and print media on issues of the environment, natural resources management and climate change. .

Ministry of Education, Science and Technology: Malawi has two institutions of higher learning or tertiary education: the University of Malawi and the University of Mzuzu. However, over the years, others have sprung up, including the University of Livingstonia at Nkhondowe in Rumphi and the Catholic University of Malawi in Limbe. Further, Government is in the process of establishing the University of Science and Technology in Thyolo, which will definitely be instrumental in climate change issues. The existing institutions offer environmental science courses at undergraduate and postgraduate levels. However, only the Malawi Polytechnic offers the Bachelor of Science (B.Sc.) in Environmental Health and a B.Sc. in Environmental Science and Technology. At the postgraduate level, only the Faculty of Science at Chancellor College offers Masters of Science (M.Sc.) degree in Environmental Sciences. There are also several primary and secondary schools that offer courses where some elements of weather and climate are included. However, as the case is with the tertiary level institutions, most schools lack basic equipment and materials for effective environmental studies, including climate change. There is need to build capacity both for teachers and teacher training institutions to adequately promote environmental education, including climate change.

Local Government: Through the Local Government Act of 1998, Malawi is implementing the decentralisation policy under which, District, Town and City Councils are mandated to take care of local development activities in all socio-economic sectors. Government has also decentralised some of its environmental functions, and with assistance from Danish International Development Agency (DANIDA) and the United Nations Development Programme (UNDP), has established the position of District Environmental Officer (DEO) in all District Councils in the country to promote environmental education and climate change initiatives at all levels. The EDOs are responsible for preparing District State of Environmental Outlook Reports and District Environmental Action Plans (DEAPs), which specifically address local environmental issues and problems.

National Assembly (Parliament): The Constitution of the Republic of Malawi recognizes the importance of sustainable management, utilization and the preservation of the environment for future generations. Because of this, Parliament has established the Parliamentary Committee on Agriculture and Natural Resources (PCANR), which deals with issues of the environment and natural resources, including climate change. In addition, Government has also the Cabinet Committee on Agriculture and Natural Resources (CCANR); and the Minister responsible for the Environment is required, under the Environment Management Act of 1996, to present a report on the state of the environment to the National Assembly once every two years where climate change issues are also highlighted. Further, Parliamentarians have a role to inform their constituents on the dangers of bush fires, land clearing and deforestation as they contribute to human-induced emissions of GHGs that lead to global warming.

Non-Governmental and Civil Society Organizations: Various NGOs and CSOs are engaged in the implementation of some activities that address climate change related adaptation measures. The activities include advocacy, public awareness campaigns on impacts and effects of climate change, and the impacts of environmental degradation on global warming, and subsequently climate change. Some of the organizations that are actively involved in advocacy include: (i) Coordination Union for the Rehabilitation of the Environment (CURE), (ii) Centre for Environmental Policy and Advocacy (CEPA), (iii) the Wildlife Environmental Society in Malawi (WESM), and (iv) the Malawi Environment Endowment Trust (MEET). A number of these organisations, especially Faith Based Organizations (FBOs) play a key role in disseminating information on environmental issues, including the implementation of adaptive and mitigative measures to address climate change.

6.6.2 Initiatives to Incorporate Climate Change into Educational Programmes

Presently, the syllabuses for primary and secondary schools do not include climate change as an independent discipline, but rather as a component of other subjects, such as geography, which includes aspects of climate, environment and sustainable development. Thus, there is need to mainstream climate change into primary and secondary school curriculum. Similarly, efforts should be put in place to strengthen tertiary education syllabuses.

6.6.3 Level of Cooperation with Bilateral and Multilateral Institutions

Although climate change is not explicitly mentioned in cooperative agreements with bi-lateral and multi-lateral institutions, let it suffice here to say that a number of institutions in Malawi are collaborating with these institutions at different levels of detail and understanding. For example, (i) Chancellor College is collaborating with Tanzania, (ii) Centre for Agricultural Development (CARD) at Bunda College of Agriculture is collaborating with Christian Aid- Malawi, and (iii) Department of Agricultural Research Services (DARS) in the Ministry of Agriculture and Food Security (MoAFS) has a number of cooperative programmes, projects and agreements with reputable international agricultural centres, such as the International Maize and Wheat Improvement Centre (CIMMYT), the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), the International Centre for Research in Agroforestry (ICRAF), and the International Institute of Tropical Agriculture (IITA). The nature and level of involvement and cooperation with multi-lateral and bi-lateral institutions is usually limited to the funding of research projects and extension programmes; joint implementation, partnerships and networking, and the development of binding and sustainable networking mechanisms.

6.6.4 Education, Training and Public Awareness Campaigns on Climate Change

Several activities have been conducted and/or planned to be conducted in an effort to raise public awareness on climate change through education, training and public awareness campaigns. Most of the climate-related projects shown in Table 6.3 have an extension component whose function is to reach out to stakeholders on environmental issues, hence climate change. The most significant is the World Environment Day (WED), which is commemorated every year. In 2007, the theme was: "Climate–change, a hot topic!"

Role and involvement of stakeholders: Most of the issues on environment and climate change are coordinated by EAD, which is the focal point for climate change activities in Malawi. There is usually very active participation of other stakeholders in the implementation of climate change activities, especially for those whose part of their mandate includes climate change, such as CURE and CEPA Table 6.3 shows some of the completed and on-going projects which have some aspects if education, training and public awareness.

International efforts to promote education, training and public awareness: Many international organizations, including bi-lateral and multi-lateral institutions, have made significant efforts to promote education, training and public awareness through the funding of research and extension programmes on climate change, host and fund the participation of scientists at various meetings, short courses and, seminars and workshops. However, there is need to include higher degree training and specialist training, especially in the fields of computer simulation modelling.

6.6.5 Needs & Priorities in Climate Change Education, Training and Public Awareness

Of all the environmental courses offered at various local institutions, climate change is not adequately covered due to lack of basic materials, equipment, infrastructure and inadequate human resources. Thus the main gaps include capacity building, especially training of staff and farming communities, and infrastructure development at all levels.

6.6.6 Activities Required to Implement Education and Training Programmes

The main assistance required from the international community is the provision of financial resources to initiate training programmes at all levels of training, from primary to university, on the job training of research and extension staff from the technical to professional grades, and technical assistance in the preparation of national communications. Thus capacity building and training are central to all public awareness campaigns and the dissemination of information and technologies. Twinning the Universities of Malawi and Mzuzu with various Universities developed countries to provide exchange programmes and build capacity in the relevant areas spelt in climate change will enhance capacities in Malawi local institutions.

6.7 Capacity Building and Integrating Climate Change Adaptation Measures into Medium- and Long-Term Planning Strategies

Non-Annex I Parties are encouraged to provide, in accordance with Decision 2/CP.7, information on how capacity building activities, as contained in the framework annexed to that Decision, are being implemented at national, and where appropriate, at sub-regional and/or regional levels. This may include, *inter alia*, options and priorities for capacity building, participation in and the promotion of South–South cooperation, the involvement of stakeholders in the coordination of capacity building activities, including the dissemination and sharing of information. Further, Parties are encouraged to include, as appropriate, information on capacity building activities for integrating adaptation to climate change into medium- and long-term planning.

6.7.1 Capacity Building Projects Supported by International Organizations

Despite the critical problems of inadequate funding to implement climate change activities, commendable efforts have been put in place to build capacity in different sectors with support from bi-lateral and multi-lateral donor institutions. Technical and financial support has been provided as follows: (i) the United States Agency for International Development (USAID) through the US Country Studies Program, for GHG emissions and Vulnerability and Adaptation (V&A) Assessments, (ii) the Global Environment Facility/United Nations Development Programme (GEF/UNDP), for the preparation of the Initial National Communication of Malawi and the Technology Transfer and Needs Assessments (TTNA) Report, (iii) the GEF, for the preparation of the National Adaptations Programmes of Action (NAPA) and the National Capacity Self-assessment (NCSA) Project, and (iv) the Miombo Network, for two delegates to attend COP11 in Montreal, Canada, the NAPA preparation process, and the establishment of the Clean Development Mechanism (CDM) Designated National Authority (DNA) in Malawi. Presently, GEF/UNDP has funded the preparation of the Second National Communication of Malawi, which has resulted in the preparation of this document.

6.7.2 Participation and Promotion of, South-South Cooperation

Malawi received technical support in 2005 from the EcoSecurities in Europe and South-South, North of South Africa for the formation of the Clean Development Mechanism Designated National Authority in the country. However, a number of project concept notes, or profiles, proposed in the NAPA document and the Initial national Communication (INC) document have not yet been funded. These require further development for them to qualify as fully fledged proposals. This requires the involvement of all stakeholders to prepare fundable research proposals, since what is in the INC and NAPA documents are simply project profiles or concept notes.

6.7.3 Capacity Building Needs in the Areas of Governance, Mitigation and Adaptation

In accordance with Article 4, paragraph 1 (g), Malawi has initiated some programmes related to capacity building in the areas of adaptation and mitigation analysis. Presently, the Designated National Authority (DNA) is not yet operational, and there are no regulations in place to guide the formulation of CDM projects. This is due to severe capacity constraints to establish and manage a functional Secretariat, with adequate staff to support the setting-up of appropriate regulations and guidelines for processing CDM projects, as well as conducting appropriate outreach programmes on CDM to potential project developers. There is need for capacity building, especially: (i) in support to undergraduate and graduate training in climate change-related disciplines, such as meteorology, climatology and atmospheric sciences, (ii) developing short courses on climate change modelling, (iii) enhancing strong networking relationships with regional and international organizations, and (iv) the training for National Experts (NEs) before the commencement of future national communications.

Further, Malawi should strengthen Climate Change coordination mechanism in the Environmental Affairs Department as prescribed in the recently government approved department restructuring programme. The strengthening of the coordination mechanism of the department in climate change programmes will include among others capacity building for staff to: (i) identify key vulnerabilities, (ii) monitor and evaluate the impact of interventions from Government and other stakeholders, (iii) supervise and prepare Malawi's future national communications for submission to UNFCCC, (iv) participate in Conference of the Parties and sessions of the Subsidiary Bodies of the Convention (traditionally, only one delegate is funded for the Subsidiary Bodies and two for the COP), (v) participate in various negotiations at COP and the sessions of the Subsidiary Bodies of the Convention, (vi) assess GHG inventories, adaptation and mitigation measures, (vii) manage the model input database, (viii) support Government efforts to integrate climate change considerations into planning of the various ministries, (ix) promote outreach and educational efforts on climate change, (xi) act as a central repository of climate change data for different stakeholders, including outreach on climate change scenarios, adaptation solutions, opportunities under CDM and other carbon financing activities, and (xii) develop strategies for encouraging participation in a low-carbon economy, especially the many opportunities that seem to exist through clean energy initiatives.

6.8 Information Sharing and Networking on Climate Change

In accordance with the UNFCCC, Paragraph 48: Non-Annex I Parties are encouraged to provide information on their efforts to promote information sharing among and within countries and regions. Information could cover, as appropriate, participation in and contribution to networks, and access to, and use of, information technologies for information exchange.

6.8.1 Efforts to Facilitate Information Sharing among Stakeholders

The National Statistical Office (NSO) established soon after independence in 1964 and operating through the National Statistics Act of 1967, is mandated to collect, compile, analyze, abstract and publish major statistical information on a wide range of topics, including the environment, hence climate change. However, the data collection and retrieval system is partly decentralized. This implies that other Government Ministries and Departments collect and compile data relevant to their situation. The NSO takes a coordinating role in the collection and compilation of data to minimize redundancy, omissions, inconsistencies and duplication. Data collected by the NSO and other institutions are referred to as "official statistics". Data and information collection is done through censuses, surveys and/or administrative records. Other participants in environmental data and information collection include: (i) research institutions, (ii) academic institutions, and (iii) private sector organizations, including NGOs. However, access to such data and information is generally difficult and limited because such data and information are compiled for internal use, and some cases the users do not acknowledge the original source of the data and information.

6.8.2 Efforts to Engage and Facilitate Regional and International Networking

The need to engage regional and international institutions into networking arrangements is more urgent now than at any other time in the past. The identified problems that constrain climate change research, systematic observation and extension delivery services can easily be addressed through networking. For example, Malawi could access training institutions and funding to support research on climate change initiatives through networking. Thus, during the preparation of the Second National Communication (SNC) of Malawi, Malawi engaged the services of an International Expert (IE) to assist in computer simulation modeling for the V&A Assessments and Mitigation Analysis studies, which took quite a long time. However, if Malawi were networking with other institutions, this IE could have been made easily available through the network exchange programmes.

6.8.3 Constraints in Facilitating Information Sharing, Dissemination and Networking

There are many problems that constrain information sharing, dissemination of technologies and networking. These include: (i) data compatibility and standardization, quality, accuracy and completeness, (ii) inadequate capacity in information and communication (ICT) personnel and infrastructure, (iii) lack of appreciation of the importance of ICT particularly by senior management, (iv) inadequate provisions of ICT in government and/or public institutions annual budget, (v) lack of a common platform for data exchange, (vi) lack of innovative financing mechanism for ICT activities, (vii) lack of the most recent literature and data on environment, (viii) unwillingness by some institutions to share data and information, (ix) lack of backup facilities for environmental data and information, (x) lack of environmental data and information cataloguing, (xi) lack of coordination among environmental information networks, steering groups and committees, (xii) inadequate capacity to generate and update environmental data, (xiii) inadequate involvement of district and sub-district level institutions in environmental information management, (xiv) absence, in some institutions, of environmental data policies and information strategies, and (xv) inadequate use and management of remotely sensed environmental data

6.9 National Adaptation Programmes of Action

This section provides information on the formulation process of the National Adaptation Programmes of Action (NAPA) and attempts that have been made to implement the proposed projects for specific agro-ecologies that are adversely affected by climate change, especially floods and droughts. In particular, the Shire Valley is targeted because it is the most vulnerable to the impacts of droughts and floods. However, this is also the area that has the greatest potential for the production of both rain-fed and irrigated crops, fish production, water and wildlife resources conservation.

6.9.1 Rationale

While Malawi has abundant natural resources, including good soils, and abundant water, wildlife, fisheries and forests, these are presently under threat from an increasing human population that is dependent on these renewable natural resources. Unsustainable utilization of these resources makes them vulnerable to the adverse impacts of climate change and climate variability. More than 90% of the people, especially resource-poor rural communities are engaged in subsistence rain-fed agriculture. However, rain-fed agriculture in Malawi is highly vulnerable to the impacts of floods and droughts. Further, it is the resource-poor communities that are more vulnerable to the impacts of floods and droughts, besides having the least capacity to adapt to the impacts of these climate-related calamities. It is against this background that Malawi prepared the NAPA document. The NAPA aims to assist vulnerable communities to cope with the adverse impacts of climate change, achieve food security, reduce poverty, improve the welfare and sustainable livelihoods of vulnerable groups; and minimize the loss of life and property.

6.9.2 Framework for Adaptation

Malawi's development aspirations are stipulated in national policies and strategies as articulated in Vision 2020 of 2000, the Malawi Poverty Reduction Strategy (MPRSP) of 2004 and the Malawi Growth and Development Strategy (MGDS) of 2006. The preparation of the NAPA document has benefited from various national action plans, including the National Environmental Action Plan of 1994 and multi-lateral environmental agreements. NAPA has prioritized the impacts of adverse impacts for climate change in eight sectors of economic growth: agriculture, water, human health, energy, fisheries, wildlife, forestry and gender.

6.9.3 Key Adaptation Needs

Droughts and floods affect most parts of Malawi. But the Shire Valley, and some areas along the Lakeshore Plain, such as central Karonga, is the most vulnerable. Thus, the developed adaptation measures and strategies focus on (i) enhancing agricultural productivity, (ii) planting trees, (iii) improving nutrition, (iv) accessing reliable and user-friendly sources of energy, (v) arresting land degradation through the use of appropriate soil and water management and conservation measures, and d(vi) reducing the incidences of insect pests and diseases. The sectors of focus included: (i) Agriculture, (ii) Water Resources, (iii) Human Health, (iv) Energy, (v) Fisheries, (vi) wildlife, (vii) Forestry and Other Land-Use, and (viii) Gender.

6.9.4 Criteria for Selecting Priority Activities

The main criteria used to select priority activities were based on the model developed by the Least Developed Countries Expert Group (LEG), but fine-tuned for local circumstances. These included: (i) technical feasibility (0.15), (ii) economic growth (0.15), (iii) synergies with policies and programmes (0.1), (iv) magnitude of the impact on vulnerable groups (0.2), (v) cost of project (0.05), (vi) stakeholder participation (0.1), (vii) losses avoided by vulnerable groups (0.05), (viii) livelihood sustainability (0.15), and (ix) response to cross-cutting issues (0.05). The values in brackets denote the relative weights assigned to each criteria. All criteria, except economic growth, were scored on a scale of 1-5 with Scale: 1 (very low), 2 (low), 3 (medium), 4 (high), 5 (very high). Economic growth was scored on a scale of 1 (1-20), 2 (21-40), 3 (41-60), 5 (81-100).

6.9.5 Ranking Adaptation Options for Urgency

More than forty adaptation options were identified in the eight priority sectors of economic growth. Using the above criteria, these were first reduced to thirty-five then fifteen. The fifteen adaptation options were further ranked based on their urgency using the methodology recommended by LEG, which looked at threats of not implementing and/or gains of implementing the selected measures. Thus, the fifteen adaptation options were reduced to the following five options: (i) improving community resilience to climate change through the development of sustainable rural livelihoods, (ii) restoring forests in the Shire Basin to reduce siltation and the associated water flow problems, (iii) improving agricultural production under erratic rains and changing climatic conditions, (iv) improving Malawi’s preparedness to cope with droughts and floods; and (v) Improving climate monitoring to enhance Malawi’s early warning capability and decision making and sustainable utilization of Lake Malawi and lakeshore area resources.

6.9.6 Efforts to Implement the Proposed Programmes of Action in the NAPA Document

Constraints and challenges. Despite the fact that the adaptation options were identified based on their urgency for implementation, none of these has been implemented so far. This is because there are many problems, barriers or challenges that constrain the implementation of these. The main barrier was lack of operationalizing the LDC Adaptation Fund by UNFCCC.

Political will. There is presently demonstrated political will to ensure that the proposed projects in the NAPA document are implemented by all those involved in climate change studies in both public and private sector organizations, including NGOs. The launching of the NAPA document by the State President on February 11, 2008, demonstrates that political will at the highest level. In his launch speech, the President called upon relevant public and private sector organizations, the international donor community, and other development partners to support Government in its efforts to implement the proposed projects. .

6.9.7 Other Initiatives on Adaptation and Mitigation to Climate Change

Besides the NAPA, Government and development partners have initiated various other activities including: (i) tree planting and management for carbon sequestration and other ecosystem services by the Department of Forestry (DoF), (ii) promotion of alternative sources of energy by the Department of Energy Affairs (DoEA), (iii) weather forecasting and early warning systems by the Department of Meteorological Services (DoMS), (iv) various relief operations by the Department of Poverty and Disaster Management Affairs (DPDMA) in the Office of the President and Cabinet (OPC), and (v) environmental micro projects in District Councils (DAs) supported by the United States Agency for International Development (USAID).

6.10 Conclusion

This Chapter has highlighted issues that have direct relevance to climate change. However, the implementation of GHG inventory, Vulnerability and Adaptation, and Mitigation Analysis is beset with constraints and gaps. These issues are discussed in Chapter 7.

Chapter 7:
Constraints and Gaps, and Related Financial, Technical and Capacity Needs

7.1 Background

This chapter provides information on major gaps, constraints and structural weaknesses in key sectors of economic growth in relation to the adverse impacts of climate change and climate variability. The main constraints identified relate to technical, financial, research and capacity needs in preparing future national communications as ably identified in the Initial National Communication (INC) of Malawi, the National Programmes of Action (NAPA), the Global Environment Facility/United Nations Development Programme (GEF/UNDP) portfolios, and presently, in the Second National Communication (SNC) of Malawi.

What follows is a brief overview of the identified constraints and challenges relating to capacity, technical, financial and research needs on climate change issues, in the following four major thematic areas: (i) **National Circumstances**, which gives a situation analysis of Malawi's abundant but limited and finite natural resources that are adversely impacted upon by climate change; especially floods and droughts, (ii) **GHG Inventories** in the following five sectors: (a) Agriculture, (b) Energy, (c) Forestry and Other Land Use, (d) Industrial Processes and Product Use, and (e) Waste Management, which contribute to global warming, (iii) **Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change** in the following seven sectors: (a) Agriculture, (b) Energy, (c) Forestry and Other Land Use, (d) Water Resources, (e) Wildlife, (f) Fisheries, (g) Human Health, which identifies measures and strategies for adapting to climate change, and (iv) **Programmes Containing Measures to Mitigate Climate Change**, in the following sectors: (a) Agriculture, (b) Energy, (c) Forestry and Other Land Use, (d) Industrial Processes and Product Use, and (e) Waste Management, which identifies mitigation options for reducing GHG emissions. The findings from this analysis provide a strategic framework for addressing the adverse impacts of climate change on vulnerable communities, fragile agro-ecosystems and sectors of economic growth. It is based on the identified challenges, problems, barriers, gaps and constraints that the proposed climate change projects presented in Chapter 8 have been formulated.

7.2 Constraints and Gaps

The major constraints and gaps have been identified in the following areas: (i) nine sectors of economic growth (Agriculture, Energy, Forestry and Other Land Use, Industrial Processes and Product Use, Waste Management, Water Resources, Fisheries, Wildlife, and Human Health, (ii) four thematic areas of programme focus (National Circumstances, GHG Inventory, Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change, and Programmes Containing Measures to Mitigate Climate Change), and (iii) institutional arrangements and funding mechanisms for climate change.

7.2.1 Sectors of Economic Growth

Agriculture Sector. Agricultural expansion over the last five decades has been blamed for accelerating deforestation and environmental degradation, including soil and land degradation, which lead to soil erosion and soil infertility. There has also been a corresponding increase in: (i) the use of nitrogenous fertilizers, (ii) number of livestock, especially cattle, and (iii) the burning of crop residues, all which contribute to GHG emissions. A conservative estimate indicates that the agriculture sector contributes 12.4% of CO_2 equivalent to global GHG emissions. Within the Agriculture Sector, fertilizer use contributes about 58% in the form of NO_2, whereas livestock contributes 20% in the form of CH_4. Generally, there have been increases in the levels CO_2 and CO, whereas those of CH_4, which average 31 Gg, has remained nearly constant, and the levels of the N_2O show a slight decline. Thus, there is need to implement strategies and measure that reduce GHG emissions by: (i) sequestering carbon through re-afforestation and afforestation programmes and the planting of trees on-farm (i.e., agro-forestry), and (ii) the use of cleaner technologies. There is also need to estimate the amount of CO_2 and CH_4 gasses that are saved from the use of crop residues and biogas production in the Agriculture Sector..

Fig. 7.1: Visoso, shifting cultivation system for millet in Northern part of Malawi

Constraints to agricultural production. There are many constraints to agricultural production, which include both biotic and abiotic factors. However, the main driving factors are water and soil fertility, besides insect pests and diseases. Further, land in Malawi is heavily degraded in most parts of the country due to increasing soil erosion hazards, deforestation, overgrazing, land fragmentation, and decreasing land holding sizes (Fig 7.1). These have led to declining soil fertility, siltation of river beds and water pollution. Ass these problems have over the decades been exacerbated by the increasing frequency and magnitude of floods and droughts. All these problems affect and impact negatively on the Agriculture Sector, which is the engine of economic growth. The main gaps in the Agriculture Sector that need to be addressed include capacity building and training at individual and institutional levels and the enforcement of policies, rules and regulations, especially on soil and water conservation, such as compliance with planting of trees on 10% of the farm or estate land.

Water Resources Sector. The Water Resources Sector (WRS) is constrained by lack of systematically updated records on the quantities of river, stream and lake waters, and from under groundwater aquifers. With the increasing frequency and magnitudes of droughts and floods, there are large fluctuations of water levels and quantities in these sources, which need to be quantified for Malawi to maintain her water security status in the future. There is need to determine the number of streams that dry-up annually, areas where water is chronically scarce and limiting, the number of boreholes drilled each year, rise and fall in lake levels, and the monitoring of groundwater levels These also constitute the major gaps in this sector.

Energy Sector. The Energy Sector is an important sector that drives the manufacturing and mining industries. However, the exploitation, production and use of energy resources results in the emission of different GHGs, including CO_2. Globally, especially in developed countries, the Energy Sector is the major contributor to GHG emissions. Further, the increase in the number of vehicles on the roads leads to increased CO and CO_2 emissions that contribute to global warming (Fig 7.2). Although attempts have been made to estimate GHG emissions from the energy sector, gaps still remain and need to be filled. There is need to keep an up to date record of imported vehicles so as to better estimate GHGs from the transport sector, which is presently increasing by the day. Presently, the use of solar, wind and other renewable energy sources is minimal, calling for concerted efforts in the harnessing of these sources.

Hence, one of the main challenges in the Energy Sector is to identify and develop user-friendly technologies that are economically affordable to the majority of the people, technologically manageable within the economic framework of Malawi and culturally appropriate to most Malawians for adoption and utilization. Although commendable progress has been made in developing different types of technologies in the sector, the problem is that the uptake of these is very slow and low, a scenario that can be attributed to poverty, lack of know-how and financial resources, and low public awareness on the availability and use of the available technologies. Since electricity is not fully accessible to the majority of Malawians (> 90%), they will continue to depend on firewood and biomass as the main source of energy supply. In addition, the existing high taxation on renewable energy technologies explains the low adoption and increased use of biomass in the country.

Forestry and Other Land-Use (FOLU) Sector. The forestry sector is faced by many problems that constrain the management and production of forest and forest products. First, there has been declining investments in industrial forest plantations over the years, coupled with high costs of processing industrial soft wood compared with hardwood materials. Second, the sector has been under threat from increasing forest fires, theft, encroachment, vandalism and accelerating deforestation, especially since the advent of multiparty politics in 1994. The high average annual deforestation rate at 2.8% (MG, 2000) is very high for Malawi, which has a limited land resource base and whose forest cover is presently estimated at 22%. Third, there is insufficient policy coherence among different government ministries and departments, especially the Departments of Forestry, National Parks and Wildlife, and the

Ministry of Agriculture and Food Security (MoAFS), to effectively and efficiently regulate the utilization and management of the forest resource by communities in both rural and peri-urban areas. Thus, there are some glaring gaps that need to be addressed in the sector. These include: (i) introducing appropriate incentives to promote investment in forest industries, (ii) conducting frequent surveys and proper documentation of forest resources, so as to update information and data on deforestation rates, and the contribution of the Forestry and Other Land-Use Sector to the Gross Domestic Product (GDP), (iii) harmonizing and conducting periodic reviews of forestry policies to better guide multiple users of forests and forest products, especially on customary land, forest and game reserves and industrial plantations, (iv) enhancing the current reforestation and environmental rehabilitation programmes in degraded areas involving local communities and District Assemblies (DAs), and (v) training of local communities and staff.

Fisheries Sector. The main constraints in the Fisheries Sector include: (i) low fish catches due to over-exploitation and environmental degradation and the pollution of the waters, (ii) use of inferior fishing methodologies and out-dated technologies, and (iii) lack of compliance with the regulatory frameworks, especially those pertaining to the closed season fishing rules. Hence, there are some gaps and challenges that need to be addressed, as follows:(i) enforcing the fisheries legislations for compliance, (ii) using modern fishing technologies for shallow water fishing by local communities, and deep water fishing by commercial fishermen, (iii) building capacity and training of fishermen on sustainable fishing methods and practices, including capacity to use satellite data for mapping potential shallow and deep water fishing grounds in Lake Malawi, (iv) proper management of the lake and river ecosystems to enhance fish catches, and (v) improving scientific knowledge on the linkages of climate change and fish production, including the implementation of measures for adapting and mitigating climate change

Wildlife Sector. The main constraints in the Wildlife Sector include: (i) increasing poaching of wildlife, (ii) limited pasture resources during the dry season, (iii) inadequate water resources during the dry season and years affected by droughts, (iv) inadequate staff with low morale, (v) lack of know-how and awareness on the importance of wildlife as a tourist

attraction, and (vi) poor community institutional set-ups, besides inadequate training on management strategies.
Fig.7.2 Gaseous emissions from vehicles on the road of Malawi

Thus, there exist gaps in: (i) various aspects of wildlife management and conservation that require to be addressed through research, (ii) poor incentives and low morale of staff to make the sector attractive for investment and tourism, (iii) meager law enforcement capacity to reduce poaching owing to lack sufficient vehicles and communication equipment, (iv) enforcement of wildlife trans-boundary agreements and regulations, (v) legal framework and compliance for collaborative management with communities, (vi) current information on eco-tourism related resources and products in national parks, wildlife reserves and nature sanctuaries, such as historical, cultural, natural, spiritual and archaeological sites. Poaching, encroachment and deforestation in wildlife parks and forest reserves greatly threaten ecosystem balance and reduces canopy cover. The tree cover in wildlife parks and forest reserves provide effective sinks for CO_2, which greatly contributes to global warming, hence climate change. Further, Malawi does not have an updated database on the dwindling rate of wildlife resources, encroachment and deforestation. If Malawi is to capitalize on tourism, as a priority sector of high growth as stipulated in the Malawi Growth and Development Strategy (MGDS), there is need to address the aforementioned constraints and by filling all the identified gaps.

Industrial Processes and Product Use (IPPU) Sector. The Industrial Processes and Product Use Sector, especially the mining sub-sector, is constrained by many factors including: (i) lack of adequate and trained manpower to update information and data on mineral resources, (ii) laxity in the enforcement of mining laws and poor harmony of regulatory frameworks among forestry, agriculture, wildlife, mining and tourism, and (iv) lack of know-how and specialist skills in mining and industrial processing.

Thus, there is need for the sector to fill the identified gaps through: (i) training of staff to update the mineral resources data and information, (ii) enforcing regulations to reduce theft, such as the disappearance of gemstone that are smuggled out of the country by small-scale miners, (iii) using new and improved mining equipment and methodologies, (iv) building capacity through training, and (v) exploiting heavy mineral sands, bauxite, gold; and phosphates.

Presently, uranium is being mined by Paladin Africa Limited of Australia at Kayelekera in Karonga district. Although mining provides the required economic benefits, it is also a potential source of environmental, soil and land degradation, and water pollution in rivers, streams and lakes, a situation that is currently exacerbated by changing climatic conditions. For example, the clearing of vegetation for mining purposes: (i) reduces the size of available C sinks, (ii) increases the amount of dust and aerosols concentration in the atmosphere, and (iii) produces fumes and smoke from the manufacturing processes that release considerable amounts of GHGs into the atmosphere, hence global warming. Thus, there is need to quantify the amounts of GHGs emitted from the mining, manufacturing and transport sub-sectors. Similarly, there is need to quantify the amount of C sequestered by trees, and how much of this C is absorbed by water bodies, especially vast water resource of Lake Malawi.

Waste Management Sector. The amounts, sources and types of wastes have been on the increase since 1999 in all urban areas of the country. The biggest challenge facing town and city dwellers is finding effective methods and strategies for managing and disposing of such municipal wastes. For example, landfills are rarely used, so that in most cases, solid wastes are just thrown into dumping sites, which are potentially hazardous to the environment and human health. This is because these dumping sites emit CH_4, which contributes to global warming. Further, even though the incineration method reduces the volume of wastes to 10%, the remaining 90% is released as GHGs, including CO and CO_2. The other main challenge is the lack of current quantitative data on the exact amounts of wastes generated in different parts of the country, and so is information on the type of waste generated. Thus, the sector is mainly constrained by inadequate financial resources and inadequate trained personnel, besides inappropriate methodologies for disposing of the available waste. .

Thus, there are several gaps that need to be filled including: (ii) recruiting more staff to manage the increasing amount of wastes, (ii) capacity building through training in waste management, (iii) compilation of a comprehensive database on waste management, including emission factors, such as: waste composition, degradable organic carbon (DOC), fractions of municipal solid waste deposited in SWDS, solid waste incinerated in hospitals and clinics, and industrial wastewater treatment plants. Further, research is required to determine minimum data sets for model verification and use. This information will facilitate simulation-based analyses and the designing of disposal sites that reduce GHG emissions. Further there is need to build capacity in computer simulation modeling because there is need to estimate gaseous emissions from various dumping sites using modeling approaches. Such analyses will enable policymakers to adopt strategies to mitigate and adapt to climate change effects that are not subjective, but based on evidence-based information.

Human Health Sector. The increase in air temperatures and rainfall will lead to increases in the incidences, prevalence and spatial distribution of malaria, cholera, diarrhea and respiratory related infections. Hence, there is need to establish the actual magnitude of the relationship between climate variability and disease incidence, occurrence and severity. This will facilitate the adoption of effective and appropriate adaptation measures to address climate change. The Human Health Sector is first and foremost constrained by the shortage of staff in nearly all health centres, especially in rural areas. This is because the sector fails to retain experienced and highly qualified workers because of lack of incentives, long working hours, non-conducive working environment, lack of modern diagnostic equipment, and huge workloads, among many other problems. There have been an increasing number of nurses that have left the country for greener pastures in the United Kingdom (UK), a situation that has severely constrained the delivery of health services in the country. Further, the sector is constrained by: (i) inadequate financial resources to purchase drugs and equipment, (ii) weak drug management and distribution systems at all levels, (iii) leakage of drugs from the system through theft; (iv) inadequate qualified personnel, especially in rural areas, (v) lack of access to pre-natal care and poor quality service delivery, (v) insufficient number of health facilities, especially in rural areas where most of the health facilities need repair; (vi) inadequate access to basic utilities, such electricity, water and telephones, (vii) inadequate transport facilities, especially ambulances (unfortunately, the newly introduced bicycle ambulances are resented by some people), and (viii) bureaucracy and institutional weaknesses that results in delays in delivering financial resources and implementation of activities at district and community levels. There is also the problem of poor sanitation and lack of clean drinking water. Most rural households still depend on shallow wells for drinking water (Fig 7.3).

Fig 7.3: A young lady in rural Malawi drawing water from a shallow well during the rainy season

Thus, there is need to urgently address these weaknesses and fill the identified gaps to improve the delivery of human health services in the country. If unchecked, the adverse impacts of climate change, especially flooding from high intensity rainfall, will exacerbate the situation, especially an increase in the incidences of water borne diseases, such as diarrhea and cholera.

7.2.2 Thematic Areas of Focus

Constraints and gaps will be presented for the following four thematic areas of focus: (i) National Circumstances, (ii) GHG Inventory, (iii) Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change, and (iv) Programmes Containing Measures to Mitigate Climate Change.

National circumstances. The salient features of Malawi's national circumstances are presented in Chapter 3, whereas as a detailed analysis of Malawi's natural resources is provided in the National Environmental Action Plan (NEAP) of 1994. However, Malawi's natural resources (land, forests, fisheries,, wildlife and water), are under threat from a combination of factors that constrain their productivity. These threats include: (i) soil erosion hazards, (ii) land and environmental degradation, (iii) air pollution, (iv) deforestation, (vi) increasing population pressure on a limited and declining land resource base. These land and environmental problems are exacerbated by: (i) increasing poverty among the majority of Malawians (an estimated 52.4% live below the poverty line and 28% live in abject poverty), (ii) high illiteracy levels (although this is partially being addressed through the universal primary education programme, which is unfortunately constrained by insufficient qualified teachers, limited learning materials and few school blocks), and (iii) lack of environmental information and awareness, which leads to low uptake of the recommended adaptation and mitigation measures and strategies. Over the last four decades, these problems have come under increasing threats from the effects of climate change. Climate change is manifested through several climatic hazards or calamities, such as: (i) intense rainfall, (ii) floods, (iii) seasonal droughts, (iv) multi-year droughts, (v) dry spells, (vi) cold spells, (vi) strong winds, (vii) thunderstorms, (viii) heat waves, (ix) landslides, (x) hailstorms, (xi) mudslides, (xii) volcanoes, (xiii) earthquakes, and (xiv) epidemics. All these have undesirable effects on the natural resource base, sectors of economic growth, vulnerable communities and fragile agro-ecosystems. However, for Malawi, the most devastating are floods and droughts, which have increased in magnitude and frequency since the early 1970s. Thus, continuing efforts are required by public and private sector organizations, including NGOs and CBOs, to institute measures and strategies for the proper management of Malawi's renewable natural resources. To this end, there is need to address the problems associated with: (i) increasing human population, which is being addressed through the Ministry of Health and Population Services (MoHPS), (ii) high illiteracy kevels, which are being addressed through the Ministry of Education, Science and Technology (MoEST) and the so many private schools that have mushroomed in the country since the advent of multi-party politics in 2004, (iii) poverty, through various pro-poor strategies and programmes, including safety nets, as outlined in the MGDS. However, the MGDS does not explicitly addressed the issues of climate change directly, but as a cross-cutting issue under the theme: "Conservation of Environment and Natural Resources", and (iv) environmental degradation, which is being addressed through the Department of Land Resources Conservation (DoLRC) in the MoAFS, and various NGOs and CBOs that focus their activities on agriculture and the environment.

To address the aforementioned problems, there is need for trained and skilled manpower in all institutions that are involved with natural resources management, conservation and utilization. Further, it has been noted that Malawi does not have a single central database center where all data and information on natural resources are stored. Presently, data on various natural resources are kept by specific respective Government Departments or Ministries responsible for collecting such data. For example, data on fisheries are kept by the Department of Fisheries (DoF) un the Ministry of Lands and Natural Resources (MoLNR). This makes data collection not only repetitive, but also tedious and leads to errors in data capture endevours. The need for creating a central databank for all natural resources management data is urgently required to ensure uniformity and consistency in the quality of data. Institutions of special interest to act as repositories of natural resources data would include: (i) National Spatial Data Centre (NSDC), (ii) National Statistical Office (NSO), and (iii) Climate Change Unit housed within EAD or the proposed Climate Change Commission to be housed in the Office of the President and Cabinet (OPC). Hence, the need for capacity building and training for staff managing the database. .

GHG Inventory. The GHGs were determined in the following diverse but interrelated sectors: (i) Energy, (ii) Industrial Processes and Product Use (IPPU), (iii) Agriculture, (iv) Forestry and Other Land-Use, and (v) Waste Management. The determination of GHG in different sectors requires the use of approaches and methodologies recommended by the Inter-governmental Panel on Climate Change (IPCC). In this study, the methodologies outlined in the Revised 1996 IPCC Guidelines, the 2007 IPCC Guidelines., the IPCC Good Practice Guidance, UNDP/GEF Handbook on "Managing the National GHG Inventory" and the IPCC Inventory Software were used. Further, although there is some strength in engaging National experts from different institutions, there is a problem of coordination, especially where resources are limiting.

The recommended methodologies require the use of emission factors and model input data based on carefully planned and executed experiments. Unfortunately Malawi does not have local database for emission factors that can be used in these studies, hence default values were used the various respective computations. This shows that there is need for technical expertise in climatology, meteorology, climate change modeling, research methodology, agriculture, engineering, forestry, fisheries, wildlife, energy, water resources and participatory approaches. Hence, there is need for capacity building and training of staff. There is also need to designate an institution that could be responsible for preparing Malawi's GHG inventory in future communications to ensure consistency and institutional memory. In this way, data management and retrieval would be improved, and this would facilitate the timely preparation of future GHG inventories.

Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change (V&A Assessments). Vulnerability and adaptation (V&) assessments were evaluated for the following sectors: (i) Agriculture, (ii) Energy, (iii) Water Resources, (iv) Fisheries, (v) Wildlife, (vi) Forestry and Other Land-Use (FOLU), and (vii) Human Health. The determination of the measures and strategies for adapting to climate change require the use of recommended approaches and methodologies as recommended by IPCC. The recommended methodologies and tools used in vulnerability and adaptation assessments are presented in Chapter 4. In brief these are available in the following documents: (i) Vulnerability and Adaptation Assessments: An International Handbook, (ii) UNEP Handbook on Methods for Climate Change: Impact Assessment and Adaptation Strategies, (iii) An Adaptation Policy Framework: Capacity Building for Stage 1 Adaptation, (iv) PRECIS, (v) Toolkit for Vulnerability and Adaptation Assessments, (vi) Integrated Modeling System for Climate Change Impact and Assessment, (vii) Guidelines for the Preparation of National Adaptation Programmes of Action (NAPA), and (viii) Annotated Guidelines for the Preparation of NAPAs. In addition, baseline climatology and climate change scenarios employed: (i) General Circulation Models, (ii) MAGIC/SCENGEN Workbook, (vi) Statistical Down Scaling Model (SDSM): A Decision Support Tool for Accessing Regional Climate Change Impacts, (vii) Socio-economic Scenarios, (viii) User's Guidebook for the Adaptation Policy Framework.

The availability of so many methods and approaches in diverse disciplines is one of the greatest challenges facing scientists involved in vulnerability and adaptation assessments studies. First, is the challenge of selecting appropriate computer simulation models for use under local climatic conditions. Second, is the challenge of assembling minimum data sets for calibrating, validating and testing the models before they are used for experimentation and forecasting future impacts of climate change on the sectors of economic growth. Hence, studies under this thematic area require highly qualified, trained and experienced scientists with a good background in basic sciences. This includes scientists with technical expertise in agriculture, engineering, mathematical sciences, climatology, meteorology, systems analysis, computer simulation modeling, and the research methodology. Clearly, Malawi has inadequate expertise in all these fields. Hence, there is need to: (i) build capacity through the training of staff at individual and institutional levels, (ii) conduct research to determine minimum data sets for model verification and experimentation, and (ii) provide adequate financial resources for conducting research and simulation modeling.

Good progress has been made in the use simulation models in some sectors (e.g., energy), but not so quite in others (e.g., the livestock sub-sector), just as the case was during the preparation of the Initial National Communication (INC) and the National Adaptations Programmes of Action (NAPA). This shows that there is inadequate staff with expertise and skills in computer simulation modeling that can be used in these studies. Further, it was noted that coordinating scientists from more than seven sectors was a difficult task to accomplish especially when there were data inconsistencies depending on the type of source of information used. The need for the use of one data source, preferably from one central database source, would remove this anomaly and problem. This calls for the creation of central databank. It would also be advisable to contract one lead institution, or a reputable consulting firm, that could be contracted for the preparation future V&A Assessments. This would ensure consistency, continuity and institutional memory. Where expertise are limited, which will always be the case, the institution will then have to hire relevant and qualified consultants to conduct the work on behalf of the institution, which in the end will be answerable to EAD or any other designated authority.

Programmes Containing Measures to Mitigate Climate Change (Mitigation Analysis). Mitigation Analyses were evaluated for the following sectors: (i) Agriculture, (ii) Energy, (iii) Forestry and Other Land-Use, (vii) Industrial Processes and Product Use (IPPU), and (vi) Waste Management. The identification of measures and strategies for mitigating climate change also requires the use of approaches and methodologies recommended by IPCC. The main sources of materials are (i) Technologies, Policies and Measures for Mitigating Climate Change by IPCC, (ii) Methodological Guidelines by UNEP, and (iii) A Guidebook by the US Country Studies Program. The available simulation models to choose from include: (i) Long-Range Energy Alternatives Planning System (LREP), (ii) Energy and Power Evaluation Program (ENPEP), (iii) MERNet: Allocation Macro-Economic Model, (iii) STAR: Services, Transport, Agriculture, Industry and Residual Energy Model, (iv) GACMO, (v) COPATH: Carbon, Pasture, Agriculture, Total Harvesting, (vi) ETO: Energy, Technology Optimization, and (vii) MARKAL-MACRO: Market Allocation Macro-economic Model, (viii) ENPE: Energy and Power Evaluation Program., and (viii) Century. Similarly, this shows that there are many models to choose from, and the question to ask is: which one?

This clearly shows that there is need for training in systems analysis and computer simulation modeling to address these pertinent issues, especially before the commencement of the preparation of the Third National Communication (TNC). Thus, there is need to: (i) build capacity through the training of staff at individual and institutional levels, and (ii) providing adequate financial resources for research and training. Training is required in the fields of agriculture, engineering, climatology, meteorology, systems analysis, computer simulation modeling and participatory research and extension methodologies. In addition, there is need to build capacity in systems analysis and computer simulation modeling in institutions of higher learning. For example, the Department of Engineering at the Polytechnic, or the Chemistry Department at Chancellor College or the Crops and

Environmental Sciences Departments at Bunda College of Agriculture or the University of Mzuzu. .

7.2.3 Institutional Arrangements and Funding Mechanisms

Institutional arrangements. The institutional arrangement for climate change has been presented in Chapter 1, which identifies EAD as the Designated National Authority (DNA) for the implementation environment and climate change issues, including the SNC of Malawi under UNFCCC, and the Clean Development Mechanism (CDM) under the Kyoto Protocol. The major collaborators and stakeholders are GEF and UNDP who finance and manage the project. Hence, the flow of funds is from GEF to UNDP-New York, UNDP–NewYork to UNDP-Malawi, UNDP-Malawi to Treasury, and Treasury to EAD. The project utilizes these funds within the framework of EAD, where, unfortunately, the PM is not a signatory. More often than not, delays have been experienced in limiting financial resources from UNDP to Treasury then to EAD. Further, even when funds were made available in EAD, delays due to bureaucracy and other logistical problems were experienced in acquiring essential goods and service, including the hiring of consultants and National Experts (NEs), which led to the loss of momentum and delays in project implementation. Thus, to address these constraints, there may be need to create an autonomous Climate Change Unit (CCU) or National Climate Change Commission (NCCC), that is self accounting, so that money from UNDP is sent directly to the Account of the Unit or Commission, but under the supervision of EAD. This underscores the fact that the project is output based and cannot afford the delays experienced under normal Government implementation modalities. Better still, the creation of an autonomous Climate Change Unit or National Commission, in line with the National Aids Commission (NAC), under the umbrella of the Office of the President and Cabinet (OPC), would perhaps be the most ideal. Climate change greatly impinges on all sectors of economic growth, including agriculture, hence the need for climate change issues to be highlighted and coordinated at national level.

Funding. Presently, matters relating to climate change are funded by bi-lateral and multi-lateral donor agencies, especially the Global Environment Facility (GEF). There is no direct funding for climate change research issues by Government. Nonetheless, some Government Departments are provided with financial resources for environmental management, some of which are used on public awareness campaigns, such as the "Environment Day", and the implementation of climate change adaptation and mitigation measures, such as tree planting, irrigation and breeding new crop varieties that are tolerant to drought. There is need for the direct funding of climate change programmes, and it is for this reason that the creation of an autonomous Climate Change Unit (CNU), or National Climate Change Commission (NCCC) that can be funded directly comes in.

7.3 Capacity, Technical, Financial and Research Needs

7.3.1 Capacity Needs

The task and responsibility of preparing national communications is a formidable one. It requires the services and involvement of many people from different disciplines and sectors who are highly trained and qualified in climate change-related fields. Thus, capacity building, especially training at individual and institutional levels is paramount and of immediate urgency if the Third National Communication (TNC) of Malawi is to be prepared promptly and timely. Training is required for higher degrees (M.Sc. and Ph.D.) across all the sectors, and so is the purchase of equipment, especially personal computers and accessories. This is where he Universities of Malawi and Mzuzu and the Department of Agricultural Research Services (DARS) can play a leading role in training staff and conducting climate change research. Training is also required for frontline extension and research staff, especially those that will be involved in data collection from field experiments.

7.3.2 Technical Needs

As alluded to earlier, there is an urgent need to train Malawian scientists in the art of conducting research, systems analysis, and computer simulation modeling. Further, there is need for higher degree training in the fields of Agriculture, Engineering, Environment, Wildlife, Meteorology, Climatology, Modeling, Statistics, Mathematical Sciences, Physics, Chemistry, Biology, Geography and Earth Sciences, Sociology and Psychology, among others. It is the blending of a technical team with these expertises that would be ideal in the preparation of national communications in the future.

7.3.3 Financial Needs

The preparation of national communications requires a lot of people with higher degree training in diverse disciplines as alluded to above. The short-comings of the INC of Malawi and the SNC of Malawi is that both documents were not adequately funded, hence some of the essential studies could not be conducted meaningfully. This time around there is very little incentive to attract the best and high caliber scientists to conduct the various studies owing to low renumeration packages for the sectoral studies. Thus, there is need for more than doubling the amount of US $400.000.00 used for preparing the SNC to US $8000,000.00 when preparing the Third National Communication (TNC). The areas covered in the various studies are also wide and diverse. For example, the V&A Assessments and the National Circumstances Thematic Areas touched on all sectors of economic growth, but were only allocated US $40,000 and 10,000, respectively.

7.3.4 Research Needs

Clearly, there is need to conduct good quality research to generate good quality data for use in the determination of greenhouse gases and verification of computer simulation models. First and foremost, there is need to conduct research to determine local emission factors for use in GHG determinations in various sectors of economic growth. The models used in adaptation and mitigation assessments were developed for specific purposes and calibrated for specific environmental circumstances in the areas or countries where they were developed. However, before they can be used in Malawi, there is need to calibrate and validate them before they are used to forecast future outcomes under local Malawi field conditions. Further, research is required to determine minimum data sets for running the computer simulation models. During the present studies, some of the models could not be run because of lack of minimum data sets to drive the model, e.g., the SPUR II Model in the Livestock sub-sector Second, once appropriate computer simulation models will have been selected, the relevant respective sectors should embark on research specifically designed to determine minimum data sets for model calibration and validation. The assembled database would by necessity contain this minimum data set as a prerequisite. Some of the priority research projects on climate change are presented in Chapter 8, and through the implementation of these, some minimum data sets could be collected and assembled. .

7.4 Summary

There are many factors that constrain the preparation of national communications at sector and thematic area levels. The constraints mainly relate to lack of data, especially emission factors and related parameters, and minimum data sets for model evaluations. The other constraints concern lack of capacity building and training of staff in various technical fields, including computer simulation modeling, and higher degree training. Further, the other major constraint is lack of adequate financial resources to carry out the various activities, lack of a consolidated database on natural resources and other systematic observation.

Chapter 8
Proposed Climate Change Projects

8.1 Background

Chapter 7 identified the need for conducting research in various fields related to climate change. The main purpose for conducting the research is to determine emission factors for use in determining GHG emissions from different sectors, and minimum data sets for calibrating, validating and testing simulation computer simulation models, and developing measures and strategies for adapting and mitigating climate change among the most vulnerable communities, sectors of economic growth and fragile agro-ecosystems.

8.2 Priority Areas of Focus

An analysis of the constraints and gaps in Chapter 7 has clearly identified the need for conducting research to address the identified problems in the climate change arena. The priority areas that need research and strengthening include: (i) policy, institutional and legal frameworks, especially mainstreaming climate change into sectoral and national policies, strategies and programmes; (ii) determination of minimum data sets, parameters and variables required for climate change detection, mitigation and adaptation to its impacts, (iv) skills and know-how for developing relevant and appropriate measures for adaptation and mitigation of climate change, especially floods and droughts, (v) public awareness campaigns to sensitize the people on the adverse impacts of climate change as manifested in the form of floods and droughts, and (vi) capacity building and training.

8.3 Previous Climate Change Studies

Three major previous initiatives on climate change-related activities have been undertaken in Malawi under the following: (i) US Country Studies Program, funded by the United States Agency for International Development (USAID), (ii) Initial National Communication (INC) of Malawi funded by the Global Environment Facility (GEF), and (iii) National Adaptation Programmes of Action (NAPA) funded by the Global Environment Facility (GEF). All these studies have identified capacity building, at both institutional and individual levels, to conduct climate change-related research in meteorology, climatology, engineering, agriculture, environment, systems analysis, energy and computer simulation modeling as the main problems constraining climate change activities in Malawi.

It was based on these studies that climate change proposed projects were developed, focusing on all sectors of economic growth (agriculture, water, energy, fisheries, land use change and forestry, wildlife, human health and gender). Further, based on the NAPA document, Malawi has prepared a project proposal entitled: "Climate Adaptation for Improved Rural Livelihoods and Agricultural Development", which builds on the efforts of the African Development Bank (ADB) funded project entitled: "Smallholder Crop Production and Marketing Project (SCPMP)".

Presently, Chapter 7 on constraints and gaps, and related technical, financial and capacity needs has reviewed the previous studies, updated the INC and identified several problems that continue to constrain the implementation of climate change programmes at local and national levels. Based on these findings, a consensus has emerged to address these with priority projects aimed at: (i) improving the quality and quantity of climate data and information for use in the determination of greenhouse gas emissions, and for model calibration, validation, testing and experimentation, (ii) developing energy balance sheets for Malawi to improve the GHG Inventory, (iii) building local capacity in computer simulation modeling, including the development of climate change scenarios; (iii) decreasing CO_2 emissions from the energy, forestry and agriculture sectors, using appropriate mitigation options, and (iv) creating a friendly environment that fosters resilience against the impacts of climate change and variability. Hence, it is from the previous studies and the current climate change situation analysis that the proposed climate change projects presented below are based.

8.4 Proposed Climate Change Projects

The proposed climate change projects will be conducted in a collaborative and holistic manner to cover a wide range of sectors of economic growth, including energy, agriculture, forestry and fisheries, and stakeholders from different scientific disciplines. A brief description of the proposed projects is given below.

8.4.1 Energy Sector

1. Renovation and Extension of the Matandani Mini Hydro-Power Station in Mwanza and Neno Districts, Southern Malawi

Project linkages to national priorities: Malawi has the lowest electrification rate in the Southern African Development Community (SADC) region, where the average rate of regional electrification is approximately 20%. In Malawi, only 4% of the population has access to electricity, with rural areas registering less than 1% electrification. Thus, the majority of the people in rural areas derive the bulk of their energy from biomass, which greatly contributes to GHG emissions.

However, Malawi has initiated a programme on rural electrification, given that poverty reduction can be addressed most expeditiously by enabling farming communities, rural merchants and craftsmen to rapidly and substantially increase their productivity if they have access to a reliable source of power. Besides providing greater access to electricity by extending the national grid, it is felt that mini- and micro-hydro-power generating plants will play a greater role in providing electricity to rural areas endowed with fast flowing rivers and streams that can be harnessed for such purposes. This has re-kindled the need to rehabilitate the Matandani Mini Hydro-Power Station in Mwanza and Neno districts.

Project rationale: Matandani Rural Growth Centre and Neno Trading Centre are 36 km away from the existing power transmission line. However, power supply to both these centres is difficult because of financial constraints to erect a power line through the numerous hills in the area. The centres have primary schools, health centres, secondary schools and other public institutions, as well as dwelling houses in the surrounding villages. It is envisaged that once renovated, the existing Matandani Mini Hydro-Power Station will provide electricity to the two centres and surrounding areas, and will serve as a model project for hydro-power generation and development using small rivers and supplying t power to communities at minimal costs. The Mini Hydro-Power Station will reduce the GHG emissions arising from the use of paraffin and biomass.

Project objectives: The objective of the project is to supply power to Neno Trading Centre, as well as Matandani and the surrounding rural areas in Mwanza and Neno districts in order to simultaneously provide power for agricultural use and commerce, and to reduce GHG emissions by replacing biomass with electricity for heating, cooking and lighting.

Project description: Originally, the Seventh Day Adventist Mission (SDAM) built the Mini Hydro-Power Station at Matandani to supply power to the mission. However, the mission was unable to produce adequate annual income to run and maintain the power station. A recent feasibility study performed by the Department of Energy Affairs (DoEA) recommended the renovating of the mission plant, and extending the facility to supply power to Neno Trading Centre and surrounding areas. The maximum power demand for the Matandani area is estimated at 26 kW, whereas that for Neno Trading Centre is 89 kW, giving a total of 115 kW. The output of the power station at Matandani is, therefore, set at 120 kW, taking into consideration a distribution loss of 5%.

Stakeholders. The main stakeholders in the Matandani Mini Hydro-Power Station include the following: (i) Matandani Seventh Day Adventist Mission (SDAM); (ii) Mwanza District Assembly, (iii) Neno District Assembly, (iv) Department of Energy Affairs (DoEA), (v) Electricity Supply Corporation of Malawi (ESCOM), (vi) Local communities, (vii) Donors community, (viii) Environmental Affairs Department (EAD), (ix) Ministry of Irrigation and Water Development (MoIWD), (x) Ministry of Agriculture and Food Security (MoAFS), and (xi) Malawi Industrial Research and Technology Development Centre (MIRTDC).

Project outputs and outcomes. The expected outputs and outcomes of the project include: (i) a renovated Old Matandani Mini Hydro-Power Station, (ii) an extended Matandani Mini Hydro-Power Station; (iii) local capacity building and expertise in running and managing a mini hydro-power plant, (iv) supply of electricity to Matandani and Neno Rural Growth Centres and rural communities, (v) reduction in GHGs from the use of biomass energy.

Project activities. The main activities will include: (i) renovating and extending the mini hydro-power plant, (ii) construction of distribution lines to Matandani, Neno and surrounding areas, (iii) quantification of current energy production and consumption, and (v) quantification of GHG emissions.

Project budget and timeframe: The cost of the renovation and extension work is estimated to cost a total of **US$ 600,000.00.** The project is expected to take 2 years to implement, including the commissioning of the hydro-power plant.

2. Establishment of an Energy Data Management System, and an Energy Balance for Malawi

Project linkages to national priorities: The provision of energy is vital for economic growth and development of Malawi. Without adequate power in the form of electricity, or liquid fuels, most economic activities in agriculture, transport, industry, mining, and construction would be slowed down. This is because economic development is directly proportional to per capita energy consumption. The establishment and expansion of manufacturing agro-processing industries will depend on the use of reliable energy sources, such as electricity, liquid fuels and coal. In view of these, it is always important to collect, update and develop an energy database sheet for Malawi. Energy balances are required in forecasting growth and trends in The Energy Sector, and how these impact the other sectors of the national economy.

Project justification: Since 1994, Malawi has not been able to prepare energy balances for the country. The lack of such data has obstructed attempts to tabulate national energy use. This effort has also been plagued by the scarcity of local professionals possessing the necessary expertise in energy budgeting and planning. At regional level, this deficiency has also created a problem for Malawi. The Southern Africa Development Community (SADC) Energy Protocol requires that each member state should report its energy balances to the Ministers of Energy on an annual basis. This information is used by SADC to compile energy balances for the entire region. At national level, the non-availability of energy balances has made planning in the energy sector problematic, and so has been the determination of GHG emissions from the Energy Sector.

Project objectives. The objectives of the project are to: (i) collect relevant energy data, and prepare a Malawi energy database, (ii) prepare energy balances and establish a framework for sustainable arrangements for preparing energy balances in the future, and (iii) provide technical expertise in the preparation of energy balances.

Project description: A number of energy studies and surveys have been conducted in urban areas to estimate energy requirements in the different industrial sectors and household level. Unfortunately, there are insufficient data in the transport, industrial and agriculture sectors, small-scale industries and rural household level. Where some data are available, these are not packaged in a way that allows one to quickly prepare energy balances. In view of this, the proposed project will assist in gathering and packaging the energy database in all the sectors of economic growth in the country.

The last credible energy balance for Malawi was prepared in 1994 and the experts who were involved at that time have since left the Department of Energy Affairs (DoEA). This has left a big gap in the DoEA that is difficult to fill. For this project, it is proposed to hire a consultant for at least a period of one year to assist with the preparation of energy balances, and training local staff in preparing annual energy balances. This arrangement will institutionalize the preparation of energy balances in DoEA.

Lead institutions. The lead institutions will be: (i) Department of Energy Affairs (DoEA), (ii) Environmental Affairs Department (EAD), and (iii) National Statistical Office (NSO).
Stakeholders. Energy issues straddle across all sectors of economic growth, including: manufacturing industries, agriculture, irrigation, consumer associations, mining, transport, health and education, among other social and economical sectors. Participating stakeholders will come from these sectors.

Project outputs and outcomes. The expected outputs and outcomes of the project are as follows: (i) Survey reports (various socio-economic sectors); (ii) computerized energy data base; (iii) energy balances (1995–2001); and (iv) sustainable framework for the preparation of energy balances. .

Project activities. The main project activities will include energy surveys in various sectors of socio-economic growth to establish the type of energy use and demand patterns. The following energy surveys will be conducted: (i) Rural household energy survey, (ii) Urban household energy survey, (iii) Energy demand survey in industries, (iv) Energy use in the agriculture sector, (v) Energy demand in social sectors, such as health and education, (vi) Energy demand in small-scale industries, such as brick burning, fish smoking, baking and beer brewing, and (v) Energy use in the transport sector.

Establishment of an energy database. The establishment of an energy database will require the acquisition and installation of high speed computers that have large storage capacity in the DoEA. This will also entail acquiring appropriate computer software for processing and analysing data, such as statistical and/or graphics software packages. It is proposed that two staff members from the DoEA should be trained in data collection, compilation and management, and to hire the services of a competent computer programmer with expertise in the preparation energy balances. Two National Experts will have to understudy the consultant over the one-year period, and undergo an on-the-job training. However, these national experts will also undergo specialized training, especially in energy database management.

Project budget and timeframe: The project is estimated to cost a total of **US $ 1, 405,000.00,** broken down as follows: (i) Surveys: US $ 900,000.00, (ii) Data base establishment: US $ 155,000.00, and (iii) Preparation of energy balances by a consultant and the two national experts: US $ 350,000.00. It proposed to conduct the project over a three-year period.

8.4.2 Water Resources Sector

1. Climate Change Adaptation Strategies for Managing Floods and Drought in Fragile and Marginal Rainfall Areas of Malawi

Project linkages to national priorities: Malawi frequently experiences floods and droughts, which result into loss of life and property and the destruction of infrastructure, including roads and buildings every year. Since the Phalombe disaster in 1991, Government has prioritized social protection and disaster management, as outlined in the Malawi Growth and Development Strategy (MGDS). It is important to note that with the high levels of poverty in the country, the poor have little resilience against disasters, and their occurrence, makes them even poorer. There is need to protect all Malawians against the adverse impacts of climate change (floods and droughts), especially among the most vulnerable rural communities.

Project justification: Floods and droughts have continuously devastated infrastructure, crop fields, and disrupted road and railway communications, water and electricity supply, and the sustainable livelihoods of family households. The most glaring example is the disrupted Bangula-Makhanga railway line and road, the destruction of buildings and crop fields in the Shire Valley, and siltation of some major rivers, such as the Mwanza, Shire, South Rukuru and Songwe. The response to these floods and droughts under emergency is, therefore, to develop measures and strategies for adapting to climate change in the areas that are traditionally prone to droughts and floods, such as the Shire Valley and areas along some parts of the Lakeshore Plain.

Project objectives: The objective of the project is to implement climate change adaptation strategies and measures for managing and conserving water resources in areas prone to floods and droughts. This will be accomplished by establishing basic information management and climate warning systems for floods, construction of flood protection works, and securing reliable water supply from rainwater harvesting structures.

Project description: This programme has four components or areas of focus. First this would involve the preparation of flood maps showing areas that are prone to floods throughout the country, define different flood levels for use in settlements, issuing flood warnings, identification, development and maintenance of flood protection works, and drought adaptation and mitigation works. Second, this would involve the installation of floods protection works and water-related warning systems for rapid response. Third, this would involve the design and implementation of flood protection works, comprising levees, dykes and the canalization of flood plains in areas frequently affected by intermittent floods. Fourth, this would involve the design and implementation of flood and drought adaptation and mitigation works for the restoration of clean potable water supply, especially in marginal rainfall areas that are also prone to droughts.

Stakeholders: This project will be implemented by the Department of Water Resources (DoWR) in collaboration with various stakeholders, including: (i) rural family households and communities, (ii) District Assemblies (DAs), (iii) Department of Meteorological Services

(DoMS), (iv) Department of Rural Development (DoRD), (v) Donors agencies, (v) Environmental Affairs Department (EAD), and (vi) Ministry of Agriculture and Food Security (MoAFS).

Project outputs and outcomes. The planned project outputs and outcomes include: (i) maps demarcating flood prone areas along rivers and lakeshore areas, (ii) flood forecasting and warning systems, such as the Lower Shire Floods Warning System, (iii) flood protection works (levees, dykes or canals) holding back flood waters, (iv) a number of small dams and other water harvesting structures, (v) capacity and training in the maintenance of flood works, expertise in the use of flood forecasting and warning systems and flood protection works, including small dams and water harvesting structures, and (vi) reduction in the number of damages caused by floods and droughts.

Project activities. The major project activities will include the following: (i) design and supervision of construction and installation works, (ii) flood zoning, delineation and mapping, (iii) establishment of flood forecasting and warning systems, (iv) construction of emergency flood protection works, (v) construction of small dams and water harvesting physical structures, and (vi) investigating the use of modeling tools, such as the Water Evaluation and Planning (WEAP) Model that is used for designing dams and drainage conduits for flood water management. Each activity would include capacity building in maintenance, operation and updating the works at local community level.

Project budget and timeframe: The proposed project budget is **US $ 5,000,000.00** over a time period of 5 years.

2. Developing Water Conservation and Management Strategies for Adapting to and Mitigating Climate Change

Project linkages to national priorities: The Malawi Growth and Development Strategy (MGDS) has identified six priority areas for implementation between 2006 and 2011. These include: (i) **agriculture and food security**, (ii) **irrigation and water development**, (iii) **transport infrastructure development,** (iv) **energy generation and supply**, (v) **integrated rural development**, and (vi) **prevention and management of nutritional disorders, malaria, diarrhea and HIV and AIDS**. All these depend on the availability of adequate water resources, which however, is threatened by climate change and climate variability, over-exploitation and pollution. The agriculture sector, which is the engine of economic growth, depends on rain-fed agriculture, making the sector highly vulnerable to the impacts of droughts. The development of water conservation and management strategies will assist Malawi to conserve water, and an opportunity for crop diversification, and the expansion of the area under irrigation.

Project justification: Water security is essential for sustainable economic growth and development. However, water security is threatened by climate change and variability. Water conservation, with multi-purpose reservoirs and dams that provide for three to four years water storage, can create the necessary water security for the growing population of Malawi. Such dams can also hold back flood waters, significantly reducing flood levels and preventing flooding waters from causing damage to buildings, infrastructure, roads, displacing people, and loss of life. Good water conservation and management practices can also generate adequate data and information that can facilitate research and the creation of a water resources database.

Project objectives: The project aims at developing water resources management infrastructures to ensure water security and developing implementation strategies for water resources conservation and management.

Project description: This project would develop two programmes for water resources conservation and management. First, is the water resources conservation programme that would aim at reviewing the literature on water resources in vulnerable areas that are mainly affected by floods and droughts resulting from climate change and variability. The review would also examine existing development proposals to identify dams and other water resources conservation projects. Second, is the water resources management programme that would develop the required water resources management strategies. This would also include monitoring and planning needs assessments for infrastructural development, maintenance and operation. This would include reviewing data and information from existing water resources management programmes and development of projects.

Stakeholders. The stakeholders will include the following: (i) Department of Water Supply (DoWS), (ii) Ministry of Agriculture and Food Security (MoAFS), (iii) Local communities in districts affected by floods and droughts; (iv) District Assemblies (DAs), (v) Department of Irrigation (DoI), (vi) Department of Energy Affairs (DoEA), (viii) Electricity Supply Corporation of Malawi (ESCOM), (ix) Donors agencies, (x) Environmental Affairs Department (EAD), and (xi) Department of Meteorological Services (DoMS).

Project outputs and outcomes. The expected outputs and outcomes of the project will include: (i) preparation of project proposals for conducting the feasibility studies on the design and construction of small-scale dams, floodplain reclamation, river training and protection works, and (ii) capacity building for the implementation and monitoring of the proposed projects, and (iii) convening a donors' conference to solicit funds and technical assistance.

Project activities. The major activities will include the following: (i) project proposal writing (ii) capacity building and training of local staff in project formulation and implementation; (iii) raising funds for the project proposals, (iv) construction of physical water conservation structures, and (v) harnessing the conserved water for irrigation purposes.

Project budget and timeframe. The project is expected to cost **US $ 344,000.00** over a period of one year.

3. Developing and Implementing a Water Demand Management System for Malawi

Project linkages to national priorities: Malawi's socio-economic growth and development depends on the implementation of strategies that reduce poverty, and increase agricultural production to ensure food security as articulated in the Malawi Growth and Development Strategy (MGDS) of 2006. Economic growth depends on the availability of adequate water resources, which although is abundant as of now, is slowly and increasingly under threat from over-exploitation. Thus, to better manage Malawi's water resources to meet the increasing demands of an increasing human population for both domestic and industrial use, there is need to develop a water demand management system to ensure equitable water distribution throughout the year among different stakeholders.

Project rationale. Water demand management is essential for generating wealth and reducing poverty. However, the available water in the country is under threat from depletion, over-use and wastage through leakages in broken pipes in urban areas, canals and irrigation schemes, and pollution from industrial wastes. The development and implementation of water demand management system would avoid unnecessary water wastage and losses, and ensure its sustainable use.

Project objectives. The objectives of the project are to: (i) identify and recommend strategies and measures for the proper utilization of water, and (ii) to empower staff in developing proposals, and local communities, in the proper management, utilization and conservation of water, especially in areas characterized by drought conditions.

Project description, This project would develop strategies for a water demand management programme as an integral component of the climate change management strategy. These programmes would address water wastage and losses due to leaking water pipes in towns, and water losses in irrigation schemes. The capacity building component of the programme would concentrate on the training of both staff and local communities to equip them with skills on water demand management systems, including policies.

Stakeholders. The lead institution is the Department of Water Resources (DoWR), whereas potential stakeholders include: (i) Local communities, (ii) District Assemblies (DAs), (iii) Department of Water Supply (DoWS), (iv) Department of Irrigation, (DoI), (v) Department of Energy Affairs (DoEA), (vi) Electricity Supply Corporation of Malawi (ESCOM), (vii) Donors agencies, (v) Environmental Affairs Department (EAD), and (vi) Department of Meteorological Services (DoMS).

Project outputs and outcomes. The expected project outputs and outcomes include the following: (i) project proposals on water demand management studies, design and construction, (ii) project proposals for mainstreaming water demand management issues into water infrastructure development, operation and maintenance, (iii) capacity building in project proposal writing and management, (iv) donors' conference to solicit financial resources and technical assistance.

Planned activities. The major activities include: (i) project proposal preparations, (ii) capacity building and training of local staff in project formulation and follow-ups for implementation; and (iii) fund raising for project proposal funding.

Project budget and timeframe. The cost of the project is estimated at **US $ 98,000.00** to be conducted over a period of 6 months

8.4.3 Agriculture Sector

1. Developing Appropriate Agricultural Technologies for Mitigating and Adapting to Climate Change in Different Agro-ecological Zones of Malawi

Project linkages to national priorities. Malawi faces a multitude of social, economic and environmental problems that are threatening the sustainable livelihoods of family households. The principal cause of the problems is the nation's high population of 13.1 million people against a background of increasing poverty and deforestation, accelerating land and environmental degradation, and increasing frequency of severe floods and droughts. However, although agriculture is the engine of economic growth, it is also highly vulnerable to the adverse impacts of climate change, especially droughts and floods.

Research is urgently required in various aspects of agricultural production, including: (i) breeding crop varieties that are tolerant to drought and low soil fertility conditions, (ii) rainwater harvesting, (iii) soil and water conservation and management, (iv) irrigation development, and (v) integrated nutrient management systems. The nutrient management system strategy would also use as much as possible of the available organic fertilizers in combination with as little as possible of the inorganic fertiliser materials to optimise crop yields, reduce GHG emissions, arrest environmental degradation, and reduce the groundwater pollution.

Project objectives. The overall objective is to develop appropriate, environmentally-friendly and agricultural technologies to increase crop and livestock productivity among resource poor farming communities. The specific objectives include: (i) screening and developing high yielding crop cultivars of cereals (maize and sorghum) and legumes (beans, ground nuts and soybeans) that are tolerant to droughts and low soil fertility, (ii) developing organic and inorganic fertilizer management strategies that optimize crop yields under limiting soil-water conditions, (ii) integrating cereals with legume to improve soil fertility through Biological Nitrogen Fixation (BNF), (iii) developing irrigation water management practices for irrigated winter cropping and supplementary irrigation in summer, (iv) developing soil and water management practices that conserve water, and (v) developing, calibrating, validating and testing computer simulation models for forecasting crop yields based on soil, weather and crop management factors.

Project description: This project covers more than five disciplines as follows: breeding, agronomy, pathology, soil science, irrigation, and crop, soil and plant modelling. The implementation of such a comprehensive project will lead to the development of new crop cultivars that are high yielding and tolerant to drought; crop husbandry and agronomic practices that ensure efficient utilization of the available fertilizer and water resources; integrated nutrient management that will optimize the use of organic fertilizers while reducing mineral fertilizers inputs; soil and water conservation practices that will lead to improved soil-water availability during times of drought; and irrigation, which will allow farmers to grow crops under controlled conditions during the dry season.

Stakeholders. The lead institution will be the Department of Agricultural Research Services (DARS) in the Ministry of Agriculture and Food Security (MoAFS). The collaborators will include: (i) University of Malawi (Bunda College, The Polytechnic and Chancellor College), (iii) University of Mzuzu, (iv) Department of Agricultural Extension Services (DAES), (v) Department of Land Resources Conservation (DLRC), (vi) Department of Meteorological Services (DoMS), and (vii) Non-Governmental Organizations (NGOs), including Farmers' Organizations (FOs) and Civil Society Organizations (CSOs).

Project outputs and outcomes. The project outputs and outcomes will include the following: (i). increased crop yields that will ensure food security and reduce hunger and poverty (ii) high yielding crop varieties or cultivars that are tolerant to drought and adapted to sole and multiple cropping systems, (iii) reduced soil erosion, surface run-off and environmental degradation for sustainable economic development, (iv) improved fertilizer use-efficiency, for increased crop production and reduced GHG emissions, (v) soil and water conservation, including rainwater harvesting, for domestic and industrial use, especially irrigation, (vi) improved agricultural crop husbandry practices for optimizing crop yields and soil-water conservation, (vii) insect pest and disease control measures identified and recommended, (ix) increased crop production per unit area, (x) improved soil fertility and (xi) reduced environmental degradation and air pollution.

Project activities. The main project activities will be as follows: (i) conducting on-farm and on- station breeding and screening trials throughout the country using participatory methodologies and farmer field schools, (ii) conducting on-station and on-farm verification trials and demonstrations in collaboration with farmers, NGOs and the grass root farmers' organizations, (iii) conducting on-station and on-farm soil fertility improvement programmes, including the determination of a minimum data sets for model calibration and validation of computer simulations models based on soil, weather, crop and livestock management data, and (v) experiment with models as tools for screening alternative production possibilities.

Project budget and the proposed timeframe. The proposed budget for the project is estimated at **US$ 1,020,000.00** for a period of three (3) years. The main areas of focus will be on: (i) integrated nutrient management, (ii) intercropping cereals with legumes, (iii) use of crop-soil-crop management-climate simulations models, (iv) breeding and screening drought and disease tolerant crop (cereals and legumes) cultivars.

8.4.4 Water Resources, Energy, Agriculture, Forestry and Other Land-Use, Wildlife and Fisheries Sectors

1. Reducing Siltation along the Shire River to Enhance Hydro-Power Generation; Boost Crop, Livestock, Wildlife and Fish Production in the Shire Valley

Project linkage to national priorities. The Shire Valley is faced with several problems associated with serious environmental degradation due to population pressure, land cover degradation, soil erosion, deforestation, fish stock reduction, loss of wildlife, food and timber genetic diversity (EAD, 1994). Soil erosion is a major land degradation problem that is threatening agricultural production and water pollution. About 11-50 tones of soil are lost per hectare annually, which results in declining soil fertility and crop yields, but increased siltation and sedimentation of river beds, including that of the Shire River that is the source of hydro-power, abundant fisheries, besides wildlife resources. Siltation in the rivers and streams cause reduced conveyance capacity, and consequently, flooding and bank overflows. as well as water treatment costs. At Nkula Hydro-Power Station, siltation hampers national electricity generation and results in frequent electricity blackouts. However, to supplement hydro-power in the generation of electricity, diesel and/or petrol generators are used, which result into increased GHG emissions. Further, frequent and severe electrical power disruptions have increased the use of biomass, including urban dwellers.

Project justification. Soil erosion, deforestation, population pressure on land resources and agricultural productivity, poverty and inappropriate agriculture practices along the river catchments lead to serious siltation of the Shire River up to the Kamuzu Barrage at Liwonde, which affects electricity generation, bio-diversity, and water quality. The decreased water quality leads to the prevalence of water hyacinth that increases the cost of power generation and water purification. Deforestation resulting from charcoal production increases GHG emissions and reduces the carbon sink that is required to mitigate climate change.

Project objectives. The objective of the project is to develop an integrated approach, which contributes to and promotes sustainable use of natural resources in the Shire Valley, through arresting land degradation, tree planting programmes, improving the management and utilization of the renewable natural resources, increased agricultural and fishery production, and the reduction of CO_2 emissions through the use of clean technologies and increasing carbon sinks through tree planting in woodlots, commercial plantations and on-farm boundaries (agro-forestry).

Stakeholders. The lead institutions will be the Departments of Agricultural Research Services (DARS) and Department of Land Resources Conservation (DLRC) in the Ministry of Agriculture and Food Security (MoAFS). These departments will work in collaboration with: (i) Department of Water Resources (DoWR), (ii) Electricity Supply Corporation of Malawi (ESCOM), (iii) Blantyre Water Board (BWB), (iv) University of Malawi (Chancellor College, Bunda College, and The Polytechnic), (v) University of Mzuzu, (vi) Environmental Affairs

Department (EAD), (vii) Department of Fisheries (DoF), (viii) Department of Forestry (DoF), (ix) Department of Energy Affairs (DoEA), (x) Blantyre City Assembly, (xi) Co-ordination Unit for the Rehabilitation of the Environment (CURE), (xii) Malawi Environmental Endowment Trust (MEET), (xiii) World Universities of Canada (WUSC), (xiv) Malawi Enterprise Development Institute (MEDI), and (xv) farming communities.

Project outputs. The main project outputs and outcomes will include: institutionalized soil and water conservation practices in relevant institutions, established payments for ecosystems services (PES), community controlled areas of marginal lands protected with forest and community-based catchment areas, reduced soil erosion and siltation of river beds, improved management of the renewable natural resources, and increased agricultural and fishery production. All these will contribute to poverty reduction, increased forestation, decreased siltation and greater conservation of the natural resource base, and increased community income from the payment of ecosystem services (PES). Consequently, this will result in increased carbon sinks, leading to decreased GHG emissions, alternative and more efficient use of energy, less flooding in the Shire Valley; enhanced and more efficient electricity generation with fewer blackouts and water abstraction, better monitoring of the natural resources and water management practices, and reduced bio-diversity loss.

Project activities. A stakeholder survey and analysis will be performed to determine the level of partner commitment and involvement in the project, as well as potential beneficial effects on the communities. A survey and analysis of land-use and land re-classification according to: (i) carrying capacity, (ii) demarcating marginal areas requiring controlled and improved management, (iii) establishing community catchment management authorities, planting trees, and (iv) introducing improved soil and water management and conservation practices, including rainwater harvesting, to reduce siltation in the Shire River and its tributaries.

Further the project will quantify the amounts of GHG emitted from trees and those resulting from the use of standby generators when hydro-power energy source is disrupted. At the end of the day, however, proper management and coordination of such a big and diverse project involving many stakeholders, requires the availability of adequate financial resources and the commitment of scientists in different sectors. .

Project budget and timeframe. The proposed budget for the project is **US$ 1,000,000,** over a period of between 3 and 5 years.

2. Determination of Emission Factors and Minimum Data Sets for Model Calibration, Validation, Testing and Experimentation

Project linkage to national priorities. The findings from various studies in Malawi, including the Second National Communication (SNC) of Malawi, have identified the limited data base as the main factor constraining climate change studies in all sectors of economic growth. For example, Malawi does not have a database for local emission factors to estimate GHGs, or sufficient minimum data sets for calibrating, validating and experimenting with computer simulation models that are so vital in climate change scenario development and use, and climate change adaptation and mitigation studies.

Project justification. If Malawi is to conduct meaningful GHG inventories and plausible adaptation and mitigation studies in various sectors, it must first invest in research to determine local emission factors and generate minimum data sets for model verification and experimentation, instead of using default values, as the case has been in the preparation of the three inventories in 1990, 1994 and 2000. .

Project objectives. The main objective of the project is to determine local emission factors and minimum data sets for model verification in the Agriculture, Water Resources, Energy, Fisheries, Wildlife, Forestry and Other Land-Use, Human Health, Industrial Processes and Product Use, and Waste Management Sectors.

Stakeholders. The lead institutions will be the Environmental Affairs Department (EAD). The main collaborators will be the nine sectors of Agriculture, Water Resources, Energy, Fisheries, Wildlife, Forestry and Other Land-Use, Human Health, Industrial Processes and Product Use, and Waste Management.

Project outputs and outcomes. The main project outputs and outcomes will include a database of emission factors for estimating GHGs and minimum data sets for model verification and forecasting future impacts of climate change.

Project activities. The project activities will include: (i) conducting research to determine emission factors and minimum data sets in different sectors, (ii) developing criteria for model selection and use, and (iii) conducting research to determine minimum data sets for the selected models. These activities will be conducted in all sectors of economic growth.

Project budget and timeframe. The proposed budget for the project US$ 5,000,000, over a period of between 2 and 3 years.

8.4.5 Capacity Building Projects

1. Establishing a Global Climate Observatory Station (GCOS) on Mulanje Mountain, Mulanje District, Southern Malawi

Project linkage to national priorities. The acquisition of a full range of climate data is essential for building a climate database that can be used for planning at local and national levels, early warning systems, forecasting weather conditions, including floods and droughts, and as input parameters into models for forecasting changes in climate in the future.

Project objectives: The objective of the project is to develop capacity in the collection and analysis of a wide range of atmospheric observations, including air temperature, rainfall, solar radiation, and wind speed and direction, in accordance with GCOS Standards, using an Automatic Weather Station (AWS).

Project activities. The main activities will include: (i) procurement and installation of equipment, and (ii) training of staff to maintain and operate the station.

Project description. Mulanje Mountain is one of 200 Global Eco-Regions in the world for the Conservation of Biodiversity, and is designated as the "Mountainous African Regional Centre for the Study of Indigenous Biota" given its enormous number of indigenous, unique, and often endangered plants, animals and microorganisms. Presently, there is the Mount Mulanje Conservation Trust Project (MMCTP), which is supported by the Global Environment Facility (GEF) under the Biodiversity Convention that is addressing sustainability of the ecosystem. Activities of the GCOS station would, therefore, augment this project such that data and information collected from the site will not only be confined to the studies of the atmosphere but also to other economic sectors, such as Forestry and Other Land-Use, Wildlife, Fisheries, Agriculture, Water Resources and Energy, among many others. Furthermore, the Mulanje Mountain Site is categorized as fragile and is prone to climatic disasters. The Phalombe Disaster that occurred in 1991 was within the neighbourhood of the mountain. Data and information collected from the top of the mountain, which is about 3,000 m asl, would be compared with data collected at ground level, which is about 600 m asl.

Stakeholders and beneficiaries: This project will take on board various stakeholders including those involved in agriculture, water, energy, mining, wildlife, forestry, fisheries and tourism at both national and local community level. Potential areas for extension in the future include: (i) Likoma and Chizumulu Islands over Lake Malawi, (ii) Zomba Mountain, (iii) Viphya Plateau, and (iv) Nyika Plateau.

Project outputs and outcomes. :It is anticipated that the data collected from the top of the mountain, and ground level, will be major inputs into climate change studies, which cut across many sectors of the economy, as indicated above. These data will equally be used as model inputs for model evaluation and perform future projections in climate change.

Project budget and timeframe. The budget is estimated at **US$ 300,000** which will be executed within a period of two years.

2. Establishment of a Centre of Excellence for Climate Change Research in Malawi

Project linkages to national priorities. The issues of climate change need to be incorporated in national development policies, strategies and programmes to minimize the adverse impacts of climate change. However, this has not been done effectively up to now as pointed out in the introduction section of this document.

Project rationale: Presently, there is no institution that is charged with the function of conducting research on climate change, meteorology or climatology. Although the Department of Agricultural Research Services (DARS) is the Government research institution whose mandate is to conduct research only, research on climate change is limited to data collection and recording by the Soil Physics Unit at Chitedze from various sites within the jurisdiction of the Ministry of Agriculture and Food Security (MoAFS). In addition, the Department of Meteorological Services (DoMS) too does not conduct research as such, but has a network of stations throughout the country that record and collect weather data [especially rainfall, air and soil temperatures, wind speed, relative humidity and sunshine hours (solar radiation)]. The need for creating a Climate Change Unit or National Climate Change Commission can not be overemphasized. This Unit or Commission could be established within as an independent body that is directly under the Office of the President and Cabinet (OPC), as the case is with the National Aids Commission, but with strong linkages with EAD, which is the Climate Change Focal Point in Malawi. It is this Climate Change Unit that would be responsible for collating and assembling data from various sources, preparation of future national communications and implement other Global Environment Facility (GEF) portfolios.

Project objectives. The main objective of the project is to strengthen the National Commission for Science and Technology in Malawi in coordinating climate change research among the different stakeholders involved in conducting research. Specifically, the project aims at: (i) performing research on all aspects of climate change and variability, (ii) developing and testing computer simulation models for predicting and forecasting probable climate changes in the future, crop yields, soil erosion and environmental degradation, (iii) developing training and extension materials and curricula for vocational, undergraduate and postgraduate students, (iv) contributing to and funding advocacy on climate change issues at local, national and regional levels, (v) facilitating networking among key players within Malawi, and collaboration between domestic and international participants, and (vi) formulating climate change policies in accordance with those outlined by the United Nations Framework Convention on Climate Change (UNFCCC), and the Kyoto Protocol, among other protocols and conventions.

Stakeholders. The lead institutions will be the Environmental Affairs Department (EAD) and the National Commission of Science and Technology. The other stakeholders would include: (i) University of Malawi (Chancellor College, Polytechnic and Bunda College), (ii) University of Mzuzu, (iii) the proposed Lilongwe University of Science and Technology (LUST), (iv) Ministry of Education, Science and Technology (MoEST), and (v) National Economic Council (NEC).

Project outputs and outcomes. The main project outputs and outcomes include: (i) Climate Change Unit or National Climate Change Commission established, (ii) a comprehensive and readily accessible database on research scientists, technologists, social scientists, modeling experts established, (iii) comprehensive data and statistics on local emission factors established, (iv) curriculum, teaching materials and modules for use in universities and colleges devised and prepared, (v) a newsletter on climate change developed and distributed to relevant stakeholders, (vi) training courses and materials for community leaders, NGOs and the print media developed, (vii) predictive models that accurately forecast incidences and extents of droughts and floods, developed (viii) socio-economic indicators associated with climate change determined, (ix) measures and strategies for adapting and mitigating climate change developed and delivered to users for implementation, (x) approaches and methodologies for measuring GHG emissions identified and developed, (xi) the composition and extent of health effects due to air pollution determined, and (xii) comprehensive programmes for monitoring GHG emissions developed.

Project budget and timeframe. A total budget of US $ 5,000,000 is estimated for the execution of the project over a period of 3-5 years.

3. Training of Professional Staff in Systems Analysis and Computer Simulation Modeling

Project linkages to national priorities. Climate change directly impacts on the agriculture sector, which is the engine of economic growth. Since Malawi depends on rain-fed agriculture, it is prudent that Malawi develops modeling capabilities to predict future climate changes, crop yields and environmental degradation. Presently, Malawi has a limited number of crop, soil and climate modelers that are not sufficient to conduct modeling studies in the various sectors of economic growth of Agriculture, Water Resources, Energy, Fisheries, Wildlife, Forestry and Other Land-Use, Human Health, Industrial Processes and Product Use, and Waste Management There is an urgent to develop a caliber of staff with expertise to forecast the impacts of climate change on food and water security, a feat that requires the use of computer simulation models, hence competent computer programmers. Further, the preparation of the Second National Communication (SNC) has highlighted that Malawi has inadequate skills in computing and modeling. Thus, training is required in model selection and use, and model use and experimentation.

Project objectives. The objective of the project is to train professional staff from public and private sector organizations, including the universities, research institutions and NGOs in systems analysis and computer simulation modeling.

Project activities. Establishment of a computing laboratory, purchase of computers and accessories, development and preparation of short courses on modeling and teaching professional staff to enable them prepare national communications without any problems or hindrances.

Stakeholders. The main stakeholders in developing training materials and the teaching of the courses will include: (i) the National Commission for Science and Technology, University of Malawi, Mzuzu University and public research institutions in agriculture, forestry, energy and water resources.

Project outputs and outcomes. The main project outputs and outcomes will include: (i) courses on systems analysis and computer simulation modeling developed, (ii) professional staff working in different sectors of economic growth trained in computer simulation model selection and use that are specific to their sectors of study, (iii) improved capacity in preparing national communications, and (iv) public awareness campaigns to sensitize communities on climate change conducted.

Project budget and timeframe. A total budget of US $ 701,000.00 is required to commence and implement the project activities over a period of three to five years.

8.5 Conclusion

Addressing climate change requires the implementation of various projects relevant to the GHG Inventory, Vulnerability and Adaptation (V&A) Assessments and Mitigation Analysis. What has been presented in this Chapter are some projects meant to address the problems arising from these issues and concerns. It is envisaged that the implementation of these projects will go a long way in alleviating the deleterious effects of climate change on various sectors of the economy.

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Appendix

Appendix 1: Glossary of Key Terms

Adaptation: in natural and human systems, this is a response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities. Thus, adaptation refers to all those responses to climate conditions that may be used to reduce vulnerability. Adaptation is a broad concept and can be used in a variety of ways: **anticipatory** (before impacts take place), and **reactive** (as a response to initial impacts). In natural systems, adaptation is reactive by definition. In human systems, adaptation can be both **anticipatory** and **reactive** and can be implemented by public and private actors. Private actors include individuals, households, communities, commercial companies, and others, such as non-governmental organizations (NGOs). Public actors include government bodies at all levels

Adaptive capacity: this is the ability of people and systems to adjust to climate change, e.g., by individual or collective coping strategies for the reduction of, and mitigation of, risks or by changes in practices, processes, or structures of systems. Adaptive capacity cannot be easily measured since it is related to general levels of sustainable development, such as political stability (civil conflict, functioning democracy), economic well being (gross domestic product (GDP) growth, incidence of poverty), human and social capital (literacy, life expectancy, level of local organization, micro-finance institutions), and climate-specific aspects (such as existing disaster prevention and mitigation systems)

Adaptive deficit: this is lack of adaptive capacity to deal with climate variability and climate change. A useful starting point in addressing adaptation can be to tackle the adaptation deficit before embarking on new adaptation activities

Baseline: this is defined as any datum against which change is measured. It might be a "current baseline" in which case it represents observable, present day conditions. It might also be a "future baseline", which is a projected future set of conditions, excluding the driving factor of interest. Alternative interpretations of reference conditions can give rise to multiple baselines

Biodiversity or biological diversity: this is the variability within species, between species, and of ecosystems

Bottom–up: this is an approach that seeks to develop and assess detailed adaptation strategies on the basis of specific perceptions of vulnerability that have emerged from the full range of stakeholders (i.e., local communities, etc.)

Climate: this can be viewed as average weather. It represents the state of the climate system over a given time period and is usually described by the means and variation of variables, such as temperature, rainfall (precipitation), and wind, most commonly associated with weather

Climate change: this is defined as: “change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural variability observed over comparable time periods

Climate variability: this refers to “variations in the mean state of and other statistics (such as standard deviation, the occurrence of extremes, etc) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability)

COP (Conference of Parties): this is the supreme decision-making body of UNFCCC. It is charged with promoting and reviewing the implementation of the Convention. The first session of the COP took place in Berlin in 1995. The Kyoto Protocol was adopted at COP3 in 1997, and the Marrakech Accords were achieved at COP7 in 2001

Coping capacity: this is the ability to adjust to climate events in the short-term

Environment: this refers to the physical factors of the surroundings of the human being, including land, water, atmosphere, climate, sound, odour, taste, and then biological factors of fauna and flora, and includes the cultural, social, and economic aspects of human activity, the natural and built environment

Evaluation: this is a process for determining systematically and objectively the relevance, efficiency, effectiveness and impact of the adaptation strategies in the light of their objectives

Food insecurity: this is a situation that arises when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development, and active healthy life. It may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food at household level. Food insecurity may be chronic, seasonal, or transitory. However, current literature is focusing on livelihood security, which is an expansion of food security to include multiple stresses and sectors that livelihoods might be exposed to

Forecast: this refers to a projection that is branded “most likely”, and becomes a forecast or a prediction. A forecast is often obtained by using deterministic models (possibly a set of such models), outputs of which can enable some level of confidence to be attached to projections

Hazard: this is a physically defined climate event with the potential to cause harm, such as a heavy rainfall events, droughts, floods, storms, long-term changes in mean climatic variables, such as temperature

Indicator: this is an item that can be clearly characterized and possibly quantified that represents an abstract concept, such as human well-being

Monitoring: this is a mechanism or mechanisms to track progress in implementation of an adaptation strategy and its various components in relation to targets

Policies and measures: these are usually addressed together, and address the need for climate change adaptation in distinct, but sometimes in overlapping ways. **Policies** typically refer to instruments of the government that can be used to change economic and other behaviors**. Policies** are usually composed of taxes, commands and control regulations (e.g., performance specifications for technologies), market mechanisms, such as trading schemes, incentives, such as subsidies for new management techniques, and information gathering (as on the likely impacts of climate change) or dissemination (as on the merits of new technologies or behaviour changes). **Measures** are usually specific and implementable actions, such as re-engineering irrigation systems, planting different crops, or initiating a new industry. Many "projects" could also be termed "measures"

Poverty - is now widely viewed as encompassing both income and non-income dimensions of deprivation, including lack of income and other material means; lack of access to basic social services, such as education, health and safe water; lack of personal security; and lack of empowerment to participate in the political process and in decision making that influences someone's life. The dynamics of poverty also are better understood, and extreme vulnerability to external shocks is now seen as one of the major features

Probability: this is defined as defines the likelihood of an event or outcome occurring. Probability can range from being qualitative, using word descriptions such as likely or highly confident, depending on the level of understanding of the causes of events, historical time series and future conditions

Projection: this can be regarded as any description of the future and the pathway leading to it

Proxy: this is something used in the place of another. Proxies fulfill three criteria: (i) summarize or otherwise simplify relevant information, (ii) make visible or perceptible phenomenon of interest, and (iii) quantify, measure and communicate relevant information

Reference scenario: this is an internally coherent description of a possible future without consideration of climate change; the reference scenario is used for comparison with scenarios that include consideration of climate change and options for adaptation

Resilience: this is a tendency to maintain integrity when subject to disturbance

Risk (climate-related): the is a result of the interaction of physically defined hazards with properties of the exposed systems (i.e., their sensitivity or (social) vulnerability) It also refers to the combination of an event, the likelihood of that event and the consequences of that event (Risk = probability of climate hazard x vulnerability)

Scenario: this is a plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with narrative storyline

Stakeholder: this include those who have interests in a particular decision, either as individuals or as representatives of a group. This includes people who influence a decision, or can influence it, as well as those affected by it

Storyline: this is a quantitative, holistic picture of the general structures and values of society. Storylines can be developed at any scale (from the global to the regional, national or local levels). They describe conditions that might be produced by human choices about economic and social policy, reproduction, occupations, and energy/technology use. Storylines are useful tools for policymakers to "vision" alternative future words

Strategy: this is a broad plan of action that is implemented through policies and measures

Sustainable development: this encompasses those processes and activities that are directed at economic, socio-political, environmental, and health well-being to improve and maintain the quality of life of the world's population and ecosystems without compromising the ability of future generations to meet their own needs. Thus, s**ustainable development** comprise: (i) **economic development,** (ii) **social development**, and (iii) **environmental protection,** which are interdependent and mutually re-enforcing pillars

United Nations Framework Convention on Climate Change (UNFCCC): this was adopted at the 1992 Earth Summit in Rio de Janeiro. Its ultimate objective is the "stabilization of greenhouse gases concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"

Vulnerability: this is a more dynamic concept than poverty, since it captures the sense that people move in and out of poverty. The **meaning of vulnerability** encompasses exposure to risk, hazards, shocks and stress, difficulty in coping with contingencies, and access to assets. In the context of climate change, **vulnerability to climate change** usually means the risk that climate change will cause a decline in the well being of poor people and poor countries. This means the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes. This vulnerability is a function of the character, magnitude, and rate of climate change variation to which a system is exposed, and its adaptive capacity

Vulnerability assessment: this is an analysis of the difference between the impacts of climate change and adaptations to those impacts.

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