REPUBLIC OF MALAWI

MINISTRY OF FORESTRY AND NATURAL RESOURCES

The Third 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 Forestry and Natural Resources, Lilongwe, Malawi,

January, 2021.

REPUBLIC OF MALAWI

MINISTRY OF FORESTRY AND NATURAL RESOURCES

The Third 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 Forestry and Natural Resources, Lilongwe, Malawi,

January, 2021.

Environmental Affairs Department

Ministry of Forestry and Natural Resources
Lingadzi House, City Centre
Private Bag 394
Lilongwe 3
Malawi.

Tel: (265) (0) 1 771 111
Fax: (265) (0) 1 773 379

ISBN 978-99908-0-889-6

9 789990 808896

Correct Citation: The Third 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 Forestry and Natural Resources, 2020, Lilongwe, Malawi.

Price: MK 50,000.00

Printing by: White Horse Designs

Table of Contents

List of Tables

List of Figures

Appendices

Foreword

Climate change management has been proven to be one of the significant elements for sustainable development and utilization of the environment and natural resources at the global level as evidenced by international agreements such as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. As a party to these important international treaties, Government of Malawi is obligated to implement measures towards low carbon and climate resilience development pathways.

Climate shocks due to climate variability and climate change have increased in frequency and intensity over the last few decades. This has adversely affected key sectors of the country's economy. Agriculture, transport, health, water, forestry, energy and other key sectors have all been affected due to prolonged dry spells, erratic rainfall and floods which have been exacerbated by climate change and climate variability. As such, Government of Malawi realizes the importance of having robust measures and strategies to address the adverse effects of climate change in response to the 2030 Sustainable Development Goals and the National Development Agenda.

The Third National Communication Report provides a comprehensive outlook of the status of climate change issues in the country and takes into consideration emerging issues since the Second National Communication which was submitted to the Conference of Parties under the UNFCCC in December 2011. The Report has highlighted mitigation and adaptation efforts that are feasible for Malawi, taking into consideration national circumstances and provisions of the various policy frameworks that guide environment and climate change management in the country. The Report also provides for an updated Greenhouse Gas inventory which establishes Malawi as a net emitter of GHG emissions.

The TNC is expected to enhance the visibility, general public awareness, knowledge and reduce the impacts of climate change in Malawi through increased involvement of all relevant stakeholders.

Nancy G Tembo M.P.

MINISTER OF FORESTRY AND NATURAL RESOURCES

Preface

The country's economy, livelihoods and ecosystems are highly vulnerable to climate change and climate variability. In 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. Government is fully aware that establishing the required management and response strategies is a daunting task because local climate change and variability are embedded in global climate systems that transcend national boundaries.

However, consolation is found 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 today 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 Third National Communication (TNC) Report. 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 First and Second National Communications. It fills gaps that were identified in the Second 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 Third National Communication of Malawi gives information on: (i) National Circumstances, (ii) Greenhouse Gases Inventory for the period 2001-2017, (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 Third National Communication. Let me also extend special thanks to the Global Environment Facility (GEF) and the United Nations Environment Programme (UN Environment) for the financial and technical support.

Yanira M Ntupanyama, PhD.

SECRETARY FOR FORESTRY AND NATURAL RESOURCES

ACKNOWLEDGEMENTS

The Environmental Affairs Department extends profound gratitude to the following institutions and individuals during the preparation of Malawi's Third National Communication (TNC) for submission to the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC):

• GEF/UNEP for providing financial and logistical support;

• UNFCCC Secretariat for providing information and guidelines for preparing sectoral reports, thematic area reports and this document, and for supporting useful and relevant workshops;

• The Chairperson and Members of the National Technical Committee on Climate Change (NTCCC), National Climate Change Steering Committee (NCSC) for their valuable contributions and guidance;

• The Climate Change Project Office for steering the preparation process;

Various national institutions, government departments, private sector organizations and the Universities of Malawi provided expertise and data which were used in the preparation of the various sectoral and thematic area reports, and contributed to the finalization of this document.

Finally, but not the least, the untiring efforts of the Project Manager, Ms Lusungu Ng'oma, Ms Flora Guba Chiwale, the Project Coordination Team, National Team Leaders, National Experts, the International Experts, the Technical Preparation Team, and EAD Staff are greatly acknowledged. Timely production of this report would not have been possible without their unparallelled contributions.

Tawonga Mbale-Luka

DIRECTOR OF ENVIRONMENTAL AFFAIRS

PROJECT MANAGEMENT, COORDINATION AND SECTOR CONTRIBUTIONS

Project Management: **Ms. Lusungu Ng'oma**, Project Manager, Environmental Affairs Department, **Ms. Flora Guba Chiwale**, Administrative Assistant, Environmental Affairs Department.

Project Coordination: **Ms. Tawonga Mbale-Luka**, National Project Director, Environmental Affairs Department, **Ms. Shamiso Najira**, Deputy Director,Environmental Affairs Department,**Mr. Evans Njewa**, National Project Coordinator, Environmental Affairs Department, **Mr. Golivati Gomani**, **Mr. Chimwemwe Yonasi**, **Ms. Hanna Siame** (Project Desk Officers), Environmental Affairs Department.

National Team Leaders: **Mr. Kenneth J. Gondwe**, National Peer Reviewer for Greenhouse Gas Inventory, Department of Mechanical Engineering, Malawi Polytechnic, University of Malawi**, Prof. Geoffrey Chavula,** National Team Leader for Vulnerability and Adaptation Assessments, University of Malawi, Polytechnic, **Prof. Maurice Monjerezi**, National Team Leader for Mitigation and Abatement Analysis, Chancellor College, University of Malawi, **Dr. Cosmos Ngongondo**, National Team Leader for National Circumstances, Chancellor College, University of Malawi.

Sector Contributions

National Circumstances: **Dr. Cosmos Ngongondo**,National Expert, University of Malawi, Chancellor College, **Dr. Mirriam Joshua,** National Expert, University of Malawi, Chancellor College**, Mr. Zuze Dulanya**, National Expert, Chancellor College, University of Malawi, **Mr. Bosco Rusuwa,** National Expert, University of Malawi, Chancellor College.

Greenhouse Gas Emissions: **Dr. Dingane Sithole**, Bees Consultancy Services (Zimbabwe), International Peer Reviewer for National Greenhouse Gas Inventory,
Dr. Suzgo Kaunda, National Expert, Energy and Transport Sector, University of Malawi, Polytechnic,
Dr. Mike Chirwa, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi (FRIM),
Mr. Henry Kadzuwa, National Expert,Forestry and Land Use Sector, Department of Forsetry, **Mr. Moses Njiwawo**,National Expert, Forestry and Land Use Sector, Department of Forestry,
Dr. Tembo Chanyenga, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi,

Dr. Eric Mbingwane, National Expert, Forestry Research Institute of Malawi,

Mr. Suzgo Chapa, National Expert, Agriculture Sector, Department of Livestock and Animal Health,

Mr. Geoffrey Longwe, National Expert, Agriculture Sector, Ministry Of Agriculture,

Mr. Boyd Mwafulirwa, National expert, Agriculture Sector, Ministry of Agriculture,

Mr. Phyllis Mkwezalamba, National Expert, Waste Sector, Lilongwe City Council,

Mr. Thokozani Mkaka, National Expert, Waste Sector, Lilongwe City Council,

Mr. Robert Kawiya, National Expert, Waste Sector,

Mr. Fredrick Munthali, National Expert, Waster Sector, National Commission for Science and Technology,

Mr. Christopher Mwambene, National Expert, Industrial Processes and Product Use, Shire River Basin Management Program,

Mr. Clement Phangaphanga, National Expert, Industrial Processes and Product Use, Ministry of Tourism, Industry and Trade.

Programmes Containing Measures to Facillitate Adequate Adaption to climate Change (V and A Assessments):

Prof. Geoffrey Chavula, National Team Leader for Vulnerability and Adaptation Assessments, Water Resources Sector, University of Malawi, Polytechnic,

Mr. Patrick Mlomba, National Expert, Water Resources Sector,

Mr. Patrick Maleta, National Expert, Water Resources Sector,

Mr. William Mitembe, National Expert, Forestry Sector,

Dr. Edward Missanjo, National Expert, Forestry Sector,

Mr. Henry Utila, National Expert, Forestry Sector, Forestry Research Institute of Malawi,

Dr.Maggie Munthali, National Expert, Forestry Sector, Department of Forestry,

Mr. Davis Kalima, National Expert, Wildlife Sector,

Mr. William Mgoola, National Expert, Wildlife Sector, Department of Wildlife,

Mr. Sipho Billiat, National Expert, National Planning Commission,

Mr. Charles Vanya, National Expert, Department of Climate Change and Meteorological Services

Mr. Saidi Banda, National Expert, Energy Sector, Department of Energy,

Mr. Charles Chisale, National Expert, Energy Sector, Department of Energy,

Mr. Fredrick Munthali, National Expert, Energy Sector, National Commission for Science and Technology,

Mr. Clement Phangaphanga, National Expert, Industry and Tourism Sector, Ministry of Tourism, Trade and Industry,

Mr. Geoffrey Mwase, National Expert, Ministry of Trade, Industry andTourism.

Mr. Hendrix Mgodie, National Expert, Health Sector, Ministry of Health,

Mr. Godfrey Kupunda, National Expert, Land Resources Sector, Department of Land Resources,

Mr. Enock Whayo, National Expert, Land Resources Sector, Department of Land Resources,

Mr. Andrew Msosa, National Expert, Land Resources Sector, Department of Land Resources,

Mr. Jefrrey Chinula, National Expert, Land Resources Sector, Department of Land Resources,

Dr. Friday Njaya, National Expert, Fisheries Sector, Department of Fisheries,

Mr. Titus Phiri, National Expert, Fisheries Sector,

Dr. William Ngochera, National Expert, Fisheries Sector, Department of Fisheries,

Mr. Godfreyy Kanyerere, National Expert,

Mr. Ignasio Ngoma, National Expert, Infrastructure Sector, University of Malawi, Polytechnic,

Mr. William Kuotcha, National Expert, Fisheries Sector, University of Malawi, Polytechnic

Dr. David Mkwambisi, National Expert, Agriculture Sector, Malawi University of Science and Technology,

Dr. Judith Kamoto, National Expert, Agriculture Sector, Lilongwe University of Agriculture and Natural Resources (LUANAR),

Mr. Harold Chisale, National Expert, Agriculture Sector, Lilongwe University of Agriculture and Natural Resources (LUANAR),

Mr. Boyd Mwafulirwa, National Expert, Agriculture Sector, Ministry of Agriculture,

Mr. Suzgo Chapa, National Expert, Agriculture Sector, Department of Livestock and Animal Health.

Programmes Containing Measures to Mitigate Climate Change (Mitigation and Abatement Analysis):

Prof. Maurice Monjerezi, National Team Leader for Mitigation and Abatement Analysis, Industrial Processes and Product Use Sector, University of Malawi, Chancellor College,

Mr. Godfrey Mnesa, National Expert, Waste Sector, University of Malawi, Chancellor College

Dr. Mike Chirwa, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi,

Mr. Henry Kadzuwa, Forestry and Land Use Sector, National Expert, Department of Forestry

Dr. Suzgo Kaunda, National Expert, Energy Sector, University of Malawi, Polytechnic

Mr. Robert Kawiya, National Expert, Waste Sector,

Mr. Thokozani Mkaka, National Expert, Waste Sector, Lilongwe City Council,

Mr. Boyd Mwafulirwa, National Expert, Agriculture Sector, Ministry Of Agriculture,

Mr. Suzgo Chapa, National Expert, Agriculture Sector, Department of Livestock and Animal Health.

Any Other Information relavant to the objective of the Convention:

Mr. Evans Njewa, Sector Coordinator, Environmental Affairs Department,

Mr. Lyson Kampira, National Expert, Environmentally Sound Technologies, Naticonal Commission for Science and Technology,

Mr. Chris Manda, National Expert, Environmentally Sound Technologies, Environmental Affairs Department,

Mr. Sipho Billiat, National Expert, Measurement Reporting and Verification (MRV), National Planning Commission,

Mrs. Yasinta Chafutsa, National Expert, Education, Training and Public Awarenes, Information, Networking and Capacity Building, Environmental Affairs Department,

Mr. Golivati Gomani, National Expert, National Policies and Strategies, Enviornmental Affairs Department,

Mr. Boniface Chimwaza, National Expert, Information and Networking, Environmental Affairs Department,

Mr. Patrick Mkwapatira, National Expert, National Climate Change Fund, Environmental Affairs Department,

Mr. Clement Tikiwa, National Expert, Capacity Building on Low Emissions Development Strategies (ECLEDS), Environmental Affairs Deaprtment,

Mr. Chimwemwe Yonasi, National Expert, Clean Development Mechanism (Transfer of technologies), Environmental Affairs Department,

Dr. Lilian Chimphepo, National Expert, Biodiversity, Environmental Affairs Department,

Mr. Peter Mmora, National Expert, Ozone depleting substances, Environmental Affairs Department,

Constraints and Gaps and related financial and capacity building needs:

Ms. Hanna Siame, Sector Coordinator, Environmental Affairs Department,

Mr. Peter Magombo, National Expert, Environmental Affairs Department,

Technical Preparation Team:

Ms. Tawonga Mbale-Luka, Director, Environmental Affairs Department,

Ms. Shamiso Najira, Deputy Director, Environmental Affairs Department,

Mr. Bennon Bibu Yassin, Deputy Director, Environmental Affairs Department,

Mr. Evans Njewa, Chief Evironmental Officer, Environmental Affairs Department,

International Expert:

Mr. Dingane Sithole, International Peer Reviewer, Bees Consultancy Pvt Limited, Zimbabwe,

Mr. Walter Svinurai, International Peer Reviewer, Bees Consultancy Pvt Limited, Zimbabwe,

Ms. Veronica Gundu, International Peer Reviewer, Bees Consultancy Pvt Limited, Zimbabwe.

Acronyms and Abbreviations

A/R	Afforestation and reforestation
ADDs	Agricultural Development Divisions
AFOLU	Agriculture, Forestry and Other Land Use
AvGas	Aviation gasoline
BAU	Business as Usual
BOD	Biological Oxygen Demand
BERL	Bio Energy Resources Limited
CEAR	Central and East Africa Railways
CHP	Combined Heat and Power Generation
CKD	Cement Kiln Dust
CO2eq	Carbon dioxide equivalent
COP	Conference of Parties
CTCN	Climate Technology Centre and Network
DAHLD	Department of Animal Health and Livestock Development
DEA	Department of Energy Affairs
EAD	Environmental Affairs Department
EF	Emission factor
EGENCO	Energy Generation Company (of Malawi)
EP&D	Economic Planning and Development
ESCOM	Electricity Supply Corporation of Malawi Limited
FAO	United Nations Food and Agricultural Organization
FCWSNET	Famine Early Warning System
FRA	Global Forest Resource
Gg	Gigagrams
GEF	Global Environment Facility
GHG	Greenhouse gas
GHG-IS	GHG-Inventory Ssytem
GoM	Government of Malawi
GWP	Global Warming Potential
Ha	Hectare
HFCs	Hydrofluorocarbons
HWP	Harvested Wood Products
IIED	Institute for Environment and Development
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
Jet A1	Jet kerosene
Kcal	Kilo calorie
KToE	Thousand Tonnes of Oil Equivalent
KVA	Kilo-Volt Ampere (unit for measuring electricity energy)
LAMNET	Latin America Thematic Network on Bioenergy
LCCS	Land Cover Classification System

LEAP	Long Range Alternative Energy planning (an energy modeling software)
LED	Light emitting diode
LPG	Liquefied Petroleum Gas
MAI&WD	Ministry of Agriculture, Irrigation and Water Development
MCF	Methane correction factor
MERA	Malawi Energy Regulatory Authority
MIC	Manufacturing Industry and Construction
MJ	Mega joule (10^6 J)
MIRTDC	Malawi Industrial Research and Technology Development Centre
MMU	Minimum Mapping Area or Unit (),
MNEP	Malawi National Energy Policy
MoU	Momerandum of Understanding
MREAP	Malawi Renewable Energy Acceleration Programme
MSC	Malawi Shipping Company
Mt	Metric tonne
MTL	Malawi Telecommunications Limited
MToE	Million Tonnes of Oil Equivalent
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action(s)
NCST	National Commission for Science and Technology
NDC	Nationally Determined Contribution
NE	Not estimated
NIR	National Inventory Report
NSO	National Statistical Office
OVOP	One Village One Product
PAESP	Promotion of Alternative Energy Sources Programme
PM	Particulate Matter
ProBEC	Programme for Biomass Energy Conservation
QA/QC	Quality Assurance and Quality control
SAR	Second Assessment Report
SCL	Shayona Corporation Limited
SEforALL	Sustainable Energy for All
SNC	Second National Communication
SSA	Sub-Saharan Africa
SWDS	Solid Waste Disposal Sites
TJ	Terajoules (unit of energy, equal to 1012 J)
TCRET	Testing and Training Centre for Renewable Energy Technologies
TNA	Technology Needs Assessment
TNC	Third National Communication
TNM	Telecommunication Network Malawi
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USGS	United States Geological Survey

UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Chemical Formulae	
C	carbon
C12H22O11	mollasses
C6H12O6	glucosa
Ca	calcium
CaCO3	calcium carbonate (limestone)
CaO	calcium oxide (lime)
CFCs	chlorofluocarbons
CH3CH2OH	Ethanol
CH4	methane
CO	carbon monoxide
CO2	carbon dioxide
H2O	water
HFCs	hydrofluorocarbons
K	potassium
Mg	magnesium
N	nitrogen
N2O	nitrous oxide
NH3	ammonia
NMVOC	non-methane volatile organic compounds
NOx	nitrogen oxides
O3	Ozone
P	phosphorus
PFC	perflourocarbon
PFCs	perfluorinated carbons
SF6	Sulphur hexafluoride
SO2	sulphur dioxide
SOx	sulphur oxides

Units of Measure	
atm	atmosphere
Cal	calories
cap	capita
Cm	centimeter
D	day
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 750.37 (Reserve Bank of Malawi, September 2020)

Executive Summary

Malawi signed the UNFCCC on 10^{th} June 1992 and ratified it on 21^{st} April 1994. Malawi also ratified the Kyoto Protocol on 26^{th} October 2001. Malawi has also ratified the Paris Agreement on 17^{th} June, 2017. As a Party both to the Convention and its Kyoto Protocol, Malawi is obliged, under Article 4.1 (a) 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 not controlled by the Montreal Protocol using comparable methodologies agreed upon by the CoP”. In 1999, Malawi sought and received funding from GEF for enabling activities for the preparation of the INC. The preparation of the INC in 2003, the National Adaptation Programme for Action (NAPA) in 2004, and the SNC in 2011 marked important milestones in Malawi’s contributions to the CoP of the UNFCCC. The preparation of the INC, SNC and the TNC including their various components was coordinated by the Environmental Affairs Department as the Focal Point for UNFCCC activities in Malawi. A National Project Steering Committee was set up to oversee implementation of the various project activities. It comprises of high level Experts drawn from key ministries, research institutions, the University and NGOs.

The findings of the INC, the NAPA and SNC were a true reflection of the climate change issues that Malawi faces and needs to address. The projected scenarios predict increased temperature, decreased rainfall, loss of arable land, increased deforestation and reduced water resources. Consequently, to address these issues, Malawi needs to approach them from a point of knowledge, accurate information on emissions and analysis of options and strategies are required.

ES 1 National Circumstances

Malawi is a land-locked country in southern Africa that lies along the southern most arm of the great East African Rift-Valley System (EARS) between latitudes 9^{o} 22’ and 17^{o} 03’ south of the equator, and longitudes 33^{o} 40’ and 35^{o} 55’ east. It is bordered by Tanzania in the north and north-east; Mozambique in the south-west, south and the east; and Zambia in the west. The country is about 910 km long and varies in width from 60 to 161 km with a total surface area of 118,484 km^2. Of this total surface area, 94,787.2 km^2 (80%) is land and the remaining 23,696.8 km^2 (20%) is covered by water.

The location of the country within the EARS has profound impacts on the relief of the country. The process of rifting was responsible for the formation of a trough filled by Lake Malawi, one of the country’s most conspicuous drainage feature and the third largest lake in Africa. The country falls into five main physiographic surfaces related to the different erosional cycles. The Rift valley floor is situated along the major drainage features of the country at about 30 – 500m asl, is very flat and is related to the Quaternary erosional cycle. Bordering the rift valley floors are the steep escarpments which are associated with major rift faults and related to the Post-African cycle. Above the escarpments are plains at an altitude of about 750-1300 m asl. These have a generally flat or rolling topography. The African surface is a relatively flat surface at 600-1400 m asl attitude. Slopes with moderate steepness at 1400-1500 are ascribed to the post-

Gondwana and the Gondwana surfaces are above 1500 with steep slopes and generally have high plateaus 600 m.

Climate

The climate of the region is largely influenced by the northward and southward seasonal migration and intensity of the Inter-Tropical Convergence Zone (ITCZ), a low pressure belt within the Congo basin caused by tropical high pressure belts over both the Indian and Atlantic Oceans (Nicholson, 2001) and the Congo Air Boundary (CAB), that is controlled by sea-surface temperature (SST) anomalies such as the Indian Ocean Dipole (IOD) and El Niño/Southern Oscillation (ENSO) system (Saji et al., 1999; Abram et al., 2007).

Malawi has two main seasons, namely the cool dry season between May and October with mean temperatures of around 13 ^{o}C in June and July and the hot wet season between November and April with temperatures between 30^{o} - 35 ^{o}C. Rainfall is variable depending on altitude and ranges from 600 mm for the rift valley floors to 1600 mm per annum for the mountainous areas. Local differences in rainfall are caused by complex topography causing deflections of moisture-bearing winds that are responsible for precipitation and rain-shadow effects in various terrains.

Institutional Arrangements for preparation of National Communications (NCs and BURs) and Climate Change Work

The Environmental Affairs Department (EAD) in the Ministry of Forestry and Natural Resources is the executing agency for the TNC process. The EAD has the overall mandate of monitoring the project to meet the objectives of the study, achieving results (outputs) and impact; and accounting for all financial resources to UNEP. The National Climate Change Technical Committee (NCCTC) provides technical guidance. Each Team comprising various and complementary experts was headed by a National Team Leader. The team members comprised a pool of experts that were involved previously in the preparation of the INC and the SNC as well as new experts. The national experts were drawn from key relevant sectors from Government ministries/departments, academic institutions, researchers, private sector organisations and NGOs.

ES 2 GHG Inventory

The TNC includes five main Intergovernmental Panel on Climate Change (IPCC) sectors, namely: Energy, Industrial Process and Product Use (IPPU), Agriculture, Forestry and Other Land-Use (AFOLU), and Waste. The GHG emissions reported in this GHG inventory are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs). The 2006 IPCC Guidelines were used to compile the Malawi TNC. The methodology used was mainly tier 1 of the 2006 IPCC Guidelines

GHG emissions

Table ES 2 below presents the GHG emissions by sector in Malawi's INC, SNC and TNC reports. GHG emissions declined from 29,229.65 Gg in 1994 to 3,613.53Gg in 2010. In 2010, Malawi sequestered more CO_2 emissions that it emitted in the AFOLU sector. However, the emissions from Energy, IPPU and Waste, as well as non-CO_2 emissions from AFOLU exceeded the amount sequestered in AFOLU, resulting in Malawi being in a net emission position of 3,356.07Gg CO_2eq in 2010.

At 1,364mtCO_2eq, the Energy sector contributed the largest proportion (36.76%) of emissions, closely followed by AFOLU with 1,205.02 mtCO_2eq (33.35%) and then Waste accounting for 1,004.06 mtCO_2eq (27.79%). IPPU accounted for the least emissions at 40.01mtCO_2eq representing 1.11% of the total GHG emissions in 2010.

There has been a significant decrease in emissions over time. Overall, the total emissions in 2010 represented a reduction of 87.64% from the 1994 emissions or 75.20% when compared with the emissions in 2000 in the SNC. Energy sector emissions declined by 70.71%, IPPU by 87.13%, AFOLU by 90.70% and Waste by 25.97% when compared with the 2000 GHG emissions reported in the SNC. The decline has been due to mitigation actions such as use of efficient firewood cooking stoves and efficient lighting technologies e.g solar powered energy sources.

Table ES 2 National greenhouse gas emissions and removal trends (CO_2eq)

IPCC Category	Total emissions (MtCO_2eq)		
	1994 (INC)	**2000 (SNC)**	**2010 (TNC)**
Energy	7,798.34	4,658.58	1,364.44
IPPU	58.38	310.76	40.01
Agriculture	3,750.45	12,961.27	1,205.022
FOLU	17,517.37		
Waste	105.11	1,356.19	1,004.06
TOTAL	29,229.65	14,628.22	3,613.53
Memo items			8,658.56

In 2010 the highest CO_2 emissions were emitted from 1.A.3 - Transport, amounting to 616.96Gg, followed by 1.A.2 - Manufacturing Industries and Construction with 258.50Gg and then 3.C - Aggregate sources and non-CO_2 emissions from land accounting for 88.71Gg. In the same year, the largest CH_4 emissions were emitted from Livestoce-3A - amounting to 64.55Gg, followed by Solid Waste Disposal on Land (3A) with 20.16 Gg (13.18%) and then 1.A.4 - Other Sectors with 14.13Gg. In 2010 N_2O emissions were 1.61Gg, mainly coming from Livestock-3A with 0.66Gg (39.41%), Wastewater Treatment and Discharge -4.D 0.57 Gg (and Fuel Combustion activities-1A with 0.30Gg.

ES 3 Vulnerability and Adaptation Assessments

The compilation of the Climate Change Vulnerability and Adaptation (V&A) Assessment Chapter of Malawi's Third National Communication has been done in compliance with

Articles 4.1(e), 4.8 and 4.9 of the United Nations Framework Convention on Climate Change (UNFCCC). Eleven of the country's key socioeconomic sectors were analyzed during the assessment, namely: Agriculture; Water Resources; Human Health; Energy; Infrastructure; Land Resources; Fisheries; Forestry; Wildlife; Industry; and Tourism. Malawi's vulnerability to climate change arises from the country's socio-economic, demographic and climatic factors. Effects of these factors are exacerbated by the country's narrow economic base, which is principally agro-based in nature; limited agro-processing capability; over-dependency on rain-fed agriculture and biomass energy; inadequate health facilities; population pressure; and poverty. These adverse effects are further aggravated by natural disasters caused by floods, droughts, strong winds, and pests and diseases.

The vulnerability assessment of the eleven sectors was undertaken by a team of national experts drawn from Government Ministries and Departments, the Academia, the Private Sector, NGOs, Civil Society Organizations, and Faith Based Organizations. The task entailed scrutinizing all sectoral adaptation options recommended for implementation by the Government of Malawi as discussed in Malawi's Initial and Second National Communication reports, focusing on methodologies adopted for conducting climate change vulnerability assessments for the various sectors; and critically analyzing the proposed adaptation strategies in respect of their relevance, effectiveness, efficiency, impact, and sustainability. The adaptive strategies were thereafter prioritized and categorized in light of their implementation arrangements, whether short-term (within 5 years), mid-term (5 to 10 years), or long term (greater than 10 years). And whether or not Malawi will need external financial and technical support from development partners to implement the proposed climate change adaptation strategies.

Projections of temperature and rainfall for Malawi were done using statistically downscaled General Circulation Models (GCMs) following the procedure recommended by the Intergovernmental Panel on Climate Change (IPCC) as discussed in the Fifth Assessment Report (AR5), IPCC (2013). Tables 1 and 2, and Figure 1 show data and information on climate change scenarios for temperature and rainfall. It is worth noting that AR5 is premised on two Representative Concentration Pathways (RCPs) of Greenhouse Gas (GHG) Emissions, namely: RCP 4.5 (Intermediate Emission), and RCP 8.5 (High Emission) as described by Moss *et al*. (2013). RCP 4.5 and 8.5 are respectively equivalent to story lines B1 and A1F1 in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007).

ES 4 Mitigation and Abatement Analysis

The mitigation analysis covered the sectors of Energy; Industrial Processes and Other Product Use (IPPU); Agriculture Forestry and other and Use (AFOLU); and Waste. However, the mitigation analysis put more emphasis on energy and forestry, as the key sectors with high mitigation potential. The analysis involved the determination of GHG emission reduction opportunities for all sectors, however, the expected contribution to abatement of the GHG emissions was determined for the forestry and energy sectors using appropriate software. Mitigation measures in the different sectors will also present environmental and socio-economic benefits, in addition to abatement of the GHG emissions.

Energy

The transport category leads in GHG emissions in the energy sector, contributing 44% of GHG emissions in the energy sector, followed by the other sectors (residential) (35%). The identified mitigation measures are based on reduction of biomass in the energy mix through a staggered increase of modern sources of energy, which includes intensification of renewable energy supply (Solar PV, biofuels, hydrokinetic and HEP). However, emissions in the energy sector are projected to increase as coal fired power plants are planned for the immediate future. The projections in LEAP show an abatement of 606 Gg CO_2 may be achieved in 2040 in the energy sector.

Agriculture, Forestry and Other Land Use (AFOLU)

The AFOLU sector is associated with a large proportion of Malawi's greenhouse gas emissions from forest losses largely due to harvested woody biomass for timber, pole harvests, fuelwood and losses due to disturbances such as forest fires. Therefore, Malawi is implementing sector-specific policies to enhance mainstreaming of adaptation and mitigation measures. These include (i) National Forest Landscape Restoration, (ii) Reducing Emissions from Degradation and forest Degradation (REDD+), (iii) National Charcoal Strategy and (iv)Tree planting (afforestation and reforestation). Additionally, there are technological options in FOLU sector that are aimed at mitigation of GHD emissions and include but are not limited to: tree survival campaigns, breeding and screening drought tolerant tree species, pest and disease control and sustainable management of forest resources. For agriculture, some of the mitigation options considered included: improved animal husbandry; dung for bio-gas, improved fertilizer application; minimizing the use of fertilizer and encouraging application of organic manure to reduce N_2O emissions; the planting of nitrogen fixing plants, incorporation of agricultural residues into the soil and zero tillage

Industrial Processes and Product Use (IPPU)

Malawi's IPPU contribution to GHG emissions remains low owing to low levels of industrialisation and an economy that is largely agri-based. Key category analysis of the IPPU GHG inventory shows that the relevant IPPU categories are mineral industry category: cement and lime production. The two main areas of mitigation in the Industrial Processes and Other Product Use (IPPU) are soil-cement stabilized blocks in place of burnt clay bricks, cement blends (e.g. using rice husks ash or coal ash) and Solvay process for lime making. Under current construction regulations, the National Construction Industry Council (NCIC) prohibits the use of traditionally fire cured bricks in the execution of large construction projects. The GHG emissions from this sector are projected to increase mainly due to increase in lime and cement throughput.

Waste

GHG emissions that have been considered in waste sector are dominated by the source categories of solid waste disposal and domestic wastewater treatment and discharge that emit methane and nitrous oxide. Emissions from waste are expected to increase because of population growth and urbanization. However, waste management is practiced with limited capacity in urban Councils (Cities and towns) and almost insignificant in the rural areas. Integrated Solid Waste Management (ISWM) principles have not been internalised as it requires high organization, high cost of infrastructure and robust supply of human resource base. Therefore, screening for mitigation of GHG in the waste sector in Malawi identified mainly two plausible options of waste reduction and composting, which have an added environmental, social and economic payback.

ES 5 Other Relevant Information

Malawi has implemented a number of climate change related responses to changing socio-economic circumstances, including development and propagation of national policies, strategies and programmes. 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, etc.

ES 6 Constraints and Gaps

This section under constraints and gaps, and related financial, technical and capacity building needs provides a brief overview of the identified constraints and challenges relating to capacity, technical, financial and research needs on climate change issues, in the following areas: Disaster Risk Reduction, Information sharing and networking, Biodiversity, Monitoring, Reporting and verification of climate change mitigation actions.

1. Inadequate historical data for hazard analysis leading to recurrence of disasters. There is need for a multi-hazard approach to disaster risk and climate change management,
2. Inadequate resources (financial and technological) for comprehensive national wide risk assessments that would help to better address the root causes of There is low uptake of modern information and communication technologies due to poverty,
3. There is limited mobile network coverage in remote areas,
4. Multiple competing priorities in institutions. The financial resources in institutions mandated to implement information and networking initiatives are not adequate,
5. There is inadequate human capacity to implement modern sophisticated but effective information and networking initiatives. For example, Environmental Affairs Department does not have a trained Information, Communication and Technology (ICT) expert,
6. There is inadequate and old (outdated) ICT equipment and infrastructure. In the fast-paced ICT world, equipment needs to be upgraded regularly. However, the cost is high,
7. Limited participation at regional and international information sharing and networking fora. Participation at conferences and training workshops requires generous financial and time investment,

8. Due to inadequate availability of these resources, Malawi’s participation to regional and international information sharing and networking fora is mostly funded by development partners. This means that the number of people and the number of times such people can participate from Malawi is dictated by the development partners’ budgets,
9. Absence of legally binding information sharing agreement between data/information producers or holders and users. Although efforts are being made under NEIN, the network is not yet formalized and sharing of data and information is purely voluntary disasters.

CHAPTER 1

BACKGROUND INFORMATION

1 Background Information

The Government of Malawi recognizes that impacts of climate change have serious implications for the country. In 2015 and 2019, Malawi experienced serious and unprecedented floods and droughts including the Cyclone Idai, on account of climate change with consequent effects on key socio-economic sectors and consequently on the economy. Globally, climate change has been recognized as one of the biggest challenges that humanity is facing requiring concerted effort by all nations. Even though Malawi's contribution to greenhouse gas emissions is low on a global scale, it is scientifically accepted that human induced activities such as deforestation and land use change, play a major role in exacerbating its impacts. Malawi's unique and fragile ecosystems are particularly vulnerable to the impacts of climate change, thereby negatively affecting livelihoods. This vulnerability is further exacerbated by the country's poor socio-economic and demographic factors such as a narrow economic base, dependence on rain-fed agriculture, high reliance on biomass energy and low adaptive capacity at the community and national levels.

1.1 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). 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 (CO2), methane (CH4), nitrous oxide (N2O) and the chlorofluorocarbons. These gases trap outgoing long wave radiation in the lower levels of the atmosphere, thereby resulting in global warming.

1.1.1 Global Climate Change and its Impacts

Globally climate change has affected livelihoods of people and economic development due to the increase of global temperature attributed to anthropogenic activities especially during the industrial revolution which resulted in burning of fossil fuels contributing to greenhouse gas emissions in the atmosphere. Notable changes include sea level rise, floods, hurricanes, tornadoes, cyclones, droughts, heatwaves and hailstorms which have all had devastating effects on different sectors. Climate change has been attributed to the greenhouse gas emissions generated from the energy, Agriculture, forestry and land use, industrial processes and other product use and waste as key sectors (IPCC 2007). The developing countries have been impacted the most due to low adaptive capacity levels which has seen key economic sectors such as agriculture, health, transport, water, energy and infrastructure being affected the most due to erratic rainfall, floods and other climate induced disasters. It is imperative to address climate change by reducing GHG emissions to ensure that ecosystems are able to adapt naturally to climate change, food production is not threatened and economic development proceeds in a sustainable manner.

1.1.2 Climate Change and Climate Variability in Malawi

Climate variability refers to variations in the prevailing state 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, or to variations in natural or anthropogenic (human-driven) external forcing. Global climate change indicates a change in either the mean state of the climate or in its variability, persisting for several decades or longer. This includes changes in average weather conditions on Earth, such as a change in average global temperature, as well as changes in how frequently regions experience heat waves, droughts, floods, storms, and other extreme weather. It is important to note that changes in individual weather events will potentially contribute substantially to changes in climate variability. Climate change could occur naturally as a result of a change in the sun's energy or Earth's orbital cycle (natural climate forcing), or it could occur as a result of persistent anthropogenic forcing, such as the addition of greenhouse gases, sulfate aerosols, or black carbon to the atmosphere, or through land-use change.

Malawi has experienced climate change and climate variability in the last decades which has contributed to various devastating climatic shocks that have increased in frequency in the last few decades. Most notable shocks are erratic rainfall, droughts, prolonged dry spells and strong winds. The changing climate has affected various sectors of the economy including agriculture, health, water, energy, transport, education, gender, forestry, wildlife and infrastructure (NAPA 2015). The phenomenon has contributed to disturbances in the social economic growth of the country especially as the economy is dependent on natural resources and agriculture.

1.2 Institutional and Legal Frameworks

1.2.1 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.

1.2.2 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.

1.2.3 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 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 agroecosystems, 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.

1.4 National Policies and Strategies and frameworks

Malawi Government has developed an enabling framework to guide the management of climate change activities, foster development, transfer of technologies and capacity building. The following are national policies and plans which integrates climate change:

1.4.1 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. Currently Malawi is developing the Vision 2063 as the successor of the Vision 2020 which will be aligned to 2030 Agenda for Sustainable Development and African Union (AU) Agenda 2063.

1.4.2 Malawi Growth and Development Strategy (2017- 2022)

The Malawi Growth and Development Strategy (MGDS) III with its theme 'Building a Productive, Competitive and Resilient Nation' was developed in 2016 when the country was experience shocks including floods and drought. This national development strategy for the period 2017 to 2022 among its commitments, highlights Malawi's obligation to implement the Sustainable Development Goals (SDGs) and AU Agenda 2063. MGDS III integrates climate change into development planning through its Key Priority Area (KPA) on agriculture, water development and climate change management. Climate change management has been attributed as an integral component of the economy in particular for the achievement food security and poverty alleviation programmes. The MGDS III also recognizes 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.

1.4.3 National Strategy for Sustainable Development (NSSD)

National Strategy for Sustainable Development (NSSD) adopted by the Malawi Government in 2004, responds 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, awareness and dissemination of climate change issues and the preparation of different country studies on climate change including this Third National Communication (TNC) are some of the activities which have been implemented in accordance with the NSSD.

1.4.4 National Resilience Strategy (2018 – 2030)

The National Resilience Strategy (NRS) developed in 2018, is a 12-year strategy planned for implementation in two five-year phases. The NRS medium-term goal is to start the transition from recurrent humanitarian appeals to protective and productive investments targeting chronically and/or predictably food insecure and poor households, while also strengthening markets, infrastructure, and economic growth supported through strong institutional coordination and multi-sectoral planning and implementation. This will be achieved through the following 4 pillars:

- Resilient agriculture: The outcome for this is increase real farm-based household incomes through crop and livestock diversification, irrigation farming, market development, improving strategic grain reserves, drought risk reduction, and increasing access to farm inputs;
- Catchment protection and management: Forest and landscape restoration, Payment for ecosystem services, sustainable energy, forest-based enterprises;
- Risk reduction, flood control, early warning and response; and
- Human capacity, Livelihoods and social protection: shock responsive social support, livelihoods and nutrition.

1.4.5 Intended Nationally Determined Contributions (2015)

In 2015, Malawi submitted its Intended Nationally Determined Contributions (INDC) to UNFCCC. The INDC contains pledges on adaptation and mitigation actions to be implemented from 2015 to 2040, some with domestic support, others need external financial and technical support. These are aimed at reducing carbon emissions and building climate resilience to contribute towards sustainable development, food security and poverty eradication.

The INDC includes mitigation measures such as renewable energy, energy efficiency, climate resilient agronomic practices, afforestation and reforestation as well as adaptation measures such as drought tolerant crops varieties, water harvesting, irrigated agriculture and aquaculture.

1.4.6 National Climate Change Management Policy (2016)

The Malawi Cabinet approved the National Climate Change Management Policy (NCCMP) in 2016. The policy aims to guide and coordinate formulation, implementation, monitoring and financing of climate change programmes in the country. The Policy further promote climate change adaptation, mitigation and capacity building for sustainable livelihoods through green economy measures for Malawi. The Policy has identified six (6) priority areas and these include:

- Climate change adaptation;

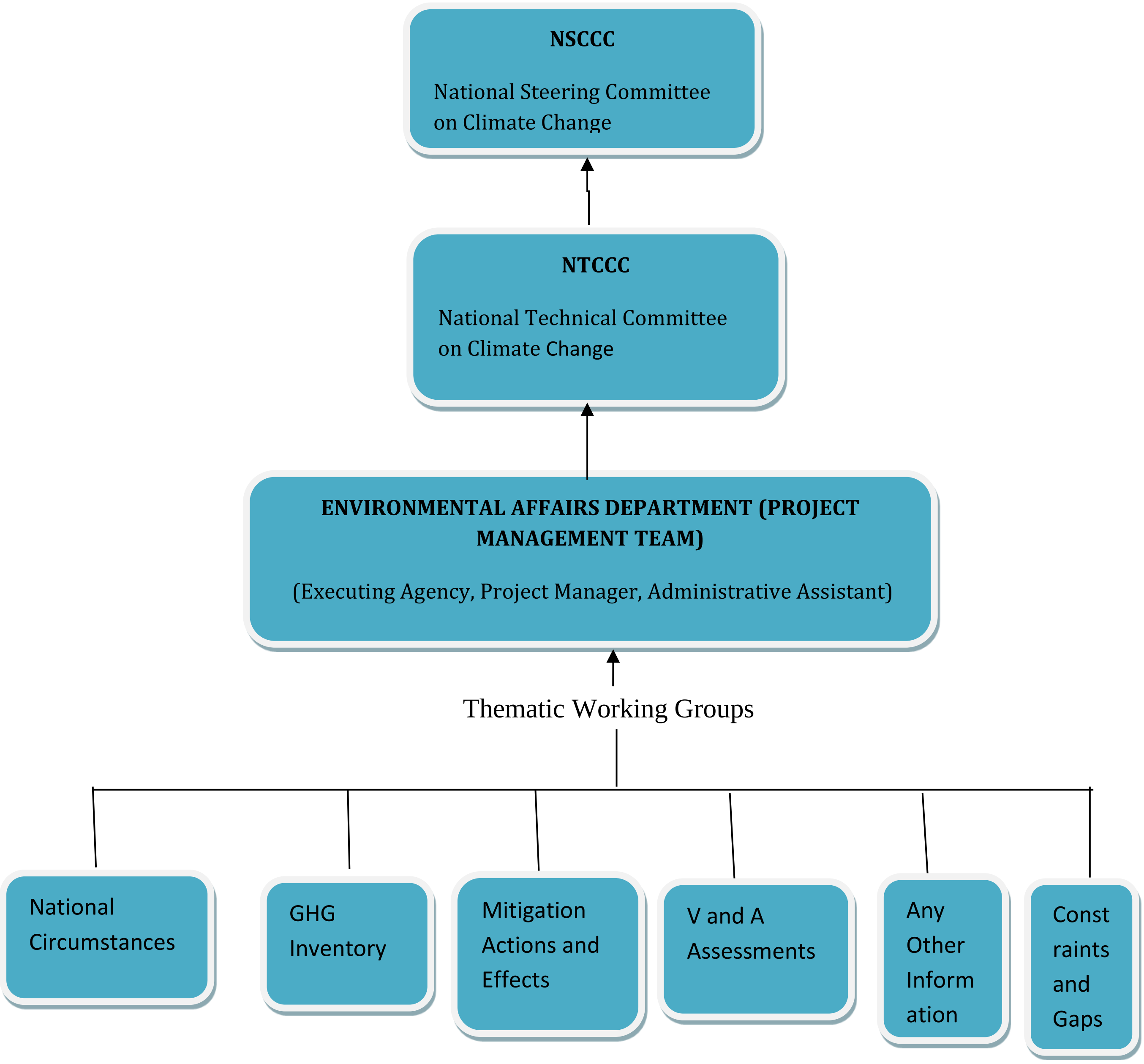
- Climate change mitigation;
- Capacity building, education, training and awareness;
- Research, technology development and transfer and systematic observation;
- Climate financing; and
- Cross-cutting issues (includes gender considerations, population dynamics and HIV and AIDS).

1.5 Institutional Arrangements

The Environmental Affairs Department (EAD) in the Ministry of Forestry and Natural Resources is the executing agency for the TNC process. The EAD has the overall mandate of monitoring the project to meet the objectives of the study, achieving results (outputs) and impact; and accounting for all financial resources to UNEP. The National Climate Change Technical Committee (NCCTC) provides technical guidance. Each Team comprising various and complementary experts was headed by a National Team Leader. The team members comprised a pool of experts that were involved previously in the preparation of the INC and the SNC as well as new experts. The national experts were drawn from key relevant sectors from Government ministries/departments, academic institutions, researchers, private sector organisations and NGOs.

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 Forestry and Natural Resources, 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.



Institutional arrangements for preparing National Communications (NCs) and Biennial Update Reports (BURs) and Climate Change Work in Malawi

1.6 Third National Communication of Malawi

The Third National Communication (TNC) of Malawi is an improvement, follow-up and continuation of activities under the Initial National Communication (INC) and the Second National Communication (SNC) that were completed in 2003 and 2011 respectively. It comprises a stocktaking exercise if the INC and SNC and sets priorities for implementation in a manner that ensures effective allocation of resources.

1.6.1 Objectives

The purpose of the TNC is to prepare the TNC of Malawi for submission to the COP of the UNFCCC as provided in Articles 4 and 12 of the Convention. Specifically, the TNC aims at: (i) enhancing the visibility and impact of climate change issues through increased involvement of all relevant stakeholders in the process, (ii) enhance general awareness and knowledge of climate change related issues in Malawi and enable their incorporation into national planning and policy frameworks as well as help in building national capacities for participation in climate change activities and in full filling Malawi's commitment to the United Nations Framework Convention on Climate Change (UNFCCC).

It also aims at 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) The Third National Communication of Malawi is also proposing climate change projects aimed at finding solutions to climate change problems that communities can adapt and/or use to mitigate climate change, and (iv) 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. 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.

1.6.2 Preparing the Third National Communication of Malawi

1.6.2.1 Preparatory process

The Third National Communication (TNC) 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, 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.

1.6.2.2 Arrangement of Chapters

The TNC 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 TNC 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 TNC 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 TNC proposes 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 TNC 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 2001 to 2017.

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/UN Environment) portfolios and programmes.

Chapter 8 presents some proposed climate change projects that need to implement with urgency that they deserve and to assist in preparing future communications.

1.7 Summary

The Chapter 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.

CHAPTER 2

NATIONAL CIRCUMSTANCES

2 National Circumstances

This chapter provides information on Malawi's national circumstances that are relevant to climate change and to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), including the preparation of Malawi's national communications to be submitted to the Conference of the Parties under the UNFCCC. These include: (i) Geographic profile, (ii) climatic profile and extremes (iii) Socio-economic and sector profiles and (iv) Natural Resources.

2.1 Sectoral Instruments for National and SADC Regional Development Priorities

Climate change has been recognized in policies and related instruments and frameworks in Malawi and the Southern Africa Development Community (SADC) regions. Such instruments at national level include the Malawi Growth Development Strategies (MDGS I, II and III), the National Climate Change Management Policy (NCCMP), the Malawi National Adaptation Plan Framework and the Malawi National Climate Change Investment Plan (NCCIP). SADC regional level instruments include SADC Climate Change Strategy& Action Plan and the SADC Protocol on Environmental Management for Sustainable Development (SADC PRMSD).

2.1.1 National Development Instruments on Climate Change

The Malawi Growth Development Strategy (MDGS) is the overarching operational medium-term framework guiding the national development process in Malawi. Presently, the development process in Malawi is being guided by the MDGS III for the 5 year period between period 2017 to 2022 under the broad theme Building a productive, competitive and Resilient Nation. Among the five Key Priority Areas (KPIs) of the MDGS III, climate change issues are being addressed under the KPI Agriculture, Water Development and Climate Change Management. At the core of the KPI are investments in climate change adaptation with expected multiplier effects on poverty alleviation, education, agriculture and water development, health, urbanization and governance. Various initiatives are therefore being implemented towards adaptation and mitigation against climate change impacts under the KPI. Expected outcomes include: improved weather and climate monitoring systems for early warning preparedness and timely response; strengthened policy operating environment for climate change and meteorological services; enhanced community resilience to climate change impacts; and enhanced climate change research and technology development. Beyond 2022, the MDGS III will be followed by a new vision framework National Transformation 2063 (NT2063).

In addition, the National Climate Change Management Policy (NCCMP, 2016) is a key instrument aimed at guiding the integration of climate change into national development planning and implementation by all stakeholders. Key in the NCCMP is the programming of national level interventions for greenhouse gas emissions (GHGS) and those aimed at promoting adaptation to adverse effects of climate change as enshrined in international frameworks such as the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol and the Paris Agreement. The NCCMP has six priority areas namely: Climate change adaptation; Climate Change mitigation; Capacity Building, Education, Training and Awareness; Research, Technology Development and Transfer, and Systematic

Observation; Climate Change Financing; and Cross-Cutting Issues such as HIV/AIDs, Gender and overpopulation.

Another key important instrument in change adaptation in Malawi is the National Adaptation Plan Framework (NAP, 2020). The NAP framework provides to the NAP process in Malawi: Guiding principles, key approaches, key priority areas, priority sectors and themes and description of the building blocks for NAP implementation. Key activities prioritized in the NAP framework are: Addressing capacity gaps and weaknesses in undertaking the NAP process; Analyzing current climate and future climate change scenarios; Assessing climate vulnerabilities and identifying adaptation options at sector, sub-national,national and other appropriate levels; Integrating climate change adaptation into national and sub-national development and sectoral planning; Developing a long-term national adaptation implementation strategy; and Reviewing the NAP process periodically to assess progress and effectiveness.

Climate change adaptation in Malawi requires critical investments, hence a need to identify financing mechanisms and critical areas to prioritise. Climate Change Investments in Malawi are guided by the National Climate Change Investment Plan (NCCIP). The NICP identifies a total of 11 national investment programmes at a total cost of USD954 min four broad themes namely: Adaptation related Investments; Mitigation related Investments; Research, Technology Development and Transfer Investments; and Capacity Development related investments. A unique feature of all the NCIP programmes is that they specifically target women, the youth and disadvantaged groups at community level, with at 50% of the women being involved in decision making. The NCIP identifies funding opportunities from Government, development partners, civil society, private sectors and carbon trading.

2.1.2 Regional Development Instruments on Climate Change

SADC region level instruments includes the SADC Climate Change Strategy and Action Plan (CCSAP, 2015). The plan recognises that the SADC region is highly vulnerable to climate change and variability, largely due to complex interactions of multiple stresses coupled with low adaptive capacities. The strategy has an overall aim of providing a broad outline for harmonized and coordinated Regional and National actions to address and respond to the impacts of climate change. At the core of the CCSAP is financial resource mobilisation at both national and international levels to support actions on climate change. Other strategic objectives in the CCSAP are: Promote establishment of a window for Climate Financing within the SADC "Regional Development Fund (RDF)" for leveraging and attracting international climate finance; Promote accreditation of the SADC Secretariat as a Regional Implementing Entity of the Green Climate Fund (GCF), GEF and the Adaptation Fund (ADF); Continuously lobby for reduction of conditionality's associated with accessing Climate Change Financing for SADC Member States through SADC Negotiators; Promote the establishment of a regionally controlled Emissions Trading System; and Promote Resource mobilisation capacity at Secretariat and Member States level.Further, the SADC Protocol on Environmental Management for Sustainable Development (SADC PRMSD) has among its specific objectives to promote effective management and response to impacts of climate change and variability. Article 12 of the SADC PRMSD calls on state parties take measures to address issues of climate change including trans-boundary considerations, through: (i) adopting the necessary legislative and administrative measures to enhance adaptation to the impacts of climate change, bearing in mind the diverse and gender differentiated levels of vulnerabilities; and (ii) taking nationally appropriate voluntary climate change mitigation measures.

2.2 Geographic Profile

2.2.1 Location and Land Area

Malawi is a land-locked country in southern Africa that lies along the southern most arm of the great East African Rift-Valley System (EARS) between latitudes 9^o 22’ and 17^o 03’ south of the equator, and longitudes 33^o 40’ and 35^o 55’ east of the Greenwich meridian (Fig 2.1). It is bordered by Tanzania in the north and north-east, Mozambique in the south-west, south and the east; and Zambia in the west. The country is 910 km long and varies in width from 60 to 161 km with a total surface area of 11.8 m ha. Of this total area, 9.4 m ha (80%) is land and the remaining 2.4 m ha (20%) is covered by water. In addition, 1.8 m ha of the total 9.4 m ha is public land, 1.2m ha is estate land, 0.3 m ha is urban land, and 6.1 m ha is customary land (EAD, 1998; Saka, Green and Ng’ong’ola, 1995; Msiska, 2007). Furthermore, arable land constitutes 39.8% of the total land area, 1.4% is composed of permanent crops, 34.0% is forest land and the remaining 24.8% is classified as other land (FAO, 2015).

2.2.2 Physiography and Relief

The location of the country within the EARS has profound impacts on the relief of the country. The process of rifting was responsible for the formation of a trough filled by Lake Malawi, one of the country’s most conspicuous drainage features and the third largest lake in Africa that dominates the east of the country’s topography on a North-South transect. The topography is greatly variable, rising from almost sea level (35 metres above sea level (m asl) on the Rift Valley Floor in Nsanje District in the South to about 3,000 m asl on the High Altitude Plateau at Sapitwa on Mulanje Mountain in Mulanje district (Pike and Rimmington, 1965).

The country falls into five main physiographic surfaces related to the different erosional cycles. The Rift valley floor is situated along the major drainage features of the country at about 30 - 600m asl is very flat and is related to the Quaternaryerosional cycle. Bordering the rift valley floors are the steep escarpments which are associated with major rift faults and related to the Post-African cycle. Above the escarpments are plains at an altitude of about 750 -1300 m asl. These escarpments have a generally flat or rolling topography. The African surface is a relatively flat surface at 600 -1400 m asl attitude.Slopes with moderate steepness at 1400 -1500 are ascribed to the post-Gondwana and the Gondwana surfaces are above 1500 with steep slopes and generally have high plateaus 600 m.

Four distinct major relief units, or agro-ecological zones (Fig. 2.2), can be distinguished as follows: (i) Highlands, such as Nyika, Viphya, Zomba, Mulanje and Dedza (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), Leptosols and Regosols and montane type of vegetation; (ii) The Plateaux (1,000–1,350 m asl) which constitutes three quarters of

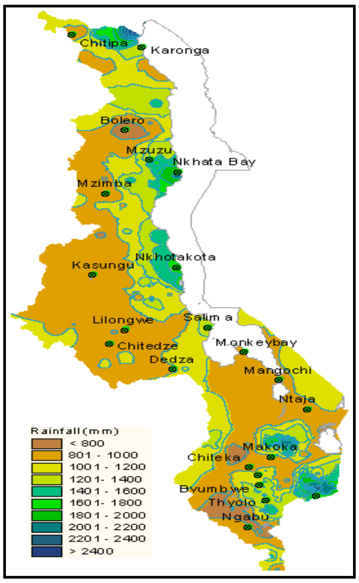
Malawi with undulating and level crests that are dominated by Latosols on upland sites and Hydromorphic soils on the poorly drained dambos, and *Brachystegia* (*Combretum-Acacia-Bauhimia*) plateau woodland; (iii) Lakeshore Plain and Upper Shire Valley (450 and 600 m asl) dominated by Calcimorphic Alluvial soils (Entisols) and Hydromorphic soils (Inceptisols) on poorly drained dambo sites, with vegetation types that include baobab and palm trees; and (iv) the Lower 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; MoAFS, 2012).

2.3 Climatic Profile and Extremes

2.3.1 Climate of Malawi

Malawi lies in the general tropical continental wet and dry climate, also known as Savanna. 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 that originate in the Indian Ocean and move from East to West general direction. A deficiency in rainfall may occur if these systems are not active in a season.

Generally, Malawi's climate is characterized by two distinct seasons: (i) a single rainy season lasting from October to April, and (ii) a dry season extending from May to September. It is cool and dry from May to August, warm and dry from September to October, and warm and wet from November to April. In some high altitude plateaus, such as the ShireHighlands in the Southern Region, rain 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 andsome 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 mostimportant climatic variables that are affected, or influenced, by climate are rainfall, air temperature and solar radiation.



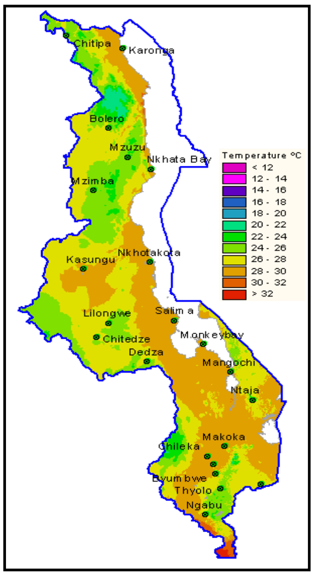


Figure 2. 1 Rainfall and Temperature distribution

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 which has been increasing (Ngongondo et al., 2011).

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 he 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 the climate is changing at a rate that is faster than at any other time in the past. These varying and changing climatic conditions have respectively normally been associated with the effects of the El Nino Southern Oscillation (ENSO) system and 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. Figure 2.5 shows the monthly distribution of observed solar radiation for Nchalo station in Chikwawa District. The station observes the highest radiation around September peaking to 25 MJ m^{-2} and lowest in June at 16 MJ $m^{-2.}$ The long-term radiation pattern for Nchalo station between 1971 and 2008 is shown in Figure 2.6. 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.

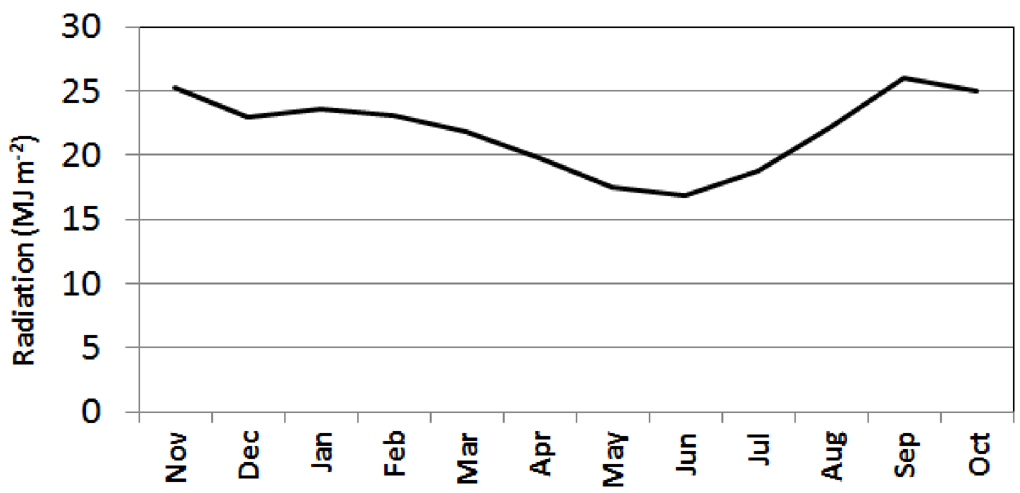
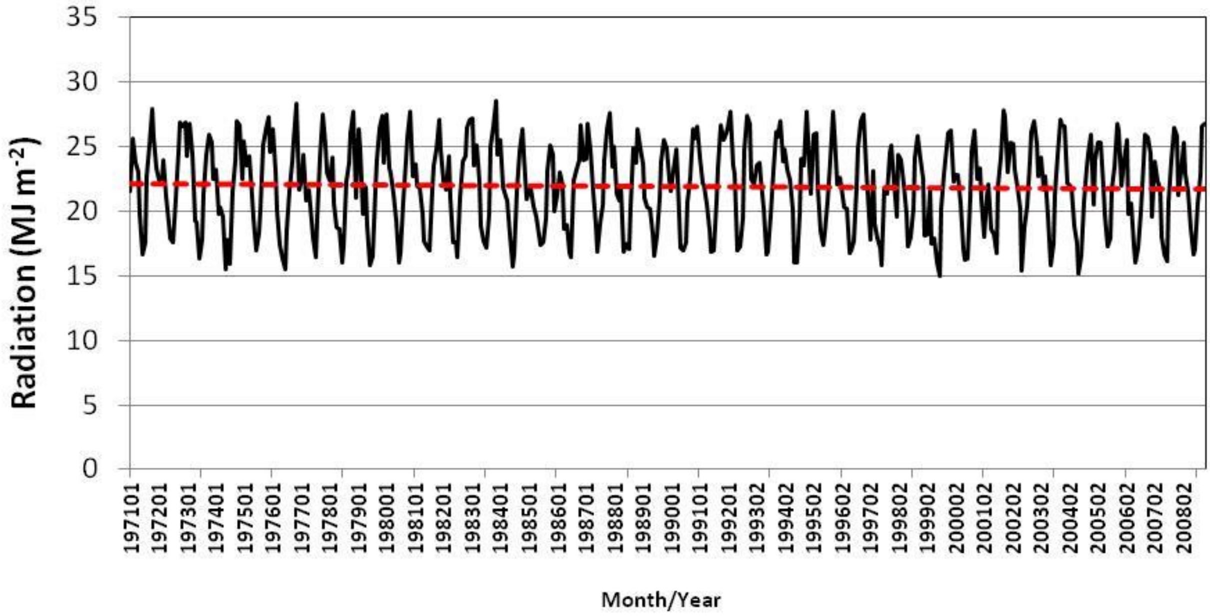


Figure 2. 2 **Monthly radiation regime for Nchalo Station (1971 – 2008)**



Data source: Department of Climate Change and Meteorological Services

Figure 2. 3 **Monthly radiation for Nchalo Station (1971 to 2008)**

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. Figure 2.4 shows the mean monthly relative humidity for Nchalo Station during 1971 to 2008.

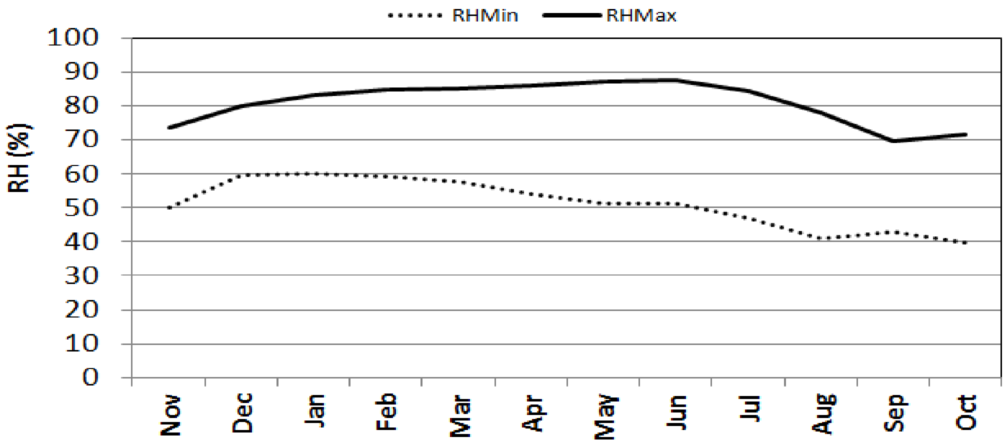


Figure 2. 4 **Monthly minimum (RHMin) and maximum (RHMax) Relative Humidity for Nchalo Station**

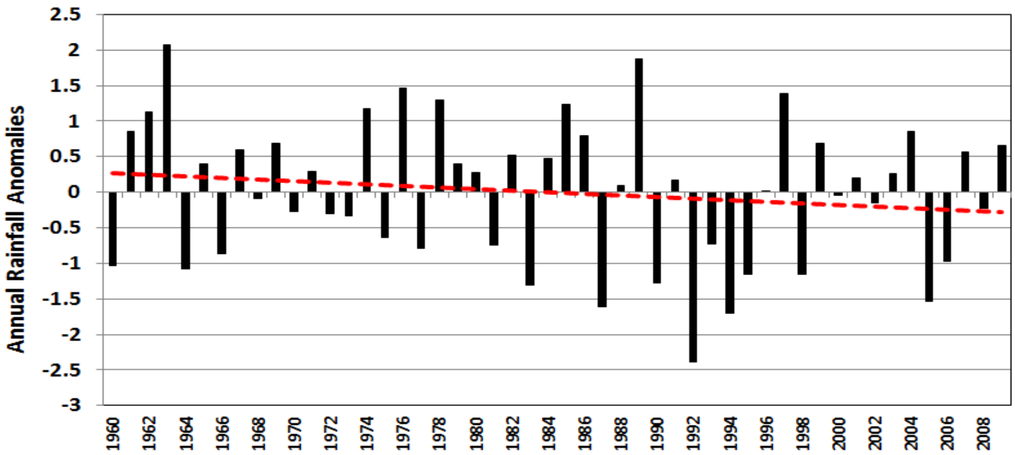
Data source: Department of Climate Change and Meteorological Services

2.3.2 Climatic Trends

Rainfall trends. Since 1961, Malawi has experienced considerable inter-annual and intra-annual climatic variations. These variations have resulted in the occurrence of extreme weather and related events, ranging from droughts (e.g. 1982/83, 1991/92 and 1994/95) to floods (e.g. 1996/97 and 2014/2015) and flash floods (e.g. 1990/91, 2000/01). For instance, when the Southern Region experienced extensive floods in the 1996/97 crop seasons, some parts of Karonga District in the north and the Lakeshore Plain were under drought conditions. These extreme occurrences within the country clearly illustrate 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 a clear decreasing trend for mean seasonal rainfall over the country as shown by the trend in rainfall anomalies in Figure 2.8a. The decreasing rainfall trend is also well illustrated for Karonga annual rainfall during the period 1961-2009 (Fig 2.8b).

Temperature trends. There is evidence that global air temperatures is changing and/or fluctuating with time. In Malawi, the evidence for increasing and decreasing mean air temperature trends is illustrated for mean annual temperature anomalies based on 28 stations over Malawi during 1971 to 2001 (Fig 2.10). Although there has been increased variation in mean annual temperatures over Malawi, the general trend shows continual increase in mean air temperatures across the country.

Hence, it can be concluded that since 1961, rainfall has been decreasing whereas air temperatures have exhibited an increasing trend over Malawi. On the other hand, the extreme weather events, especially floods and droughts, have also been increasing in intensity, frequency and magnitude. As a result of these, Malawi has experienced more than 40 weather-related disasters from 1970 to 2008, 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. Decrease in mean seasonal rainfall and increase in mean monthly temperatures are all signs that the climate is changing and strategies must be put in place to address its adverse impacts. Malawi's Third National Communication (TNC) document is therefore timely in this regard.



Source: Based on Ngongondo et al. (2015)

Figure 2. 5 Annual Rainfall anomalies over Malawi (1960-2009)

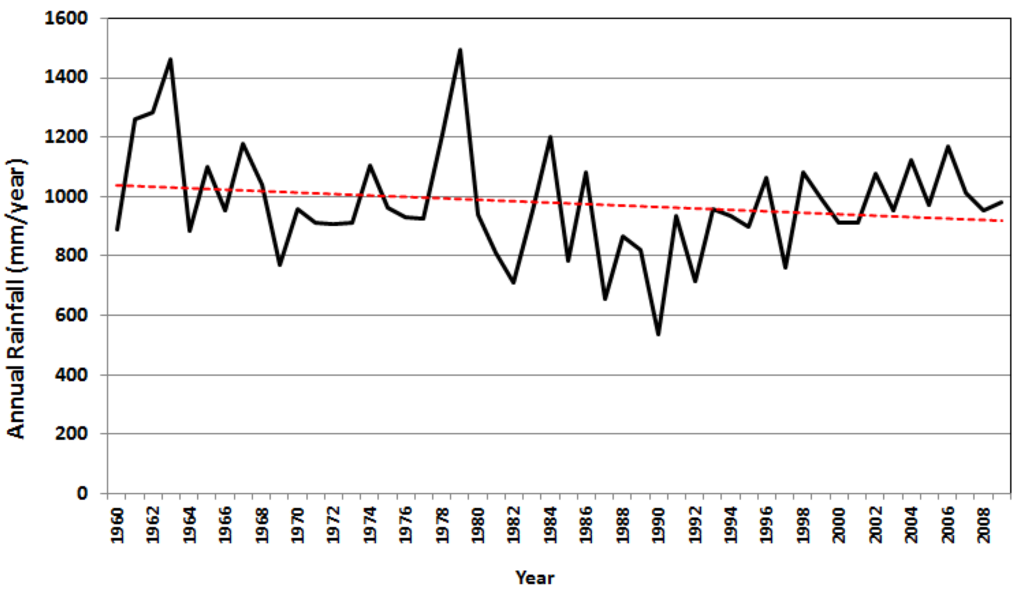
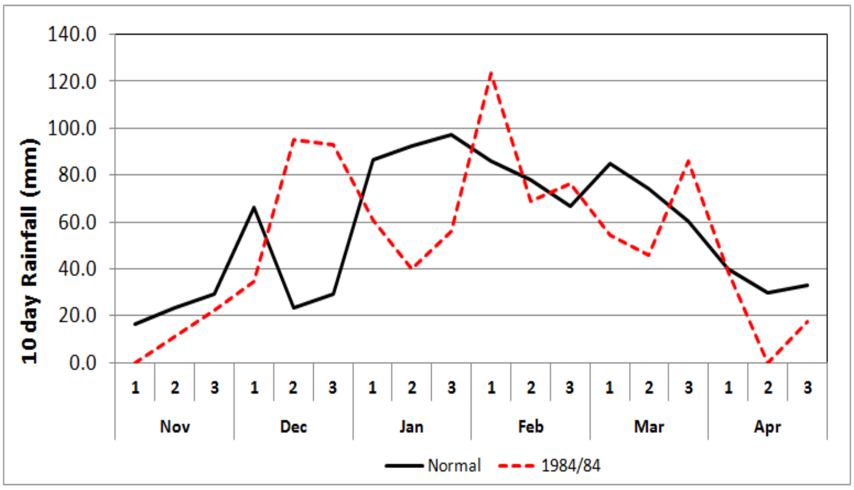
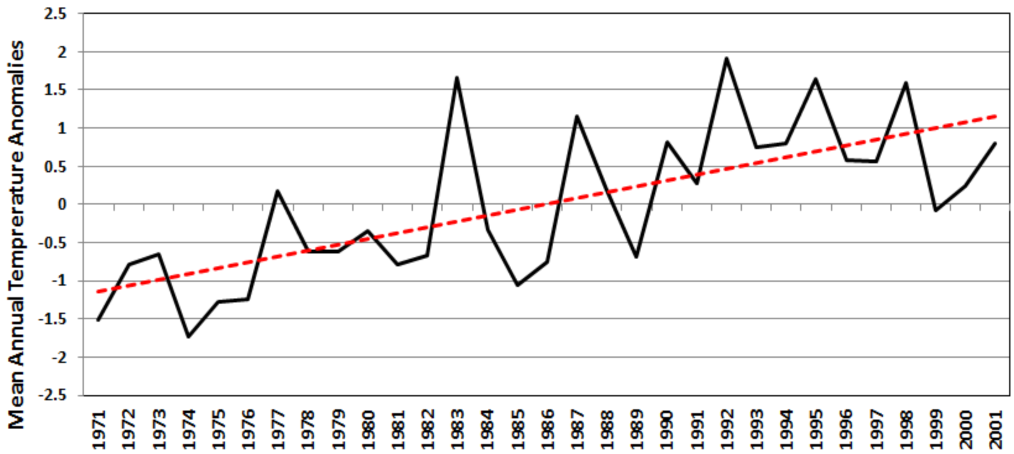


Figure 2. 6 Annual rainfall variability and decreasing trends in mean seasonal rainfall, Karonga Boma, 1960-2009



Data Source: Weedon et al. (2011)

Figure 2. 7 Rainfall variation during 10-day period from November to April in 1983/84 for Salima District

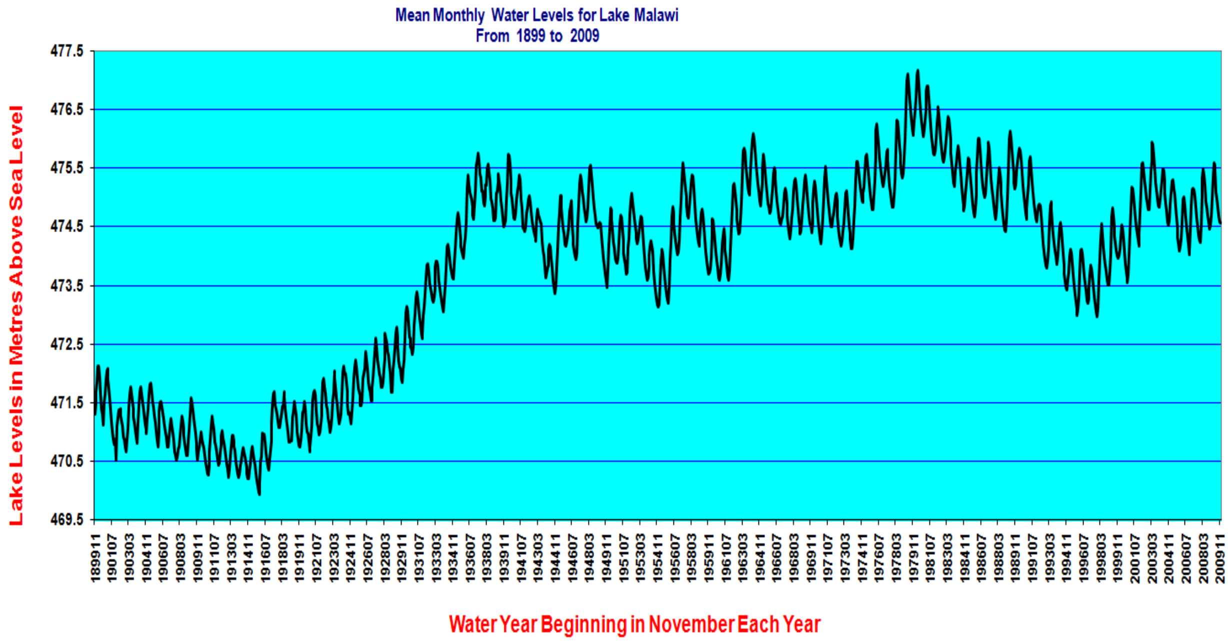


Source: based on Ngongondo et al. (2015)

Figure 2. 8 Temperature fluctuations at over Malawi (1971-2001)

2.3.3 Lake Water Level Fluctuations

Lake Malawi's level fluctuations are influenced by both tectonism and climatic extremes. Geological evidence from sediment cores shows that lakes in Malawi have dried at various times from the late Pleistocene period (Lancaster, 1981; Owen et al, 1991; Thomas et al, 2009). In addition, instrumental records also show various fluctuations in the past 150 years of the lake's history (Fig. 2.11). The hydrograph of Lake Malawi shows water level fluctuations from 1899 to 2009. Lake Malawi water levels can thus be regarded as an ideal 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, from Fig 2.11, four distinct water level fluctuation periods can be seen. First, from 1900 to 1915, there was an oscillating and declining trend that has been attributed to declining rainfall regimes during this time period. This period also shows the lowest lake levels in recent years with an average lake level of 471.0 m asl. Secondly, from 1915 to 1935, without outflows from the Shire River, the lake levels exhibited a general ascending trend attributed to the blockage of the Shire River channels and stable rainfall regime in the catchment 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 level during the period was 472.3 m asl.



Data source: Ministry of Agriculture, Irrigation and Water Development

Figure 2. 9 Lake Malawi water level hydrograph, 1899-2009

A third period is evident from 1935 to 1980 where the levels peaked to around 477.16 m asl in May 1980 due to high rainfall in the immediate preceding years (Drayton, 1984), with an average of 474.81 m asl. The outflow through the Shire River has been continuous during the period, with a lake water level hydrograph that was almost uniform. The period 1979 to 1983 reported was the highest recorded water levels for the Lake. 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. However, during this period, there were years of low (drought) and high rainfall (floods), which resulted in high lake water levels. Fourth, a decreasing pattern is evident from 1980 to around 1995 after which the levels seem to be going up. Since 1931, the lowest lake water levels of 472.9 m also were recorded in November 1997 as a result of two severe droughts in the 1991/92 and 1994/95 rainy seasons.

These water level fluctuations equally affected the Shire River, the only outlet of Lake Malawi to the Indian Ocean through the Zambezi River. The water level fluctuations for the Shire River (Fig. 2.12) are measured at Liwonde where the outflows are controlled (Kidd, 1983). 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 has 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. Lake Malawi has an estimated total catchment area of 125,000 km^2 that includes a large network of rivers, such as the Songwe, North Rukuru, South Rukuru, Dwangwa, Linthipe and Bua on the Malawi side.

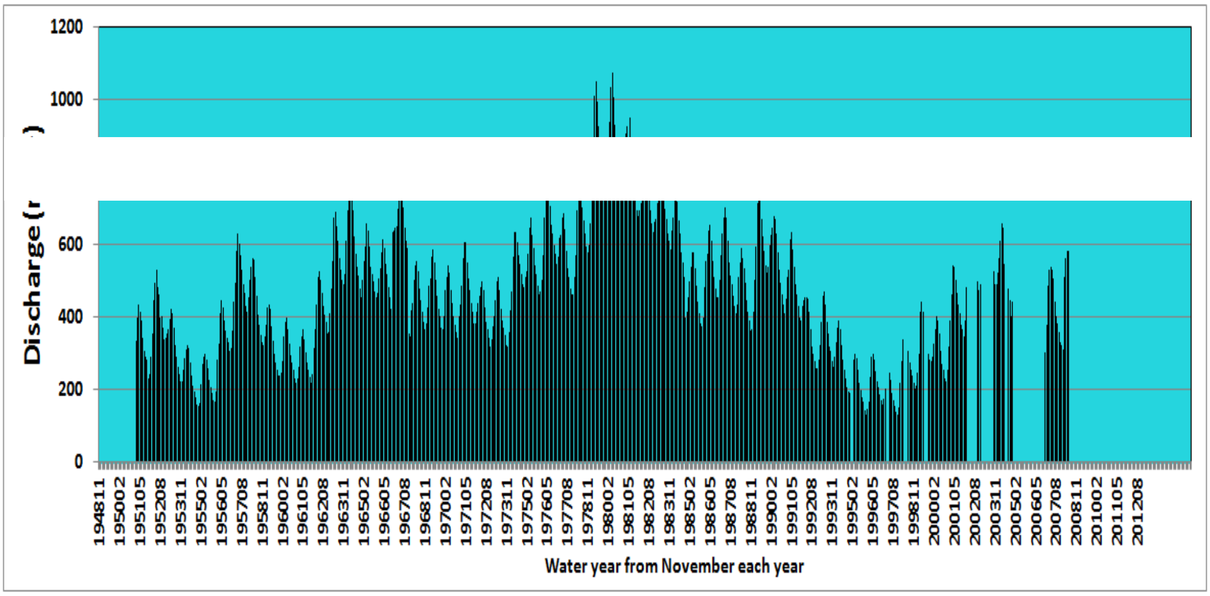


Figure 2. 10 Shire River monthly flows at Liwonde, 1948-2007;

According to the Global Climate Risk Index (2017) released by the Germanwatch, Malawi is among three countries that have been affected most by weather related loss events in recent years. Between 1979 and 2008, natural disasters affected nearly 21.7 million people and killed about 2,596 people (Runduka et al., 2010). 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 insect pest infestations, (xii) heat waves, (xiii) landslides/ mudslides/ avalanches (xiv) hailstorms, (xvi) cyclones (xvii) epidemics.

However, the most common and pertinent hazards for Malawi 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 2.1).

Table 2. 1 Extreme weather events recorded in Malawi

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
1991/92	National		Drought, national disaster	Worst drought
2001/02	National		Drought	Worst drought
February 15, 1961	Zomba Plateau	349mm		High intensity, short duration
December 6, 1980	Dwangwa (Nkhota Kota)	323mm		“
October 26, 1950	Lujeri (Mulanje)	315mm		“
February 17, 1950	Namwera (Mangochi)	308mm		“
October 10, 1961 and January 12, 2015	Blantyre	304mm 398mm		“ ‘’

Source: Department of Relief, Disaster and Preparedness (2008)

Frequency, spatial and temporal distribution. The Department of Disaster Preparedness, Relief and Rehabilitation (DDPRR) and global disaster databases have so far recorded more than 270 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 (76%) of these, which numbered 205, are climate-related, making climate change a major cause of disasters in the country (Table 2.1).

Table 2. 2 Distribution of climate related disasters in Malawi, 1946-2008

Type of hazard	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-08	Total
Cyclone	1	4	-	-	-	1	1	8
Drought	1	-	-	-	1	2	1	8
Floods	-	-	-	5	29	44	61	149
Hailstorm		-	-	-	1	11	-	14
Landslide/ avalanche	2	-	-	-	2	2	-	7
Strong winds	-	-	-	1	2	8	6	19
Total	4	4	0	6	35	68	69	205

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 is still patchy for the pre-independence period. This may be due to lack of recorded information or owing to lack of recorded during that period or an indication that there were no significant hazardous events at the time. It is clear though that there is a glaring of information that needs to be filled to understand the nature and scale of various hazardous events that have affected the country from time to time.

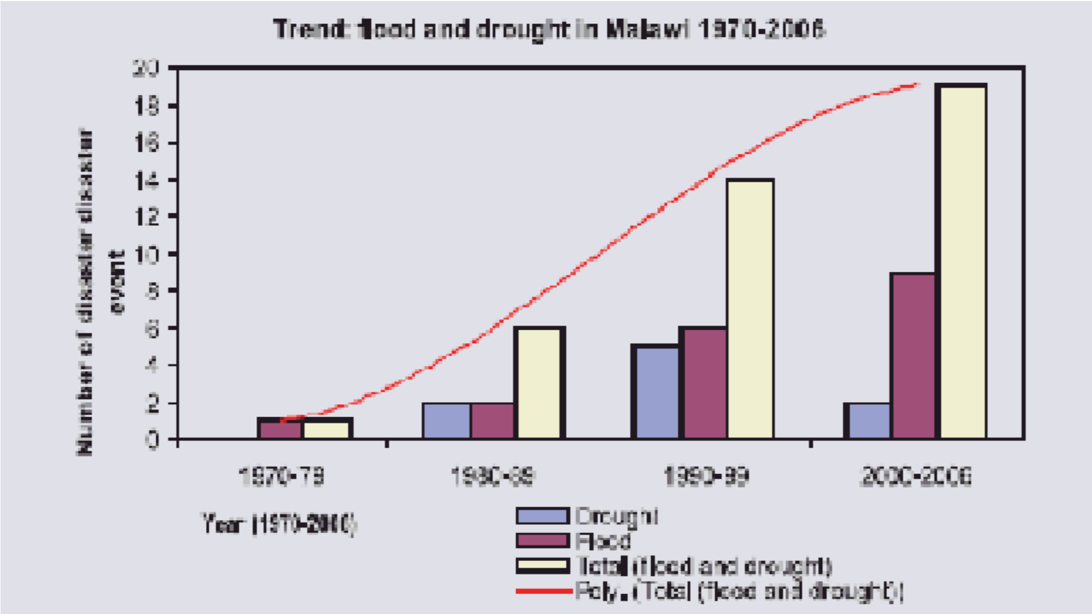
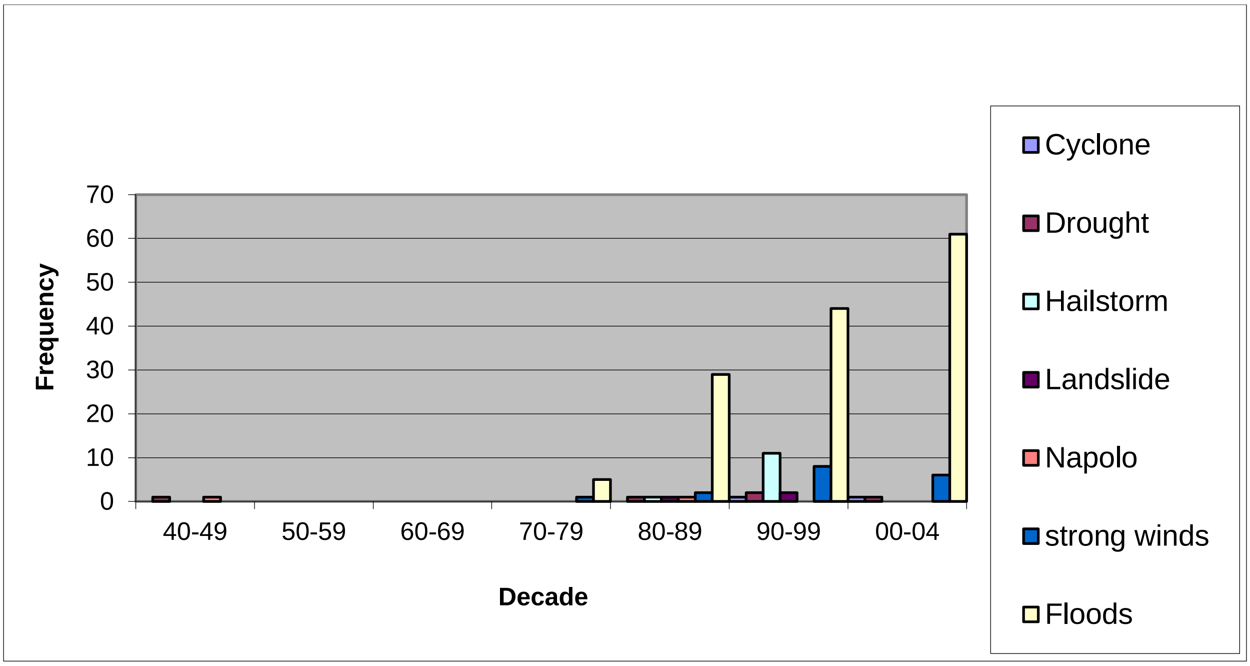


Figure 2. 11 Drought and flood trends in Malawi, 1970-2006

Source: ActionAid (2006)

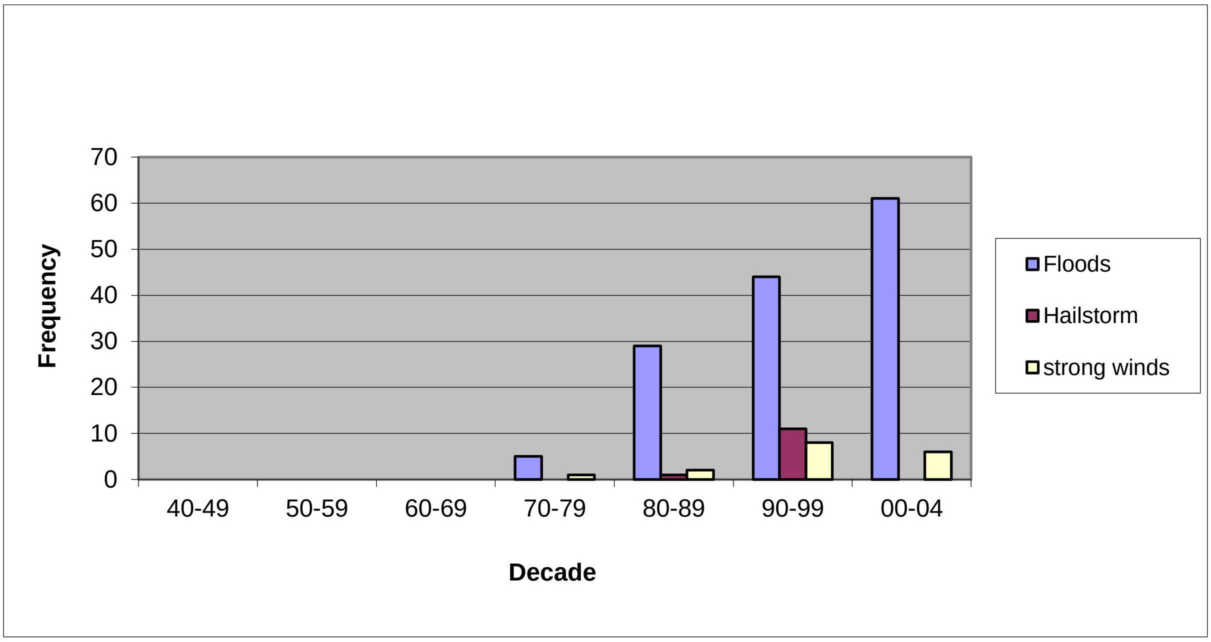
Floods are the most dominant climate-related disaster (>74%), and show an increasing trend since the 1970s (Fig 2.13). Closely associated with the increasing trend of floods is the incidence of strong winds (Fig 2.14). This association is related to these two disasters (i.e. floods and strong winds) being linked to the rain bearing systems. Although the frequency is much lower, there has been an increasing trend since 1970.

Cyclones and landslides/ avalanches (or Napolos) are less common compared to floods. However, their impacts can be devastating as illustrated by the Zomba Mountain, Phalombe and Chilobwe events in 1946 and1991 respectively. 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 districts) over the last sixty years. However, once these strikes, 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.



Data Source: Department of Disaster Preparedness, Relief and Rehabilitation (2008)

Figure 2. 12 Frequency of climate-related disasters recorded since 1946



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

Figure 2. 13 Frequency distribution of floods, hailstorms and strong winds, 1946-2008

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, 2001/02 and 2014/15 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, 1994/95 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 2.16), whereas a devastated maize field in the Lower Shire Valley in Chikwawa district is depicted in (Fig 2.17).

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 2.18). Floods also disrupt electricity generation, destroy transport network (such as roads and railways), 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 extremes 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).

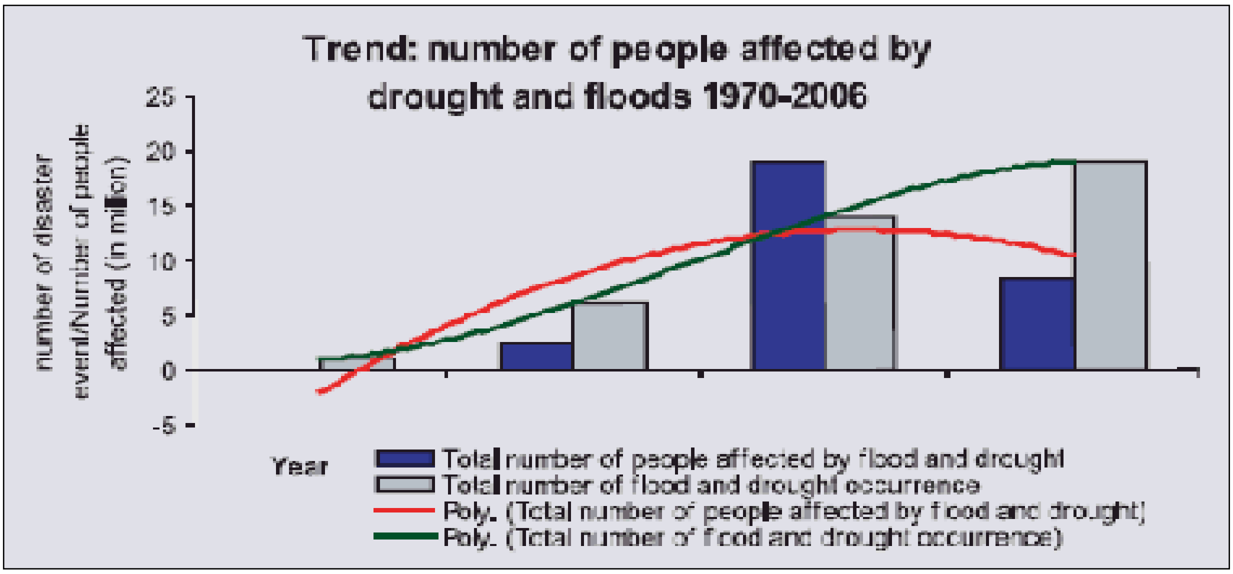


Figure 2. 15 Number of people affected by drought and floods 1970-2006

2.4 Socio-Economic Profile

2.4.1 Population Profile

Malawi's official population as in 2009 was estimated at 14.33 million, up from 13.1million people in 2008, representing an overall population increase of 2.1% that has been growing almost constant at the rate of 2.8% per annum up to 2013, rising up to 3.1% in 2014 (NSO, 2008). The population density is 168 persons /km^2, up from 139 in 2008, making Malawi one of the most densely populated countries in the world. The spatial population distribution in the country indicates that 48.3%, 39.5% and 12.2% 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, the same as reported in the 1998 and 2008 Population and Housing Census Reports (NSO, 2002, & 2008). The population of those 18 years and above is about 48% of the total population suggesting a dominance of the young population (52%) of which 48% are below 15 years. The overall average life expectancy as of 2008 was about 48.5 years (NSO, 2015). This is below the 2008 average life expectancy for Africa which was estimated at 53 years.
(http://www.who.int/gho/mortality_burden_disease/life_tables/situation_trends_text/en/.
Some basic demographic, health and economic indicators are given in Tables 2.3.

2.4.1.1 Population Growth

The population of Malawi has grown exponentially over the last hundred years, from a meagre 737,200 in 1901 to an estimate of 139 million in 2008 (Fig. 2.5). The population growth rates fluctuated between 2.0% (1998) and 3.7% (1987), mainly because 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 5 children per woman (GOM, 2000a, 2005a). The statistics suggest that the country's population is increasing by about half a million per year. The population density increased from 105 persons/ km^2 in 1998 to 139 in 2009.

Table 2. 3 Malawi basic demographic indicators, 2008

Indicator	2008	Unit
Population	13.1	Million
Urban population	15.4	% of total
Rural population	84.6	% of total
Population density	139	Persons per km^2
Population growth	2.8	%/year
Life expectancy at birth (male)	47.4	Years
Life expectancy at birth (female)	50.6	Years
Fertility rate	6.3	Birth per woman
Female headed households	25	% of all households
Literacy	56	% of total population
Average household size	4.8	Number of people

Source: NEC (2003); NSO (2000, 2008, 2014, 2015); RBM (2005); GoM (2011)

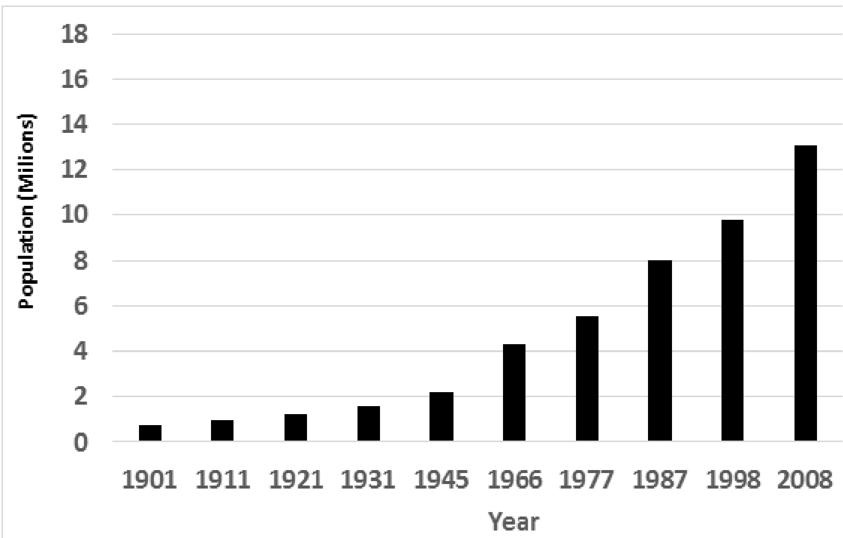


Figure 2. 16 Population growth of Malawi, 1901-2014

2.4.1.2 Population Distribution

Malawi population is predominantly rural with about 86% living in the rural and the remainder (14%) in urban. This urban proportion makes Malawi one of the least urbanised nations in Southern Africa (UN-DESA, 2012). Despite this, "Malawi was categorised as the fastest urbanising country in the world in 2004, with three times the global rate and nearly twice Africa's rate of 3.5 percent per annum" (Joshua et al.,2014). Currently, the urbanisation rate is at 6.3% per annum, one of the highest in Africa (GoM, 2011; Joshua et al., 2014).

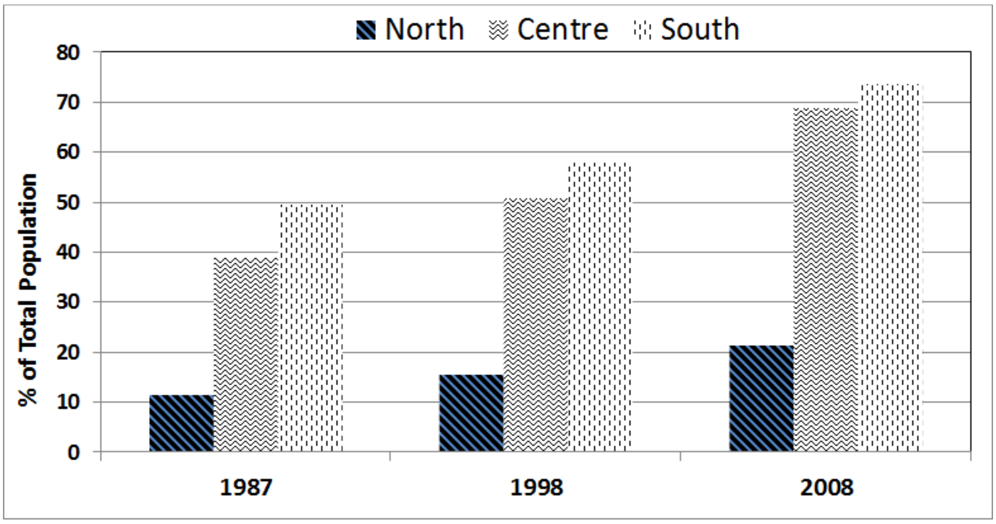


Figure 2. 17 Population distribution by region in Malawi, 1987, 1998 and 2008

Source: NSO (2002, 2008).

2.4.1.3 Economy

Malawi's economy is largely agrobased, with the sector supporting about 80% of rural people's livelihoods and contributing about 30% to GDP and 80% of export revenue. Performance of the other sectors is dependent on agriculture which is largely rainfed and hence highly vulnerable to climate change and climate variability.

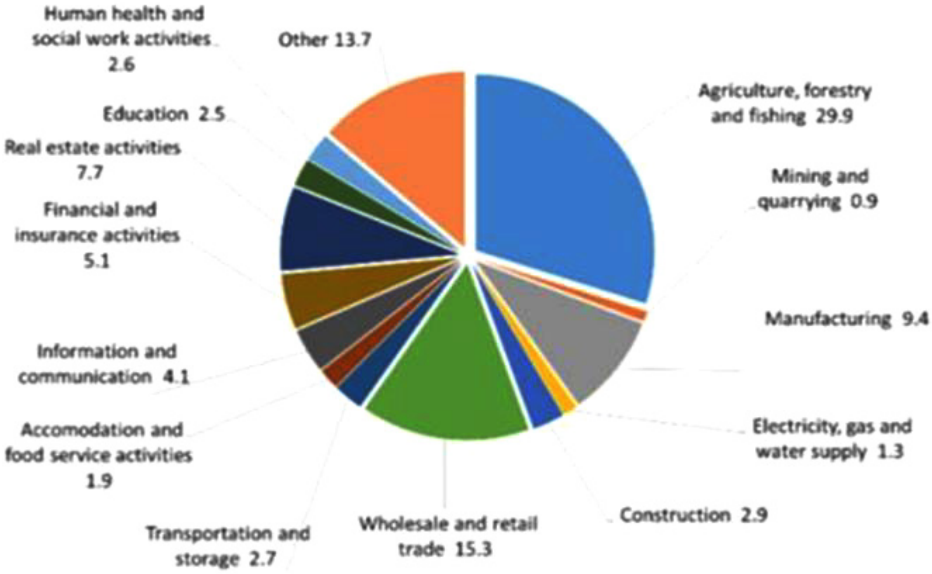


Figure 2. 18 **GDP Shares of the Malawi Economy in 2015**

Source: National Statistical Office and Ministry of Finance, Economic Planning and Development datacensus Population distribution

2.4.1.4 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 and 2011(GoM, 2006; 2011). Malawi's infrastructure development strategy focuses on the following: (i) transport (road, rail, air and water), (ii) energy, (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, landslides, mudslides, floods, droughts, cyclones and strong winds.

2.4.1.5 Transport

2.4.1.5.1 Road transport

Transport facilities (roads, rail, water and air) are generally inadequate and in poor condition to adequately meet the needs of a growing and vibrant population estimated at estimated at 17.2 million in 2017 by the World Bank. This situation is exacerbated by resource constraints and the fact that Malawi is landlocked. However, over the last two decades, 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. The country has registered slow progress. 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 (Tables 2.4), which shows an increase of 76,146 from 20,000 recorded vehicles in 1992. The distribution of vehicles, by category type (Table 2.4), indicates that goods vehicles dominate the market, although this trend is currently declining. The increased number of vehicles is adding substantial quantities of GHGs to the atmosphere. This situation is exacerbated by the usage of secondhand imported cars and tyres some of which are detrimental to the environment. The bulk of the roads in Malawi are not bituminised and are therefore highly vulnerable to flooding. Additionally, proportion of light passenger vehicle is much higher (over five times) than heavy passenger vehicles. This is probably due to poor public transport system. This private car ownership has therefore created traffic congestion in the roads specifically, in urban areas consequently leading to possible increases in GHGs emissions.

Table 2. 4 Trends in registered number of private vehicles by category as of 2007

Serial	Vehicle category	Total Number of Registered vehicles in2007 96,146
1	Motorcycle (less than 3 wheels)	8,018
2	Motor Tricycle	641
3	Light passenger vehicle (less than 12 persons)	38,796
4	Heavy passenger vehicle (12 or more persons)	8,312
5	Light load vehicle (GVM 3500 kg or less)	22,452
6	Heavy load vehicle (GVM>3500 kg, not to draw & equipped to draw)	14,467
7	Agricultural tractor & trailers	1,283
8	Trailers & other	2,177

Source: Malawi Road Traffic Directorate (2007)

2.4.1.5.2 Water transport

Water transport is characterised by underexploited and inadequate access to ports. 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.

2.4.1.5.3 Rail transport

Rail transport is yet to develop to full capacity. 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, the portion between Nsanje and Beira has been out of order since the beginning of the civil war in Mozambique in the 1970s. In addition, the track between Nsanje and Luchenza has not been operation since 1997 when floods destroyed vital bridges and washed away parts of the tracks. 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 Blantyre, 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 in Karonga district. Because of their locations within the low-lying areas such as the Malawi Rift, the railway lines are highly vulnerable to flooding, especially in the Shire Valley and along the Lakeshore Plain.

2.4.1.5.4 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, Likoma, Kasungu, Dedza and Nsanje. However, aircraft operation is affected by heavy rains, fog and clouds that interfere with aircraft navigation. These climatic extremes are expected to increase in frequency and magnitude in the future in response to changes in climate.

2.4.1.5.5 Transport System and Malawi's economy

However, since Malawi's transport system of roads, rail, water and air are in a poor state and inadequate, these result in high costs of production, where transportation represents 55% of costs, compared with 17% in other less developed countries (GoM, 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. Additionally, this development has potential effects on reducing current carbon emissions from the transport sector because this may reduce volume of freight handled by air and trucks (road transport)

2.5 Water Supply and Sanitation

2.5.1 Access to improved sources of drinking water

According to USAID (2010), estimates the proportion of households with access to improved water of drinking in Malawi as of 2009 was about 80%. From these, 95% were urban dwellers while 77% were in rural areas. This implies that the urban areas have more access to improved sources of water than rural areas. The statistics further show "use of improved source of drinking water increases with increasing education level of household head and increasing household wealth" (NSO 2015). Households with household head with secondary education and in those in the richest wealth index quintile have almost universal access to improved sources of drinking water (NSO 2015).

2.5.2 Access to improved sanitation facilities

It is widely agreed that "Inadequate disposal of human excreta and personal hygiene are associated with a range of diseases including diarrheal diseases" (NSO, 2015). According to USAID (2010), about 56% of Malawi had access to improved sanitation facilities as of 2009. Those living in urban areas constituted 51% of these while those in rural were about 57%. The situation is probably resulting from declining trend in rural areas). (GoM 2012).

2.6 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 and geological/ mineral resources. A brief overview of these natural resources is presented below together with policy and legal frameworks for environmental management and climate change.

2.6.1 Land Resources

Malawi's total land area of 9.4 m ha is presently supporting a human population of 13.1m (projected to grow to 17m in 2018) 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).

Thus, only 31% of the country's total land area is suitable for rain-fed agriculture at traditional level of management due to variations in topography, slope, rainfall, temperature, soil type and soil depth. This scenario presents 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.

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 (GoM, 2007) is addressing some of these constraints.

2.6.2 Fish Resources

The fishes of Malawi, particularly those in Lake Malawi, are one of the most diverse in the world with more than 800 species of cichlids alone (Genner and Turner, 2005; Genner and Turner, 2015). The total number of described Malawian fish species represents about 15% of the global total number of fresh water fishes and approximately 4% of the world's fish species (Konings, 1990; Ribbink, 2001). Most of these cichlid fishes have evolved in this lake within a geologically short period and occur nowhere else as natives (Genner and Turner, 2005). The main fish types in Lake Malawi include *Oreochromis karongae, Oreochromis squamipinnis, Oreochromis lidole* (collectively known as Chambo), *Oreochromis shiranus* (makumba), *Bagrus meridionalis* (Kampango), *Lethrinops spp* (Chisawasawa), *Clarias gariepinus* (Mlamba), *Bathyclarias* spp (Bombe), *Labeo mesops* (Ntchila), *Opsaridium microlepis* (Mpasa), *Opsaridium microcephalum* (Sanjika), *Engraulicypris sardella* (Usipa), *Rhamphochromis* spp (Ncheni), *Diplotaxodon* spp. (Ndunduma), various types of small brightly coloured rocky shore-dwelling cichlids like *Maylandia zebra* and *Labeotropheus trawavasae* (collectively called mbuna), *Dimidiochromis kiwinge* (Mayani) and *Copadichromis spp* (Utaka). Close to 30 fish species occur in the riverine ecosystems of Malawi and these are mostly types that are also widely distributed in Africa, including fish families of Cyprinidae, Cichlidae, Mormyridae, Clariidae, Bathyclariidae, Bagridae, Distichodontidae, Protopteridae, Malapteruridae and Mochokidae Amphilidae, Alestidae, Mastacembelidae and the introduced family Salmonidae (Likongwe, 2005; Kadye et al., 2008; Tweddle and Skelton, 2008). The fish fauna of the country's largest lake (Lake Malawi), is dominated by cichlids but cyprinids are the commonest in the rivers that drain into this lake (Likongwe, 2005; Kadye et al., 2008). Most of the large cyprinids of the genera *Barbus*, *Labeo*, and *Opsaridium* seasonally migrate upstream into inflowing rivers for breeding at the beginning of the rainy season (Tweddle and Skelton, 2008; Limuwa et al., 2012).

The fisheries sector is one of the most economically important in Malawi, providing employment and contributing to food security for millions of rural poor Malawians. It contributes about 4% to the Gross Domestic Product and provides about 70% of the animal protein and 40% of total protein intake for the majority of Malawians. The sector, comprising capture fisheries, aquaculture and the aquarium trade, provides employs over 200,000 people, economically supporting about 14% of Malawians along the shores of Lake Malawi through fishing, processing, marketing, fishing gear construction and other fisheries-related activities. The fisheries sector is largely artisanal in nature, with small-scale fisher folks accounting for about 90% of the annual fish production. Localized overfishing of fish stocks from the shallower margins of southern Lake Malawi has led to a decline in catches and consequently substantial losses in fishers' earnings. Fish farming has increased over the years. Presently, small-scale fish farmers produce a combined 2,500tonnes per year. The aquarium trade mainly involves exploitation of 'Mbuna' fish for export trade. Mbuna fish are part of the rich biodiversity of Lake Malawi that also attracts a lot of tourists.

The capture fisheries production varies annually but averages 70,000 tonnes per annum (2000-2010 estimates). The total annual fish catches grew slowly to 7,000 tonnes between the 1940s to the 1950s, but dramatically increased from 20,000 tonnes in 1965 to 84,000 tonnes in the 1970s, and has since been fluctuating between 60,000 and 80,000. The increase in catches may have come about mainly due to, incremental large financial investments in the fishing industry and associated increased fishing effort, improvements in road networks the introduction of the nylon fishing net as well as high demand for Malawi's fish, especially the tasty Chambo (*Oreochromis karongae*, *O. lidole* and *O. squamipinnis*). Total annual fish catches declined by 24,000 tonnes to 51,000 tons in 1981 but later began to pick up again, reaching a record 88,000 tons in 1987. More than half of the fish production in Malawi comes from Lake Malawi, with an estimated value in the order of US$50.0 million. The rest of the production comes 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, the large-scale commercial fisheries, mostly in southern Lake Malawi, accounted for up to 15% of the total landed fish catches. Commercial fishermen use various fishing gears, including bottom trawling and mid-water trawling. Small-scale fishermen mostly use Chilimilanets, Gill nets, Kambuzi seines, Chambo seines, Nkacha nets, Usipa seines, longlines, handlines and cast nets. Occasionally and in some places, a locally available poisonous plant known as *Katupe* is applied into water sections of blocked river flows to indiscriminately kill fish.

The common methods of fish processing used in Malawi include sun-drying, smoking, para-boiling and pan-roasting. Fish smoking contributes to deforestation because of its demand for firewood. Some fish is also iced and sold fresh in towns. Occasionally, fish is frozen and delivered to supermarkets. There is very little value adding in the fisheries industry. Although the quality of fish is generally acceptable for the local market, consumers are increasingly becoming quality-conscious. There is need for proper fish handling and processing by addressing public services and infrastructure issues along the whole fish value chain.

There are also some legal and institutional constraints which have had a negative effect on the management of Malawi's fish stocks, including weaknesses in the fisheries regulations, low enforcement capacity of the fisheries regulations, breaking-up of traditional systems of management for the control and exploitation of fish resources as well as lack of awareness and information on fishery regulations and compliance. The proper management of Malawi's aquatic ecosystems may now require considerations of environmental degradation and climate change adaptation measures and strategies. The implementation of the decentralization policy over the last couple of years has created an opportunity for empowering rural communities in the management of their own fish resources, including the enforcement of the Fisheries Act.

2.6.3 Biodiversity

Malawi has diverse habitats and ecosystems including woodlands, montane grasslands, wetlands and fresh water bodies that harbour a rich variety of flora and fauna, including more than 5000 plants and over 8,500 invertebrate species. Nematodes, crustaceans and insects dominate the invertebrate species count while earthworms, myriapods and arachnids are poorly represented. The country has about 280 non-insect aquatic invertebrate species comprising mollusks, nematodes, crustaceans, rotifers, annelids and acarins. Chironomids, insect nymphs and water mites are also widespread. Eighty three amphibian species, mostly frogs and toads, occur in Malawi. Over 120 reptile species occur in the country, twelve of which are natives. There are about 648 bird species in Malawi, 94 of which are in restricted places. A hundred and ninety two species of mammals occur in Malawi. The level of endemism in Malawi's diverse flora and fauna is as high as 90% in the case of cichlid fishes. Approximately 47 species of mollusks, 12 species of reptiles and about seven species of amphibians are endemic to Malawi. There is no detailed account of the status of endemic and/or rare plant species in Malawi. By 2002, however, there were 14 endangered, 89 vulnerable, and 25 critically endangered plant species in Malawi according to the IUCN Red List Data. About 114 plant species are known to occur only in few places in Malawi, none of which is formally protected. Malawi has only eleven plant species under legal protection. These resources offer a diversity of potential aesthetic, scientific, cultural and recreational benefits. They are also a source of great genetic diversity and provide useful resources such as wild edible food like fruits, vegetables, mushrooms, tubers, caterpillars, bush meat and honey, are a source of medicine, fuel wood, timber, poles, construction materials and art and craft materials.

Ecosystem Diversity: Terrestrial Ecosystems

Malawi's terrestrial ecosystems comprise forests, mountains and grasslands. The country has 87 forest reserves, five national parks, four wildlife reserves and three nature sanctuaries that were established to protect important wildlife populations, major water catchment areas, and landscapes of high aesthetic value and to preserve them for scientific and recreational uses. Some of the protected terrestrial ecosystems are briefly described below.

National Parks

Lengwe National Park (887km^2) in southern Malawi is mainly an open deciduous woodland and dense thicket habitat that is dominantly home to the *Nyala* antelope. Buffaloes are also a common sight in this park. The area is hot and dry, and the only source of consistent water is from rain. Many man-made water holes have been constructed to attract and maintain the animal population.Nyika National park (3,134km^2) sits on montane grassland with patches of forests and *miombo* woodland. Nyika grasslands are rich in wildflowers such as orchids. The montane vegetation supports a large number of antelopes like duiker, eland, roan and Zebra as well as a number of smaller mammals such as warthog and bush pig. Although Elephants and buffalo usually keep to the lower ground on the northern edge of the park, lions and elephants have recently been sighted on the high plateau. The park boats over 400 species of birds, including the rare Denham's bustard and the wattled crane and the red-winged francolin, an endemic to the area.An acacia and mopane woodland with baobab, the Liwonde

National park (548km^2) is renowned for elephants, buffaloes, crocodiles, hippopotamus, lions, warthogs, several species of antelopes (like impala, kudu and waterbucks) and more than 400 species of birds many other mammals. Kasungu National Park (2, 316km^2), is a seasonal *miombo* forest traversed by a number of rivers, notably the Dwangwa and Lingadzi Rivers. The park is an important habitat for hippos but is also known for its big population of elephants. Other animals common in the park include Sable antelope, roan antelope, kudu, impala, hartebeest, zebra and buffalos.

Game reserves

The Majete Game reserve, deciduous woodland, covers about 70,000 hectares of land and harbours about 4,000 animals, including elephant, eland, zebra, giraffe, leopard, baboons, many species of monkeys, and warthogs. Large numbers of hippos and crocodiles are found in streams and along the banks of the Shire River. Majete is very dry and hot in summer, and several man-made watering holes have been constructed to sustain the wildlife population. Nkhotakota Game reserve (1802km^2) is home to several mammals including buffaloes, bushbuck, bush pig, common duiker, eland, elephants, grysbok, kudu, reed buck, roan, sable, warthog, water buck, zebra, baboon, leopard and lion. Vwaza Marsh Game Reserve (986km*2*) is an ecosystem typified by mopane woodland and Miombo forests. It harbours large herds of buffalo and elephants and a large variety of antelopes including roan, greater kudu, Lichtenstein's hartebeest, eland and impala. Located in the southern Malawi, Mwabvi Game Reserve (135km^2) is a mixed Mopane, Combretum and brachystegia woodland interspaced with open savanna, dambo, and riverine habitats. The reserve has several mammals including Kudu, Impala, Buffalo and other antelopes.

Ecosystem Diversity: Mountain Ecosystem Resources

There a number of high altitude plateaus (1,350 to 3,000 m asl) that comprise Malawi's mountain ecosystems. 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 2.24) accounts for a large number of flora and fauna that are endemic, endangered and/or threatened by extinction, therefore requiring protection. Mulanje Mountain is therefore 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 biodiversity of Mulanje Mountain 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.

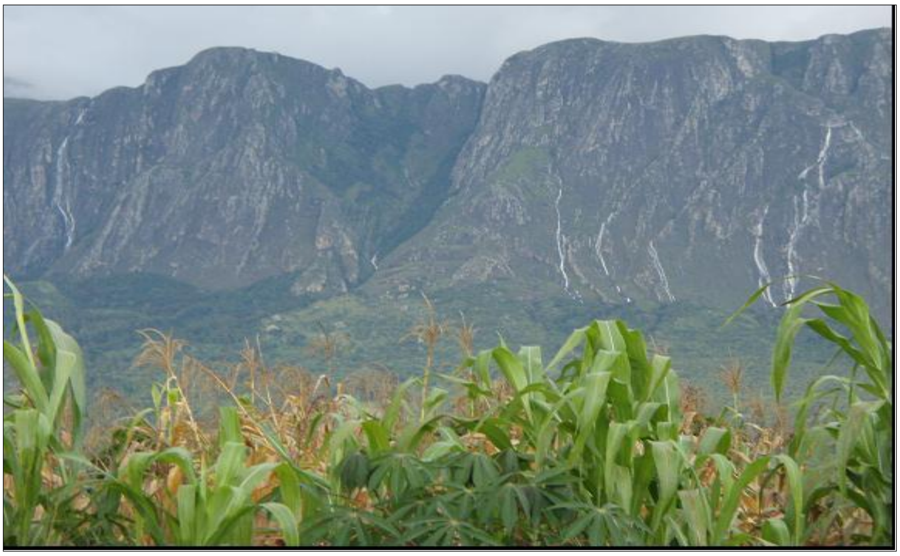


Figure 2. 19 The Mulanje Mountain massif, Mulanje district, southern Malawi

Threats to biodiversity

The greatest threat to biodiversity in Malawi is the unprecedented loss of habitats, fragmentation of species habitats and isolation of remaining communities due to unsustainable land use practices. Agriculture, urbanization, infrastructure development and human settlements are the major drivers of habitat loss and fragmentation in Malawi. The agriculture sector has been embroiled in the continuous cultivation of land in wetlands and riverbanks, encroachment into protected areas and cultivation on mountain slopes. Developmental activities have contributed to habitat loss through conversion of arable land, wetlands and forests for road construction, urbanization and human settlements. Damming of rivers for irrigation and water supply has also led to changes in ecosystems downstream. *Potamodromous* fish species face more serious threats from unsustainable agricultural practices in catchment areas where there is a complete damming of rivers without provision of fish ladders to enable migration of the fish into the rivers to spawn. In addition, cultivation on riverbanks has been suggested to be responsible for the degradation and eventual loss of spawning habitats due to siltation, exacerbated by pesticide pollution. For instance, *Labeo mesops* (*ntchila*), which used to be the most abundant species, has almost disappeared because of loss of spawning habitats along the rivers and river mouths.

High population and density are considered the greatest causes of biodiversity degradation since more land is cleared for settlement and in search of fertile areas to increase food production. Deforestation has resulted in soil erosion and reduction in species composition and abundance and has increased sedimentation and siltation of many rivers and lakes. The increased population has also brought about great demand for fish for domestic consumption leading to an increase in the number of fishermen, localized fishing, and reduced fish catches. In recent years, fish landings have fallen dramatically due to overfishing and environmental degradation. There has been a decline in the stocks of *Oreochromis* spp. (chambo) in both Lakes Malawi and Malombe from 8,500 to 6,000 tonnes between 1984 and 2000, representing about 75% reduction in fish catches. The high population and density have also resulted in increased demand for indigenous plant resources for food, medicine, fodder, and fuelwood and construction material and has led to these becoming locally rare. Wildlife is equally threatened due to increased population since deforestation for cultivation and settlements destroys natural habitats for large animals. Increased population also has resulted in increased demand for game meat. For example, over a million birds are captured in Lake Chilwa every year primarily for food and for sale. As long as the population growth rate remains high, pressure on land for settlements, agriculture and resource use will remain the biggest challenge to achieving sustainable biodiversity conservation.

The majority people in Malawi live below the poverty line. Under abject poverty, people are forced to heavily depend on natural resources for energy (fuel wood), food, construction material, medicine, and fodder. Poverty forces people to trade-off long term sustainable resources for short term consumption because they depend entirely on the existing natural resources.

2.6.4 Wildlife Resources

Malawi has an array of habitats and ecosystems including woodlands, montane grasslands, wetlands and fresh water bodies of varying sizes that harbour a rich variety of flora and fauna The spatial distribution of these resources is highly variable and influenced by topography, climate, vegetation type, and more importantly, human activities.

Mammals

Malawi hosts about 192 mammal species, some of which are listed as threatened under IUCN (total = eight, IUCN 2013). Substantial hippopotamus populations are protected within Liwonde National Park, Kasungu National Park and Vwaza Wildlife Reserve. Two species of otters, the Cape clawless (*Aonyx capensis*) and the spotted-necked otter (*Lutra maculocollis*), occur in Malawi. Black rhinos which were extinct have been reintroduced in Liwonde National Park and Majete Wildlife Reserve. Majete Wildlife reserve has also reintroduced 217 elephants, 11 black rhino and over 300 buffalos.

Amphibians

About 83 species of amphibians have been recorded in Malawi, 6 of which 6 are endemic. About 12 of the amphibian species are threatened and while 11 are listed in the IUCN Red Data-list as shown in Table 2.5.

Table 2. 5 List of Amphibians that are available in Malawi

Scientific name	English Name	Degree of Threats	Current Localities
Arthroleptis francei	France's Squeker	EN	Mulanje
Arthroleptis reichei	Eiche's squeaker	NT	Misuku hills
Mertensophryne nyikae	Nyika dwarf toad	VU	Nyika plateau
Hyperolius pictus	Variable reed frog	LC	Nyika plateau
Hyperolius spinigularis	Spiny throated reed frog	LC	Mulanje mountain
Phrybobatrachus stewartae	Stewart's puddle frog	DD	
Phrynobatrachus ukingensis	Ukinga puddle frog	DD	Misuku, Rumphi, Zomba
Amietia johnstoni	Johnston's river frog	EN	Mulanje mountain
Nothophryne broadleyi	Mongrel frog	EN	Mulanje mountain
Scolecomorphus kirkii	Kirk's caecilian	LC	Southern Malawi
Ptychadena broadleyi	Broadley's ridged frog	EN	Mulanje mountain, Zomba plateau

Key: EN (endangered), NT (near threatened), VU (vulnerable), LC (least concerned), DD (data deficient).

Plants

Malawi's rich plant diversity comprises over 6,000 species (122 of which are endemic) of flowering and non-flowering plants. There is a great diversity of wild flowers in Malawi, mostly in national parks, wildlife reserves, forest reserves, and protected hill slopes. A large number of orchid species, estimated at over 400 species also exist in the country. Malawi also grows a wide range of cereals, pulses, and tubers. Over 248 plant species are threatened based on the 2013 IUCN Red Data List. It may be the case that many more plant species are threatened but are not included on the IUCN Red Data List because of lack of information about their conservation status.

Reptiles

Malawi has 145 species of reptiles belonging to 19 families and 72 genera. The majority of Malawian reptiles are snakes of the family Colubridae (43 species), lizards of the families Scincidae (20 species) and Geckonidae (16 species). There are eight endemic reptile species, six of which are restricted to Mulanje Mountain while the other two occur in Nyika Plateau, Misuku Hills and Ntchisi Forest Reserve. Eight species, namely theNile crocodile(*Crocodylus* *niloticus*), the Mulanje Dwarf Chameleon (*Chamaeleo mlanjensis*), the Nyika Dwarf Chameleon (*Chamaeleo goetzei nyikae*), Pitless Pigmy Chameleon (*Rhampholeon nchisiensis*), the Dwarf Gecko (*Lygodactylus bonsi*), the Legless Skink (*Melanoseps ater*), Arnold's (Mulanje) Skink (*Proscelotes mlanjensis*), and the (Cross-barred Tree Snake *Dipsadoboa flavida flavida*) stand as threatened under IUCN.

Birds

To date, over 630 bird species have been recorded to occur in Malawi, with the Yellow-throated Apalis (*Apalis flavigularis*), as the country's only endemic bird, restricted to Mulanje, Zomba and Malosa mountains in Southern Malawi. The distribution of two species, the Thyolo Alethe (*Alethe choloensis*) and the Spotted Ground Thrush (*Zoothera Guttata*) has been highly affected by habitat loss. Other popular species that are not under conservation concern in Malawi include the Wattled Crane (*Bugeranus carunculatus*) of Nyika plateau. All vultures are locally critically endangered and have since disappeared from the majority of protected areas.

There are several other rare animal species that are endemic and endangered and need to be protected. These include: (i) *Cercopithecus albogularis* (Blue Monkey), (ii) *Loxodonta Africana* (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.

2.6.5 Wetland Resources

Malawi has some of Africa's most important wetland ecosystems, including areas along the shorelines of lakes Malawi, Chiuta and Chilwa, a diversity of dambo ecosystems and the marshes of the Shire River system. The main wetland ecosystems in Malawi include the following areas: (i) Lake Chilwa, Zomba district, (ii) Elephant and Ndindi Marshes along Shire River in Chikwawa and Nsanje districts, respectively, (Fig 2.25) (iii) Vwaza Marsh at Lake Kazuni in Mzimba and Rumphi districts, (iv) Lake Chiuta in Machinga district and (v) Lake Malawi lakeshore districts. These wetlands constitute 20% of the country's territorial area and are rich in flora and fauna. Wetlands such as Elephant Marsh and Lake Chilwa play an important ecological function as bird sanctuaries and destinations for migratory birds. In 1996, Malawi ratified the Ramsar Convention and Lake Chilwa was designated a wetland of international importance in 1997 because of its physical, biological, ecological and socio-economic attributes to people and the environment. The lake Chilwa wetland contains over 3,500 to 4,000 plant species, and more than 1,000 species of animals and micro-organisms. Climate change, especially in the form of droughts, adversely affects the flora and fauna in these wetlands. Although these wetlands are a hub of diversity, they are also a source of natural methane (CH_4) gas emissions, which is greenhouse gas that contributes to global warming.

Figure 2. 20 Wetlands along the Shire River; Shire Valley

2.6.6 Soil Resources

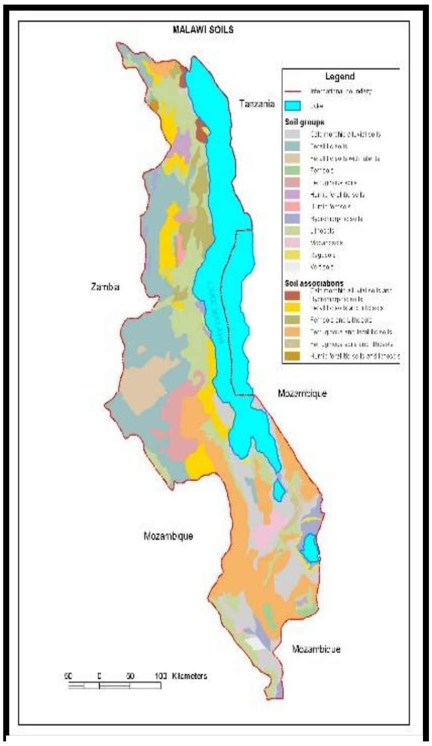


Figure 2. 21 Soils of Malawi

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). 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 (Fig. 2.21).

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 2.6 (Lowole, 1995, Lowole, 2008), personal communication). The most predominant soil classes include Lithosols (25%), Xanthic Ferralsols (15%), Eutric Fluvisols, Cambisols (9%) and Ferric Luvisols (7%).

2.6.7 Geology and Mineral Resources

The Geology of Malawi is dominated by metamorphic rocks of Precambrian to lower Palaeozoic age which are the oldest rocks. These oldest rocks are overlain sedimentary rocks of Permo-Triassic age and intruded by a variety of alkaline rocks of Jurassic to Cretaceous age. These are overlain by younger sediments (Tertiary to Quaternary agea) deposited in the major drainage basins of the country (Carter and Bennett, 1973; Kroner et al., 2001;).

The country is endowed with a variety of mineral resources with high potential for exploitation. The rare earth metals are a particularly distinctive feature of Malawi geology. There is potential for Oil, Gas and unconventional hydrocarbons in the Tertiary to recent sediments of Lake Malawi. Mineral and hydrocarbon deposits in Malawi can be grouped into four major associations as summarised in **Table 2.6.**

Table 2. 6 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)

Other minerals of high economic value are shown in Table 2.8 and Fig 2.27. 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. Principal commodities exploited include gemstones, sand, rock aggregate, coal and limestone.

Table 2. 7 Major Mineral groups in Malawi

Rock association	Potential Mineral Deposits
Residual weathering, placer and rift-related sedimentation	Bauxite, nickel, Titanium/REE/Zr, gold and gemstone placers
Sedimentary and volcanic cover rocks	Coal, Uranium, industrial minerals, gemstones
Alkaline Magmatism	Rare Earth metals, coltan, metals, nuclear metals, phosphate
Basement metamorphic and igneous rocks	Precious and base metals, industrial minerals, gemstones

Source: British Geological Survey (BGS, 2009)

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 LaFarge Cement Company. 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.

Table 2. 8 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 volcanic

Source: DoM (2007); Chipeta et al.(2008)

The need to develop a viable mining industry for Malawi is however clear. So far, the economy is heavily dependent on rain-fed agriculture, which is vulnerable to climate change.

Hence, the development of a mining industry is one way of diversifying the economy away from rain-fed-agriculture, there by also diversifying the foreign exchange base for the country.

2.6.8 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*.

2.6.9 Water Resources

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 depend 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.

2.6.10 Energy

The country relies heavily on biomass fuel and has one of the least per capita consumption of energy in sub-Saharan Africa (Taulo et al, 2015). Biomass fuel accounts for nearly 93% of the energy needs, petroleum products account for 3.5%, hydro-electricity constitutes 2.3% while coal constitutes 1% of the energy consumed. The remaining 0.2% comes from renewable energy sources (REIAMA, MEP).

Inadequate supply due to ageing infrastructure, high demand due to rapid population growth coupled with environmental degradation and climatic extremes are some of the problems rocking the country's power sector. As a way to improve the situation, there have been efforts to explore and exploit some of the existing the alternative energy sources and reduce the energy production monopoly by ESCOM, the country's sole electricity producer by bringing in independent power producers to supplement the efforts by the country's sole supplier. The Millennium Challenge Account (MCA) is at the moment supporting Energy sector reforms including splitting the roles of generation and distribution which are seen as one way to improve the efficiency of the power suppliers.

2.6.10.1 Energy Consumption

Almost all the households (97%) in Malawi use solid fuels (solid materials used) as a primary source of energy for cooking (GoM, 2012; NSO, 2014). This situation has persisted for several decades (GoM 2009b 2010; MCC 2010). The situation is worse in the rural areas where proportion is at 99%. Male and female-headed households show similar proportions 97% and 98%, respectively. By consumption quintile, there is universal use in the lowest quintile while 10% in the highest quintile use alternative sources of energy. Firewood is most common source of fuel used for cooking estimated at 88% followed by charcoal, 9%, electricity and others at 1% (GoM, 2012). Table 2.9 shows sources of energy at national and regional level.

Table 2. 9 Source of fuel for cooking at domestic level

Background characteristics	Firewood (%)	Electricity (%)	Charcoal (%)	Crop residue/Saw Dust/ Anima l Waste (%)
Malawi	87.7	2.5	8.9	0.8
Urban	41.9	12.6	44.6	0.5
Rural	96.2	0.6	2.3	0.9
North	95.3	1.1	3.5	0.1
Centre	89.9	2.1	7.6	0.3
South	83.8	3.1	11.5	1.5

Source: NSO (2014)

From Table 2.9, most households use firewood across the country. On the other hand, charcoal usage dominates in urban areas at 46%. This can partially be attributed to unreliable electricity supply where less than 1% of the rural population has access to electricity (Gamula et al., 2013). The overdependence on biomass and other fossil fuels is also evident at sector level as shown in Table 2.10. These patterns threaten Malawi's climate as forest resources being depleted are sinks of carbon dioxide (CO_2).

Table 2. 10 Total energy demand by sector by fuel in Malawi in 2008

Sector	Energy demand by fuel type (TJ)					
	Biomass	Coal	Electricity	Petroleum	Total	(%)
Household	127,574	5	1798	672	130,049	83.2
Industry	10,004	3481	2010	3130	18,625	11.9
Transport	270	15	35	5640	5960	3.8
Service	452	174	477	558	1661	1.1
Total	**138,300**	**3675**	**4320**	**10,000**	**156,295**	
% of Total	**88.5%**	**2.4%**	**2.8%**	**6.4%**	**100%**	**100**

Source: Gamula et al. (2013)

2.6.10.2 Alternative Energy Resources

Malawi is well endowed with a variety of sources of energy: biomass, coal, and many perennial rivers for hydropower generation, solar energy for heat and electricity generation, wind energy for water pumping and other minor applications, hot springs for geothermal power and uranium deposits for nuclear power generation. Petroleum products are exclusively imported (MEP, 2002).

2.6.10.3 Biomass and bio-energy

Biomass in the form of wood fuel is the largest form of primary energy consumed in Malawi, accounting for 97% of the total primary energy supply in the country (GoM, 2010b). Major sources of biomass available include fuelwood and forestry and agricultural residues, animal dung, energy crops and municipal wastes. Forest reserves are the main sources of fuelwood and contribute nearly 75% of the total biomass supply (Jumbe and Angelsen, 2011). Forests cover 3.2 million hectares, approximately 36% of the total land area with total available biomass resources being 275.5 million tonnes (Kambewa and Chiwaula, 2010). Sustainable fuel wood supplies from forests are estimated to be 42.4 million cubic metres of solid wood equivalent. Total demand for biomass energy is estimated at 8.92 million total wood equivalent or 13.38 million cubic metres solid wood.

Annual average production of sugarcane in Malawi is estimated at 2.5 million tons/year leaving behind over 950 000 tons which is a significant power source. There are two sugar mills in Malawi having potential to generate 62 MWe of electricity but currently only 18 MWe has been utilised. Bagasse-based electrical generation estimated at 251GWh, corresponds to about 25% of national electricity generation (UNEP, 2013). The country can also explore biogas potential of municipal solid waste (MSW) as well. Current estimated municipal solid waste (MSW) generation per day is 720 tons which gives theoretical potential for biogas production of 32,683 m^3/day corresponding to 70.6 MWh_{el}/y or 58.8 MWh_{th}/y (Karekezi *et al.,* 2003).

2.6.10.4 Coal

Coal is Malawi's most abundant fossil resource with probable coal reserves estimated at 1 billion metric tonnes and 22 million of which are proven reserves of a bituminous type. The coal deposits are scattered in various coal fields to the north and south of the country. The Ngana coal field with estimated proven reserves of 16 MT is the largest but with probable reserves estimated at 70 million tonnes (GoM, 2010c). Further exploration work might increase the total reserves of coal in the country.

A number of collieries in the northern and southern coal field mine the coal. Total annual production increased from about 34 000 metric tons in 2001 to about 80000 metric tons in 2010 (GoM, 2010c). Presently, the main consumers of the coal in Malawi are the tobacco processing, textile and sugar production, and beer brewing and cement industries. However due to inadequate supplies of electricity from hydro, feasibility studies are underway to establish two coal-fired all two coal-fired power stations at Zalewa and Salima with capacity of 300 MW and 100 MW respectively (Chiyembekeza, 2013). Due to the abundance of the coal resources in Malawi and its low prices, it could be the energy for the future for Malawi.

2.7. Hydrocarbon resources

Malawi does not have oil deposits, and relies entirely on imported petroleum products. However, previous work has shown geological successions and structures that have potential to host these resources within the Malawi Rift. Surestream and Simkara are some of the exploration companies that are currently carrying out exploration activities for hydrocarbons.

About 97% of the refined petroleum products used in Malawi are imported with the remaining 3% coming from locally-produced ethanol (NCST, 2011). The transport sector is the major consumer of the liquid fuels accounting for nearly 90% of the total consumption. The remaining 10% is used in the domestic, agricultural and manufacturing sectors.

2.8 Nuclear Energy

Malawi has uranium deposits in Karoo sedimentary basins in the north of the country and the the largest one is found at Kayerekera. The known recoverable resource of uranium at Kayelekera Mine is estimated at 63 000 tons, which is equivalent to 378 tons of U-235 (GoM, 2003). The deposit at Kayerekera was actively mined from 2009- 2014 when it went under care and maintenance due to the global decline in Uranium prices. In 2010, when the mine was fully operational, annual production output was estimated at 790 tons of uranium (U_30_8). Another deposit which is yet to be quantified is at Illomba in Chitipa district.

2.8.1 Renewable energy resources

Malawi has a large potential for renewable energy exploitation in a number of areas, the significant ones being solar energy, biomass, and hydropower with potential for geothermal and wind energy. Except for large scale hydropower, which serves as a major source of electricity, the current state of exploitation and utilization of the renewable energy sources in the country is very low, limited largely to pilot and demonstration projects. This section gives a review on the available energy potential of different renewable energy sources and the current status of exploitation is presented.

2.8.2 Hydropower

Malawi has an estimated gross theoretical potential of 1670 MW and the average power generation of 15 000 GWh/year. The technical and economically feasible hydro capacity has been estimated at 6 000 and 7 000 GWh/year, respectively (Taulo, 2007). Current hydropower generation is about 17% of the nation's hydropower potential and represents 98% of total installed grid-connected electricity generation capacity. Hydropower potential of Malawi is concentrated on the Shire River. The capacity ranges from 18 to 140 MW. The estimated hydro potential of the Shire River is about 600 MW, equivalent to an annual production of 3500 GWh (ibid). In addition, several smaller rivers such as the Songwe, South Rukuru, Dwangwa and Bua, have limited potential at a number of sites estimated to total about 300-400 MW (WEC, 2002).

In addition, Malawi also has huge untapped small hydropower potential (with capacities of less than 10 MW each) which are spread out across the country. The gross theoretical small hydro potential of the country is 150 MW, out of which only 4.5 MW of the economically feasible potential has been developed (MEM, 1997). The exploitability of these is limited by their projected costs, but they could be useful for off-grid or stand-alone-mini grid electrification.

2.8.3 Solar energy

Solar energy presents considerable potential that can contribute to a large extent to fill the gap of energy needs in Malawi. The country receives about 2138 to 3087 hours of sunshine and 2133 kWh/m^2/year. The global solar radiation on a horizontal surface ranges between 4.3 kWh/m^2/day minimum and 7 kWh/m^2/day maximum. The annual daily mean global solar radiation is about 5.86 kWh/m^2/day, equivalent to 250 million tonnes of oil equivalent. Maximum irradiation of 6.5-7.0 kWh/m^2/day occurs in September - October and the minimum of 4.3-4.6 kWh/m^2/day occurs in January-February or in June-July according to location. Peak hourly solar radiation is more than 1000 kWh/m^2 during November to December (Chima, 1998). Considering that many parts of the country receive 8 to 12 hours of sunshine per day of 244 W/m^2, the potential for using solar for electricity generation is very high. The total available solar energy potential over the total geographical area (i.e. 94,280 km^2), of Malawi is calculated to be 356,284,837 MWh/year.

2.8.4 Wind energy

Wind energy has been used on a small scale to supply water for both livestock and irrigation in Malawi. Although there is a dearth of information on the wind energy characteristics of the country, it seems the wind speeds are moderate to low, typically in the range of 2.0 - 7.0 metres/second (GoM, 2003). Preliminary results from studies conducted by Malawi's Meteorological Department suggest that the wind resource in Malawi cannot contribute significantly to a firm power generation; and that low speed aerogenerators could be operated for various applications such as milling of grains, pumping water and even lighting purposes in small remote villages around Malawi. It is particularly suited to water pumping as intermittent wind could still supply the needs when an adequate storage facility is incorporated. However, such assertion is contrasted by recent research findings which indicate that there is considerable potential for wind in the country. At present, the DoEA is collaborating with Malawi Renewable Energy Acceleration Programme (M-REAP) at the University of Malawi, an initiative funded by the Scottish Government, to undertake detailed wind measurements at five strategic sites as part of developing Malawi's wind atlas.

2.8.5 Geothermal energy

Geothermal energy has been extensively used for power generation and direct power applications in many countries of the world (Fridleifsson, 2003). As a consequence of Malawi's location in the East African Rift System (EARS), the country is endowed with significant potential reserves of geothermal energy. There are approximately 55 geothermal spots in Malawi, but three major ones identified for detailed investigation are: Chiweta, Mwankeja, and Nkhotakota. The combined geothermal potential from these major areas is 200 MWe (Gondwe et al., 2012). As for geothermal projects, some studies have been conducted to design a prototype Geothermal Power Plant for producing electricity. One of the ongoing related projects is a 30 MW Geothermal Power Plant at exploring stage in Nkhotakota, to be upgraded to 100 MW depending on the results of exploration drilling.

CHAPTER 3

GREENHOUSE GAS EMISSIONS FOR THE PERIOD 2001 TO 2017

3 National Greenhouse Gas Inventory

This chapters presents Malawi's Greenhouse Gas Inventory for the period beginning 2001 to 2017. It includes five main IPCC sectors, namely: Energy, Industrial Process and Product Use (IPPU), Agriculture, AFOLU, and Waste. The emissions reported in this GHG inventory are carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). The 2006 IPCC Guidelines were used to compile the inventory. Table 3.1 presents the methodologies used.

Table 3. 1: Methodologies used

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Method
1A1.Energy industries	T1
1A2.Manufacturing industries and construction	T1
1A 3.Transport	T1
1A 4.Other sectors	T1
1A 5.Other	T1
1B 1.Fugitive emissions from Solid fuels	T1
1B 2. Fugitive emissions from Oil and natural gas	NO
1C. CO_2 transport and storage	NO
2A.Mineral industry	T1
2B.Chemical industry	T1
2C.Metal industry	T1
2F.Product uses as ODS substitutes	NE
3A.Enteric fermentation	T1
3B.Manure management	T1
3C.Rice cultivation	T1
3D.Agricultural soils	T1
3E.Prescribed burning of savannas	T1
3F.Field burning of agricultural residues	T1
3G. Liming	T1
3H. Urea application	T1
3I.Other carbon-containing fertilizers	T1
3J.Other	T1
4A. Forest land	T1
4B. Cropland	T1
4C. Grassland	T1
4D. Wetlands	T1
4E. Settlements	T1
4F. Other land	T1
4G. Harvested wood products	T1
4H. Other	T1
5A.Solid waste disposal	T1
5B.Biological treatment of solid waste	NE
5C.Incineration and open burning of waste	NE
5D.Waste water treatment and discharge	T1
5E.Other	T1

The Global Warming Potentials (GWP) from the IPCC Second Assessment Report (SAR) were used to convert the GHG emissions to CO_2eq. The GWPs from the SAR are presented in Table 3.2.

Table 3. 2 SAR GWP values for 100-year time horizon

Gas	Chemical formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide 310	N_2O	310

Source: IPCC SAR

Table 3. 3 GHG Emissions in units of mass for 2010

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
Total National Emissions	468.71	1.61	1.61							
1 - Energy	939.02	0.30	0.30				NA	NA	NA	NA
1.A - Fuel Combustion	936.58	0.30	0.30				NA	NA	NA	NA
1.A.1 - Energy Industries	3.12	0.10	0.10				NA	NA	NA	NA
1.A.2 - Manufacturing Industries and	258.50	0.122	1				NA	NA	NA	NA
1.A.3 - Transport	647.47	0.13	0.03				NA	NA	NA	NA
1.A.4 - Other Sectors	27.49	14.13	0.16							
1.A.5 - Non-Specified	NO	NO	NO							
1.B - Fugitive emissions										
1.B.1 - Solid Fuels	NE	9.97	NE							
1.B.2 - Oil and Natural	NO	NO	NO				NO	NO	NO	NO
1.B.3 - Other emissions	NO	NO	NO				NO	NO	NO	NO
1.C - Carbon dioxide										
1.C.1 - Transport of CO2	NO			NO	NO	NO	NO	NO	NO	NO
1.C.2 - Injection and	NO		NO	NO	NO	NO	NO	NO	NO	NO
1.C.3 - Other										
2 - Industrial Processes	40.01	NE	NE							
2.A - Mineral Industry	40.01	NE								
2.A.1 - Cement production	16.07	NE								
2.A.2 - Lime production	23.84	NE								
2.A.3 - Glass Production	NO	NO								
2.A.4 - Other Process Uses	0.10	NO								
2.A.5 - Other (please	NA	NA								
2.B - Chemical Industry	NO	NO	NO	NA	NA	NA				
2.C - Metal Industry	NO	NO	NO	NA	NA	NA				
2.D - Non-Energy Products from Fuels and	NO	NO	NO				NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone	NE		NE	NE	NE	NE				
2.G - Other Product	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.H - Other	NA	NA	NA							
3 - Agriculture, Forestry,	-519.45	71.87	0.69				NA	NA	NA	NA
3.A - Livestock		64.55	0.66				NA	NA	NA	NA

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
3.B - Land	-562.58	NE	NE				NA	NA	NA	NA
3.C - Aggregate sources and non-CO2 emissions	88.71	7.32	0.03				NA	NA	NA	NA
3.D - Other	-45.58						NA	NA	NA	NA
4 - Waste	9.13	38.25	0.62				NA	NA	NA	NA
4.A - Solid Waste Disposal		20.16	NE				NA	NA	NA	NA
4.B - Biological Treatment		NE	NE				NA	NA	NA	NA
4.C - Incineration and	9.13	3.82	0.05				NA	NA	NA	NA
4.D - Wastewater		14.26	0.57				NA	NA	NA	NA
4.E - Other (please	NA	NA	NA				NA	NA	NA	NA
5 - Other	NA	NA	NA				NA	NA	NA	NA

Table 3. 4 GHG emissions in CO_2eq for 2010

Categories	Net CO_2	CH_4	N_2O	Total
Total National Emissions and Removals	468.71	2,644.47	500.35	3,613.53
1 - Energy	**939.02**	**332.02**	**93.40**	**1,364.44**
1.A - Fuel Combustion Activities	936.58	315.55	93.40	1345.54
1.A.1 - Energy Industries	3.12	16.02	31.53	50.67
1.A.2 - Manufacturing Industries and Construction	258.50	0.12	1.00	259.62
1.A.3 - Transport	647.47	2.72	9.87	660.07
1.A.4 - Other Sectors	27.49	296.69	51.00	375.18
1.A.5 - Non-Specified				
1.B - Fugitive emissions from fuels	NE	16.46		18.90
1.B.1 - Solid Fuels	NE	16.46		18.90
1.B.2 - Oil and Natural Gas	NO	NO	NO	
1.B.3 - Other emissions from Energy Production	NO	NO	NO	
1.C - Carbon dioxide Transport and Storage				
1.C.1 - Transport of CO2	NE			
1.C.2 - Injection and Storage	NE			
1.C.3 - Other	NO			
2 - Industrial Processes and Product Use	**40.01**	**0.00**	**0.00**	**40.01**
2.A - Mineral Industry	40.01			40.01
2.A.1 - Cement production	16.07			16.07
2.A.2 - Lime production	23.84			23.84
2.A.3 - Glass Production	NO			
2.A.4 - Other Process Uses of Carbonates	0.10			0.10
2.A.5 - Other (please specify)				
2.B - Chemical Industry		NO		
2.C - Metal Industry		**NO**		
2.D - Non-Energy Products from Fuels and Solvent Use		NO		
2.E - Electronics Industry				
2.F - Product Uses as Substitutes for Ozone Depleting				
2.G - Other Product Manufacture and Use	**NA**			
2.H - Other	NA			
3 - Agriculture, Forestry, and Other Land Use	**-519.45**	**1509.29**	**215.18**	**1,205.02**
3.A - Livestock		1355.61	205.29	1560.89
3.B - Land	-562.58			-562.58
3.C - Aggregate sources and non-CO2 emissions sources on land	88.71	153.68	9.90	252.29
3.D - Other	-45.58			-45.58
4 - Waste	**9.13**	**803.17**	**191.77**	**1,004.06**
4.A - Solid Waste Disposal		423.42		423.42
4.B - Biological Treatment of Solid Waste				
4.C - Incineration and Open Burning of Waste	9.13	80.28	15.59	104.99
4.D - Wastewater Treatment and Discharge		299.47	176.18	475.65
4.E - Other (please specify)				
5 - Other				

3.2 Key Category Analysis

The key category analysis was performed using the 2006 IPCC GHG Inventory Software and shown in Table 3.5 (level).and Table 3.6 (trend).

Table 3. 5: Key category analysis by level

IPCC Category code	IPCC Category	GHG	2010 Ex,t (Gg CO_2 eq)	|Ex,t| (Gg CO_2 eq)	Lx,t (%)	Cumulative Total of Column F(%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-2498.48	2498.	27.5	27.50
3.B.2.b	Land Converted to Cropland	CO_2	1589.39	1589.	17.5	45.00
3.A.1	Enteric Fermentation	CH_4	1246.56	1246.	13.7	58.72
1.A.3.b	Road Transportation	CO_2	616.96	616.9	6.79	65.52
4.A	Solid Waste Disposal	CH_4	423.42	423.4	4.66	70.18
1.A.4	Other Sectors – Biomass	CH_4	401.23	401.2	4.42	74.60
4.D	Wastewater Treatment and Discharge	CH_4	299.47	299.4	3.30	77.89
3.B.3.b	Land Converted to Grassland	CO_2	261.89	261.8	2.88	80.77
3.A.2	Manure Management	N_2O	205.29	205.2	2.26	83.03
3.B.6.b	Land Converted to Other land	CO_2	188.29	188.2	2.07	85.11
4.D	Wastewater Treatment and Discharge	N_2O	176.18	176.1	1.94	87.05
1.A.2	Manufacturing Industries and Construction - Solid	CO_2	154.05	154.0	1.70	88.74
3.B.1.b	Land Converted to Forest land	CO_2	-128.45	128.4	1.41	90.16
3.C.7	Rice cultivations	CH_4	122.40	122.4	1.35	91.50
3.A.2	Manure Management	CH_4	109.05	109.0	1.20	92.71
1.A.2	Manufacturing Industries and Construction -	CO_2	104.45	104.4	1.15	93.85
3.C.3	Urea application	CO_2	88.71	88.71	0.98	94.83
4.C	Incineration and Open Burning of Waste	CH_4	80.28	80.28	0.88	95.72
1.A.4	Other Sectors – Biomass	N_2O	71.52	71.52	0.79	96.50
3.D.1	Harvested Wood Products	CO_2	-45.58	45.58	0.50	97.00
1.A.1	Energy Industries - Biomass	N_2O	31.52	31.52	0.35	97.35
3.C.1	Emissions from biomass burning	CH_4	31.28	31.28	0.34	97.70
1.A.3.a	Civil Aviation	CO_2	29.88	29.88	0.33	98.02
1.A.4	Other Sectors - Liquid Fuels	CO_2	27.49	27.49	0.30	98.33
3.B.5.b	Land Converted to Settlements	CO_2	24.78	24.78	0.27	98.60
2.A.2	Lime production	CO_2	23.84	23.84	0.26	98.86
1.B.1	Solid Fuels	CH_4	16.46	16.46	0.18	99.04
2.A.1	Cement production	CO_2	16.07	16.07	0.18	99.22
1.A.1	Energy Industries - Biomass	CH_4	16.01	16.01	0.18	99.40
4.C	Incineration and Open Burning of Waste	N_2O	15.59	15.59	0.17	99.57
3.C.6	Indirect N2O Emissions from manure	N_2O	9.69	9.69	0.11	99.68
1.A.3.b	Road Transportation	N_2O	9.61	9.61	0.11	99.78
4.C	Incineration and Open Burning of Waste	CO_2	9.13	9.13	0.10	99.88
1.A.1	Energy Industries - Liquid Fuels	CO_2	3.12	3.12	0.03	100.00
1.A.3.b	Road Transportation	CH_4	2.72	2.72	0.03	99.91
1.B.1	Solid Fuels	CO_2	2.44	2.44	0.03	99.94
1.A.2	Manufacturing Industries and Construction - Solid	N_2O	0.75	0.75	0.01	99.95

1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0.64	0.64	0.01	99.95
1.A.3.a	Civil Aviation	N_2O	0.26	0.26	0.00	99.96
1.A.2	Manufacturing Industries and Construction -	N_2O	0.26	0.26	0.00	99.96
3.C.5	Indirect N2O Emissions from managed soils	N_2O	0.20	0.20	0.00	99.96
2.A.4	Other Process Uses of Carbonates	CO_2	0.10	0.10	0.00	99.96
1.A.2	Manufacturing Industries and Construction -	CH_4	0.09	0.09	0.00	99.96
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.08	0.08	0.00	99.96
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.07	0.07	0.00	99.97
1.A.2	Manufacturing Industries and Construction - Solid	CH_4	0.03	0.03	0.00	99.97
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.01	0.01	0.00	99.97
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0.01	0.01	0.00	99.97
1.A.3.a	Civil Aviation	CH_4	0.00	0.00	0.00	99.97
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.00	0.00	0.00	99.97
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0.00	0.00	0.00	99.97
2.B.6	Titanium Dioxide Production	CO_2	0.00	0.00	0.00	99.97
1.A.1	Energy Industries - Solid Fuels	CO_2	0.00	0.00	0.00	100.00

3.3 General Quality Assurance and Quality Control

In accordance with the IPCC requirements, all GHG Inventories should undergo Quality Assurance and Quality Control. Malawi's National GHG Inventory has undergone a number of reviews on a number of levels by internal and external reviewers outside EAD. It has also undergone international peer reviews by reviewers recognized by UNFCCC both local and international to ensure Quality Assurance and Quality Control. In addition, it has also undergone international peer review by experts from the UNFCCC who came up with a number of recommendations to improve the draft inventories and these were shared with the Team of Reviewers from Zimbabwe, Bees Consultancy Services. The inventory was also presented to national stakeholders for review, comments and validation. The Inventory was thereafter finalized once all the comments were addressed.

3.3.1 Quality Control

Malawi's GHG Inventory has undergone Quality Control checks in terms of the calculations, data processing and completeness of the data. In situations where data was not available notational keys have been inserted to indicate as such. The quality control process has been undertaken with reference to the Good Practice Guidance which ensures data completeness, correctness and integrity and also identify errors and omissions. The GHG Inventory was reviewed by international recognised peer reviewers both from the UNFCCC and independent Consultants.

3.4 Uncertainty assessment

Uncertainty assessment was conducted using the IPCC Inventory software (Table 3.6). The highest combined uncertainties emanated from the Energy sector, largely driven by solid and liquid fuels use in that sector.

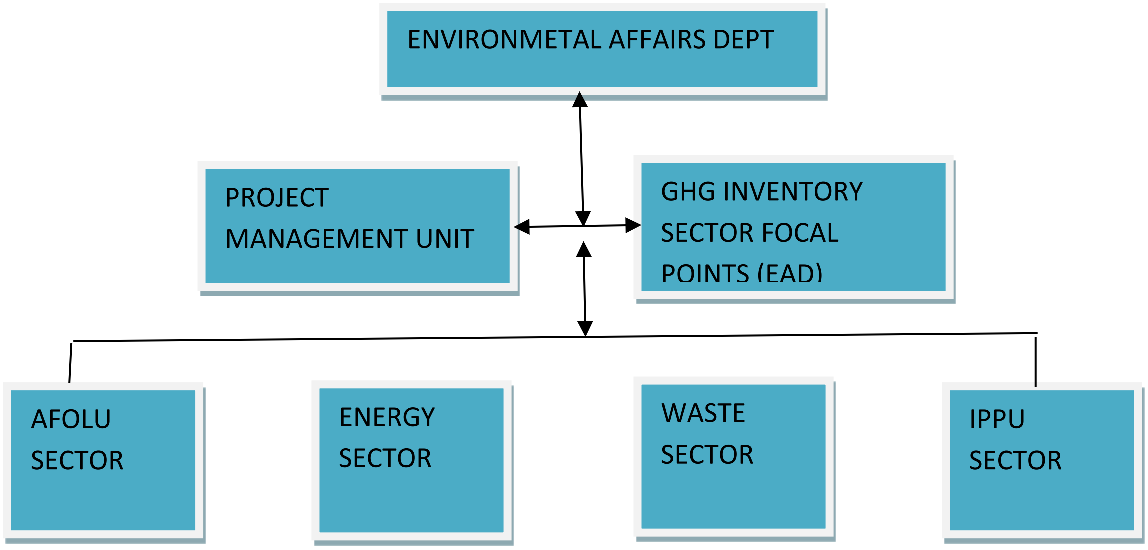
Table 3. 6: Uncertainty analysis for the reporting year, 2010

2006 IPCC Categories	Gas	Year T emissions or removals (Gg CO_2 eq)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
1.A.1.c.i - Manufacture of Solid Fuels – Biomass	N_2O	31.52	5.00	304.5	304.59
1.A.4.b - Residential – Biomass	N_2O	71.52	5.00	297.7	297.77
1.A.1.c.i - Manufacture of Solid Fuels – Biomass	CH_4	16.01	5.00	245.4	245.51
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	2.72	5.00	244.6	244.74
1.A.4.b - Residential - Liquid Fuels	N_2O	0.07	5.00	236.3	236.42
1.A.1.a.i - Electricity Generation - Liquid Fuels	N_2O	0.01	5.00	228.7	228.84
1.A.4.b - Residential – Biomass	CH_4	401.23	5.00	227.2	227.33
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	9.61	5.00	209.9	210.00
1.A.4.b - Residential - Liquid Fuels	CH_4	0.08	5.00	200.0	200.06
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N_2O	0.26	5.00	150.0	150.08
1.A.3.d.ii - Domestic Water-borne Navigation - Liquid	N_2O	0.01	5.00	140.0	140.09
2.A.1 - Cement production	CO_2	16.07	35.00	0.00	35.00
1.A.4.b - Residential – Biomass	CO_2	7671.45	5.00	18.69	19.35
1.A.1.c.i - Manufacture of Solid Fuels – Biomass	CO_2	2846.89	5.00	18.69	19.35
2.A.2 - Lime production	CO_2	23.84	15.00	0.00	15.00

2006 IPCC Categories	Gas	Year T emissions or removals (Gg CO_2 eq)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
1.A.4.b - Residential - Liquid Fuels	CO_2	27.49	5.00	6.14	7.92
1.A.1.a.i - Electricity Generation - Liquid Fuels	CO_2	3.12	5.00	6.14	7.92
1.A.2 - Manufacturing Industries and Construction - Solid	CO_2	154.05	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction -	CO_2	104.45	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Solid	N_2O	0.75	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction -	N_2O	0.26	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction -	CH_4	0.09	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Solid	CH_4	0.03	5.00	5.00	7.07
1.A.3.d.ii - Domestic Water-borne Navigation - Liquid	CO_2	0.64	5.00	4.30	6.60
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO_2	29.88	5.00	4.17	6.51
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	616.96	5.00	3.07	5.87
1.B.1.a.i.1 – Mining	CO_2	2.14	0.00	0.00	0.00
1.B.1.a.i.1 – Mining	CH_4	16.46	0.00	0.00	0.00
3.A.1.a.i - Dairy Cows	CH_4	87.28	0.00	0.00	0.00
3.A.1.a.ii - Other Cattle	CH_4	668.84	0.00	0.00	0.00
3.A.1.c – Sheep	CH_4	31.72	0.00	0.00	0.00
3.A.1.d – Goats	CH_4	408.86	0.00	0.00	0.00
3.A.1.h – Swine	CH_4	49.86	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	N_2O	5.17	0.00	0.00	0.00
3.A.2.a.ii - Other cattle	N_2O	199.10	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	CH_4	0.89	0.00	0.00	0.00
3.A.2.a.ii - Other cattle	CH_4	21.58	0.00	0.00	0.00
3.A.2.c – Sheep	CH_4	1.27	0.00	0.00	0.00
3.A.2.d – Goats	CH_4	35.45	0.00	0.00	0.00
3.A.2.h – Swine	CH_4	49.86	0.00	0.00	0.00
3.B.1.a - Forest land Remaining Forest land	CO_2	-2498.48	0.00	0.00	0.00
3.B.1.b.i - Cropland converted to Forest Land	CO_2	-106.45	0.00	0.00	0.00
3.B.1.b.ii - Grassland converted to Forest Land	CO_2	-9.30	0.00	0.00	0.00
3.B.1.b.iii - Wetlands converted to Forest Land	CO_2	-12.70	0.00	0.00	0.00
3.B.2.b.i - Forest Land converted to Cropland	CO_2	1589.38	0.00	0.00	0.00
3.B.2.b.iii - Wetlands converted to Cropland	CO_2	0.01	0.00	0.00	0.00
3.B.3.b.i - Forest Land converted to Grassland	CO_2	261.89	0.00	0.00	0.00
3.B.5.b.i - Forest Land converted to Settlements	CO_2	24.78	0.00	0.00	0.00
3.B.6.b.i - Forest Land converted to Other Land	CO_2	188.29	0.00	0.00	0.00
3.C.1.a - Biomass burning in forest lands	CH_4	27.15	0.00	0.00	0.00
3.C.1.b - Biomass burning in croplands	CH_4	0.18	0.00	0.00	0.00
3.C.1.c - Biomass burning in grasslands	CH_4	3.95	0.00	0.00	0.00
3.C.3 - Urea application	CO_2	88.71	0.00	0.00	0.00
3.C.5 - Indirect N2O Emissions from managed soils	N_2O	0.20	0.00	0.00	0.00
3.C.6 - Indirect N2O Emissions from manure	N_2O	9.69	0.00	0.00	0.00
3.C.7 - Rice cultivations	CH_4	122.40	0.00	0.00	0.00
3.D.1 - Harvested Wood Products	CO_2	-45.58	0.00	0.00	0.00
4.A - Solid Waste Disposal	CH_4	423.42	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CO_2	9.13	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CH_4	80.28	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	N_2O	15.59	0.00	0.00	0.00
4.D.1 - Domestic Wastewater Treatment and Discharge	CH_4	299.47	0.00	0.00	0.00
4.D.1 - Domestic Wastewater Treatment and Discharge	N_2O	176.18	0.00	0.00	0.00

3.5 Inventory management system

The EAD has overall responsibility for the inventory. A number of relevant agencies and organizations were involved in providing data. Focal persons were appointed in the key institutions. Key public institutions and companies that prided data provision included the National Statistical Office (NSO), Department of Mines, Department of Economic Planning and Development, Ministry of Commerce, Trade and Industry, Shayona Cement Limited. AFOLU: Activity data was collected from public and private sector organizations.



Institutional Arrangements for preparing GHG Inventories

3.6 Key institutions and their roles

Table 3. 7 Key institutions and their roles

Institution	**Role(s)**
Environment Affairs Department	Overall responsibility for inventory
Department of Energy Affairs	Data provider-Energy
Malawi Energy Regulatory Authority	Data provider-Energy
National Statistical Office	Data provider-All sectors
Department of Mines	Data provider-Energy
Department of Economic Planning and Development	Data provider -All sectors
Ministry of Commerce, Trade and Industry	Data provider-IPPU
Shayona Cement Limited	Data provider-IPPU
Department of Mines	Data provider-Energy
Malawi Revenue Authority	Data provider -All sectors
Ministry of Agriculture	Data provider-AFOLU
Irrigation and Water Development	Data provider AFOLU
Irrigation and Water Development (MAI&WD).	Data provider AFOLU
Department of Animal Health and Livestock Development	Data provider AFOLU
And Agricultural Development Divisions (ADDs).	Data provider AFOLU
Famine Early Warning System (FEWSNET)	Data provider AFOLU
Agriculture Organization Databank	Data provider AFOLU

Karonga town Council	Data provider-Waste
Mzuzu City Council	Data provider-Waste
Kasungu town Council,	Data provider Waste
Central Region: Lilongwe City Council,	Data provider Waste
Salima town/district Council,	Data provider Waste
Dedza town Council	Data provider Waste
Blantyre City Council,	Data provider Waste
Zomba City Council,	Data provider Waste
Mulanje town Council	Data provider Waste
Mangochi town Council	Data provider Waste
Balaka town Council	Data provider Waste
Machinga town Council.	Data provider Waste

3.7 Data management and archiving

EAD will establish and document the process for making the inventory a continuous process. Arrangements will be put in place between the inventory compilers and data providers. The arrangements may be legal instruments, Memorandum of Understanding (MoUs), or any formal arrangements, as applicable. EAD will also document and archive all information relating to the planning, preparation, QA\QC and management of inventory activities. The GHG Inventory management system has been put in place and its main objective is to collect and archive data on a continuous basis.

3.8 Inventory improvement plan

Table 3. 8 Improvement plan

Identified gap	Planned improvement	Status
The type of arrangements established between data providers and inventory compilers or the role of involved institutions were not described.	Include a description of the arrangements and institutions involved in the inventory process	EAD to establish and document the process for making the inventory a continuous process. Arrangements have been put in place between the inventory compilers and data providers. The arrangements will be legal instruments, MoUs, or any formal arrangements, as applicable. MOUs yet to be signed between EAD and the inventory compilers.
The processes for archiving the data and outputs of the inventory processes, for instance, inventory planning, preparation, and management	Document and archive all information relating to the planning, preparation, QA\QC and management of inventory activities.	The GHG Inventory management system has been put in place and its main objective is to collect and archive data on a continuous basis.

Identified gap	Planned improvement	Status
of inventory activities and QC activities, were not reported.		
Malawi Energy sector is dominated by biomass (85.6%), but non-CO_2 emissions from biomass were not estimated.	Estimate CO_2 emissions, but should not be included in national CO_2 emissions from fuel combustion. Include other GHG emissions from biomass fuel should be included in the national total.	This will be rectified in the Fourth National Communication.

3.9 Research and systematic observation

Malawi has made some strides in developing local emission factors for AFOLU specifically for livestock. The Lilongwe University of Agriculture and Natural Resources (LUANAR) has been leading the process which is still in progress.

3.10 Energy sector

3.10.1 Introduction

Malawi has undertaken two GHG inventories of emissions by sources in the Energy sector. Both inventories used Reference Approach (top-down) method, following the revised 1996 IPCC Guidelines for conducting GHG inventory, due to unavailability of key activity data. The INC, covered the period from 1990 to 1994 whilst the SNC covered the period from 1995 to 2000. The two inventories covered CO_2, CH_4, N_2O, nitrogen oxide (NO_X) and CO. Emissions from fuel combustion in the sub-categories of mobile (using petroleum) and stationary (using coal) were estimated. The 2006 IPCC Guidelines were used in the TNC the GHG Inventory for the Energy sector of Malawi covers the period from 2001 to 2017. The gases covered are direct GHGs in the sector, namely: CO_2, CH_4 and N_2O. Table 3.9 shows the GHGs emitted in the Energy sector in 2010.

Table 3. 9 GHGs (Gg) emitted from the Energy sector in 2010

Categories	CO_2	CH_4	N_2O
1 - Energy	939.02	20.79	0.37
1.A - Fuel Combustion Activities	936.58	20.01	0.37
1.A.1 - Energy Industries	3.12	0.76	0.10
1.A.1.a - Main Activity Electricity and Heat Production	3.12	NE	NE
1.A.1.a.i - Electricity Generation	3.12	NE	NE
1.A.1.a.ii - Combined Heat and Power Generation (CHP)			
1.A.1.a.iii - Heat Plants			
1.A.1.b - Petroleum Refining			
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries		0.76	0.10
1.A.1.c.i - Manufacture of Solid Fuels		0.76	0.10
1.A.1.c.ii - Other Energy Industries			
1.A.2 - Manufacturing Industries and Construction	258.50	0.01	NE
1.A.3 - Transport	647.47	0.13	0.03
1.A.3.a - Civil Aviation	29.87	0.004	0.216
1.A.3.a.i - International Aviation (International Bunkers) (1)	1.4935	0.0002	0.0108
1.A.3.a.ii - Domestic Aviation	28.3765	0.0038	0.2052
1.A.3.b - Road Transportation	616.96	0.13	0.03
1.A.3.b.i - Cars			
1.A.3.b.i.1 - Passenger cars with 3-way catalysts			
1.A.3.b.i.2 - Passenger cars without 3-way catalysts			
1.A.3.b.ii - Light-duty trucks			
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts			
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts			
1.A.3.b.iii - Heavy-duty trucks and buses			
1.A.3.b.iv - Motorcycles			
1.A.3.b.v - Evaporative emissions from vehicles			
1.A.3.b.vi - Urea-based catalysts	NE		
1.A.3.c - Railways	NE	NE	NE
1.A.3.d - Water-borne Navigation	0.64	NE	NE
1.A.3.d.i - International water-borne navigation (International bunkers) (1)			

Categories	CO_2	CH_4	N_2O
1.A.3.d.ii - Domestic Water-borne Navigation	0.64	NE	NE
1.A.3.e - Other Transportation			
1.A.3.e.i - Pipeline Transport			
1.A.3.e.ii - Off-road			
1.A.4 - Other Sectors	27.49	19.11	0.23
1.A.4.a - Commercial/Institutional			
1.A.4.b - Residential	27.49	19.11	0.23
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	NE	NE	NE
1.A.4.c.i - Stationary	NE	NE	NE
1.A.4.c.ii - Off-road Vehicles and Other Machinery			
1.A.4.c.iii - Fishing (mobile combustion)			
1.A.5 - Non-Specified			
1.A.5.a - Stationary			
1.A.5.b - Mobile			
1.A.5.b.i - Mobile (aviation component)			
1.A.5.b.ii - Mobile (water-borne component)			
1.A.5.b.iii - Mobile (Other)			
1.A.5.c - Multilateral Operations (1)(2)			
1.B - Fugitive emissions from fuels			
1.B.1 - Solid Fuels			
1.B.1.a - Coal mining and handling		9.969	
1.B.1.a.i - Underground mines		9.969	
1.B.1.a.i.1 - Mining		9.146	
1.B.1.a.i.2 - Post-mining seam gas emissions		0.823	
1.B.1.a.i.3 - Abandoned underground mines			
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	NO	NO	
1.B.1.a.ii - Surface mines	NO	NO	
1.B.1.a.ii.1 - Mining	NE	NE	
1.B.1.a.ii.2 - Post-mining seam gas emissions	NO	NO	
1.B.1.b - Uncontrolled combustion and burning coal dumps			
1.B.1.c - Solid fuel transformation			
1.B.2 - Oil and Natural Gas	NO		
1.B.3 - Other emissions from Energy Production			
1.C - Carbon dioxide Transport and Storage	NO		
1.C.3 - Other	NA		
Memo Items (3)			
International Bunkers			
1.A.3.a.i - International Aviation (International Bunkers) (1)			
1.A.3.d.i - International water-borne navigation (International bunkers) (1)			
1.A.5.c - Multilateral Operations (1)(2)			
Information Items			
CO_2 from Biomass Combustion for Energy Production	10518.339		

Table 3. 10 **GHG (CO_2eq) emissions from Energy in 2010**

	Emissions (Gg)				**% contribution**
Categories	**CO_2**	**CH_4**	**N_2O**	**Total (CO_2eq)**	
1 - Energy	939.02	436.63	113.99	1,489.65	100.00%
1.A - Fuel Combustion Activities	936.58	420.17	113.99	1,470.74	98.73%
1.A.1 - Energy Industries	3.12	16.02	31.53	50.67	3.40%
1.A.1.a - Main Activity Electricity and Heat Production	3.12	NE	0.01	3.13	0.21%
1.A.1.a.i - Electricity Generation	3.12	NE	0.01	3.13	0.21%
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	0.00	16.01	31.52	47.53	3.19%
1.A.1.c.i - Manufacture of Solid Fuels	0.00	16.01	31.52	47.53	3.19%
1.A.2 - Manufacturing Industries and Construction	258.50	0.12	1.00	259.62	17.43%
1.A.3 - Transport	647.47	2.72	9.87	660.07	44.31%
1.A.3.a - Civil Aviation	29.87	0.004	0.216	30.14	2.02%
1.A.3.a.i - International Aviation (international bunkers) (1)	1.4935	0.0002	0.013	0.507	0.14%
1.A.3.a.ii - Domestic Aviation	28.3765	0.0038	0.247	28.633	1.92%
1.A.3.b - Road Transportation	616.96	2.72	9.61	629.28	42.24%
1.A.3.c - Railways					0.00%
1.A.3.d - Water-borne Navigation	0.64		0.01	0.64	0.04%
1.A.3.d.ii - Domestic Water-borne Navigation	0.64		0.01	0.64	0.04%
1.A.4 - Other Sectors	27.49	401.31	71.59	500.39	33.59%
1.A.4.b - Residential	27.49	401.31	71.59	500.39	33.59%
1.A.5 - Non-Specified					0.00%
1.B - Fugitive emissions from fuels					
1.B.1 - Solid Fuels					
1.B.1.a - Coal mining and handling	NE	9.969	16.46	26.43	1.8%
1.B.1.a.i - Underground mines	NE	9.969	16.46	26.43	1.8%
1.B.1.a.i.1 - Mining	NE	9.146	16.46	26.43	1.8%
1.B.1.a.i.2 - Post-mining seam gas emissions	NE	0.823	NE	0.823	0.08%
1.B.2 - Oil and Natural Gas					
1.B.3 - Other emissions from Energy Production					
1.C - Carbon dioxide Transport and Storage					
1.C.1 - Transport of CO_2					
1.C.2 - Injection and Storage					
1.C.3 - Other					

The total GHG emissions in the Energy sector is dominated by CO_2 (63.04%), the rest being CH_4 and N_2O. This is because; most of the sources of GHG are from fossil fuel combustion, whose main gaseous product is CO_2. Total GHG from the Energy sector from 2001 to 2017 are presented in figure 3.1.

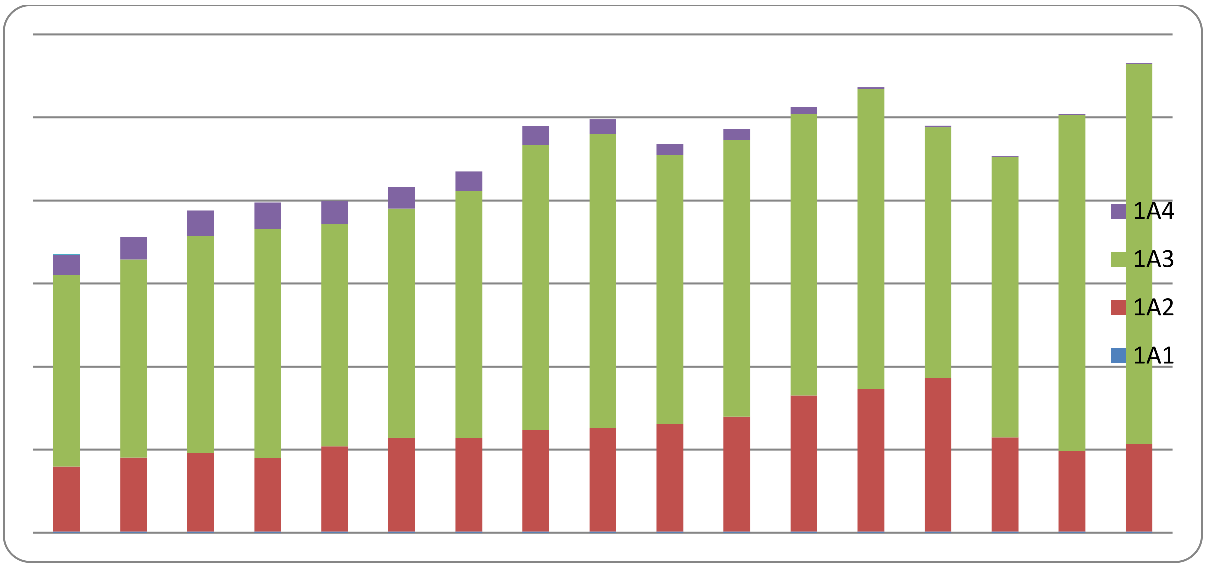
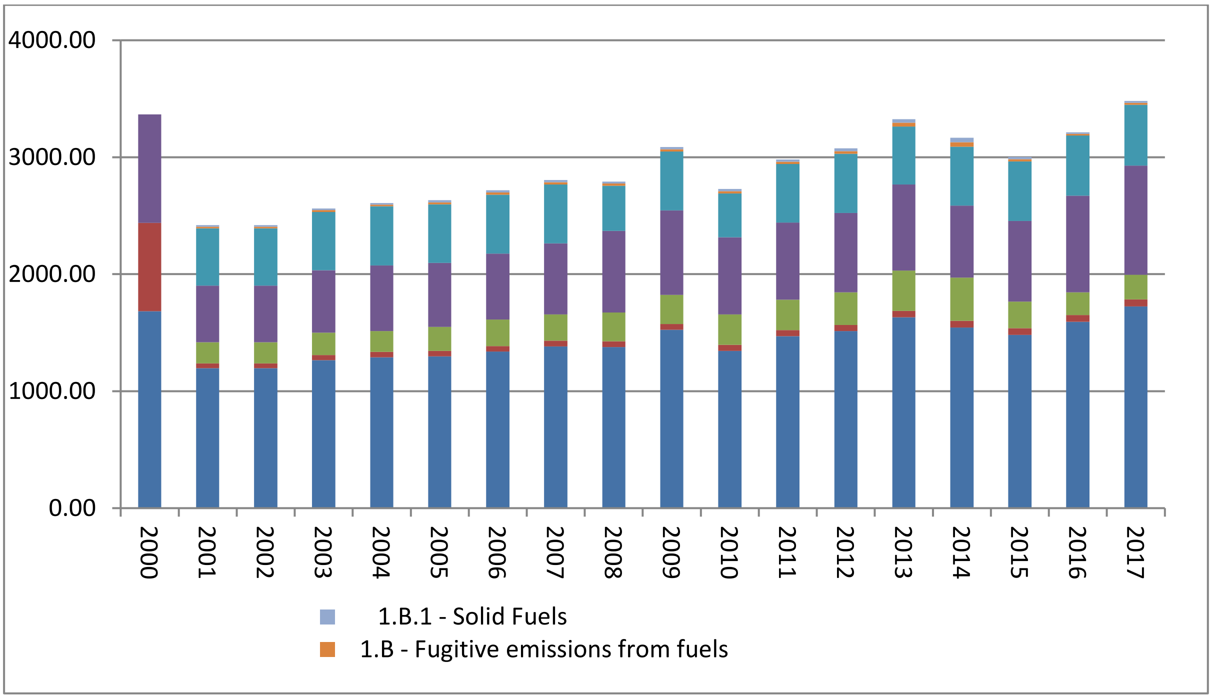


Figure 3. 1: Trends of CO_2 emissions from Energy Sector from year 2001 to 2017

The trend shows a general increase in the GHGs from the Energy sector over the period 2001 to 2017. The total emissions increased from 669.61 to 1,130.77 Gg of CO_2, from the year 2001 to 2017, respectively. From SNC, the total emission in 2000 was 726 Gg of CO_2eq. The SNC reported for biomass emissions in the Energy sector. However, to avoid double counting, emissions from biomass are reported in the AFOLU in the TNC, as dictated by the IPCC Guidelines for conducting national GHG inventory (IPCC, 2006).



3.10.2 Key Category Analysis

Key category analysis was done using the IPCC Inventory Software version 2.54. Tables 3.10 and 3.11 show the results based on level assessment and trend assessment, respectively.

Table 3. 11 Energy sector Key Category Analysis results based on level assessment

IPCC Category code	IPCC Category	GHG	"|Ex,t| (Gg CO_2 eq)"	Lx,t (%)	Cumulative (%)
1.A.3.b	**Road Transportation**	**CO_2**	**616.96**	**41.42**	**41.42**
1.A.4	**Other Sectors - Biomass**	**CH_4**	**401.23**	**26.93**	**68.35**
1.A.2	**Manufacturing Industries and Construction - Solid Fuels**	**CO_2**	**154.05**	**10.34**	**78.69**
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO_2**	**104.45**	**7.01**	**85.70**
1.A.4	**Other Sectors - Biomass**	**N_2O**	**71.52**	**4.80**	**90.50**
1.A.1	**Energy Industries - Biomass**	**N_2O**	**31.52**	**2.12**	**92.62**
1.A.3.a	**Civil Aviation**	**CO_2**	**29.88**	**2.01**	**94.63**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**27.49**	**1.85**	**96.47**
1.B.1	Solid Fuels	CH_4	16.46	1.11	97.58
1.A.1	Energy Industries - Biomass	CH_4	16.01	1.08	98.65
1.A.3.b	Road Transportation	N_2O	9.61	0.64	99.30
1.A.1	Energy Industries - Liquid Fuels	CO_2	3.12	0.21	99.51
1.A.3.b	Road Transportation	CH_4	2.72	0.18	99.69
1.B.1	Solid Fuels	CO_2	2.44	0.16	99.85
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N_2O	0.75	0.05	99.90
1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0.64	0.04	99.95
1.A.3.a	Civil Aviation	N_2O	0.26	0.02	99.96
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.26	0.02%	99.98%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.09	0.01%	99.99%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.08	0.01%	99.99%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.07	0.00	100.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CH_4	0.03	0.00	100.00
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.01	0.00	100.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0.01	0.00	100.00
1.A.3.a	Civil Aviation	CH_4	0.00	0.00	100.00
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.00	0.00	100.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0.00	0.00	100.00

The identified key categories are:

i. 1.A.3.b Road Transportation
ii. 1.A.4 Other Sectors - Biomass
iii. 1.A.2 Manufacturing Industries and Construction - Solid Fuels
iv. 1.A.2 Manufacturing Industries and Construction - Liquid Fuels

v. 1.A.4 Other Sectors - Biomass
vi. 1.A.1 Energy Industries - Biomass
vii. 1.A.3.a Civil Aviation
viii. 1.A.4 Other Sectors - Liquid Fuel

Table 3. 12 **Energy sector Key Category Analysis results based on trend assessment**

IPCC Category code	IPCC Category	Greenhouse gas	1990 Year Estimate Ex0 (Gg CO_2 eq)	2010 Year Estimate Ext (Gg CO_2 eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
1.A.1	Energy Industries - Liquid Fuels	CO_2	0	3.12	0	0	0
1.A.1	Energy Industries - Liquid Fuels	CH_4	0	0.00	0	0	0
1.A.1	Energy Industries - Liquid Fuels	N_2O	0	0.01	0	0	0
1.A.1	Energy Industries - Biomass	CH_4	0	16.01	0	0	0
1.A.1	Energy Industries - Biomass	N_2O	0	31.52	0	0	0
1.A.2	Manufacturing Industries and	CO_2	0	104.45	0	0	0
1.A.2	Manufacturing Industries and	CH_4	0	0.09	0	0	0
1.A.2	Manufacturing Industries and	N_2O	0	0.26	0	0	0
1.A.2	Manufacturing Industries and	CO_2	0	154.05	0	0	0
1.A.2	Manufacturing Industries and	CH_4	0	0.03	0	0	0
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N_2O	0	0.75	0	0	0
1.A.3.a	Civil Aviation	CO_2	0	29.88	0	0	0
1.A.3.a	Civil Aviation	CH_4	0	0.00	0	0	0
1.A.3.a	Civil Aviation	N_2O	0	0.26	0	0	0
1.A.3.b	Road Transportation	CO_2	0	616.96	0	0	0
1.A.3.b	Road Transportation	CH_4	0	2.72	0	0	0
1.A.3.b	Road Transportation	N_2O	0	9.61	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0	0.64	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0	0.00	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0	0.01	0	0	0
1.A.4	Other Sectors - Liquid Fuels	CO_2	0	27.49	0	0	0
1.A.4	Other Sectors - Liquid Fuels	CH_4	0	0.08	0	0	0
1.A.4	Other Sectors - Liquid Fuels	N_2O	0	0.07	0	0	0
1.A.4	Other Sectors - Biomass	CH_4	0	401.23	0	0	0
1.A.4	Other Sectors - Biomass	N_2O	0	71.52	0	0	0
1.B.1	Solid Fuels	CO_2	0	2.44	0	0	0
1.B.1	Solid Fuels	CH_4	0	16.46	0	0	0

3.10.3 Energy sector GHG methodology

In this NIR, the development of GHG inventory in the Energy sector has involved several steps. The first step involved stakeholder consultations, where among others, previous national experts for the INC and SCN projects, officials from EAD and Department of Energy Affairs (DEA) were consulted. The second step involved reviewing relevant literature including INC, SNC, the 2006 IPCC GHG guidelines and other related reports and publications.

A questionnaire was used as a tool to collect the activity data. The process of developing the questionnaire was informed from the review of the 2006 IPCC GHG Inventory Software under the Energy Sector and the 2006 IPCC GHG Guidelines, as well as expert judgment of the sectoral experts. In order to make sure that the questionnaire was efficient, it underwent a review by experts, which were identified by the EAD. The respondents were purposefully selected from organizations engaged in activities that emit GHG from the Energy sector in Malawi. These organizations were identified through desk study, consultations and Energy sector inventory compilers' knowledge on the Malawi's energy sector. The activity data from the organisations was then arranged according to the societal and economic activity in the Energy sector.

The GHG inventory in the Energy sector employed the sectoral approach, using the Tier 1 IPCC methodology. Tier 1 methodology was chosen due to absence of country specific emission factors. The availability of information on how energy is used at sector level of the Malawian economy informed the choice of using the sectoral approach. Under the Tier 1 approach, emissions are estimated based on amount of fuel combusted and the average emission factors.

3.10.4 GHG emissions by category

This section presents GHGs from the Energy sector by category

3.10.4.1 1. A.1 - Energy Industries

Table 3.21 presents the GHGs from Energy Industries. The emissions are dominated by CH_4 and N_2O from the manufacture of solid fuels.

Table 3. 13 GHGs from 1.A.1 - Energy Industries

Categories	CO_2	CH_4	N_2O	Total (CO_2eq)
1.A.1 - Energy Industries	**3.12**	**16.02**	**31.53**	**50.67**
1.A.1.a - Main Activity Electricity and Heat Production	3.12	0.00	0.01	3.13
1.A.1.a.i - Electricity Generation	3.12	0.00	0.01	3.13
1.A.1.a.ii - Combined Heat and Power Generation (CHP)	0.00	0.00	0.00	0.00
1.A.1.a.iii - Heat Plants	0.00	0.00	0.00	0.00
1.A.1.b - Petroleum Refining	0.00	0.00	0.00	0.00
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	0.00	16.01	31.52	47.53
1.A.1.c.i - Manufacture of Solid Fuels	0.00	16.01	31.52	47.53
1.A.1.c.ii - Other Energy Industries	0.00	0.00	0.00	0.00

3.10.4.2 1. A.3 - Transport

The Malawi's transport system, carrying cargo and passengers within and outside of the country, comprises the following modes of transport: road, water, rail and air. The transport sub-category is the main consumer of petroleum in Malawi, and therefore, its significance in GHG emissions is recognised. Emissions from International Aviation are assumed to be only 5% of the total emissions in the civil aviation. This is so because most of the international planes come to Malawian aiports already fuelled elsewhere. GHG emissions from transport are shown in Table 3.13.

Table 3. 14 GHG emissions from transport

Categories	**CO_2**	**CH_4**	**N_2O**	**Total (CO_2eq)**
1.A.3 - Transport	647.47	2.72	9.87	660.07
1.A.3.a - Civil Aviation	29.88	0.00	0.26	30.14
1.A.3.a.i - International Aviation (International Bunkers) (1)	1.494	0.00	0.013	1.507
1.A.3.a.ii - Domestic Aviation	28.396	0.00	0.247	28.633
1.A.3.b - Road Transportation	616.96	2.72	9.61	629.28
1.A.3.b.i - Cars				
1.A.3.b.i.1 - Passenger cars with 3-way catalysts				
1.A.3.b.i.2 - Passenger cars without 3-way catalysts				
1.A.3.b.ii - Light-duty trucks				
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts				
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts				
1.A.3.b.iii - Heavy-duty trucks and buses				
1.A.3.b.iv - Motorcycles				
1.A.3.b.v - Evaporative emissions from vehicles				
1.A.3.b.vi - Urea-based catalysts				
1.A.3.c - Railways				
1.A.3.d - Water-borne Navigation	0.64		0.01	0.64
1.A.3.d.i - International water-borne navigation (International				
1.A.3.d.ii - Domestic Water-borne Navigation	0.64		0.01	0.64
1.A.3.e - Other Transportation				
1.A.3.e.i - Pipeline Transport				
1.A.3.e.ii - Off-road				

3.10.4.3 Reference Approach Data

This inventory has used the sectoral approach to estimate the GHG emissions in the Energy sector, using the 2006 IPCC GHG Inventory Software. Another set of estimations, using the same software, was conducted using the reference approach. The aim was to compare the variance and thus, validate the sectoral approach estimations.

3.10.4.4 Comparison between Sectoral Approach and Reference Approach

This inventory employed sectoral approach of the Tier 1 IPCC Methodology. It was indicated in the methodology, another set of calculations, was conducted using the reference approach using the same 2006 IPCC GHG Inventory software. The aim was to compare the variance and thus, validate the sectoral approach. The difference between the two approaches, in terms of percentage, was the largest for aviation gasoline (4.76%) followed by kerosene (-4.64%) and gas/diesel oil (-4.50%). This validates the sectoral approach, according to IPCC (IPCC, 2006). Table 3.14 presents the results of comparison between SA and RA.

Table 3. 15 Comparison between RA and SA for 2010 reference year

	Reference Approach				**Sectoral Approach**		**Difference**	
Fuel	**Apparent Consumption (TJ)**	**Excluded consumption (TJ)**	**Apparent Consumption (excluding non-energy use and feedstocks) (TJ)**	**CO_2 Emissions (Gg)**	**Energy Consumption (TJ)**	**CO_2 Emissions (Gg)**	**Energy Consumption (%)**	**CO_2 Emissions (%)**
Motor Gasoline	3303.01		3303.01	228.90	3568.81	228.90	-7.45	0.00
Aviation Gasoline	10.14		10.14	0.71	10.14	0.71	0.00	0.05
Jet Kerosene	407.93		407.93	29.17	407.93	29.17	0.00	0.00
Other Kerosene	382.37	0.00	382.37	27.48	426.17	27.49	-10.28	-0.05
Shale Oil	0.00		0.00	0.00			0.00	0.00
Gas/Diesel Oil	6673.60	0.00	6673.60	494.29	9210.60	494.51	-27.54	-0.04
Residual Fuel Oil	0.00		0.00	0.00			0.00	0.00
Liquefied Petroleum Gases	27.77	0.00	27.77	0.00	27.77	1.75	0.00	-100.00
Other Bituminous Coal	0.00		0.00	0.00	10216.80	0.00	-100.00	0.00
Sub-Bituminous Coal	1603.02		1603.02	154.00	1603.02	154.05	0.00	-0.03

The memo items recorded were CO_2 emissions from biomass (Table 3.15)

Table 3. 16 Memo items

	Emissions(Gg)						
Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
International Bunkers				0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)				0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)				0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)				0	0	0	0
Information Items							
CO_2 from Biomass Combustion for Energy Production	10518.339						

3.10.5 Planned improvements

Recommendations on the improvement of the quality of the inventory in the next national communication are suggested as follows:

(i). There should be a deliberate policy to compel government department, companies and other stakeholders to provide information for such a national cause

(ii). Getting the data in the organised and in form required for the analysis was not easy from most of public and private organisations. It is recommended to have a data management plan for all government departments and enrage private sector to also have it.

(iii). The project to generate emission factors for Malawi in the Energy sector should be finalised before the next inventory

3.11 Industrial Processes and Product Use

3.11.1 Introduction

The IPPU sub-sectors that are relevant to Malawi are: 2A-Mineral industry, 2A1-Cement production and 2A2- Lime production. The mining industry in Malawi continues to grow and remains an important sector to propel the country's economy. In 2014, the cement and lime industries alone employed 1,694 direct employees and generated MK238.14 million in revenue in the same year (GoM, 2014). In the construction industry, lime and cement companies, contribute greatly to saving of the country's foreign exchange earnings by availing their products locally, thus cutting on imports. In 2012, property worth MK5, 053.7 million was completed using locally produced cement (NSO, 2015). The GHGs emitted from IPPU sector in 2010 are presented in Table 3.16.

Table 3. 17 GHGs emitted from IPPU in 2010

Categories	**(Gg)**			**CO_2 eq (Gg)**		
	CO_2	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF6**
2 - Industrial Processes and Product Use	40.01					
2.A - Mineral Industry	40.01					
2.A.1 - Cement production	16.07					
2.A.2 - Lime production	23.84					
2.A.3 - Glass Production	NO					
2.A.4 - Other Process Uses of Carbonates	NO					
2.A.4.a - Ceramics	NO					
2.A.4.b - Other Uses of Soda Ash	NO					
2.A.4.c - Non-Metallurgical Magnesia Production	NO					
2.A.4.d - Other (please specify) (3)	NA					
2.A.5 - Other (please specify) (3)	NA					
2.B - Chemical Industry						

2.B.1 - Ammonia Production						
2.B.2 - Nitric Acid Production						
2.B.3 - Adipic Acid Production						
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production						
2.B.5 - Carbide Production						
2.B.6 - Titanium Dioxide Production						
2.B.7 - Soda Ash Production						
2.B.8 - Petrochemical and Carbon Black Production						
2.B.9 - Fluorochemical Production						
2.B.10 - Other (Please specify)(3)						
2.C - Metal Industry						
2.D - Non-Energy Products from Fuels and Solvent Use(6)						
2.E - Electronics Industry						
2.F - Product Uses as Substitutes for Ozone Depleting Substances		NE				
2.G - Other Product Manufacture and Use						
2.H - Other						

Malawi's IPPU contribution to the national totals remains low owing to low levels of industrialisation and an economy that is largely agro-based. The IPPU sector contributed only 0.78% of the total country GHG emissions in 2010. The cement industry continues to be a major contributor of CO_2 emissions in Malawi for in the IPPU sector followed by lime production as indicated in Figure 3.2.

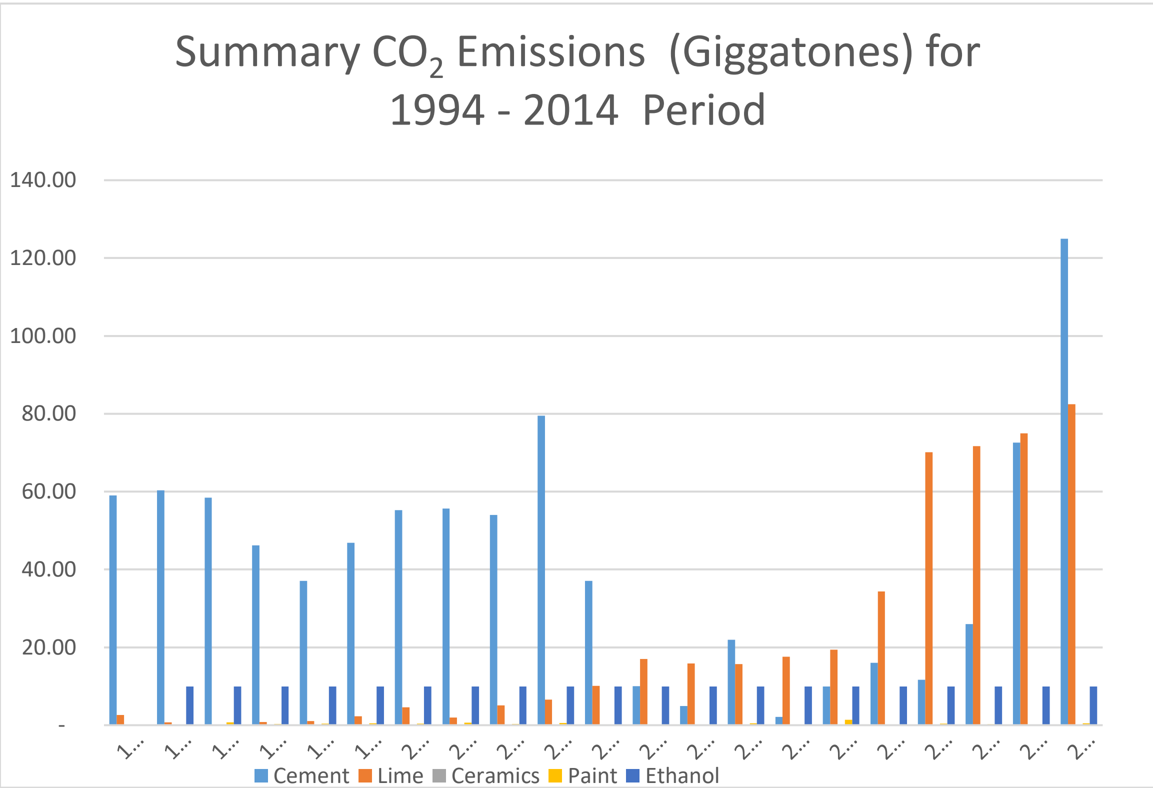


Figure 3. 2 Summary CO_2 Emission for IPPU Sector

3.11.2 Methodology

Several approaches were employed so as to get the requisite data. These include;

- Literature review of the Initial and Second National Communications was undertaken to determine the adequacy of the GHG inventories compiled. The 2006 IPCC Guidelines were also examined alongside data from the National Statistical Office (NSO), Department of Mines, Department of Economic Planning and Development, Ministry of Commerce, Trade and Industry and the United States Geological Survey (USGS);
- Visits were made to product producer such as Shayona Cement Limited, Department of Mines and the Malawi Revenue Authority to fill gaps observed in the literature secured.
-

A review was conducted of the GHG emissions from the inventory figures arrived at during the INC of 1994 and SNC and the figures were compared with those arrived at during the TNC compilation as shown in Table 3.17 below.

Table 3. 18 Comparative Analysis of INC and SNC Inventories with TNC figures

Year	INC and SNC Inventory		Recalculation in TNC	
	CO_2 Emission from Lime	CO_2 Emission from Cement	CO_2 Emission (Gg) from Lime	CO_2 Emission from Cement
1994	1.7551	56.62	2.7	59.03
1995	0.507	59.022	0.8	60.37
1996	0.128	46.46	0.2	58.49
1997	0.538	37.388	0.8	46.19
1998	0.733	47.308	1.1	37.05
1999	1.572	55.732	2.3	46.88
2000	3.132	56.081	4.6	55.23

It is clear from the table that:

- Lime emission figure for the INC (1994) is lower than that for TNC. This can be attributed to variation of the global emission factor of 0.5071 tonne CO_2 / tonne of lime produced used in 1994 to 0.75 tonne CO_2 / tonne of lime produced used in the TNC based on the 2006 IPCC Guidelines;
- Carbon emissions from cement production have risen from 56.62 Gg in 1994 to 59.03 in the TNC. In the INC, the figure was based on lime used using a default factor of 0.4985 CO_2 / tonne of cement produced that has been revised upwards to 0.52 CO_2 / tonne of clinker produced.
- The trend, however remains the same in that from 1995 there was a decrease in carbon dioxide emissions from both cement and lime production due to, among others, an economy that took a downward turn (SOER, 2010), reduced production of lime as fuelwood became scarce (USGS, 2010) and closure of production plant at Changalume Factory owned by Lafarge in 2002; and
- From 1998, there was an increase in the emission levels due to increased activity emanating from opening of Malawi’s second cement factory in Kasungu owned by Shayona.

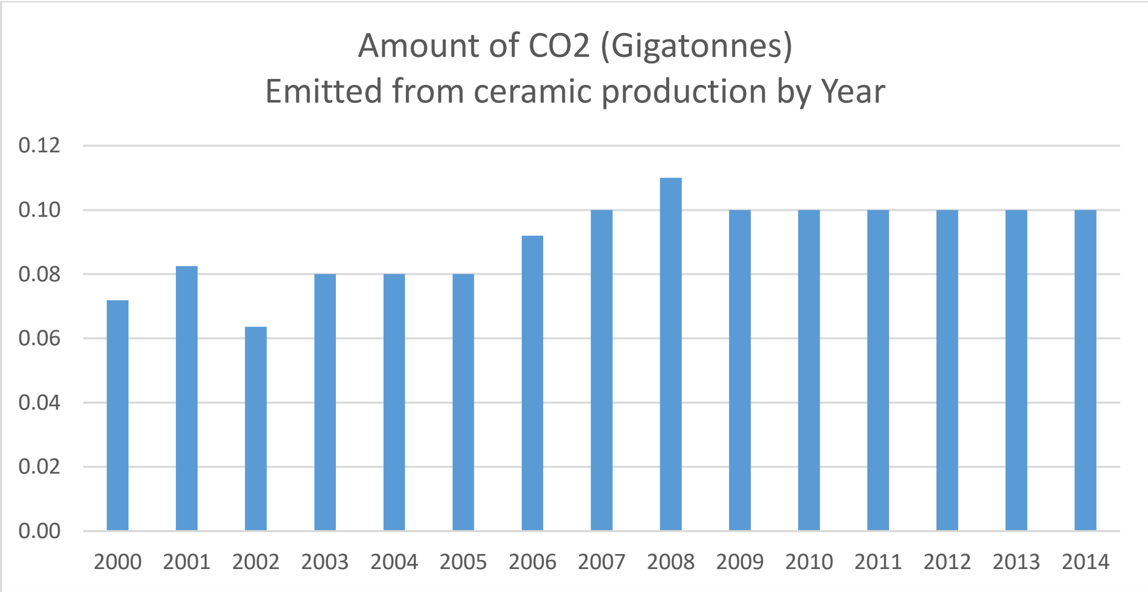
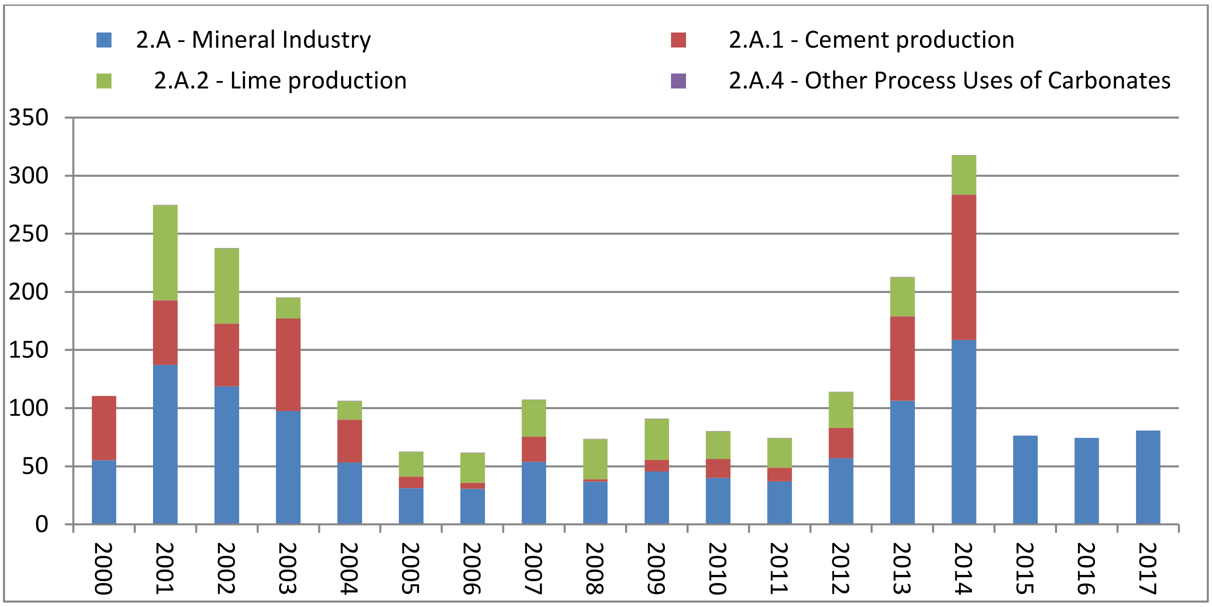


Figure 3. 3 CO_2 Emissions from Ceramics Industry (2000 – 2014)



Overall emissions trend from IPPU

3.11.2.1 Product Uses as Substitutes for Ozone Depleting Substances – Other Applications-2F6

This inventory does not cover the following sub-categories that were not occurring in Malawi:

i. 2A3-Glass Production2A4 Mineral Other Process Uses of Carbonates-
ii. 2B1 Ammonia Production
iii. 2B2 Nitric Acid Production
iv. 2B3 Adipic Acid Production
v. 2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production

vi. 2B5 Carbide Production,
vii. 2B6 Titanium Dioxide Production
viii. 2B7 Soda Ash Production
ix. 2B8 Petrochemical and Carbon Black Production
x. 2B9 Fluorochemical Production
xi. 2C1 Iron and Steel Production
xii. 2C2 Ferroalloys Production
xiii. 2C3 Aluminium Production PFCs
xiv. 2C4 Magnesium Production
xv. 2C5 Lead Production 2
xvi. 2C6 Zinc Production
xvii. 2D Non-Energy Products from Fuels and Solvent Use
xviii. 2E Electronics Industry
xix. 2F1 Product Uses as Substitutes for Ozone Depleting Substances-NE
xx. 2G Other Product Manufacture and Use

3.11.3 Improvement plan

There were limitations encountered in the course of conducting the study, the most notable of which were:

- Reluctance to release data from companies. Some companies treated data as confidential and were unwilling to provide such data to the study team, hence the need to have a more legally binding doment between EAD and data providers such as an MoU
- Completeness of data availability for the reporting periods. While data was required for the period from the year 2001 to 2017, it was difficult to get data for some years for certain sector such as ceramics and ethanol beginning 2014 to 2017 as such extrapolation would be employed during the next cycle.

3.12 Agriculture, Forest and Other Land-Uses

3.12.1 Introduction

Malawi has an agro-based economy with the agriculture sector accounting for over 35.5 % of GDP, employing about 84.5 % of labour force and accounting for 82.5 % of foreign exchange earnings. The main agricultural export crop is tobacco, followed by tea, sugar and coffee. Agricultural expansion and biomass energy demand have been some of the major issues driving forest loss in Malawi. Biomass accounts for over 95% of the total primary energy supply in the country (GoM, 2010) with forest reserves as the main sources of fuelwood and contribute nearly 75% of the total biomass supply besides being the highly encroached areas (Jumbe and Angelsen, 2011).

The SNC covered 1996 to 2000 and several major agricultural source categories that substantially contribute to GHG emissions were identified in the inventory. These include: (i)

Enteric fermentation and manure management (31.64 Gg of CH4), (ii) field burning of agricultural residues (1.57 Gg), and (iii) rice cultivation (5.12 Gg of CH_4) (Matita et al., 2000). In the TNC, GHGs will be estimated from the following source categories: (i) Enteric fermentation and manure management, (ii) rice cultivation, and (iii) open burning of agricultural residues, (iv)Indirect N_20 from manure management and managed soils, (v) Direct N_2O from Managed soils.

In the TNC the overall net emission position from AFOLU was 1,205.02Gg CO_2eq in 2010, largely driven by forest land (3B1). The largest amount of CO_2 emissions was from Cropland (3B2) amounting to 1,589.39Gg, while Livestock (3A1) contributed the highest quantity of CH_4 at 1355.61GgCO_2eq. The largest amount of N_2O was 205.29GgCO_2eq from manure management (3A2). The summary of emission from AFOLU in 2010 is shown in Table 3.18.

Table 3. 19 GHG emissions from AFOLU for 2010

Categories	Net CO_2 emissions / removals (Gg)	CH_4 Emissions ((GgCO_2eq)	N_2O Emissions (GgCO_2eq)
3 - Agriculture, Forestry, and Other Land Use	-519.45	1509.29	215.18
3.A - Livestock		1355.61	205.29
3.A.1 - Enteric Fermentation		1246.56	
3.A.1.a - Cattle		756.12	
3.A.1.a.i - Dairy Cows		87.28	
3.A.1.a.ii - Other Cattle		668.84	
3.A.1.b - Buffalo			
3.A.1.c - Sheep		31.72	
3.A.1.d - Goats		408.86	
3.A.1.e - Camels			
3.A.1.f - Horses			
3.A.1.g - Mules and Asses			
3.A.1.h - Swine		49.86	
3.A.1.j - Other (please specify)			
3.A.2 - Manure Management(1)		109.05	205.29
3.A.2.a - Cattle		22.47	204.27
3.A.2.a.i - Dairy cows		0.89	5.17
3.A.2.a.ii - Other cattle		21.58	199.10
3.A.2.b - Buffalo		NO	NO
3.A.2.c - Sheep		1.27	0.09
3.A.2.d - Goats		35.45	
3.A.2.e - Camels			
3.A.2.f - Horses			
3.A.2.g - Mules and Asses			
3.A.2.h - Swine		49.86	0.93
3.A.2.i - Poultry			
3.A.2.j - Other (please specify)			

Categories	Net CO_2 emissions / removals (Gg)	CH_4 Emissions ($GgCO_2eq$)	N_2O Emissions ($GgCO_2eq$)
3.B - Land	-562.58		
3.B.1 - Forest land	-2626.93		
3.B.1.a - Forest land Remaining Forest land	-2498.48		
3.B.1.b - Land Converted to Forest land	-128.45		
3.B.1.b.i - Cropland converted to Forest Land	-106.45		
3.B.1.b.ii - Grassland converted to Forest Land	-9.30		
3.B.1.b.iii - Wetlands converted to Forest Land	-12.70		
3.B.1.b.iv - Settlements converted to Forest Land			
3.B.1.b.v - Other Land converted to Forest Land			
3.B.2 - Cropland	1589.39		
3.B.2.a - Cropland Remaining Cropland			
3.B.2.b - Land Converted to Cropland	1589.39		
3.B.2.b.i - Forest Land converted to Cropland	1589.38		
3.B.2.b.ii - Grassland converted to Cropland			
3.B.2.b.iii - Wetlands converted to Cropland	0.01		
3.B.2.b.iv - Settlements converted to Cropland			
3.B.2.b.v - Other Land converted to Cropland			
3.B.3 - Grassland	261.89		
3.B.3.a - Grassland Remaining Grassland			
3.B.3.b - Land Converted to Grassland	261.89		
3.B.3.b.i - Forest Land converted to Grassland	261.89		
3.B.3.b.ii - Cropland converted to Grassland			
3.B.3.b.iii - Wetlands converted to Grassland			
3.B.3.b.iv - Settlements converted to Grassland			
3.B.3.b.v - Other Land converted to Grassland			
3.B.4 - Wetlands			
3.B.4.a - Wetlands Remaining Wetlands			
3.B.4.a.i - Peatlands remaining peatlands			
3.B.4.a.ii - Flooded land remaining flooded land			
3.B.4.b - Land Converted to Wetlands			
3.B.4.b.i - Land converted for peat extraction			
3.B.4.b.ii - Land converted to flooded land			
3.B.4.b.iii - Land converted to other wetlands			
3.B.5 - Settlements	24.78		
3.B.5.a - Settlements Remaining Settlements	NE		
3.B.5.b - Land Converted to Settlements	24.78		
3.B.5.b.i - Forest Land converted to Settlements	24.78		
3.B.5.b.ii - Cropland converted to Settlements			
3.B.5.b.iii - Grassland converted to Settlements			
3.B.5.b.iv - Wetlands converted to Settlements			
3.B.5.b.v - Other Land converted to Settlements			
3.B.6 - Other Land	188.29		

Categories	Net CO_2 emissions / removals (Gg)	CH_4 Emissions ($GgCO_2eq$)	N_2O Emissions ($GgCO_2eq$)
3.B.6.a - Other land Remaining Other land			
3.B.6.b - Land Converted to Other land	188.29		
3.B.6.b.i - Forest Land converted to Other Land	188.29		
3.B.6.b.ii - Cropland converted to Other Land			
3.B.6.b.iii - Grassland converted to Other Land			
3.B.6.b.iv - Wetlands converted to Other Land			
3.B.6.b.v - Settlements converted to Other Land			
3.C - Aggregate sources and non-CO2 emissions	88.71	153.68	9.90
3.C.1 - Emissions from biomass burning		31.28	
3.C.1.a - Biomass burning in forest lands		27.15	
3.C.1.b - Biomass burning in croplands		0.18	
3.C.1.c - Biomass burning in grasslands		3.95	
3.C.1.d - Biomass burning in all other land			
3.C.2 - Liming			
3.C.3 - Urea application	88.71		
3.C.4 - Direct N2O Emissions from managed soils(3)			
3.C.5 - Indirect N2O Emissions from managed soils			0.20
3.C.6 - Indirect N2O Emissions from manure management			9.69
3.C.7 - Rice cultivations		122.40	
3.C.8 - Other (please specify)			
3.D - Other	-45.58		
3.D.1 - Harvested Wood Products	-45.58		
3.D.2 - Other (please specify)			

Eight categories were the main contributors to GHG emissions or sinks in 2010. These key categories in terms of level are presented in Table 3.18. The categories cumulatively contributed 96.03% and these were:

- 3.B.1.a-Forest land Remaining Forest land
- 3.A.1-Enteric Fermentation
- 3.B.2.b-Land Converted to Cropland
- 3.B.3.b-Land Converted to Grassland
- 3.A.2-Manure Management
- 3.B.6.b-Land Converted to Other land
- 3.B.1.b-Land Converted to Forest land
- 3C7-Rice Cultivations

Table 3. 20 AFOLU sector key category for 2010 by level

IPCC Category code	IPCC Category	GHG	2010 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t (%)	Cumulative Total of Column F (%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-	2,498.4	38.1	38.14
3.B.2.b	Land Converted to Cropland	CO_2	1,589.3	1,589.3	24.2	62.41
3.A.1	Enteric Fermentation	CH_4	1,246.5	1,246.5	19.0	81.44
3.B.3.b	Land Converted to Grassland	CO_2	261.89	261.89	4.00	85.44
3.A.2	Manure Management	N_2O	205.29	205.29	3.13	88.57
3.B.6.b	Land Converted to Other land	CO_2	188.29	188.29	2.87	91.45
3.B.1.b	Land Converted to Forest land	CO_2	-128.45	128.45	1.96	93.41
3.C.7	Rice cultivations	CH_4	122.40	122.40	1.87	95.28
3.A.2	Manure Management	CH_4	109.05	109.05	1.66	96.94
3.C.3	Urea application	CO_2	88.71	88.71	1.35	98.30
3.D.1	Harvested Wood Products	CO_2	-45.58	45.58	0.70	98.99
3.C.1	Emissions from biomass burning	CH_4	31.28	31.28	0.48	99.47
3.B.5.b	Land Converted to Settlements	CO_2	24.78	24.78	0.38	99.85
3.C.6	Indirect N2O Emissions from manure	N_2O	9.69	9.69	0.15	100.00
3.C.5	Indirect N2O Emissions from managed soils	N_2O	0.20	0.20	0.00	100.00
3.C.4	Direct N2O Emissions from managed soils	N_2O	0	0	0.00	100.00
3.C.2	Liming	CO_2	0	0	0.00	100.00
3.C.1	Emissions from biomass burning	N_2O	0	0	0.00	100.00
3.B.5.a	Settlements Remaining Settlements	CO_2	0	0	0.00	100.00
3.B.4.b	Land Converted to Wetlands	N_2O	0.00	0.00	0.00	100.00
3.B.4.b	Land Converted to Wetlands	CO_2	0.00	0.00	0.00	100.00
3.B.4.a.	Peatlands remaining peatlands	CO_2	0.00	0.00	0.00	100.00
3.B.4.a.	Peatlands remaining peatlands	N_2O	0.00	0.00	0.00	100.00
3.B.3.a	Grassland Remaining Grassland	CO_2	0.00	0.00	0.00	100.00
3.B.2.a	Cropland Remaining Cropland	CO_2	0.00	0.00	0.00	100.00

3.12.2 GHG Emissions from Agriculture

3.12.2.1 Methodology for the Agricultural sector

The quantities of GHGs emitted from the different source categories were estimated using the 2006 IPCC Guidelines. No national emission factors are available in Malawi. Hence, default emission factors sourced from the IPCC Guidelines were used in the calculations. The total amount of CH_4 emitted through enteric fermentation 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 GHG emissions, in CO_2eq units, from enteric fermentation and manure management from livestock.Equation 10.25 from the 2006 IPCC Guidelines was employed to calculate direct N_2O emissions from livestock manure for each species and subcategory of each species. N_2O emissions from each species were summed up to derive total N_2O emissions. The Tier 1 approach was also used to calculate CH_4 emissions from rice cultivation.

3.12.2.2 GHG Emissions from livestock – 3A

The main ruminant animals in Malawi are cattle, goats and sheep. Cattle are the most important source of CH_4 because of their large numbers, large sizes and large ruminant digestive systems. The increases in population are attributed to increase in adoption of animal husbandry practices and injections from Government livestock programmes, especially on goats and injections from Non- Governmental Organization in dairy, goats and chicken species. Most of the livestock are indigenous breeds and are generally raised by smallholder farmers under extensive management systems.

A total of 64.55Gg CH_4 and 0.66Gg N_2O were emitted from domestic livestock in 2010 (Table 3.19). Increases in methane production were attributed to ever increasing livestock populations from 2006 to 2017.

Table 3. 21 GHG emissions from livestock - 3A

Categories		CH_4	N_2O
3 - Agriculture, Forestry, and Other Land Use	**-**	**71.87**	**0.69**
3.A - Livestock	0.00	64.55	0.66
3.A.1 - Enteric Fermentation	0.00	59.36	0.00
3.A.1.a - Cattle	0.00	36.01	0.00
3.A.1.a.i - Dairy Cows		4.16	
3.A.1.a.ii - Other Cattle		31.85	
3.A.1.b - Buffalo			
3.A.1.c - Sheep		1.51	
3.A.1.d - Goats		19.47	
3.A.1.e - Camels			
3.A.1.f - Horses			
3.A.1.g - Mules and Asses			
3.A.1.h - Swine		2.37	
3.A.1.j - Other (please specify)		0.00	
3.A.2 - Manure Management (1)	0.00	5.19	0.66
3.A.2.a - Cattle	0.00	1.07	0.66
3.A.2.a.i - Dairy cows		0.04	0.02
3.A.2.a.ii - Other cattle		1.03	0.64
3.A.2.b - Buffalo			
3.A.2.c - Sheep		0.06	
3.A.2.d - Goats		1.69	
3.A.2.e - Camels			
3.A.2.f - Horses			
3.A.2.g - Mules and Asses			
3.A.2.h - Swine		2.37	
3.A.2.i - Poultry			
3.A.2.j - Other (please specify)			

The major sources of methane from enteric fermentation were cattle, goats and sheep. There was a 104.20% increase in CH_4 from enteric fermentation from the 29.07Gg emitted in 2000 as reported in the SNC to the 59.36Gg emitted in 2010.

3.12.2.3 Emissions from managed soils

Table 3.21 presents the GHG emissions from managed soils in 2010

Table 3. 22 GHG emissions from managed soils for 2010

Category	Net CO_2	CH_4	N_2O
3.C.2 - Liming			
3.C.3 - Urea application	88.71		
3.C.4 - Direct N_2O Emissions from managed soils(3)			
3.C.5 - Indirect N_2O Emissions from managed soils			0.20
3.C.6 - Indirect N_2O Emissions from manure management			0.03
3.C.7 - Rice cultivations		5.83	
3.C.8 - Other (please specify)			

3.12.2.4 GHG Emissions from Liming - 3.C.2

Not estimated (NE)

3.12.2.5 GHG Emissions from Urea Application - 3.C.3

Figure 4.2 presents the amount of inorganic fertiliser applied for the period 2001 to 2017. The general increase in quantities of fertiliser applied is attributed to increased fertilizer usage as a result of implementation of Government Farm Subsidy Programme in Malawi.

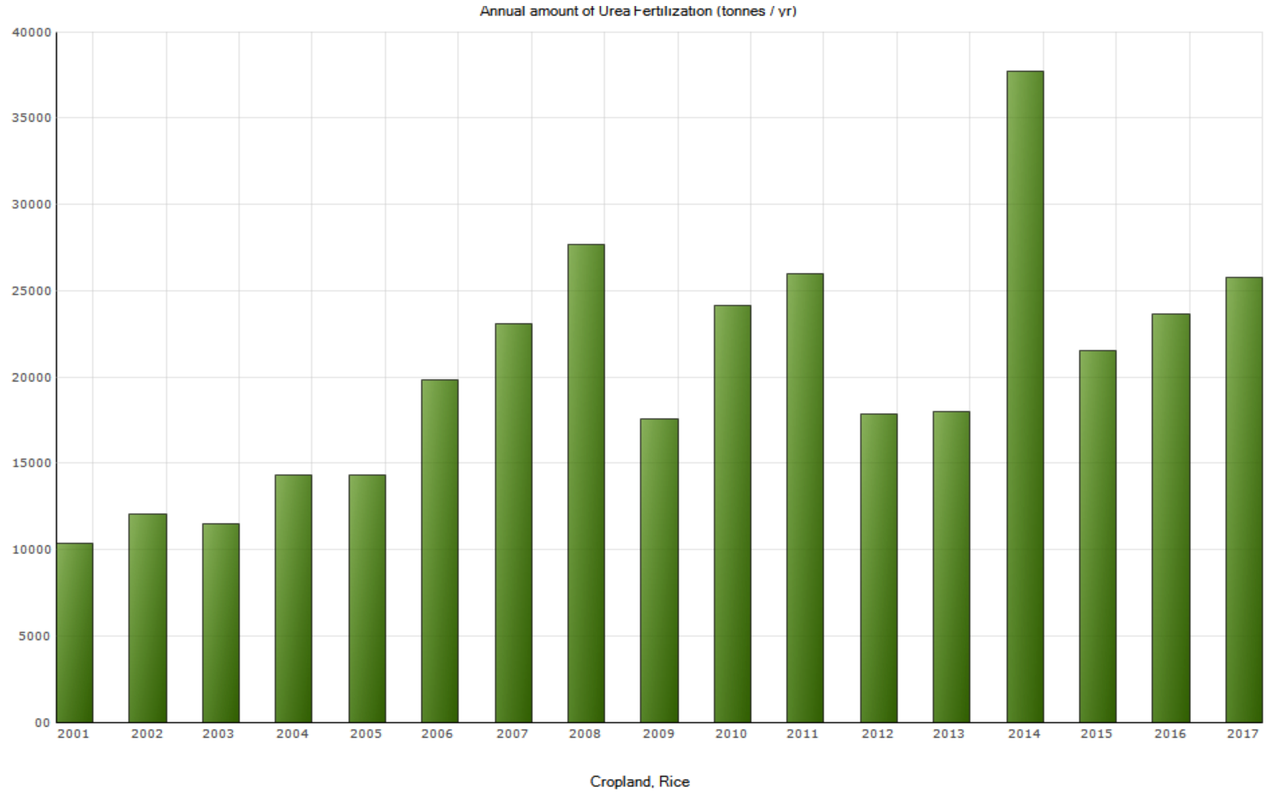


Figure 3. 4 Inorganic fertilizer use in Malawi, 2001-2017

In 2010, 88.71Gg of CO_2 were emitted from urea application (Figure 3.16). Total non-CO_2 for the period under review is 1,192.93Gg. This is five times higher than that reported in the GHG SNC inventory of 1996-2000(225Gg).

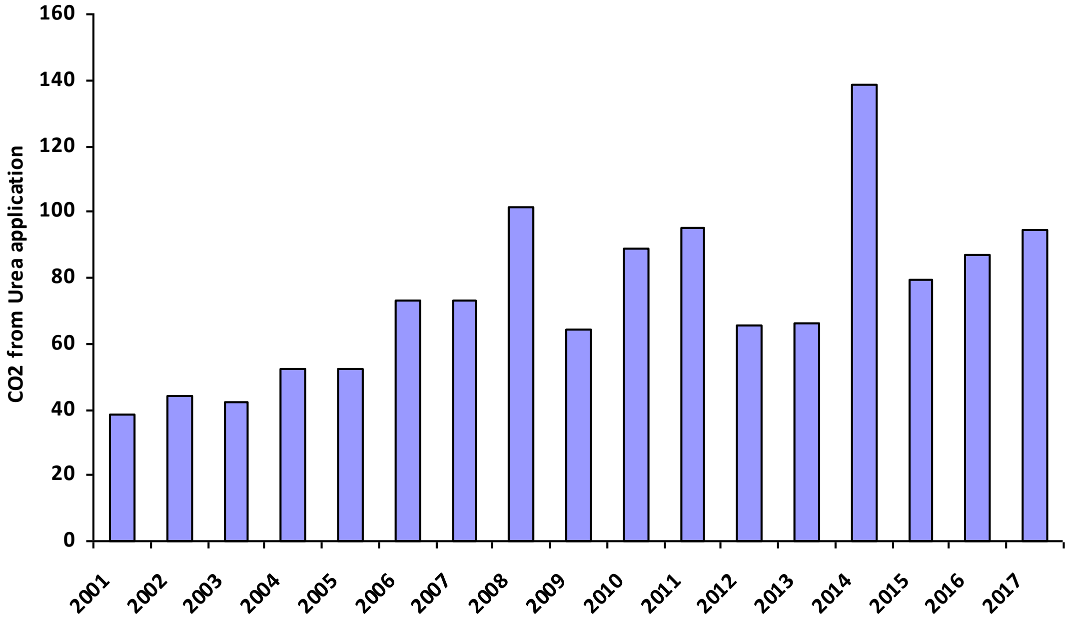


Figure 3. 5 **CO_2 emissions from urea application**

3.12.2.6 Direct N_2O Emissions from Managed soils -3C4

Direct N_2O emissions from managed soils were not estimated

3.12.2.7Indirect N_2O Emissions from Managed soils - 3C5

Figure 3.6 shows the annual quantities of indirect N_2O emitted from managed soils.

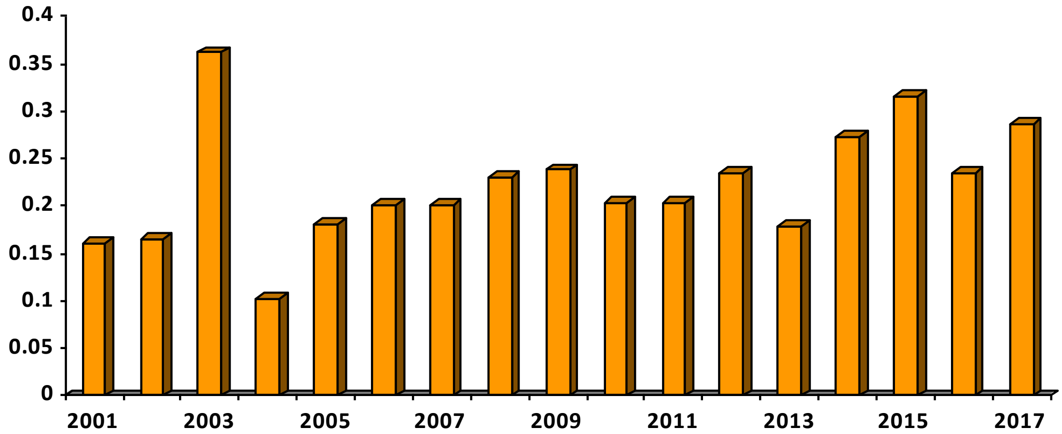


Figure 3. 6 **Indirect N_2O from manure**

3.12.2.8 Indirect Nitrous emissions from Livestock – 3.C.6

Despite the emissions coming from only one source category livestock, it is on the higher side. GHG inventory 1996-2000 established that 9.57 Gg from manure management. In the TNC, big contribution of nitrous emissions 63.4% came from poultry possible because of the concentrate diets that these species consume that have a relative higher crude protein percentage compared to diets of ruminants. In Malawi, 65% of the poultry population are commercial chickens and within this category, broilers are the predominant species. In the reporting period, there was a relative jump in poultry population from 2001 -2017 (Table 4.3) due to an increased number of entrepreneurs venturing into commercial poultry production. Due to high global warming potential of N_2O of 310 relative to 1 for CO_2, higher emissions from poultry should be a concern to the nation.

In the TNC, it was established that a total of 826.5 Gg of N_2O (Figure 3.19). A bigger contribution of N_2O came from goats, cattle and swine. Due to high global warming potential of N_2O of 310, high emissions of N_2O from these species should be a concern to the nation. There has been big jump due to increases of these species in the reporting period and also increases in fertilizer usage as a result implementation of Government Input Subsidy Programme starting from year 2004.

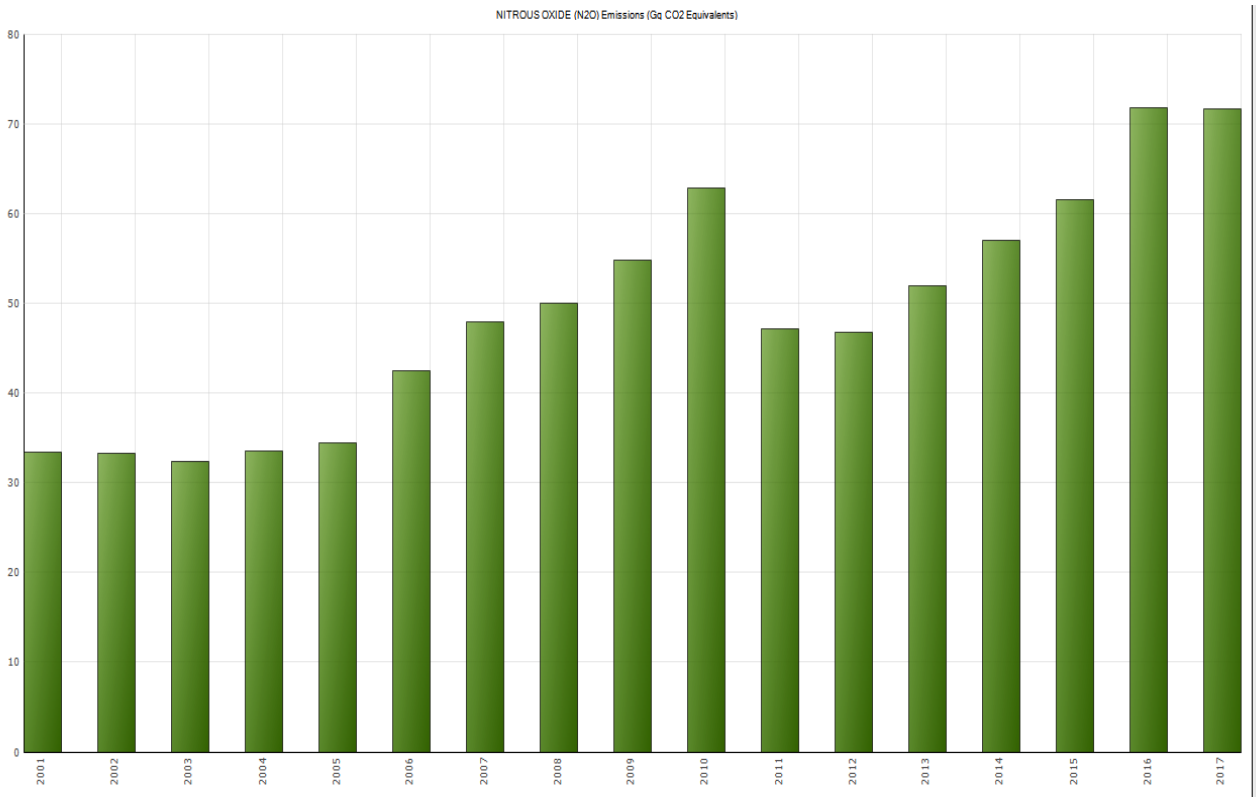


Figure 3. 7 Indirect N_2O Emissions (Gg/year), 2001-2017

3.12.2.9 Rice Cultivations – 3.C.7

In Malawi, rice is mainly produced in areas along the lakeshore plain and river valleys, under two water production regimes: (i) rain-fed with intermittent irrigation during the wet months of December to May, and (ii) flood irrigation during the dry months of May to October. Figure 4.6 shows the total harvested land area for rice by year. The annual amount of CH_4 emitted was calculated based the area, number and duration of the crops grown, water regimes before and during the cultivation period, and organic and inorganic soil amendments according to Neue and Sass (1994) and Minami (1995). Soil type, temperature and rice cultivar also affect CH_4 emissions.

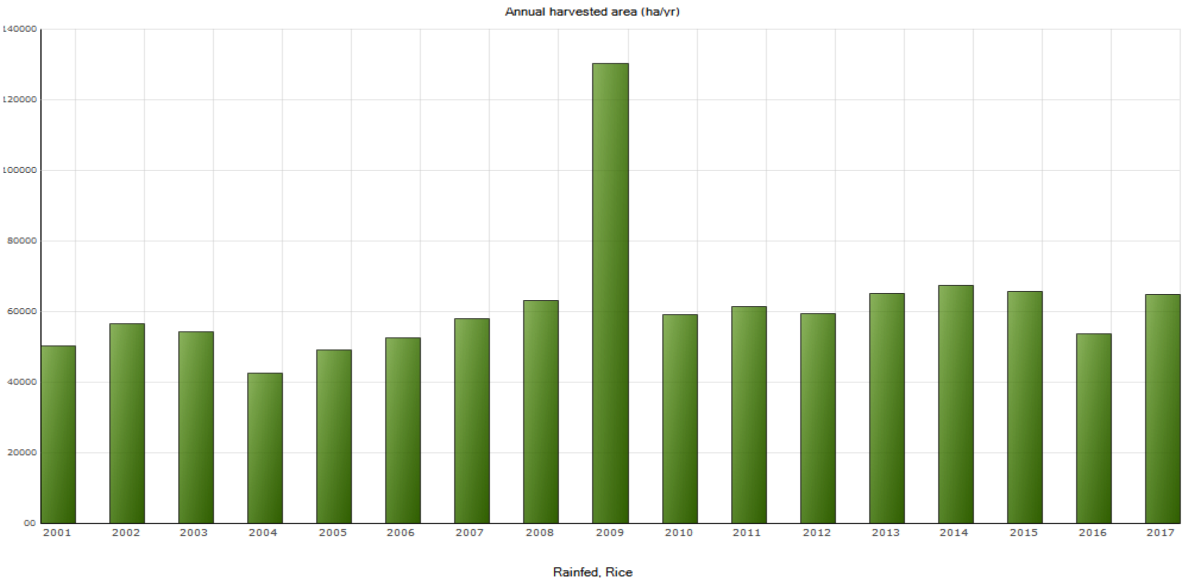


Figure 3. 8 Total harvested land area (Ha) for rice by year 2001-2017

A total of 103.9 Gg of CH_4 was emitted from rice cultivation in the period under review (2001-2017) as shown in Figure 3.20. This is relatively higher compared to the 5.13 Gg reported in the SNC,. The increase is attributed to establishment of new rice schemes by Government and development partners and also extension of existing rice schemes. In 2009, there was more rice cultivation because there was Government subsidy fertilizers for rice.

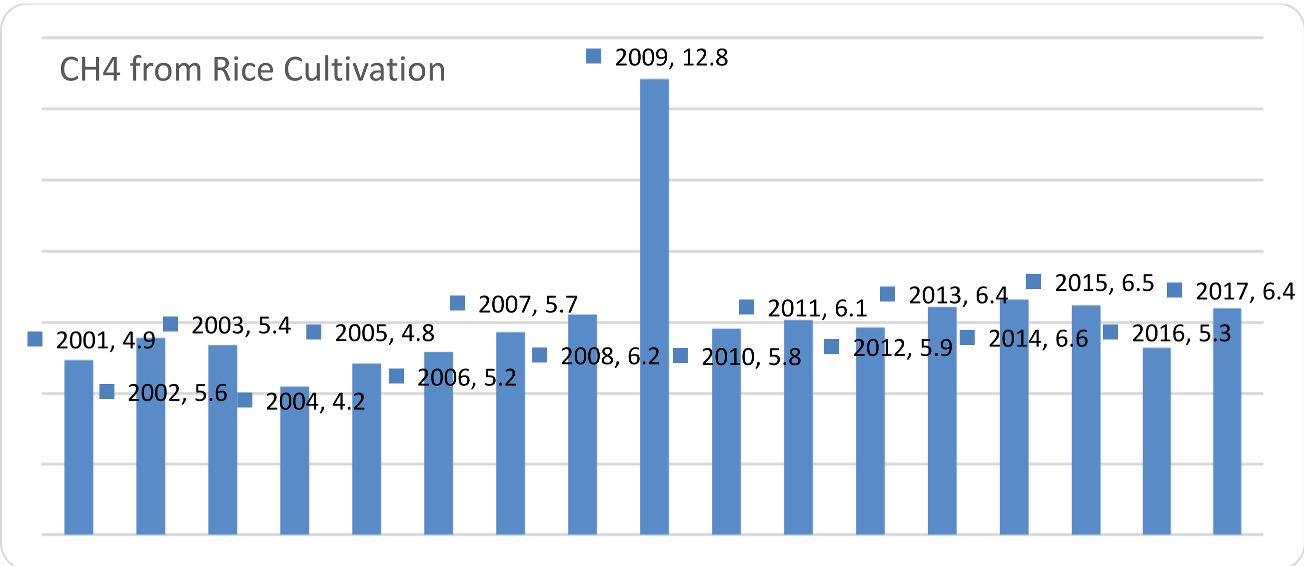


Figure 3. 9 CH_4 emissions (Gg) from rice cultivation, 2001-2017

A total of 24.05 Gg of CH_4 were emitted from rice cultivation as shown in Figure 4.7 over a nine-year period (2001-2017). About 99.5% of this was emitted from the intermittent flooded rice source category, whereas the continuously flooded rice source category contributed 0.5%. The CH_4 emissions from continuously flooded rice were generally lower because of the low hecterage grown to rice under this system of cultivation. The CH_4 emissions for the 1996-2000 GHG Inventory of 5.13 Gg is almost 5 times lower the present emission value of 24.05 Gg. This large increase in the present value can be attributed to expansion of old rice schemes and creation of new ones by Government projects as well as by Non-Governmental Projects.

3.12.2.10 GHG emissions and sinks from land - 3B

This section only covers emissions and removals in land uses other than agriculture. Besides agriculture, it does not include aggregate sources and non-CO_2 emission sources thus, liming, urea application, direct and indirect N_2O emissions from managed soils and manure management, and rice cultivation – all considered under the Agriculture section. Biomass burning in croplands is, however, included. Table 3.22 presents the emissions from land (3B) in 2010.

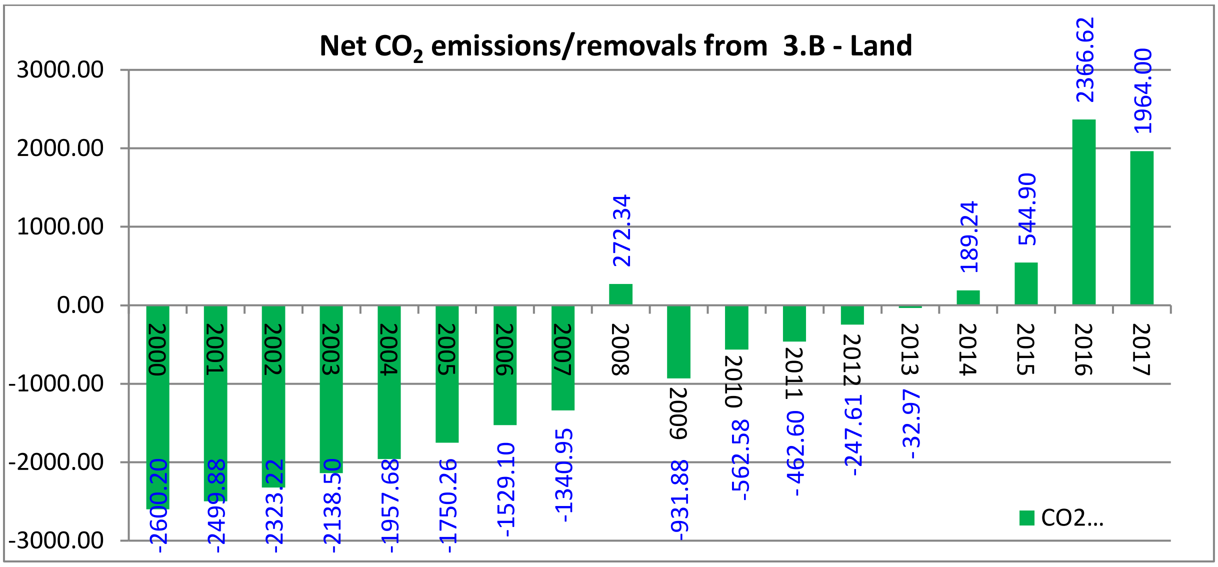


Table 3. 23 GHG emissions from land in 2010

Category	CO_2 emissions/ removals (Gg)	CH_4 emissions	N_2O emissions
3.B - Land	**-562.58**	**NE**	**NE**
3.B.1 - Forest land	-2626.93		
3.B.1.a - Forest land Remaining Forest land	-2498.48		
3.B.1.b - Land Converted to Forest land	-128.45		
3.B.1.b.i - Cropland converted to Forest Land	-106.45		
3.B.1.b.ii - Grassland converted to Forest Land	-9.30		
3.B.1.b.iii - Wetlands converted to Forest Land	-12.70		
3.B.1.b.iv - Settlements converted to Forest Land			
3.B.1.b.v - Other Land converted to Forest Land			
3.B.2 - Cropland	1589.39		
3.B.2.a - Cropland Remaining Cropland			
3.B.2.b - Land Converted to Cropland	1589.39		
3.B.2.b.i - Forest Land converted to Cropland	1589.38		
3.B.2.b.ii - Grassland converted to Cropland			
3.B.2.b.iii - Wetlands converted to Cropland	0.01		
3.B.2.b.iv - Settlements converted to Cropland			
3.B.2.b.v - Other Land converted to Cropland			
3.B.3 - Grassland	261.89		
3.B.3.a - Grassland Remaining Grassland			
3.B.3.b - Land Converted to Grassland	261.89		
3.B.3.b.i - Forest Land converted to Grassland	261.89		
3.B.3.b.ii - Cropland converted to Grassland			

Category	CO_2 emissions/ removals (Gg)	CH_4 emissions	N_2O emissions
3.B - Land	**-562.58**	**NE**	**NE**
3.B.3.b.iii - Wetlands converted to Grassland			
3.B.3.b.iv - Settlements converted to Grassland			
3.B.3.b.v - Other Land converted to Grassland			
3.B.4 - Wetlands			
3.B.4.a - Wetlands Remaining Wetlands			
3.B.4.a.i - Peatlands remaining peatlands			
3.B.4.a.ii - Flooded land remaining flooded land			
3.B.4.b - Land Converted to Wetlands			
3.B.4.b.i - Land converted for peat extraction			
3.B.4.b.ii - Land converted to flooded land			
3.B.4.b.iii - Land converted to other wetlands			
3.B.5 - Settlements	24.78		
3.B.5.a - Settlements Remaining Settlements			
3.B.5.b - Land Converted to Settlements	24.78		
3.B.5.b.i - Forest Land converted to Settlements	24.78		
3.B.5.b.ii - Cropland converted to Settlements			
3.B.5.b.iii - Grassland converted to Settlements			
3.B.5.b.iv - Wetlands converted to Settlements			
3.B.5.b.v - Other Land converted to Settlements			
3.B.6 - Other Land	188.29		
3.B.6.a - Other land Remaining Other land			
3.B.6.b - Land Converted to Other land	188.29		
3.B.6.b.i - Forest Land converted to Other Land	188.29		
3.B.6.b.ii - Cropland converted to Other Land			
3.B.6.b.iii - Grassland converted to Other Land			
3.B.6.b.iv - Wetlands converted to Other Land			
3.B.6.b.v - Settlements converted to Other Land			

3.12.2.11 Methodology for the FOLU Sector

The FOLU inventory adopted the 2006 IPCC Guidelines for the estimation of the emissions and removals while employing both tier 1 and 2 estimation levels. As more refined activity data and new emission factors were developed, especially for the Miombo woodlands, recalculations were made for the period outside the reporting period, 2001 to 2017, further down to the year 1990. Activity data from the JICA-Malawi Government mapping initiative covered epochs 1990, 2000 and 2010. Data between the three epochs was linearly interpolated while extrapolation was conducted for the period 2011 to 2017. Due to paucity of data in literature for uncertainty tests, unlike in other sectors like energy, uncertainty tests were not conducted for the FOLU sector.

The GHGs were estimated using Approach 1 (reporting total land-use area without conversions between land uses) and partly approach 2, where land use conversions and data between land cover classes is available. The classes are Forestland, Cropland, Grasslands, Wetlands, Settlements, and Other Land. Except for wetlands, all the other five classes are considered as managed in the country's context. The six land classes are nationally defined.

3.4.2.3 Aggregate sources and non-CO_2 emissions sources on land - 3.C

The non-CO_2 emissions from land In 2010 are shown in Table 3.22.

Table 3. 24 **Non-CO_2 emissions sources on land - 3.C for 2010**

	Net CO_2	CH_4	N_2O
3.C - Aggregate sources and non-CO_2 emissions sources on land(2)	88.71	7.32	0.03
3.C.1 - Emissions from biomass burning	0.00	1.49	0.00
3.C.1.a - Biomass burning in forest lands		1.29	0.00
3.C.1.b - Biomass burning in croplands		0.01	0.00
3.C.1.c - Biomass burning in grasslands		0.19	0.00
3.C.1.d - Biomass burning in all other land		0.00	0.00

3.4.2.4 Emissions from biomass burning – 3.C.1

Only losses of carbon stocks due to fires were considered in this inventory. Other disturbances such as wind, and pest and disease outbreaks were considered insignificant. The statistics of the burnt areas were acquired from Global Forest Resource (FRA) assessment and distributed proportionately to forest sub-types and other land classes. Biomass burning utilized combustion values and fuel loads from regionally existing studies (Hoffa et al., 1999).

The FOLU sector contributes N_2O, Carbon dioxide (CO_2) and CH_4 and Carbon monoxide (CO) gases to the national emissions. In the reporting period, CO_2 was clearly the most significant for the FOLU sector. However, with regard to biomass burning, over the reporting period, CO_2 was the most significant gas (35,093.9 1Gg of CO_2eq) as compared to the other gases (Figure 3.25) with the amounts varying from year to year (Table 3.49). The second most significant gas was CO at 315.6 1Gg of CO_2 eq. The least significant gas was N_2O with less than 1Gg of CO_2eq for the whole reporting period. Malawi's initial communication also showed similar trends with relatively high CO for LUCF.

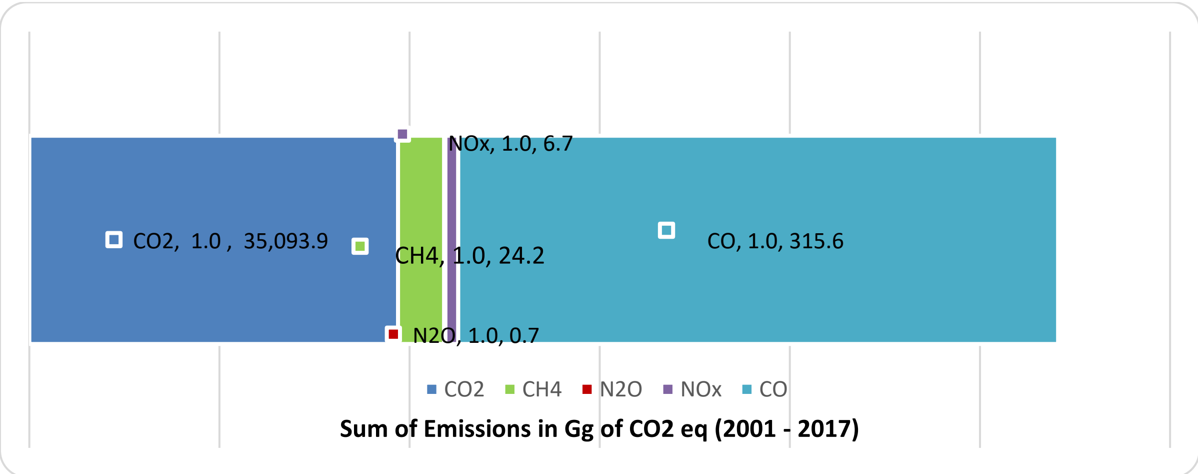


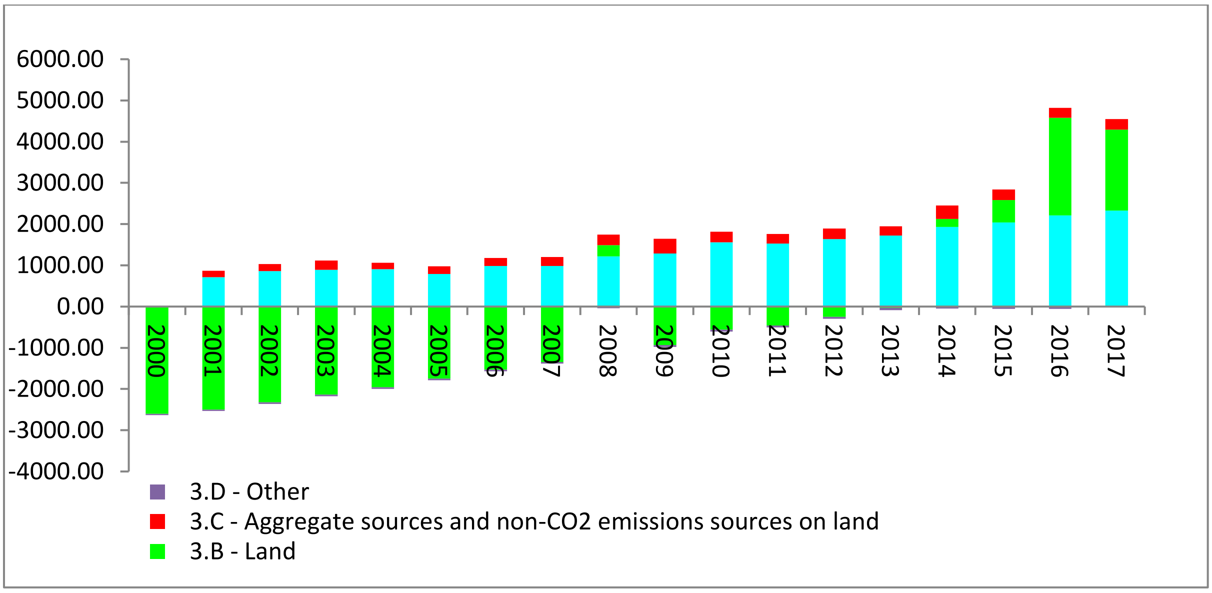
Figure 3. 10 **Emissions from biomass burning (2001 – 2017)**

The trend of non-CO_2 emissions from biomass burning is shown in Table 3.24. The emissions were fluctuating over the whole time series.

Table 3. 25 **Trends in gases for biomass burning (1990 – 2017)**

Year	Source	CH_4 (Gg)	N_2O (Gg)	NOx	CO (Gg)
1990	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1991	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	0.000
1992	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1993	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	0.000
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.000	0.000
1994	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1995	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	0.000
1996	3.C.1.a - Biomass burning in forest lands	0.475	0.014	0.112	7.258
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.450
	3.C.1.c - Biomass burning in grasslands	0.069	0.002	0.040	0.000
1997	3.C.1.a - Biomass burning in forest lands	0.289	0.008	0.068	4.420
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.454
	3.C.1.c - Biomass burning in grasslands	0.042	0.001	0.024	0.402
1998	3.C.1.a - Biomass burning in forest lands	0.381	0.011	0.090	5.825
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.456
	3.C.1.c - Biomass burning in grasslands	0.055	0.002	0.032	0.000
1999	3.C.1.a - Biomass burning in forest lands	0.351	0.010	0.083	5.367
	3.C.1.b - Biomass burning in croplands	0.010	0.000	0.009	0.342
	3.C.1.c - Biomass burning in grasslands	0.051	0.002	0.029	0.488
2000	3.C.1.a - Biomass burning in forest lands	0.097	0.003	0.023	1.479
	3.C.1.b - Biomass burning in croplands	0.018	0.000	0.017	0.699
	3.C.1.c - Biomass burning in grasslands	0.014	0.000	0.008	0.134
2001	3.C.1.a - Biomass burning in forest lands	0.690	0.020	0.162	10.549
	3.C.1.b - Biomass burning in croplands	0.022	0.001	0.020	0.735
	3.C.1.c - Biomass burning in grasslands	0.100	0.003	0.058	0.000
2002	3.C.1.a - Biomass burning in forest lands	0.435	0.013	0.102	6.658
	3.C.1.b - Biomass burning in croplands	0.006	0.000	0.005	0.189
	3.C.1.c - Biomass burning in grasslands	0.063	0.002	0.036	0.605
2003	3.C.1.a - Biomass burning in forest lands	0.959	0.028	0.226	14.665
	3.C.1.b - Biomass burning in croplands	0.006	0.000	0.006	0.219
	3.C.1.c - Biomass burning in grasslands	0.140	0.004	0.080	1.334
2004	3.C.1.a - Biomass burning in forest lands	0.283	0.008	0.067	4.328
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.094
	3.C.1.c - Biomass burning in grasslands	0.041	0.001	0.024	0.394
2005	3.C.1.a - Biomass burning in forest lands	1.255	0.037	0.295	19.191
	3.C.1.b - Biomass burning in croplands	0.004	0.000	0.004	0.140
	3.C.1.c - Biomass burning in grasslands	0.183	0.006	0.105	1.745
2006	3.C.1.a - Biomass burning in forest lands	0.245	0.007	0.058	3.744
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.028
	3.C.1.c - Biomass burning in grasslands	0.036	0.001	0.020	0.000

2007	3.C.1.a - Biomass burning in forest lands	0.259	0.008	0.061	0.000
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.019
	3.C.1.c - Biomass burning in grasslands	0.038	0.001	0.022	0.360
2008	3.C.1.a - Biomass burning in forest lands	0.755	0.022	0.178	11.549
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.099
	3.C.1.c - Biomass burning in grasslands	0.110	0.003	0.063	1.050
2009	3.C.1.a - Biomass burning in forest lands	0.291	0.009	0.069	4.455
	3.C.1.b - Biomass burning in croplands	0.007	0.000	0.006	0.227
	3.C.1.c - Biomass burning in grasslands	0.042	0.001	0.000	0.000
2010	3.C.1.a - Biomass burning in forest lands	1.293	0.038	0.304	19.775
	3.C.1.b - Biomass burning in croplands	0.009	0.000	0.008	0.294
	3.C.1.c - Biomass burning in grasslands	0.188	0.006	0.108	1.798
2011	3.C.1.a - Biomass burning in forest lands	0.639	0.019	0.150	9.775
	3.C.1.b - Biomass burning in croplands	0.002	0.000	0.002	0.000
	3.C.1.c - Biomass burning in grasslands	0.031	0.003	0.053	0.889
2012	3.C.1.a - Biomass burning in forest lands	1.272	0.037	0.299	19.458
	3.C.1.b - Biomass burning in croplands	0.002	0.000	0.002	0.068
	3.C.1.c - Biomass burning in grasslands	0.185	0.006	0.106	1.769
2013	3.C.1.a - Biomass burning in forest lands	0.938	0.028	0.221	0.000
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.099
	3.C.1.c - Biomass burning in grasslands	0.136	0.004	0.078	1.305
2014	3.C.1.a - Biomass burning in forest lands	1.618	0.048	0.381	24.751
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.039
	3.C.1.c - Biomass burning in grasslands	0.080	0.007	0.135	0.000
2015	3.C.1.a - Biomass burning in forest lands	1.448	0.043	0.341	22.153
	3.C.1.b - Biomass burning in croplands	0.004	0.000	0.004	0.147
	3.C.1.c - Biomass burning in grasslands	0.211	0.007	0.121	2.014
2016	3.C.1.a - Biomass burning in forest lands	1.618	0.048	0.381	24.751
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.039
	3.C.1.c - Biomass burning in grasslands	0.235	0.007	0.135	2.251
2017	3.C.1.a - Biomass burning in forest lands	0.741	0.022	0.174	11.334
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.114
	3.C.1.c - Biomass burning in grasslands	0.108	0.003	0.062	0.000



Overall emissions on land

Planned improvements

While there is need to improve the monitoring system through sustained capacity building and improvement of its core elements such as data archiving, specific to the inventory, in the next inventory cycle, there is need to:

- Classify crop types into perennial and annual cropland and determine their distribution extent within the country.
- Further classify forest land and cropland into two key soil types (HAC and LAC) and determine their distribution by Malawi's climate – tropical dry climate**.**
- Properly document the sector's uncertainties of the estimates as well as overall uncertainties of the whole inventory.
- Extend calculations of HWP data to year 1911 other than the existing year of 1961 as in the current inventory.

3.13 Waste Sector

In 2010, the Waste sector in Malawi contributed 1004.06Gg CO_2eq with 47.37% coming from Wastewater Treatment and Discharge (4D), 42.17% from Solid waste disposal (4A), and 10.46% from Incineration and open burning of waste (4.C).

Table 3. 26 Waste sector GHG emissions by mass (Gg)-2010

Source category	CO_2	CH_4	N_2O	Total	%
4 - Waste	9.13	803.17	191.77	1004.06	100.00%
4.A - Solid Waste Disposal		423.42		423.42	42.17%
4.A.1 - Managed Waste Disposal Sites					
4.A.2 - Unmanaged Waste Disposal Sites					
4.A.3 - Uncategorised Waste Disposal Sites					
4.B - Biological Treatment of Solid Waste					
4.C - Incineration and Open Burning of Waste	9.13	80.28	15.59	104.99	10.46%
4.C.1 - Waste Incineration					
4.C.2 - Open Burning of Waste	9.13	80.28	15.59	104.99	10.46%
4.D - Wastewater Treatment and Discharge		299.47	176.18	475.65	47.37%
4.D.1 - Domestic Wastewater Treatment and Discharge		299.47	176.18	475.65	47.37%
4.D.2 - Industrial Wastewater Treatment and Discharge					
4.E - Other (please specify)					

3.13.1 Methodology

3.13.1a Data Collection

The data collection procedure was in two fold;

1. Sample collection and Laboratory analysis
2. Structured questionnaire interview

3.13.1b Waste Management and GHG emissions

The treatment and disposal of municipal, industrial and other solid waste releases large amounts of methane (IPCC, 2006). Methane produced at solid waste disposal sites (SWDS) contributes about 3 to 5% of the annual global anthropogenic GHG emissions (IPCC, 2001; *World Bank, 2012*). Further, degradable organic carbon methane production starts one or two years after waste is deposited in landfills (Chipofya, 2003). In Malawi, there was steady increase of CH_4 emissions from solid waste from 2001 to 2017.

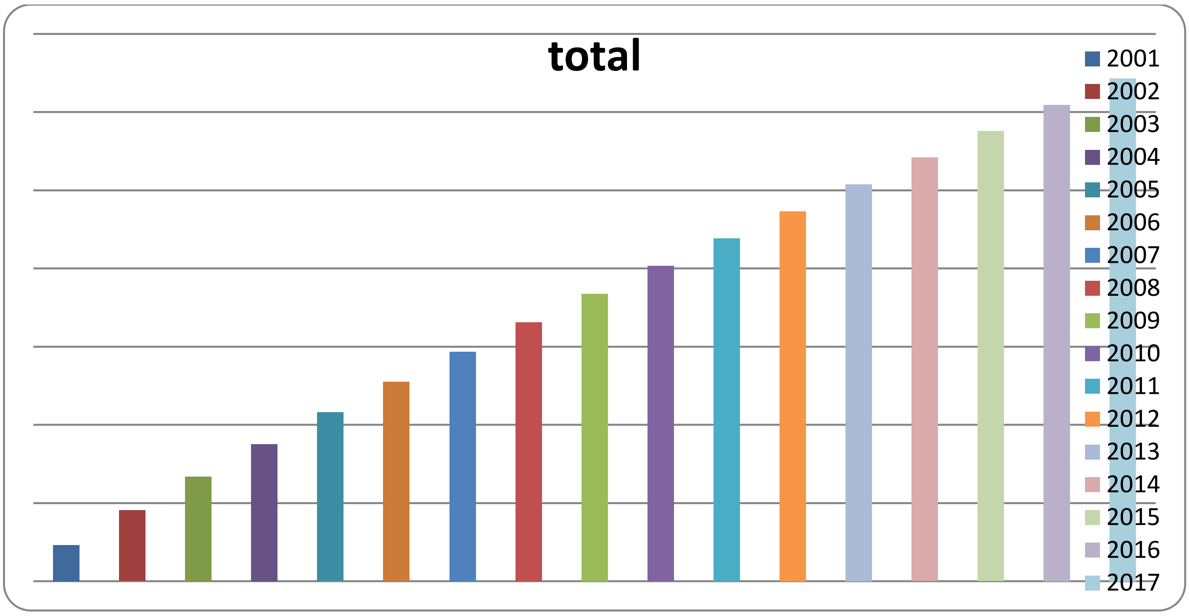


Figure 3. 11 **Methane emissions from Solid Waste (2001-2017)**

3.13.2 Wastewater Treatment and Discharge- 4D

It was observed that most Councils had no wastewater treatment facility, let alone formal disposal area for their public. However, few councils had such a facility, namely; Blantyre, Lilongwe, Mzuzu, Zomba, and Balaka/Liwonde, despite the fact that the facilities from the mentioned Councils had also challenges when it comes to functionality.

Greenhouse gas emissions were estimated from domestic wastewater treatment. The IPCC default parameters used to estimate emissions from water treatment are presented in Table 3.26 and the emissions are shown in Table 3.27.

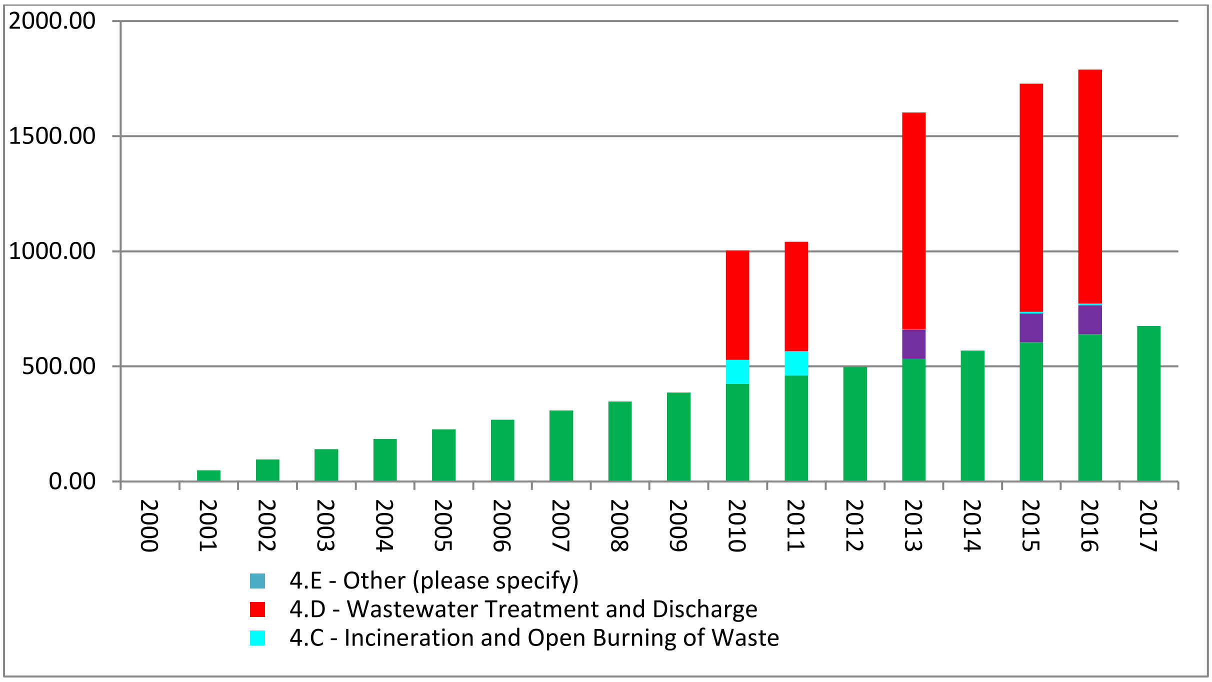
Table 3. 27 Parameters used to calculate GHG emissions from waste water treatment

Type of treatment or discharge	Maximum methane producing capacity (BO-kg CH_4/kh Biological Oxygen Demand (BOD)	Methane correction factor (MCF)	Emission factor (kgCH_4/kgBOD)
Centralized aerobic treatment	0.6	0	0
Aerobic deep lagoon	0.6	0.8	0.48
Septic system	0.6	0.5	0.3
Latrine	0.6	0.1	0.06

Table 3. 28 Methane and nitrous oxide emissions from wastewater treatment

Year	2010	2011	2012	2013	2014	2015	2016
CH_4 (CO_2eq)	299.47	-	-	836.53	--	885.76	911.44
N_2O (CO_2eq)	176.18	--	--	105.90	--	106.00	105.90

Emissions from biological treatment of solid waste (4B), as well as those from Incineration and Open Burning of waste (4C) and were not reported in this inventory because of lack of data.



Overall emission from waste sector

3.13.2.1 Waste sector QA/QC

Since the study had a number of limitations which could compromise the results, the team resorted to using both the calculated values for activity data the default values, of which according to the IPCC guidelines the eastern African values were very much relevant to the Malawi data, due to similarity in climate, at the same time economic status and other social and environmental factors that have a bearing on waste type and methods of management.

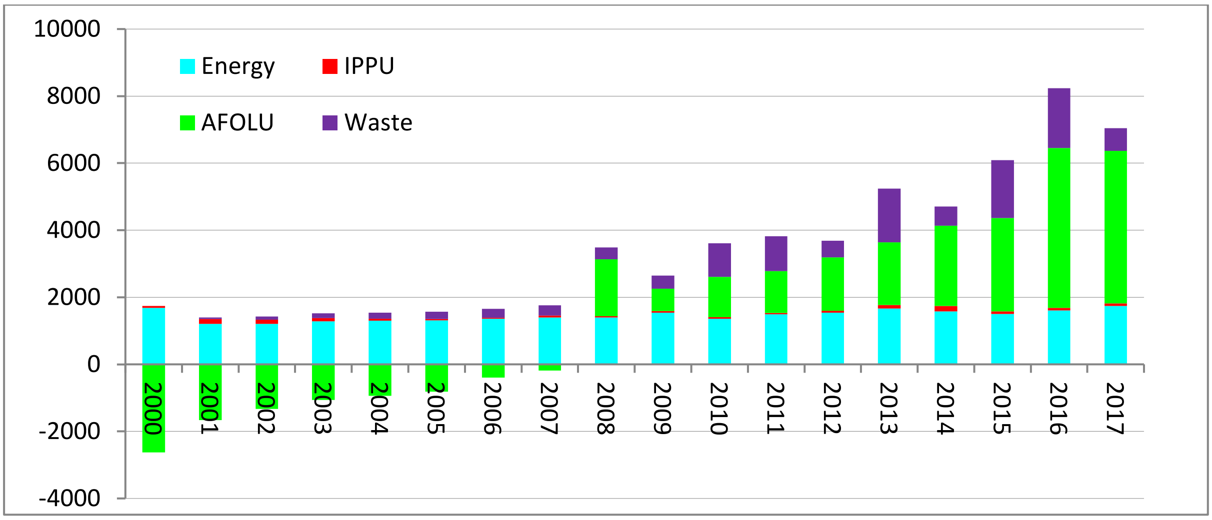
3.13.2.2 Improvement Plan

- There is a need to frequently carry on laboratory tests on the various required parameters for GHG emission calculation even at Council level, so that we can easily develop our estimate Country Specific EF values in near future for easy calculation without major discrepancies,
- There is also a need to promote the arrangement of mainstreaming the calculation exercise into day to day work for ownership and consistency of data from various points of data collection
- Institutions responsible for waste management should keep data on waste management, just as they do with other Environmental sectors like Forestry. This can be in form of

developing a template which can be used to capture basic activity data which may be readily available for use when needed.

- Frequently carry on laboratory tests on the various required parameters for GHG emission calculation even at Council level, so that we can easily develop our estimate Country Specific EF values in near future for easy calculation without major discrepancies.
- Investigate reasons why some areas generate more waste than others and what should be done to manage the waste properly to minimize emissions of GHGs.

3.14 Overall Emissions Trends by sector and Gas



Year	***1994***	***2000***	***2010***	***2017***	*Percentage change between 1994 and 2017*[d]
Gas ($GgCO_2eq$)					
CO_2	18231.28	-921.26	468.71	3271.65	*-82.05%*
CH_4	3945.9	17.25	2,644.47	3342.5	*-15.29%*
N_2O	2405.6	16.26	500.35	428.58	*-82.18%*
HFCs					
PFCs					
SF_6					
Total	24582.78	-887.75	3,613.53	7042.72	*-71.35%*

GHG Emissions and removals by year and sector

Year	*1994*	*2000*	*2010*	*2017*	*Percentage change between 1994 and 2017[d]*
Sectors (CO_2eq)					
Energy	3717.87	*1683.82*	*1,364.44*	*1740.37*	*-53.19%*
Industrial Processes and Product Use	**50.12**	*55.23*	*40.1*	*80.58*	*60.77%*
Agriculture, forestry and other land use	20716.44	-2626.8	*1205.02*	*4546.7*	*-78.05%*
Waste			*1,004.06*	*675.07*	
Total	24582.78	-887.75	3,613.53	*7,042.72*	

APPENDICES

Appendix **1. 1** Waste analysis data

Description:	fraction of municipal solid waste comprised of type	dry mass fraction of waste type	carbon mass fraction of dry mass	fossil carbon mass fraction of carbon mass	fossil carbon mass fraction of waste (wet basis)
UNITS:	fraction	fraction	fraction	fraction	fraction
municipal waste	WF	dm_WF	CF_dm	FCF_CF	FCF_WF
paper/cardboard	7.7%	90.0%	46.0%	1.0%	0.032%
textiles	1.7%	80.0%	50.0%	20.0%	0.136%
food waste	53.9%	40.0%	38.0%	0.0%	0.000%
wood	7.0%	85.0%	50.0%	0.0%	0.000%
garden (yard) and	0.0%	40.0%	49.0%	0.0%	0.000%
disposable nappie	0.0%	40.0%	70.0%	10.0%	0.000%
rubber and leathe	1.1%	84.0%	67.0%	20.0%	0.124%
plastics	5.5%	100.0%	75.0%	100.0%	4.125%
metal	1.8%	100.0%	0.0%	0.0%	0.000%
glass	2.3%	100.0%	0.0%	0.0%	0.000%
other inert waste	11.6%	90.0%	3.0%	100.0%	0.313%
unknown	7.4%				0.000%

Appendix 1. 2 Laboratory test findings (First analysis)

ID	DRY MATER %	F. CARBON %	PROTEIN %	NITROGEN %	POTASSIUM (g/kg)	PHOSPHORUS (mg/g)
Soche Dry Sludge(A)	56.85	43.16	9.62	1.54		
Soche Wet Sludge(I)	16.08	16.93	4.97	0.8		
Soche Dry Sludge 2(G)	9627	39.5	1.73	0.28		
Blantyre Municipal Waste(B)	59.29	25.48	5.38	0.86		
LL Mtandire Solid Waste(C)	94.97	8.37	1.73	0.38	22.53	8.72
LL Dumpside Area 38(U)	98.03	21.99	2.38	0.52	18.32	7.8
LL Composite Solid Waste(Q)	73.54	20.36	3.25	0.63	18.32	14.75
Kauma Sludge (liquid)(Z1)	29.89	42.24	3.93	0.2	4.31	12.8
Kauma Dry Sludge(Z2)	4.47	60.53	1.27	1.15	1.92	2.28
Kanengo Sludge(Y2)	5.15	56.21	0.91	2.42	1.66	1.14
Mzuzu Dry Sludge(E)	76.36	54.86	15.12	0.14		
Mzuzu Municipal Waste(F)	78.73	16.22	0.86	0.82		
Mzuzu Wet Sludge(P)	32.42	24.48	5.13	0.33		
Balaka Wet Sludge(H)	68.18	5.89	2.09	1.52		
Balaka Dry Sludge(T)	97.2	29	9.47	0.31		
Balaka Municipal Waste(S)	99.01	7.79	1.95	0.83		
Zomba Wet Sludge(N)	18.98	62.16	5.18	1		
Zomba Dry Sludge(O)	97.53	20.93	6.25	0.93		
Zomba Dry Sludge 2(W)	63.92	44.82	5.8	0.49		
Zomba Municipal WasteX	93.09	12.67	3.11	0.22		
Liwonde Municipal Waste(V)	96.28	7.76	1.4	0.32		
Luchenza Municipal Waste(J)	86.17	6.03	2.04	0.98		
Dedza Municipal Waste(Y)	95.38	29.47	6.15	0.9		
Kasungu Municipal Waste(D)	92.95	12.74	1.14	0.18		
Kalonga Municipal Waste(R)	98.51	11.21	3.25	0.52		
Kalonga Dry Sludge(M)	89.16	28.8	8.43	1.35		
Mangochi Municipal Waste(L)	98.96	6.76	1.59	0.25		
Salima Municipal Waste(K)	99.15	11.07	0.87	0.14		

Appendix 1. 3 Laboratory test findings (Second analysis)

SAMPLE ID	PROTEIN(%)	TOTAL NITROGEN(%)	CARBON CONTENT (%)	DRY MATTER(%)	Fr. Of C. IN DRY MATTER	P (mg/100g)
B a1	3.171	0.507	7.691	83.949	0.092	84.99
B a2	2.843	0.455	8.093	82.935	0.098	86.81
B b1	2.844	0.455	9.509	77.593	0.123	102.91
B b2	2.625	0.42	7.567	77.024	0.098	102.64
S a1	2.298	0.368	7.138	75.539	0.095	79.456
S a2	2.845	0.455	6.037	75.517	0.08	81.074
S b1	2.4	0.384	6.719	75.781	0.089	179.709
S b2	2.618	0.419	6.976	73.706	0.095	180.346
D a1	1.309	2.209	14.28	59.238	0.241	114.832
D a2	1.2	0.191	19.835	63.447	0.312	114.195
D b1	2.4	0.384	9.369	60.705	0.154	94.086
D b2	2.732	0.437	8.81	61.144	0.144	94.99
M a1	2.156	0.415	4.725	85.43	0.055	95.086
M a2	2.298	0.367	3.236	88.368	0.037	94.722
M b1	2.297	0.368	5.21	84.206	0.062	94.177
M b2	3.282	0.425	10.028	76.495	0.131	94.359
K a1	1.3	0.21	10.753	93.551	0.115	74.431
K a2	1.29	0.22	10.847	94.706	0.215	74.704
K b1	3	0.48	20.296	99.035	0.109	88.808
K b2	3.001	0.478	25.989	98.923	0.262	87.898

Key:

B = Balaka, S= Salima, D = Dedza, M = Mangochi, K = Kasungu, Fr. of C = Fraction of Carbon, P = Phosphorus

Appendix 1. 4 summary tables for INC, SNC and TNC

Summary Report of National Greenhouse Gas Inventories for 1994 (Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_X	CO
Total National Emissions and Removals	**19247.28**	**-1016.00**	**187.90**	**7.77**	**26.31**	**951.80**
1. Energy - Sectoral Approach (Not done)						
- Reference Approach (Below)	**660.88**	**0.00**	**135.09**	**0.71**	**24.03**	**879.58**
2. Industrial Processes	**58.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
3. Agriculture	**0.00**	**0.00**	**48.50**	**7.05**	**2.24**	**72.20**
4. Land Use Change and Forestry	**18528.02**	**-1016.00**	**0.02**	**0.01**	**0.04**	**0.02**
5. Waste	**0.00**	**0.00**	**4.29**	**0.00**	**0.00**	**0.00**

Total emissions in terms of carbon dioxide equivalent for the period 1995 to 2000.

	1995	1996	1997	1998	1999	2000
1 Energy Sector						
1A Fuel combustion activities	742.88	752.41	807.69	843.27	781.83	726.13
1B Fugitive emissions from fuels	0.57	0.57	1.02	0.95	0.58	0.68
1C Carbon dioxide transport and storage	NA	NA	NA	NA	NA	NA
2 Industrial Processes and Product Use (IPPU)						
2A Mineral Industry	59.53	46.59	37.93	48.04	57.30	59.18
2B Chemical industry	NA	NA	NA	NA	NA	NA
2C Metal Industry	NA	NA	NA	NA	NA	NA
2D Non-energy products from fuels and solvent use	0.07	0.16	0.73	0.31	0.42	0.50
2E Electronics industry	NA	NA	NA	NA	NA	NA
2F Product uses as substitutes of ODS	NE	NE	NE	NE	NE	NE
2G Other product manufacture and use	NA	NA	NA	NA	NA	NA
2H Other (Please specify)	NA	NA	NA	NA	NA	NA
3 Agriculture, Forestry and other land use						
3A Livestock	747.30	730.69	664.63	762.31	740.90	810.75
3B Land	17800.00	18089.00	18377.00	18666.00	18954.00	19243.00
3C Aggregate sources and non-CO2 emissions sources on land	2459.669	2406.592	2514.025	2195.056	2174.688	2280.547
3D Other	NE	NE	NE	NE	NE	NE
4 Waste						
4A Solid waste disposal	150.20	156.59	163.08	169.84	176.65	184.57

4B Biological treatment of solid waste	NE	NE	NE	NE	NE	NE
4C Incineration and open burning of waste	83.60	87.32	91.36	94.97	99.36	105.90
4D Waste water treatment and discharge	14.79	15.44	16.07	16.80	17.50	18.29
4E Other (please specify)	NE	NE	NE	NE	NE	NE
Overall Total Emissions	23108.80	23342.38	23840.55	23776.20	23559.389	23294.50

Summary of GHG Emissions in units of mass for 2010

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
Total National Emissions	468.71	1.61	1.61							
1 - Energy	939.02	0.30	0.30				NA	NA	NA	NA
1.A - Fuel Combustion	936.58	0.30	0.30				NA	NA	NA	NA
1.A.1 - Energy Industries	3.12	0.10	0.10				NA	NA	NA	NA
1.A.2 - Manufacturing Industries and	258.50	0.122	1				NA	NA	NA	NA
1.A.3 - Transport	647.47	0.13	0.03				NA	NA	NA	NA
1.A.4 - Other Sectors	27.49	14.13	0.16							
1.A.5 - Non-Specified	NO	NO	NO							
1.B - Fugitive emissions										
1.B.1 - Solid Fuels	NE	9.97	NE							
1.B.2 - Oil and Natural	NO	NO	NO				NO	NO	NO	NO
1.B.3 - Other emissions	NO	NO	NO				NO	NO	NO	NO
1.C - Carbon dioxide										
1.C.1 - Transport of CO2	NO			NO	NO	NO	NO	NO	NO	NO
1.C.2 - Injection and	NO		NO	NO	NO	NO	NO	NO	NO	NO
1.C.3 - Other										
2 - Industrial Processes	40.01	NE	NE							
2.A - Mineral Industry	40.01	NE								
2.A.1 - Cement production	16.07	NE								
2.A.2 - Lime production	23.84	NE								
2.A.3 - Glass Production	NO	NO								
2.A.4 - Other Process Uses	0.10	NO								
2.A.5 - Other (please	NA	NA								
2.B - Chemical Industry	NO	NO	NO	NA	NA	NA				
2.C - Metal Industry	NO	NO	NO	NA	NA	NA				
2.D - Non-Energy Products from Fuels and	NO	NO	NO				NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone	NE		NE	NE	NE	NE				
2.G - Other Product	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.H - Other	NA	NA	NA							
3 - Agriculture, Forestry,	-519.45	71.87	0.69				NA	NA	NA	NA
3.A - Livestock		64.55	0.66				NA	NA	NA	NA
3.B - Land	-562.58	NE	NE				NA	NA	NA	NA
3.C - Aggregate sources and non-CO2 emissions	88.71	7.32	0.03				NA	NA	NA	NA
3.D - Other	-45.58						NA	NA	NA	NA
4 - Waste	9.13	38.25	0.62				NA	NA	NA	NA
4.A - Solid Waste Disposal		20.16	NE				NA	NA	NA	NA
4.B - Biological Treatment		NE	NE				NA	NA	NA	NA
4.C - Incineration and	9.13	3.82	0.05				NA	NA	NA	NA
4.D - Wastewater		14.26	0.57				NA	NA	NA	NA
4.E - Other (please	NA	NA	NA				NA	NA	NA	NA
5 - Other	NA	NA	NA				NA	NA	NA	NA

CHAPTER FOUR

PROGRAMMES CONTAINING MEASURES TO FACILLITATE ADEQUATE CLIMATE CHANGE ADAPTATION

4.1 Programmes Containing Measures to Facillitate Adequate Adaptation

The compilation of the Climate Change Vulnerability and Adaptation (V&A) Assessment Chapter of Malawi's Third National Communication has been done in compliance with Articles 4.1(e), 4.8 and 4.9 of the United Nations Framework Convention on Climate Change (UNFCCC). Eleven of the country's key socioeconomic sectors were analyzed during the assessment, namely: Agriculture; Water Resources; Human Health; Energy; Infrastructure; Land Resources; Fisheries; Forestry; Wildlife; Industry; and Tourism. Malawi's vulnerability to climate change arises from the country's socio-economic, demographic and climatic factors. Effects of these factors are exacerbated by the country's narrow economic base, which is principally agro-based in nature; limited agro-processing capability; over-dependency on rain-fed agriculture and biomass energy; inadequate health facilities; population pressure; and poverty. These adverse effects are further aggravated by natural disasters caused by floods, droughts, strong winds, and pests and diseases.

The vulnerability assessment of the eleven sectors was undertaken by a team of national experts drawn from Government Ministries and Departments, the Academia, the Private Sector, NGOs, Civil Society Organizations, and Faith Based Organizations. The task entailed scrutinizing all sectoral adaptation options recommended for implementation by the Government of Malawi as discussed in Malawi's Initial and Second National Communication reports, focusing on methodologies adopted for conducting climate change vulnerability assessments for the various sectors; and critically analyzing the proposed adaptation strategies in respect of their relevance, effectiveness, efficiency, impact, and sustainability. The adaptive strategies were thereafter prioritized and categorized in light of their implementation arrangements, whether short-term (within 5 years), mid-term (5 to 10 years), or long term (greater than 10 years). And whether or not Malawi will need external financial and technical support from development partners to implement the proposed climate change adaptation strategies.

Projections of temperature and rainfall for Malawi were done using statistically downscaled General Circulation Models (GCMs) following the procedure recommended by the Intergovernmental Panel on Climate Change (IPCC) as discussed in the Fifth Assessment Report (AR5), IPCC (2013). Tables 1 and 2, and Figure 1 show data and information on climate change scenarios for temperature and rainfall. It is worth noting that AR5 is premised on two Representative Concentration Pathways (RCPs) of Greenhouse Gas (GHG) Emissions, namely: RCP 4.5 (Intermediate Emission), and RCP 8.5 (High Emission) as described by Moss *et al.* (2013). RCP 4.5 and 8.5 are respectively equivalent to story lines B1 and A1F1 in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007).

RCP 8.5 or Scenario A1F1 is consistent with the following scenarios: (a) three times today's CO_2 emissions by 2100; (b) rapid increase in methane emissions; (c) increased use of croplands and grassland driven by an increase in population growth; (d) a world population of 12 billion by 2100; (e) lower rate of technology development; (f) heavy reliance on fossil fuels; (g) high energy intensity; and (h) no implementation of climate change policies.

Table 4. 1 Temperature Scenarios

Location	Near Century Period: 2011-2040.	Mid Century Period: 2041-2070.	End Century Period: 2071-2100.
Lower Shire Valley	0.03^{o}C-0.04^{o}C: temperature increase.	1.4^{o}C-2.8^{o}C: temperature increase.	2.5^{o}C-4.2^{o}C: temperature increase.
Shire Highlands	0.034^{o}C: temperature increase (Jun-Dec).	1.0^{o}C: temperature increase.	1.5^{o}C-2.4^{o}C: temperature increase.
Central Areas	0.7^{o}C-0.9^{o}C: temperature increase.	1.3^{o}C: temperature increase.	Temperature increase.
Lakeshore Areas	0.8^{o}C-0.9^{o}C: temperature increase.	1.5^{o}C-2.0^{o}C: temperature increase.	2.5^{o}C-3.0^{o}C: temperature increase.
Northern Areas	0.2C-0.9^{o}C: temperature increase.	1.4^{o}C-1.9^{o}C: temperature increase.	1.7^{o}C-2.3^{o}C: temperature increase.

Table 4. 2 Rainfall Scenarios

Location	Near Century Period: 2011-2040.	Mid Century Period: 2041-2070.	End Century Period: 2071-2100.
Lower Shire Valley	800 mm – 1000 mm: mean rainfall.	January rainfall to increase by 8% while summer will be drier by 3% to 5%.	Rainfall to decrease by about 15%.
Shire Highlands	1000 mm – 1200 mm: mean rainfall.	Winter rainfall to increase by 15% while summer rainfall will decrease by 10%	Summer rainfall to decrease by 25%.
Central Areas	800 mm -1100 mm: mean rainfall.	October to December rainfall to decrease by 10% to 22%.	October to December rainfall to decrease by 20% to 56%.
Lakeshore Areas	March to April rainfall will increase by 5% to 25%.	Winter rainfall will decrease by 65%.	There will be a general decrease in rainfall by 60%.
Northern Areas	Increase in rainfall by 3% to 8% during the period January to April.	October to December rainfall to decrease by 10% to 36%.	Rainfall to decrease by 56%.

RCP 4.5, which is comparable to SRES B1, is consistent with the following scenarios: (a) lower energy intensity; strong reforestation programmes; (b) decreasing use of croplands and grasslands due to yield increases and dietary changes; (c) stringent climate policies; (d) stable methane emissions; and (e) CO_2 emissions increase only slightly before decline commences around the year 2040.

The A2 Storyline describes a very heterogeneous world, with self-reliance and preservation of local identities as the underlying theme. Fertility patterns across regions converge very slowly, which results in continuously increasing population growth. Economic development is primarily regionally oriented, with more fragmented and slower per capita economic growth and technological change than other storylines. Scenario A1B depicts a scenario with a balance across all sources, where balance is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies. The main finding from the comparison of SRES with scenarios described in the Fifth Assessment Report is that the uncertainties as represented by the ranges of main driving forces and emissions have not changed very much.

The following conclusions may be drawn from climate change scenario analysis results presented in Tables 1 and 2 about future expected temperature and rainfall regimes in Malawi using the two RCPs: (a) there is a positive trend in temperature rise, i.e., there will be an increase in temperature in Malawi with climate change; (b) minimum temperatures exhibit a faster rise in temperature with climate change than maximum temperatures; (c) generally, there is an insignificant decrease in rainfall during the OND period, and an increase during JFM; (d) future temperatures will rise by 1.3 ^{o}C to 2.6 ^{o}C; and (e) El Nino conditions will likely increase climate extremes, resulting in the increased severity, or magnitude/intensity, and frequency of floods, droughts, and strong winds. What is clear from the description of climate change scenarios for Malawi presented above is that floods, droughts and strong winds will continue to wreak havoc in the country. Thus, the country's vulnerability to the vagaries of severe floods, droughts, and strong winds should be taken as a serious cause for worry by the Government of Malawi and the citizenry, and hence the urgent need by the country to implement robust climate change adaptation strategies in order to avert impending disasters associated with these three hazards.

Studies done by McSweeney *et al*. (2008) show a temperature increase of 0.9 ^{o}C between 1960 and 2006 for Malawi, an average rate of 0.21^{o}C per decade. The increase in temperature has been most rapid in December-January-February (DJF) and slowest in September-October-November (SON). Daily temperature observations show an increase in the frequency of hot days and nights in all the seasons. The frequency of cold days and nights has significantly decreased in all the seasons, except in SON. Observed rainfall over Malawi does not show statistically significant trends. Also, there are no statistically significant trends in the extremes indices calculated using daily precipitation observations (McSweeney *et al.*, 2008).

4.1.1 Agriculture

Agriculture is the mainstay of Malawi's economy, contributing about 40% to the country's GDP and grossing about 90% of export earnings. The sector is dualistic, comprising both smallholder and estates, with the former contributing over 70 % of the total agricultural production in the country. The agriculture sector faces technological, financial, social political, and climate related challenges which have constrained Malawi from attaining higher productivity and sustainable growth, and ultimately poverty reduction. Effects of climate change and weather variability, manifested in the frequent occurrence of weather-related disasters such as severe floods, droughts and dry spells, are greatly undermining productivity of Malawi's agriculture sector and food security.

Crop production is currently the most important sub-sector, making the biggest contribution to the trade (domestic and international) and food security, with maize as the main staple food grown on 80% of the arable land. However, according to the country's National Agriculture Policy (GoM, 2016), the crop production sector is underperforming, mostly due to: endemic poverty, land degradation, erratic weather conditions coupled with overdependence on rain-fed production, pests and diseases, limited irrigation and water harvesting especially among smallholder farmers, low adoption of improved agricultural technologies amidst low innovative and technical skills, poor stakeholder collaboration (e.g. limited engagement of smallholder farmers in knowledge generation and dissemination), lack of emphasis of multidisciplinary approaches in agricultural research and development, postharvest losses, limited agro-processing and value addition, poor market linkages, limited financing, low access to farm inputs, low mechanisation, poor road/transport, communication and energy infrastructure to facilitate rural agro-industrial growth and unfavourable regulatory interventions, inconsistent or incoherent policies/strategies. Thus, a multifaceted approach is necessary, not only to overcome the challenges, but also to improve Malawi's economic performance and food security in the wake of threats from climate change. More specifically, greater investment is needed to develop climate-resilient crop production/management besides improvements across the value chain and innovation system interaction among different stakeholders.

Although livestock production constitutes a relatively small sub-sector in the overall agricultural contribution to the economy, contributing about 7% to the total GDP and 12% of the total value of agricultural production, recent trends show an increase in its contribution. According to GoM (2017b), the value of livestock has increased from MK174billion in 2008 to MK317 billion in 2016, with the value of livestock products increasing from MK69 billion to MK760 billion in the same period. Records also show that there has been an increase in per capita meat consumption from 10.95kg in 2009 to 24.06kg in 2016, with per capita milk consumption increasing from 3.1kg to 5.1kg. The rising livestock consumption trends demands a transformation in the livestock sector to significantly increase productivity, resilience and supply of livestock and livestock products, not only to meet the growing demand, but more importantly to improve its contribution to the national economy- projected to double by 2022. A systematic review of the livestock sector policies, plans and reports reveals gaps such as: poor policy implementation arrangements resulting in failure to translate strategies into specific actions; inadequate expansion in institutional and human capacity; low training demand for livestock-related programmes in higher education institutions; weak collaboration and partnerships amongst key stakeholders such as farmers, public sector, industry, NGOs, development partners, academic and research institutions for effective technology generation and innovation; policy inconsistency and incoherence with other sectoral policies and strategies within the agriculture sector e.g. policy strategies and programmes promoting climate smart agriculture oftentimes overlook the livestock value chain leading to potential conflicts and negative tradeoffs. It is thus imperative to urgently conduct policy reform to address the identified gaps so as to advance integrated agriculture and improve productivity, while aligning the policy to national goals and other policy instruments such as the National Agriculture Policy and the National Resilience Strategy.

Land is constraining factor in agricultural production in Malawi. The country has a land area of 9.4276 million hectares (94,276 km^2) of which 2.5 million hectares is the total land area under cultivation (GoM, 2016). National statistical data indicates that smallholder farmers cultivate small and fragmented land holdings averaging 0.61 hectare. In spite of erratic rains, over 95% of the total land cultivated remains under rain-fed agriculture. Since land resources are vital for sustainable agricultural production and development, prudent utilization of the available natural resource base is needed; for example through agricultural intensification and livelihood diversification. Major issues related to land resources include declining land productivity, deforestation, soil erosion, water shortages, loss of biodiversity and limited land use planning, zoning and enforcement.

In Malawi, irrigation development is widely recognised to have the potential to contribute to sustainable agricultural transformation and national economic growth as articulated in its National Agriculture Policy. Irrigation can lessen the adverse effects of droughts or dry spells thus can increase production and productivity of crops and livestock, while also enabling the use of labour that would have otherwise been idle during the dry season. Though there is such recognition of the importance of irrigated agriculture, only 104,000 hectares of cultivable land is under irrigation nationwide (GoM, 2016). Given the frequent occurrence of unpredictable rainfall and subsequent water shortages, Malawi needs to considerably invest in, and emphasise on water harvesting to complement irrigation efforts- if irrigation development is to be sustained. Major issues in irrigation include inadequate capital and human capacity, land degradation, water scarcity, poor linkages between irrigation and other key stakeholders such as research, extension and land resources conservation - presenting a fragmented approach to the development of irrigated agriculture, and limited private sector investment. While the government has taken positive steps to tap from existing irrigation potential, notably through the Green Belt Authority and numerous irrigation projects across the country, challenges remain that impede development of the sub-sector.

4.1.2 Vulnerability of Agriculture

Malawi is vulnerable to floods, droughts and strong winds (particularly those that are associated with tropical cyclones). Principally, all flood disasters in Malawi are caused by high intensity rainfall resulting from three key synoptic systems, namely: the Inter Tropical Convergence Zone (ITCZ), the Zaire Air Boundary/Congo Air Mass, or Tropical Cyclones. The joint effect of these three synoptic systems only exacerbates the severity of flooding in the country. Most of the droughts episodes that Malawi experiences are caused by the El Nino and the Southern Oscillation (ENSO) phenomena, with serious repercussions on crop and livestock production.

Additionally, the country experiences long dry spells that occasionally disrupt the rainfall season and cause crop failure. The unimodal pattern of rainfall results in the seasonality of crop production, and forces farmers to stay idle during the dry season. The increase in human population growth calls for improved agricultural production to match the demand for food. Livestock productivity is highly constrained by lack of adequate feed and drinking water in the dry season.

Over the past five decades, Malawi has experienced more than 19 major flooding events and seven droughts. In 2015, Malawi was affected by the worst floods it has experienced in 50 years due toextreme rainfall that took place early that year. The floods affected 1,101,364 people, displaced 230,000 people and killed 106 people, with another 172 people reported missing (UNDAC, 2015).Standing and stored crops were also washed away, and animals were lost. Parts of the Early Warning System, including hydrological and meteorological gauging stations, were damaged as well. Flood mitigating structures such as dykes, and productive infrastructure such as irrigation, livestock disease control structures and fisheries infrastructure were affected.

Most smallholder farmers are resource poor; as such, they have very limited capacity to contain shocks arising from climate change, particularly floods, strong winds, and droughts. Food security is a concern in many of the affected districts. Smallholder farmers' livelihoods were severely affected by the 2015 floods as there was disruption of food availability and access in the affected districts. The direct flood damage included loss of standing crops; damaged crop lands; livestock losses; damage to fisheries (most of the fish ponds were washed away); damaged irrigation systems; partially and completely damaged roads, bridges and culverts; disruption to economic empowerment groups; losses to non-farm working days; increases in therapeutic feeding programs; and damages to shallow wells, boreholes, piped water schemes and hydrological gauging stations (GoM, 2015). Lack of diversity has made the agricultural sector in Malawi vulnerable to market and climate induced shocks.

Agriculture production (crops and livestock) in Malawi has had a slow increase in productivity over years because of its vulnerability to climate change. This is attributed to food and animal resource challenge compounded by climate change effects of droughts and floods. Other gaps for the agriculture sector are shown in Table below:

GAPS FOR THE AGRICULTURE SECTOR

- Limited agro-processing facilities;
- Over-dependency on rain-fed agriculture and biomass energy;
- Poverty exacerbated by drought, floods, hailstorms and population pressure;
- Lack of insurance schemes to compensate farmers in the event that a climate induced shock strikes compounds the situation further as assets and livelihoods are destroyed by these events living them with nothing to rely on;
- Inadequate hazard maps; and
- Inadequate crop diversification.

4.1.3 Potential Adaptation Strategies

Various adaptation strategies and actions, the scope and scale ranging from short-term (<5 years), medium-term (5<10 years) and long-term (≥10years) were developed, promoted and applied to address adverse impacts of climate change in the agriculture sector in the past ten years (See Tables 2,3,4 and 5)

Short-term strategies/actions mostly involve applying coping mechanisms to deal with actual or expected climate change impacts, with eventual return to the status quo. While medium-term interventions produce change in some aspects of the system (i.e. incomplete transformation), long-term strategies/actions deliver complete system transformation. Since long-term interventions aim to achieve more than climate change goals, considerable time, effort and resources are prerequisite for the implementation of such interventions (Moser and Ekstrom, 2010).

Most of the measures that local communities/farmers have applied, in response to climate change impacts, are mostly short-term coping mechanisms e.g. casual labour, sales of household assets and relying on remittances (see Tables 6, 7 and 8) hence not necessarily to adapt to the impacts themselves. This implies that there is inadequate preparedness, education and public awareness on climate change and its potential impact on social-economics, livelihoods and the environment in general. This nonetheless presents an opportunity for Malawi and its development partners to invest more in public awareness and education on climate change and its impacts to empower communities to appropriately adapt otherwise they 'die'.

Table 4. 3 Autonomous and Planned Adaptation strategies in the agriculture sector against drought and dry spells (2011-2019)

Climatic event(s)	Impact on agriculture & livelihoods	Main adaptation measures	
		Autonomous	**Planned**
• Drought conditions in 2015 & 2016 • Delayed on-set of rains • Shorter rainy seasons Erratic rainfall Localised dry spells (almost yearly	• Crop failure leading • Poor yields • Food scarcity, • high food prices, • Hunger, • Poverty & malnutrition. • Increased seed costs • Scarcity of water, • Poor production of livestock & fish • Reduced farm labour/power Loss of biodiversity • Increased land degradation • Increased soil Stagnated agro-industry	**<u>Short Term</u>** • Casual labour • Reducing number of meals/days • Eating less nutritious foods or wild plants • Remittances from family and friends • Income generating activities • Selling household assets (livestock, radios, bicycles, mobile phones) • Bicycle hire business	**<u>Short Term</u>** • Providing food aid • Cash transfers to vulnerable groups • Providing farm inputs for winter cropping **<u>Medium-long-term</u>** • Promoting drought tolerant or early maturing planting material • Livestock & fish management • Promoting legumes • Breeding • Improved seed systems ○ promoting seed multiplication ○ establishing community seed banks

		Medium Term • Staggered cultivation of green maize, sweet potatoes, cabbages & tomatoes along river banks through irrigated/winter farming • Construct ponds or shallow wells **Long Term** • Use of local varieties • Promotion of hybrid varieties Increase in agro-input dealers	• Crop/livestock intensification & diversification omixed crop/livestock systems oconservation agriculture, o agroforestry & community-based natural resources management • Promotion of irrigated agriculture and distributing irrigation equipment • Promoting in-situ & ex-situ rain water harvesting Promoting drought-resilient water & catchment conservation • Integrated pest management • Promotion of good agronomic practices • Promotion of farming as a business • Provision of agricultural input subsidies & incentives Training households in food budgeting, utilisation & preservation

			• Value addition & agro-processing • Promotion of metallic silos & PICSA bags for effective grain storage- • Agricultural commercialisation • Practicing Conservation Agriculture • Weather-indexed insurance • Promoting livestock water points & fodder banks • Livestock disease surveillance to control parasites and vectors Government is setting up/enhancing warehousing facilities

Table 4. 4 Autonomous and Planned Adaptation strategies in the agriculture sector against Floods and dry spells (2011-2019)

Climatic event(s)	**Impact on agriculture & livelihoods**	**Main adaptation measures**	
		Autonomous	**Planned**
• Floods • Flash floods • Cyclone Idai • Heat waves	• Destruction of crops • Significant damage to crops • Flood-induced hunger, malnutrition & poverty • diminished household adaptive capacity Accelerated land degradation • Limited agro-industrial growth • Derailed development process with significant decelerated GDP growth • Water scarcity • Poor yields • Food insecurity • Loss of livestock • Loss of income • Reduced farm working hours- reduced efficiency	**<u>Short term</u>** • Casual labour • Remittances/gifts	**<u>Short term</u>** • Restocking strategic grain reserves • Food & household assets' distribution • Distributing farm inputs **Medium and Long term** • Flood forecasting and warning • Flood mitigation infrastructure • Up-scaling of early warning systems nationwide • Promoting integrated catchment conservation & river bank rehabilitation

			• Promoting on-farm soil & water conservation practices including drainage systems • Social protection programmes • Climate smart agriculture, reforestation • Donor funded programmes • Policies and action plans • Promotion of resilient and diversified agricultural production systems • Promoting rain water harvesting technologies o constructing water reservoirs & efficient use of water • Developing new irrigation schemes (using drip irrigation kits) &

			rehabilitating/modernising old schemes • Regeneration of indigenous trees • Agriculture & mechanisation Promoting aquaculture, • Up-scaling feed preservation & fodder banks • Livestock disease surveillance.

Data sources: Malawi Floods Post Disaster Needs Assessment report (2019 & 2015); MVAC 2019; FEWS NET 2019; Shire River Basin Management Programme report; MoAIWD annual progress reports; GoM, 2015b; key informants & stakeholder workshop data

Table 4. 5 Autonomous and Planned Adaptation strategies in the agriculture sector against migratory pests

Climatic event(s)	**Impact on agriculture & livelihoods**	**Main adaptation measures**	
		Autonomous adaptation	**Planned adaptation**:
Migratory pests (fall armyworm, false army worm, African armyworm & red locust	• Severe crop damage • Poor harvests • High food prices • Increased poverty • Increased production costs from pesticide use • Environmental pollution due to excessive use of pesticides	**Short-term** •Using indigenous knowledge for pest control plant-based solution o Application of sand o Application of soap solution onto infested maize to control stalk borer infestation	**Medium-long term** • Promotion of early planting • Migratory pests' surveillance • Provision of insecticide • Capacity building in integrated pest management • Establishing locally-based plant clinics • Promoting proper post-harvest practices to further reduce storage losses • Promoting good animal welfare, health & disease control e.g. standard livestock structures

Data sources: Malawi Floods Post Disaster Needs Assessment report (2019 & 2015); MVAC 2019; FEWS NET 2019; Shire River Basin Management Programme report; MoAIWD annual progress reports; GoM, 2015b; key informants & stakeholder workshop data

Further, local indigenous knowledge systems and practices that local communities apply to adapt to climate change impacts (e.g. control of pests) have neither been scientifically proven nor documented to enable up-scaling to other communities. This suggests that climate scientists/researchers do not sufficiently involve local communities in their quest to find better adaptation solutions to existing problems. Exclusion of locally generated knowledge in climate science/research/development not only undermines innovative and transformative community based adaptation, but also inevitably erodes ownership of the 'top-down' interventions developed (Chinseu *et al*., 2019). Hence greater and active engagement of communities (from inception stage) in science, technology and innovation is imperative to facilitate co-generation of sustainable adaptation options.

Analysis of qualitative data from key informants revealed that some rural communities, particularly smallholder farmers engage in maladaptation. Some of the practices being implemented which constitute 'maladaptation' include: (1) irrigated farming/winter cropping on the actual river bed or <10 metres from the river bank, contravening Malawi's agronomic guidelines - this instigates soil erosion and river bed siltation which eventually leads to flooding, and also contributes to water pollution from pesticide/chemical fertiliser use which may lead to fish kills); (2) deforestation - for production of charcoal/firewood to cope with disasters. Apart from accelerating soil erosion and subsequent surface runoff, careless cutting down and/or burning trees emits carbon dioxide into the atmosphere – a gas considered to be one of the drivers of climate change; (3) continuous (maize) monocropping - which degrades soil structure and fertility thus not only undermining crop production, but also resilience of the farming system to climate change impacts (Thornton et al., 2018). To address maladaptation and issues of vulnerability, strong science, technology and innovation linkages among scientists, local communities/intended users and other relevant stakeholders are thus recommended. This can enable co-generation and utilisation of knowledge which can empower vulnerable groups to appropriately adapt to negative climatic impacts.

Notable Programmes and Projects integrating climate change adaptation under agriculture
(2011-2019)

Table 4. 6 shows public programmes and projects that incorporate (d) climate change adaptation in Malawi's agriculture sector (2011- 2019)

Programme/project	**Period**	**Funding source**	**Geographic coverage**
Agriculture Sector Wide Approach (ASWAPsp II)	2017-2020	Multi Donor Trust Fund	12 districts
Agriculture Sector Wide Approach (ASWAPsp I)	2010-2014	Multi Donor Trust Fund	12 districts
Sustainable Agriculture Productivity Programme (SAPP)	2012-2021	IFAD	6 districts
Malawi Drought Recovery and Resilience Project	2017-2021	World Bank	28 districts
Malawi Floods Emergency Recovery	2015-2018	World Bank	15 districts
Programme for Rural Irrigation Development –PRIDE	2017-2023	IFAD	8 districts
Shire Valley Irrigation Project (SVIP)	2013-2018	under the Green Belt Initiative	7 districts
Shire Valley Transformation Programme (SVTP) -in 3 phases	2018-2031	World Bank, AfDB & GEF	2 districts
Shire River Basin Management Programme	2012-2027	IDA (World Bank), GEF & Least Developed Countries Fund (LDCF)	Along Shire River Basin
Fertiliser Input Subsidy Programme (FISP)	annually from 2005 to-date	Malawi Government & Donors	28 districts
Small Stock Development Programme	2012-2020	Malawi Government	28 districts
Agriculture Infrastructure and Youth in Agribusiness Project	2016-2021	AfDB	2 districts

Table 4.6: shows that programmes and projects on climate change adaptation are mostly funded by the international donor community. This implies that adaptation activities are bound to cease upon programme/project expiration, unless other funding arrangements are secured. Further, the scope of most of the adaptation programmes/projects is in the short-medium term (<10 years); meaning that the programmes/projects expire before

resilience/adaptive capacity is sufficiently built. This culminates in incomplete system transformation (i.e. a system requires long-term scope/scale to completely transform- Moser and Ekstrom, 2010). Also, as most of the programmes/projects are currently sporadic i.e. targeting a small geographical area, and not the entire country, it follows that the majority of the Malawian population has limited knowledge on climate change, its impacts on their livelihood and how to ‘adapt’.

4.2 Water

Malawi is generally rich in both surface and ground water resources. Surface water resources comprise a network of rivers (e.g., Shire, Ruo, Linthipe, Bua, Dwangwa, Rukuru, songwe, Ruhuhu, Kiwira, etc) and lakes (Lake Malawi, Lake Chilwa, Lake Chiuta), Figures 1A and 1B. The country’s drainage system has been divided into 17 Water Resources Areas (WRAs), two of which drain outside the Lake Malawi/Shire system, i.e., they drain into Lake Chilwa and Lake Chiuta. Water Resources Areas (WRA) are further subdivided into 78 Water Resources Units (WRUs), Figure 2 (Kululanga and Chavula, 1993).

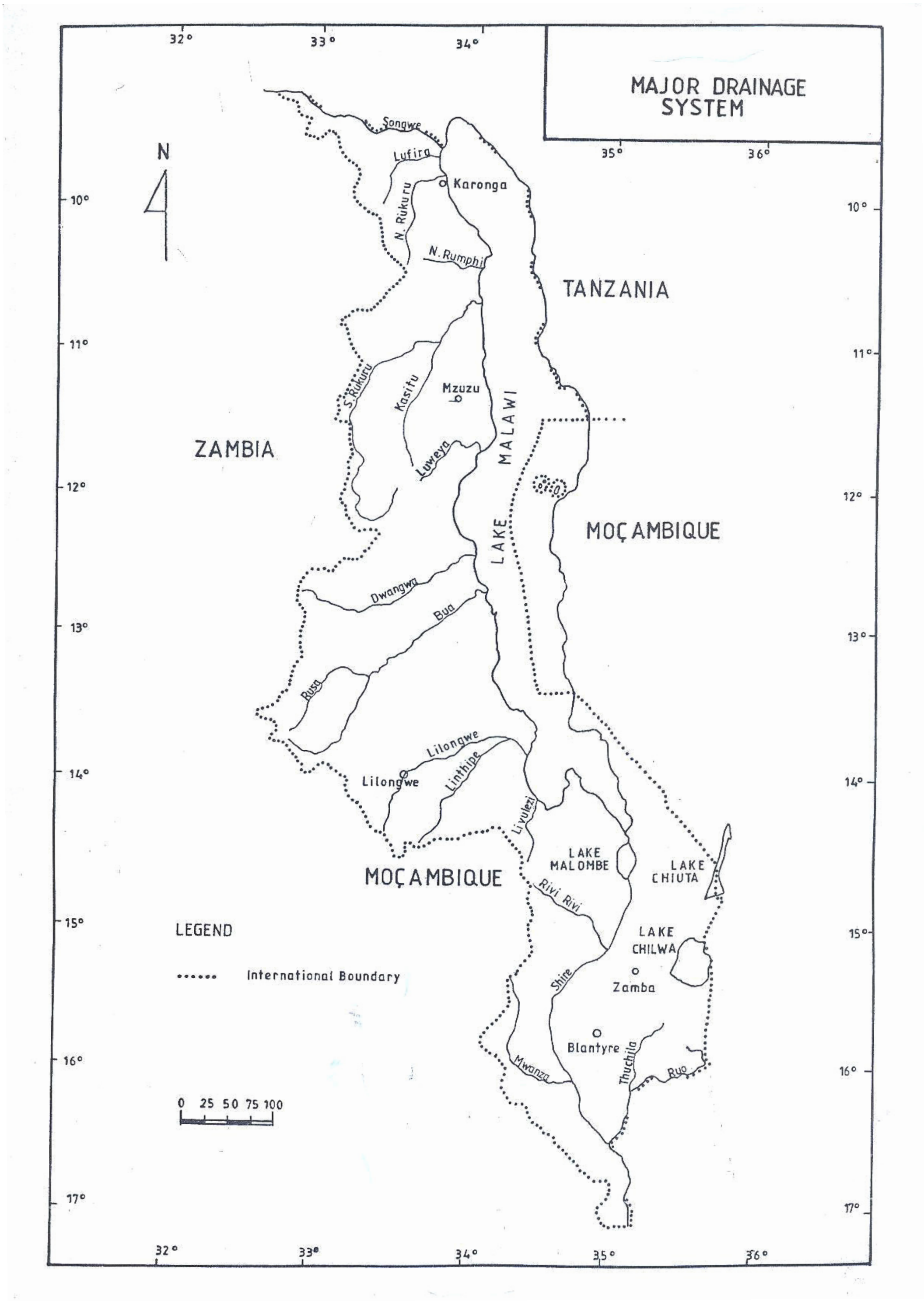
Lake Malawi Figures 1A and 1B is the third largest lake in the East African Rift System (EARS); located at the border between Malawi, Mozambique, and Tanzania. The lake has a great influence on the country’s water balance. The catchment area of Lake Malawi is 97,740 km^2, of which 64,373 km^2 lies in Malawi, 26,600 km^2 in Tanzania, and 6,768 km^2 in Mozambique (Department of Water/UNDP, 1986). The maximum length of the lake is approximately 570 km, but it is comparatively narrow, with an average width of about 48 km (Kanyika, 2000). Lake Malawi has a mean depth of 260 m and a maximum depth of 700 m, a surface area of 29,743 km^2, a volume of 7,723 km^3, and a mean lake level of 474 m above sea level (Department of Water/UNDP, 1986; Menz, 1995). The lake is drained at its southern end by the Shire River, a tributary of the Zambezi River. The average annual rainfall over the catchment area and the lake is 996 mm and 1410 mm, respectively (Shela, 2000). An estimate of annual lake evaporation is 2113 mm (Kanyika, 2000). The total inflow into Lake Malawi is 927 m^3/s, out of which 400 m^3/s is from Malawi, 486 m^3/s from Tanzania and 41 m^3/s from Mozambique. The average outflow is 395 m^3/s. The highest annual outflow of 825 m^3/s occurred during the 1979/1980 hydrological season, with the highest monthly (Kululanga and Chavula, 1993). The water level plot for Nkhata Bay Boma shows a declining trend for Lake Malawi (Figure 3), and Figure 4 shows temperature trend for the lake over the period 1920 to 2020.

The catchment area of Lake Chilwa is estimated to be 5,000 km^2. Most of the rivers that drain their water into Lake Chilwa arise from the northern slopes of Zomba and Mulanje Massif. All the rivers are perennial in their upper reaches, but they gradually lose their flow and recharge aquifer systems in the Chilwa-Phalombe plains due to the porous nature of the area (Kululanga and Chavula, 1993).

The quantity of surface water resources in Malawi, especially in rivers, is highly dependent on the availability of rainfall which sustains runoff. Surface water resources are more abundant during the rainy season than during the dry season. Incidents of floods are a common feature in the country, particularly in the Lower Shire Shire Valley (Chikwawa and Nsanje districts), and Salima and Karonga districts. For example, the severe flooding that took place in 2015 affected 15 out of 28 districts in Malawi, resulting in severe loss of life and serious damage to property and crops.

Runoff depths of each Water Resources Area are presented in Table 4.6. It is clear from Table 1 that runoff is generally high along the shore of Lake Malawi. This is also true of rivers that drain the Mulanje Massif.

Figure 4. 1 Map of Malawi Drainage Basin (Source: Water Department/UNDP, 1986



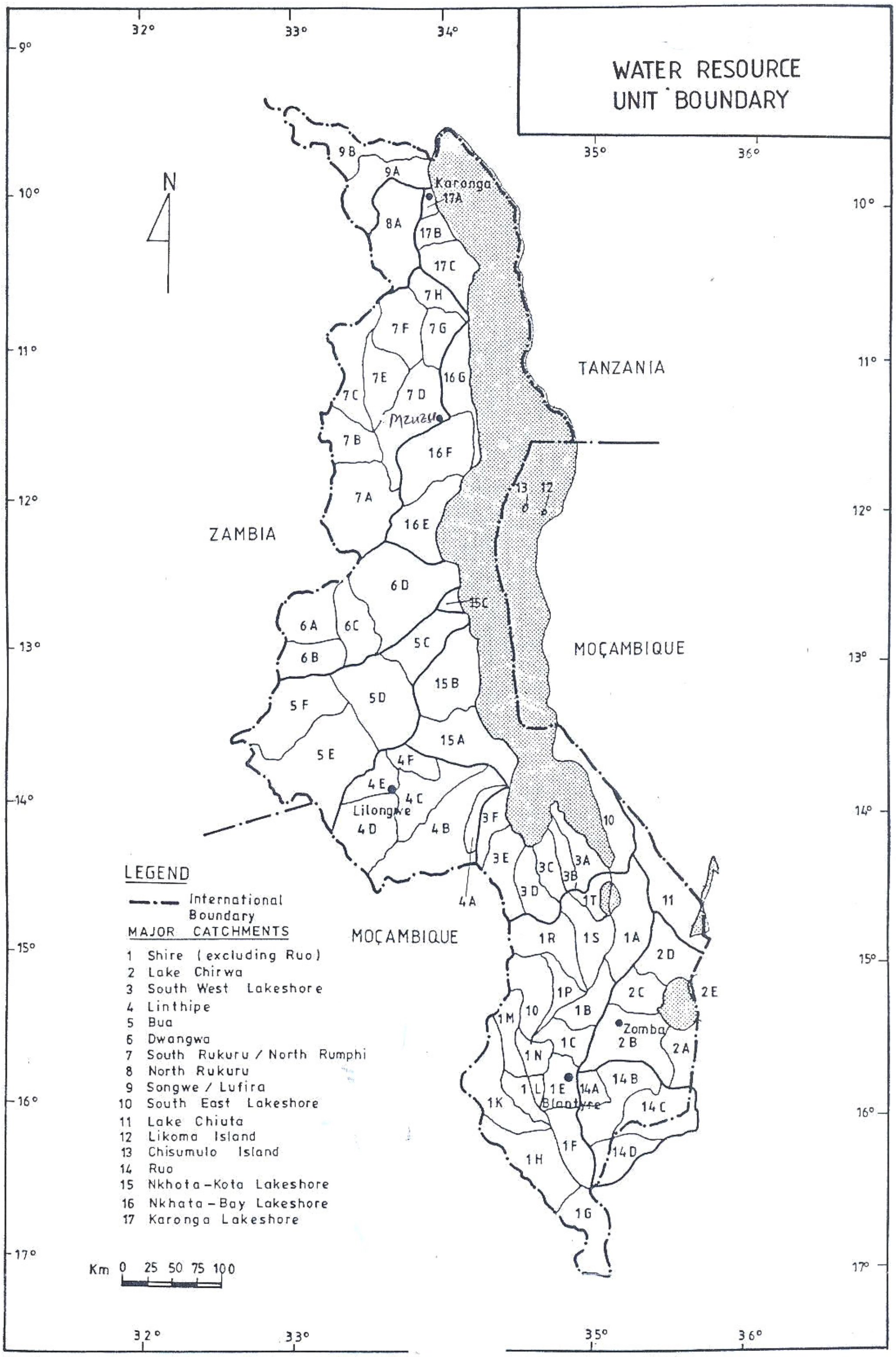


Figure 4. 2 Water Resources Units (Source: Water Department/UNDP, 1986)

Table 4. 7 Surface Runoff (Source: Kululanga and Chavula, 1993).

Name of River Basin	Catchment Area (km^2)	Rainfall (mm)	Runoff (mm)	Runoff (m^3/s)	Runoff (%)
Shire	18945	902	137	82	15.2
Lake Chilwa	4981	1053	213	34	20.2
South West Lakeshore	4958	851	169	27	19.9
Linthipe	8641	964	151	41	15.7
Bua	10654	1032	103	35	10.0
Dwangwa	7768	902	109	27	12.1
South Rukuru	11993	873	115	44	13.2
North Rumphi	712	1530	674	15	44.1
North Rukuru	2091	970	252	17	26.0
Lufirya	1790	1391	244	114	17.5
Songwe	1890	1601	327	120	20.4
South East Lakeshore	1540	887	201	10	22.7
Lake Chiuta	2462	1135	247	19	21.8
Likoma Island	18.7	1121	280	-	-
Chizumulo Island	3.3	1121	280	-	-
Ruo	3494	1373	538	60	39.2
Nkhotakota Lakeshore	4949	1399	260	41	18.6
Nkhata Bay Lakeshore	5458	1438	461	80	32.1
Karonga Lakeshore	1928	1028	361	22	35.1

Many river basins in the country are under severe pressures due to deforestation, unsustainable agriculture, settlements, mining, industry, commerce, tourism and climate change. These activities have influenced changes in water quality especially due to sediment loads, industrial wastes, chemicals from agricultural lands, and the proliferation of aquatic vegetation.

The quality of surface water resources is influenced by three major factors, namely: the chemical composition of the parent rocks at the base of the water body or traversed by the river, agricultural actives taking place in the catchment area, and effluent discharges (including disposal wastes from residential areas and industrial sites).

The chemistry of the majority of surface water resources is characterised by alkaline earth (calcium and magnesium) dominance in the cation group, and by the carbonate system in the anion group. Most of the water can be classified as soft to moderately soft, with hardness less than 100 mg/L of $CaCO_3$. Values of Total Dissolved Solids (TDS) content are generally less than 100 mg/L. Known areas of hard water are confined to the following WRUs: 1C, 1E, 1R, 4E, 4F and part of 5D (Figure 3). The hardness of water in WRUs 1C, 1E, and 1R is attributable to locally occurring outcrops of limestones; whereas in 4E, 4F, and part of 5D the hardness is non-carbonate, but caused by evaporite deposits of gypsum prevalent in dambos.

The biological quality of rivers, especially those flowing through the cities of Blantyre (e.g., Mudi, Chitawira, and Naperi), Zomba (Likangala and Mulunguzi), Lilongwe (e.g., Lilongwe, Lingadzi), and Mzuzu (e.g., Lunyangwa) is generally poor because of effluent discharges and poor siting of pit latrines. Values as high as 20,000 faecal coliforms per 100 ml have been observed in Lilongwe and Likangala Rivers downstream of the sewage plants during periods when the treatment plants have broken down.

Malawi has three major aquifer systems, namely: the extensive but low yielding weathered Precambrian Basement Complex aquifer of the plateau area (1-2 L/s), the high yielding alluvial aquifer of the lake shore plains and the Lower Shire Valley and the Lake Chilwa - Mphalombe Plain (>15 L/s), and the medium yielding aquifer of the fracture zone in the rift valley escarpment (5-7 L/s), Figures 5 and 7. The prolonged in situ weathering of the crystalline basement rocks has produced a layer of unconsolidated saprolite material (Figure 7) that forms an important source of water supply for domestic requirements. The weathered zone is best developed over plateau areas where it is commonly 15-30 m thick and locally even thicker (Water Department/UNDP, 1986). Towards the crest of the escarpment, the uplift associated with the development of the rift valley has resulted in the rejuvenation of rivers and increased erosion, and thus the thickness of the aquifer tends to be reduced in these areas. It also thins towards bedrock outcrops. The saprolite thickness tends to be greatest along fracture zones.

Alluvial aquifers are fluvial and lacustrine sediments that are highly variable in character in both vertical sequence and lateral extent. They occur in several basins which, apart from Lake Chilwa, are all located along the rift valley floor: Karonga Lakeshore; Salima-Nkhotakota Lakeshore; Upper Shire Valley, and Lower Shire Valley.

Groundwater resources are mostly used for domestic consumption in rural areas, and a few urban centers. Usage of groundwater for irrigation potential is limited by the low yielding aquifers and is generally restricted to small gardens in many areas (Atkins, 2011). Notable among these is Ngolowindo Irrigation Scheme in Salima District that has a total land area of 17 ha.

On a national scale, groundwater quality is generally acceptable for human consumption. Groundwater resources in the basement complex aquifer are characterized by the dominance of alkaline earths in the cation group, and by the carbonates in the anion group (Water

Department/UNDP, 1986). Total dissolved solids content values are generally less than 1000 mg/L and typically around 350 mg/L. Groundwater in the alluvial aquifers is more mineralized than in the basement aquifers.

4.2.1 Importance of Water

Malawi's water resources are used for a number of purposes, key among which include domestic consumption; agricultural production; hydropower generation; development of the fishery industry; transport (navigation); industrial production and mining; tourism; and aesthetic value of the land. Pillar number one of the Malawi Growth and Development Strategy III (MDGS III) of 2017 is *"Agriculture, Water Development and Climate Change Management"*. This is a clear manifestation that the Government of Malawi places great importance on water resources for the socio-economic development of the country. As such, it is absolutely necessary that these precious resources (i.e., surface and ground water resources) are managed prudently in order to achieve water security for the present generation and posterity, if Malawi's agro-based economy is going to be sustained.

4.2.2 Vulnerability of Water

Detailed vulnerability assessment studies for water resources in Malawi to impacts of climate change were done by Chavula and Chirwa (1996) using climate change scenarios. In their studies, rainfall and temperature scenarios were generated by "Model for the Assessment of Greenhouse-gas Induced Climate Change" (MAGICC)/"SCENario GENerator" (SCENGEN) software. Rainfall and temperature data obtained from MAGICCC/SCENGEN were then used as inputs to WatBal Model, a water balance model developed by David Yates (Yates, 1994). Information used in the compilation of adaptation strategies for the water resources sector for the Second National Communication for Malawi (GoM, 2002) was obtained from a report compiled by Chavula and Chirwa (1996). WatBal evaluates the availability of water resources in a given catchment area by taking into consideration impacts of climate change.

From model simulation results of the WatBal, Chavula and Chirwa (1996) made the following conclusions about river basins in Malawi, with climate change scenario: (a) with CO_2 doubling, temperature will increase by 2.5°C to 4.7°C while precipitation will either increase by 4.2% to 32.6%, or decrease by 5.6% to 7.6%; (b) precipitation increase is expected to be high in the northern and central regions of Malawi; (c) runoff will either increase or decrease; and (d) rivers in Malawi are very sensitive to changes in temperature and rainfall. And (d) is supported by the drying up of several rivers in Malawi during drought periods (e.g., the drought season of 1991/92), and the frequent flooding that takes place throughout the country during periods of excessive rainfall (e.g., the 1991 Phalombe disaster, and the devastating floods of 2015 when a number of rainfall stations in the country recorded high rainfall values – see Table 2). Chavula and Chirwa (1996) findings are supported by findings by IGAD and ICPAC (2007).

Table 4. 8 Rainfall Records for the January, 2015 Floods (Source: MASDAP, 2015)

8th Jan 2015		**9th Jan 2015**		**12th Jan2015**	
Station	**Rainfall(mm)**	**Station**	**Rainfall(mm)**	**Station**	**Rainfall(mm)**
Mimosa	117.4	Zomba Agr	54.7	Chichiri	398
Chingale	102.3	Malomo	36.6	Mpemba	287.5
Zomba RTC	91.4	Dedza	36	Mimosa	267.4
Neno	70	Luepmbe	35	Zomba RTC	177.2
Mulanje Boma	61.4	Supuni	34.6	Ndirande Hill SS	175.6
Mwenilondo	53	Madisi	31	Zomba NSO	173.1
NSO	47	Chikweo	30.9	Chileka	167
Sipuni	45.2	Chikweo	30.9	Kasongo	165.9
Naminjiwa	44.5	Kasongo	26.4	Chingale	145.2
Vua	39.6	Nkhulambe	25	Mikolongwe	122.8
Nkula Falls	39.2	Neno	25	Tamani Agric	108
Mpemba	35.5	Dwangwa	23.2	Escom Nkula	107
Thuchira Estate	35.5	Mzimba	21.9	Ntaja	105
Monkeybay	35.1	Salima	21	Neno	99.2
Lupende	35	Ngabu	18.7	Mposa	97.8
Mangochi	34.7	Chileka	16.1	Lirangwe	86.1
Mlare	31.4	Billy Ngabu	11.5	Bazale Agric	83.5
Chileka	30.4	Dowa Agr	9.8	Supuni	82

Temperature and rainfall data used in the current report were developed using statistically downscaled General Circulation Models (GCMs), following the procedure recommended by the Intergovernmental Panel on Climate Change (IPCC) in a report titled "Fifth Assessment Report" (IPCC, 2013), as discussed in Section 4.0.

Malawi is vulnerable to floods, droughts and strong winds (particularly those that are associated with tropical cyclones), and these observations are in agreement with climate change scenarios developed for the country using the two RCPs and WatBal Model simulations conducted by Chavula and Chirwa (1996).

Principally, all flood disasters in Malawi are caused by high intensity rainfall resulting from three key synoptic systems: the Inter Tropical Convergence Zone (ITCZ), the Zaire Air Boundary/Congo Air Mass, or Tropical Cyclones (Figure 16). The joint effect of these three synoptic systems only exacerbates the severity of flooding in the country. Notable flood events that have taken place in Malawi include the Zomba and Phalombe flash floods of 1946 and 1991, respectively. The Zomba flash floods locally known as *Napolo* were caused by high intensity rainfall resulting from the joint effect of the ITCZ and the Zomba Cyclone when 711 mm of rainfall fell in 36 hours (Water Department/UNDP, 1986), leaving in its wake severe loss of life and serious damage to property. During the Phalombe flash floods of 1991, 417 mm rainfall fell within a period of three days resulting in the failure of Michesi Hill, causing severe loss of life and extensive damage to property. In 2015, Malawi experienced severe flooding when more than 15 districts were affected by flood disasters. These floods were a direct results of record-breaking high rainfall that Malawi experienced during the first two weeks in the month of January after the onset of rains (Tables 5). Flood prone river basins in Malawi include the Songwe, Lufilya, Limphasa/Luweya, Likangala/Thondwe, and the Shire/Ruo.

Figure 4.3 shows four homogeneous rainfall regions of Malawi and the stations within them and the typical seasonal cycle of rainfall (mm per month) in each region whereas Table 3 shows rainfall onset, end, and duration (Nicholson *et al*, 2013). Figure 4.4 shows mean annual and seasonal rainfall in mm (based on the period 1962 - 2009).

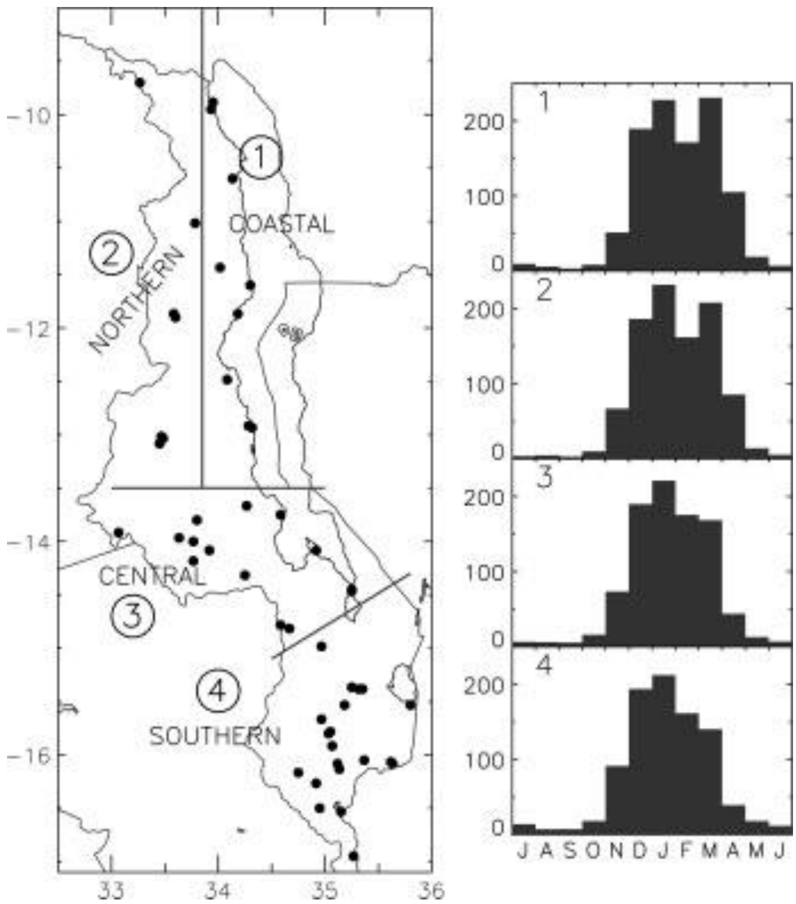
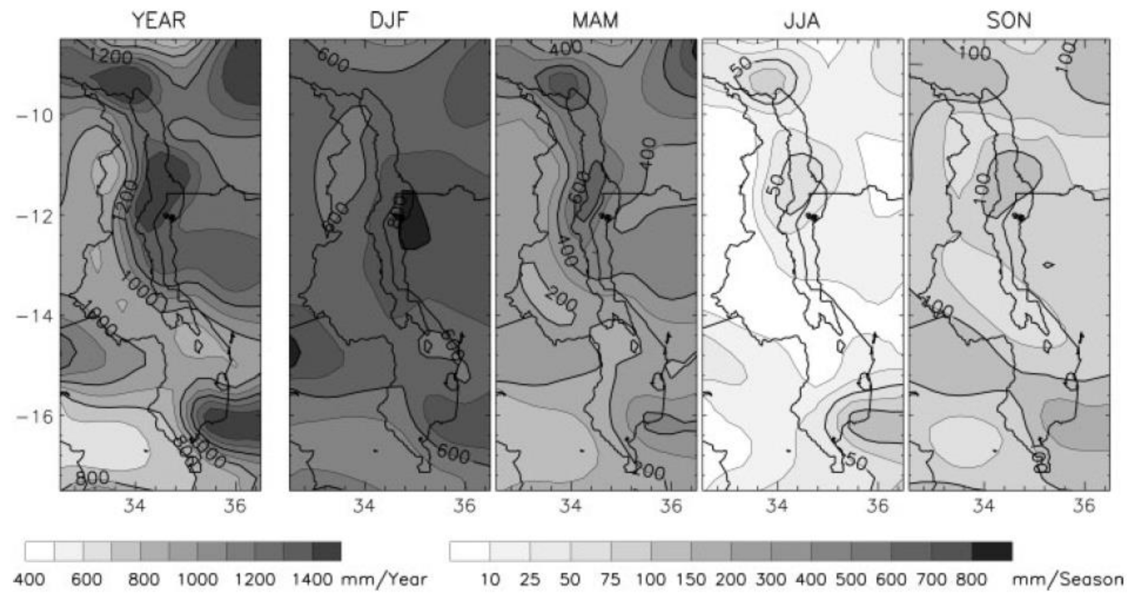


Figure 4. 3 Four homogeneous rainfall regions of Malawi and the stations within them Right: The typical seasonal cycle of rainfall (mm per month) in each region (Source: Nicholson *et al*, 2013).



:

Figure 4. 4 Mean annual and seasonal rainfall in mm based on the period 1962 - 2009 (Source: Nicholson *et al*, 2013)

Table 4. 9 Rainfall onset, end, and duration in Malawi (Source: Nicholson *et al*, 2013)

Region	1	1	1	1	2	2	2	2
Station	1	2	3	4	5	6	7	8
Onset	12/4	11/19	11/23	12/1	11/27	12/6	11/27	12/1
End	4/20	4/28	5/8	4/14	4/4	3/19	3/30	3/20
Duration	138	161	167	134	129	104	124	108

Region	3	3	3	3	3	3	3	4	4	4	4	4	4
Station	9	10	11	12	13	14	15	16	17	18	19	20	21
Onset	12/4	12/3	11/28	11/27	11/27	12/4	11/23	11/27	11/15	11/14	11/13	11/29	11/25
End	3/24	4/1	3/21	3/23	3/27	3/19	3/27	3/17	3/17	4/4	4/5	3/13	3/19
Duration	111	120	114	117	122	106	126	111	123	142	144	105	114

Figures 4.3 and 4.4 demonstrate that rainfall in Malawi is concentrated in the months of December to March. In three of the four regions, maximum rainfall occurs in January. In the region along the western lakeshore, the maximum occurs in March (Figure 17).

Furthermore, Figure 4.4 appears to show a rainfall maximum over the lake. It should be noted that the contours over the lake were extrapolated from land-based gauge data. However, an analysis of data from satellite imagery done by Nicholson and Yin (2002) confirmed the existence of maximum rainfall over the lake and along its western shore. This maximum appears to be related to topographic effects, as opposed to the effects of the lake itself, because the annual means for over-lake and over-land rainfall are similar. This contrasts strongly with results obtained for Lakes Victoria and Tanganyika by Nicholson and Yin (2002) where lake effects respectively enhance rainfall by 35 and 11%.

At the national level, the Ministry of Agriculture, Irrigation, and Water Development (MAIWD) and the Department of Climate Change and Meteorological Services (DCCMS) are respectively responsible for flood forecasting and the issuance of flood warnings and weather and climate forecasting and the issuance of warnings pertaining to weather and climate. At the district level, the District Civil Protection Committees (DCPCs), Area Civil Protection Committees (ACPCs), Village Civil Protection Committees (VCPCs) and the community themselves are responsible for issuing early warning messages about floods and droughts to vulnerable communities. The NGO community also plays an important role in disseminating early warning messages to the citizenry at district level. At the community level, CPCs gather information about impending floods using upstream gauging stations, and issue early warnings to the general public through well-established channels of communication. However, it has been noted from past experience that because of the tortuous nature of information flow from data collection points at upstream gauging stations to the issuance of flood warnings, some warnings have been issued way after the disaster has truck people living in flood prone areas. That is the more reason why the telemetry system that is being installed in the Shire River Basin under the Shire River Basin Management Programme (SRBMP) is very commendable as it has shown to have adequate lead time at the model calibration stage.

However, at present Malawi still uses the manually operated system for flood forecasting and flood warning in the country; and it is only the Lower Shire Valley that has such a system in place. In essence, the system entails collecting water level data from gauging stations on the

Ruo and the Shire, and transmitting them to MAIWD for analysis by hydrologists, with the subsequent issuance of flood warnings to communities living in flood prone areas. The system relies on the accuracy of water level data recorded by Gauge Readers stationed at Sandama, Sankhulani, and Chiromo along the Ruo, and Chikwawa along the Shire, complemented with rainfall data collected by DCCMS. Although in the past the system was dogged by inefficiencies arising from MAIWD's inability to pay honoraria to gauge readers on time, this problem is being addressed by the Government of Malawi. From the study done by DoDMA (GoM, 2015), it is clear that the services of the Central East African Railways and the Police at Sandama, Sankhulani and Chiromo will continue to be sought in transmitting water level data to Flood Officers based at MAIWD at Tikwere House in Lilongwe for analysis and the subsequent issuance of flood warnings to vulnerable communities in the Lower Shire Valley. As such, the country will continue to use the manually operated flood forecasting and warning system until such a time when the telemetry system will be validated the Shire River Basin and installed in all flood areas in Malawi.

A detailed description of the procedure adopted for flood forecasting and flood warning for the Lower Shire Valley by MAIWD is presented in the following discussion for the three monitoring gauging stations, namely: Sandama, Sankhulani/Sinoya, and Chiromo. Water level data for the Ruo at Sandama Regular Gauging Station (R.G.S) 14.D.3 will be measured and reported by the Gauging Assistant to Flood Officers based at Tikwere House in Lilongwe as follows:

a) Yellow Alert Level will correspond to water level between 2.8 m and 3.1 m on the staff gauge. The stage will then be continuously observed/monitored within this range till the water level recedes;

b) Red Alert Level will correspond to a water level of 3.1 m on the staff gauge. The Gauge Reader will be required to report by telephone to Flood Officers at Tikwere House after every rise interval of 0.1 m above 3.1 m height of water level on the staff gauge;

c) Police Alert Level will correspond to a stage of 3.5 m, with water level still rising. The Gauge Reader will be required to report by SMS or telephone Flood Officers at Tikwere after every rise or fall to 0.05 m above 3.5 m on the staff gauge; and

d) M.B.C Alert Level will correspond to a stage of 3.8 m, with water level still rising. The Gauge Reader will be required to send water level data by SMS or telephone to Flood Officers at Tikwere House at hourly intervals.

Water level data of the Ruo at Sankhulani/Sinoya, R.G.S. 14.D.1. Reporting of water level data will be done as follows:

a) Yellow Alert Level will correspond to water level between 8.0 m and 8.2 m on the staff gauge. The gauge reader will be required to observe continuously water level from 8.0 m on the staff gauge till it recedes;

b) Red Alert Level will correspond to a stage of 8.2 m on the staff gauge. The Gauge Reader will be required to send a message by SMS or telephone to Flood Officers at

Tikwere House. Reporting will be done for every fall or rise interval of 0.1 m above 8.2 m of stage;

c) Police Alert Level will correspond to a stage of 8.4 m. The Gauge Reader will report by SMS or telephone to Flood Officers after every rise or fall of 0.1 m above 8.6 m of stage through the Central East African Railways Ltd.; and

d) M.B.C. Alert Level will correspond to a stage of 8.6 m and rising. The Gauge Reader will send water level data by SMS or telephone to Flood Officers at the Ministry through Central East African Railways or the Police at hourly intervals.

Water level data of the Ruo at Chiromo, R.G.S. 1.G.1, will be monitored and reported as follows:

a) Yellow Alert Level will correspond to a stage of between 6.0 m and 6.3 m on the staff gauge. The stage will be observed continuously till it recedes;

b) Red Alert Level will correspond to a stage 6.3 m. The Gauge Reader will send an SMS or telephone message to Flood Officers at Tikwere House through Central East African Railways Ltd. Reporting will be done for every fall or rise interval of 0.1 m above 6.3 m of stage;

c) Police Alert Level will correspond to a stage of 6.5 m. The Gauge Reader will report by SMS or telephone to Flood Officers at Tikwere House after every rise or fall of 0.1 m above 6.5 m of stage through the Central East African Railways Ltd or the Police at hourly intervals; and

d) M.B.C Alert Level will correspond to a stage of 6.8 m and rising. The Gauge Reader will send water level data by SMS or telephone to Flood Officers at Tikwere House through Central East African Railways Ltd or the Police at hourly intervals.

Early warning systems for floods being used in other flood prone areas in the country, including the districts of Karonga, Rumphi, Nkhata Bay, Nkhotakota, Salima, Dedza, and Phalombe, use a simplified version of the flood routing principle, empirical in nature but not scientifically verified. Essentially, the system involves observing stage at upstream gauging stations by local communities and predicting flood stages at downstream points. Flood warnings are issued once flood levels at monitoring gauging stations are reached and exceeded.

In some instances, upstream staff gauges are painted using three different colours according to the height of water level in the respective rivers and the associated flood condition downstream, namely: Green, Yellow, and Red. Green shows that the water level in the river in question is below the threshold of flood occurrence (i.e., safe), Yellow represents a situation where the community downstream should be placed on high alert since floods may occur, while Red is indicative of danger as the flood will definitely occur downstream. Thus, upstream communities monitor water levels and communicate the information to downstream communities. For example, when the upstream communities observe that the water level has reached the Yellow mark on the staff gauge, they inform downstream communities to be on high alert whereas when the water level reaches the Red mark on the staff gauge, downstream communities are advised to evacuate to higher ground as floods are definitely going to take place.

The accuracy of the manual system is heavily dependent on the quality of hydrological and meteorological data collected at upstream gauging/meteorological stations to provide timely data (localized) on river flow and rainfall. So far, the limited territorial coverage of hydrometeorological stations is a major challenge for rapid flood risk assessment for small river basins. As such, more accurate forecasts on rainfall and their dissemination are needed to improve the accuracy of warnings about potential flood risks.

According to Tropical Ocean and Global Atmosphere (TOGA), a drought may be defined as a condition that prevails when water demand far exceeds the supply for a particular purpose (TOGA, 1992). Generally, a drought event may be classified into three categories, namely: meteorological drought, hydrological drought, or agricultural drought (Figure 19). Meteorological drought occurs when rainfall received at a particular locality is well below the normal average for an extended period. Hydrological drought takes place when there is a sustained deficiency in both surface runoff and ground water, resulting in lack of water for efficient agricultural production, reduced supply for hydroelectric power generation, and shortage of water for domestic consumption. Agricultural drought occurs when rainfall amounts and distribution, soil water and evaporation losses combine to cause crop or livestock yields to diminish dramatically (TOGA, 1992).

Values are usually attached to the definitions of drought. For example, in India an area is said to be drought prone if rainfall tends to decrease by more than 30% over the mean. Similarly in South Africa drought conditions occur when the amount of rainfall in any particular period is 70% of the normal, i.e., when there is a departure of 30% from the normal; and the drought episode becomes severe when two consecutive seasons experience 70% of normal rainfall or less. The United States Climatic Analysis Center (CAC) defines drought as a condition that prevails when seven consecutive weeks of rainfall falls below 60% of the normal (Kamdonyo, 1992).

Nearly all droughts that have taken place in Malawi have been associated with the El Nino and Southern Oscillation (ENSO) phenomena. Recent studies about the ENSO warm phase episode in southern Africa show the existence of two drought cells, both of which affect Malawi, mainly the southern part of the country (Eastman *et al*., 1996). The first drought cell shows a path originating from Namibia but covering Botswana, Zimbabwe, southern Zambia, northwest Mozambique and the southern part of Malawi. The second drought cell has its center located near southern Mozambique and southern Zambia and appears to expand outwards. This drought cell too affects Malawi, particularly the southern part of the country. There are no signs at the moment to suggest the abetment of these drought cells from wreaking havoc in the country as attested by findings of climate change studies done by Chavula and Chirwa (1996). Malawi has experienced a number of severe droughts in the past, notable among these occurred in 1948/49 and 1991/92 seasons. The magnitude and frequency of these droughts will increase with climate change. Figures 20 to 25 depict Lake Chilwa under normal and drought situations.

As far as early warning messages about droughts are concerned, the DCCMS issues out seasonal forecasts about the expected crop yield in the country just before the rainy season commences. The process of generating the seasonal forecasts begins with a meeting convened by the SADC Office for meteorologists drawn from the region at which climate model simulations are done in order to predict the status of the rainfall season. After the regional meeting, country representatives brief their respective governments about the seasonal forecast. In the case of Malawi, the Technical Committee on Food Security, which comprises MAIWD, Ministry of Finance, Economic Planning and Development, the Reserve Bank of Malawi, Agriculture Development Divisions (ADDs), and Civil Society Organizations is given a briefing on the seasonal forecast. The Committee is chaired by the Ministry of Finance, Economic Planning and Development. The ADDs then brief officers at Rural Development Projects (RDPs) about the seasonal forecast, who in turn brief extension staff at Extension Planning Areas (EPAs). It is the Field Assistants stationed at EPAs that inform farmers at the community level about whether/not the country will experience drought. Where seasonal forecasts predict impending droughts, farmers are advised to grow drought tolerant crops, or to plant early maturing varieties, and to practice irrigated agriculture. In some instances farmers are advised to insure their crop, mainly tobacco, against drought events. Dry spells are normally forecasted by DCCMS and the information is disseminated to the general public through weather bulletins.

The main shortfall with the early warning system for droughts at the moment is that it mainly focuses on food security rather than being a multisectoral tool where the impact of droughts on water resources, health, energy, DRM, and tourism are considered. Also, there is need to build capacity in Climate Modeling at the Department of Climate Change and Meteorological Services which at the moment is inadequate. At the local level, three challenges have been noted about early warning systems for droughts. Firstly, when seasonal forecasts are disseminated by DCCMS, they provide information on a general drought situation for the entire country and not specific to areas of interest. And in most cases, the forecasts do not accurately predict the situation on the ground, thereby rendering them untrustworthy and unreliable.

Secondly, there is limited capacity at the district level to downscale national forecasts to specific areas of interest, so farmers can be given accurate information about the drought situation in their respective areas.

Finally, it has been noted from previous studies that there is limited human capacity at the district level to dissemination seasonal forecast to local communities (GoM, 2015). Since forecasts about droughts are communicated to local communities by agriculture extension staff at district level, who are themselves not experts in meteorology, they normally do not articulate these droughgt forecasts to farmers in a manner that farmers would understand the information and use it to avert drought disasters.

Malawi is also vulnerable to strong winds caused by tropical cyclones, when they veer away from their normal east to west path in the Mozambique Channel, and make a landing on the adjacent land, in countries such as Mozambique, Malawi, and Mozambique. In 2019, these three countries were severely battered by Cyclone Idai. Figure 16, shows some of the previous cyclones that made a landing in Malawi, with the Zomba Cyclone in 1946 being the most critical one.

Generally, warnings about Tropical Cyclone are disseminated through radios, newspapers, television, fax, telephone, and the Police by DCCMS, notwithstanding the fact that not all people in Malawi own radios and TV sets! The main challenge with cyclones is the unpredictability of the path they may follow thereby making it very difficult to accurately determine their exact position with the passage of time. The issuance of early warnings for southeast trade winds locally known as *Mwera* is done by DCCMS through its weather bulletins. But in most cases warnings issued to the general public are not heeded because of inadequate accuracy considering that the predictions are model based and hence results are statistical in nature. Consequently, there have been cases in the past when fishermen have drowned in Lake Malawi for not heeding early warnings for *Mwera* winds.

4.2.3 Potential Adaptation Strategies

A number of adaptation strategies for the water sector were proposed in Malawi's Initial National Communication (GoM, 2002) and the Second National Communication (GoM, 2011). These include the following:

Adaptation Measures for Droughts (GoM, 2002):

(a) Construction of more dams to retain surface runoff during the rainy season, as nearly 24% of annual rainfall is lost as surface run-off;
(b) Increased sustainable utilization and monitoring of groundwater resources;
(c) Conjunctive use of surface and groundwater resources;
(d) Sustainable agricultural practices including soil and water;
(e) Proper water use to improve water conservation;
(f) Expansion of rainfall harvesting techniques;
(g) Leakage monitoring and control in piped networks to avoid water loss;
(h) Public awareness campaigns for water conservation measures.

Adaptation Measures for Floods (GoM, 2002):

(a) Construction of upstream storage dams for purposes of mitigating flood hazards;
(b) Construction of dykes, canals or bunds to re-direct or divert flows to minimize flood damages, although this is generally very expensive;
(c) Increased afforestation in catchment areas to cover areas not yet considered;
(d) Extension of the installation of telemetry flood forecasting and warning systems to other flood prone areas for timely evacuation of people;
(e) Delineation of flood prone areas with flood zoning maps and the development of appropriate adaptation strategies and measures;
(f) Extensive public awareness campaigns;
(g) Improved wetlands conservation measures; and
(h) Effective early warning systems.

Adaptation strategies highlighted in the Second National Communication (GoM, 2011) include the following: construction of multipurpose dams, implementation of water demand management projects, construction of new water points, and improving the early warning system for floods and droughts. Multipurpose dam sites were already identified in the National Water Resources master Plan (NWRMP) on North Rukuru, South Rukuru, Bua and Lilongwe/Linthipe Rivers for which feasibility and design studies are required before construction can of the same commence. Among the dam sites, the ones that have already been 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.

In this study, we have decided to settle on three key water resources adaptation strategies for implementation as follows: (1) construction of more storage dams throughout the country in order to enhance water storage, and reduce annual runoff losses, which now stand at 24% country wide; (2) catchment protection, since most of the catchments in the country are seriously degraded and improvement in the management of flood and drought disasters.

4.3 Human Health

Climate change affects the health sector by enhancing the prevalence of various human diseases and these include a wide range of non-communicable as well as infectious diseases such as vector and water borne diseases, and malnutrition. Furthermore, climate change has the potential to cause floods, droughts, and storms, resulting in increased deaths, injury, and changing disease scenarios (Table 1, and Figures 1 and 2). Identification of communities and places vulnerable to these changes can help health authorities assess and prevent associated adverse impacts on human health. These adverse impacts can be averted by putting in place a combination of strategies such as strengthening key health system functions and improving the use of early warning systems for climate and weather information for planning and climate risk management.

Climate change raises important ethical concerns in several ways. First, on a global scale, the nations with the highest prevalence of climate-sensitive diseases (e.g., malnutrition, diarrhea and vector-borne diseases) are the least responsible for carbon emissions that to date are causing today’s climate change.

Figures 3 and 4 show two different maps revealing the growing ethical crisis of climate change (Patz and Hatch, 2014). Figure 3 shows conflations and deflations of geographical areas of the globe according to carbon dioxide emissions. For example, countries like the US are much larger than usual, and some countries like Africa are much smaller than their normal geographical size - revealing the discrepancy of varying carbon dioxide (CO_2) emissions globally. Figure 4 shows

Table 4. 10 Summary of the known effects of weather and climate on Health (Source: WHO, 2003)

Health outcome	Known effects of weather and climate
Cardiovascular respiratory mortality and heat stroke mortality	• Short-term increases in mortality during heat-waves • V- and J-shaped relationship between temperature and mortality in populations in temperate climates • Deaths from heat stroke increase during heat waves
Allergic rhinitis	• Weather affects the distribution, seasonality and production of aeroallergens
Respiratory and cardiovascular diseases and mortality	• Weather affects concentrations of harmful air pollutants
Deaths and injuries	• Floods, landslides and windstorms cause death and injuries
Infectious diseases and mental disorders	• Flooding disrupts water supply and sanitation systems and may damage transport systems and health care infrastructure • Floods may provide breeding sites for mosquito vectors and lead to outbreaks of disease • Floods may increase post-traumatic stress disorders
Starvation, malnutrition and diarrheal and respiratory diseases	• Drought reduces water availability for hygiene • Drought increases the risk of forest fires • Drought reduces food availability in populations that are highly dependent on household agriculture productivity and/or economically weak
Mosquito, tick-borne diseases and rodent-borne diseases(such as malaria, dengue, tick-borne encephalitis and Lyme diseases)	• Higher temperatures shorten the development time of pathogens in vectors and increase the potential transmission to humans • Each vector species has specific climate conditions (temperature and humidity) necessary to be sufficiently abundant to maintain transmission
Malnutrition and undernutrition	• Climate change may decrease food supplies (crop yields and fish stocks) or access to food supplies
Waterborne and foodborne diseases	• Survival of disease-causing organisms is related to temperature • Climate conditions affect water availability and quality • Extreme rainfall can affect the transport of disease-causing organisms into the water supply

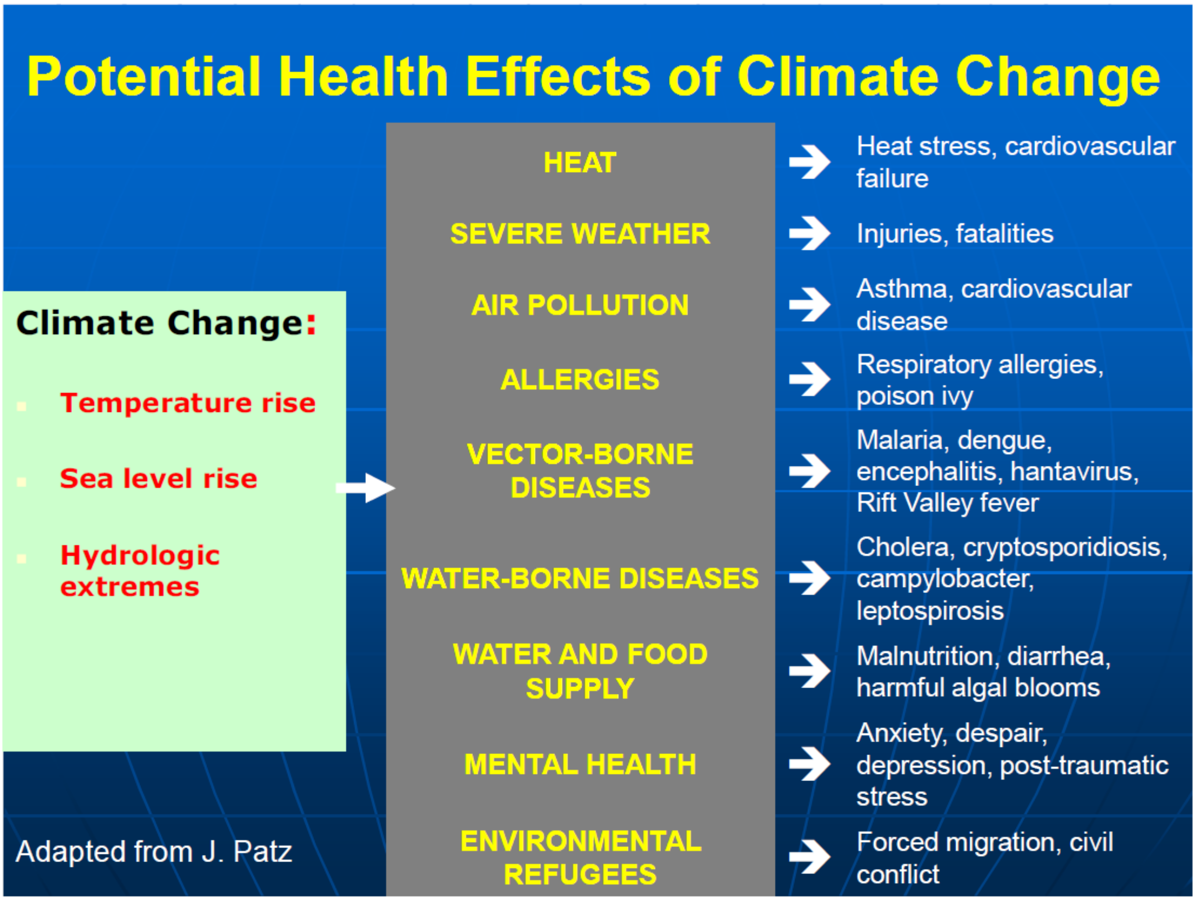


Figure 4. 5 Potential Health Effects of Climate Change

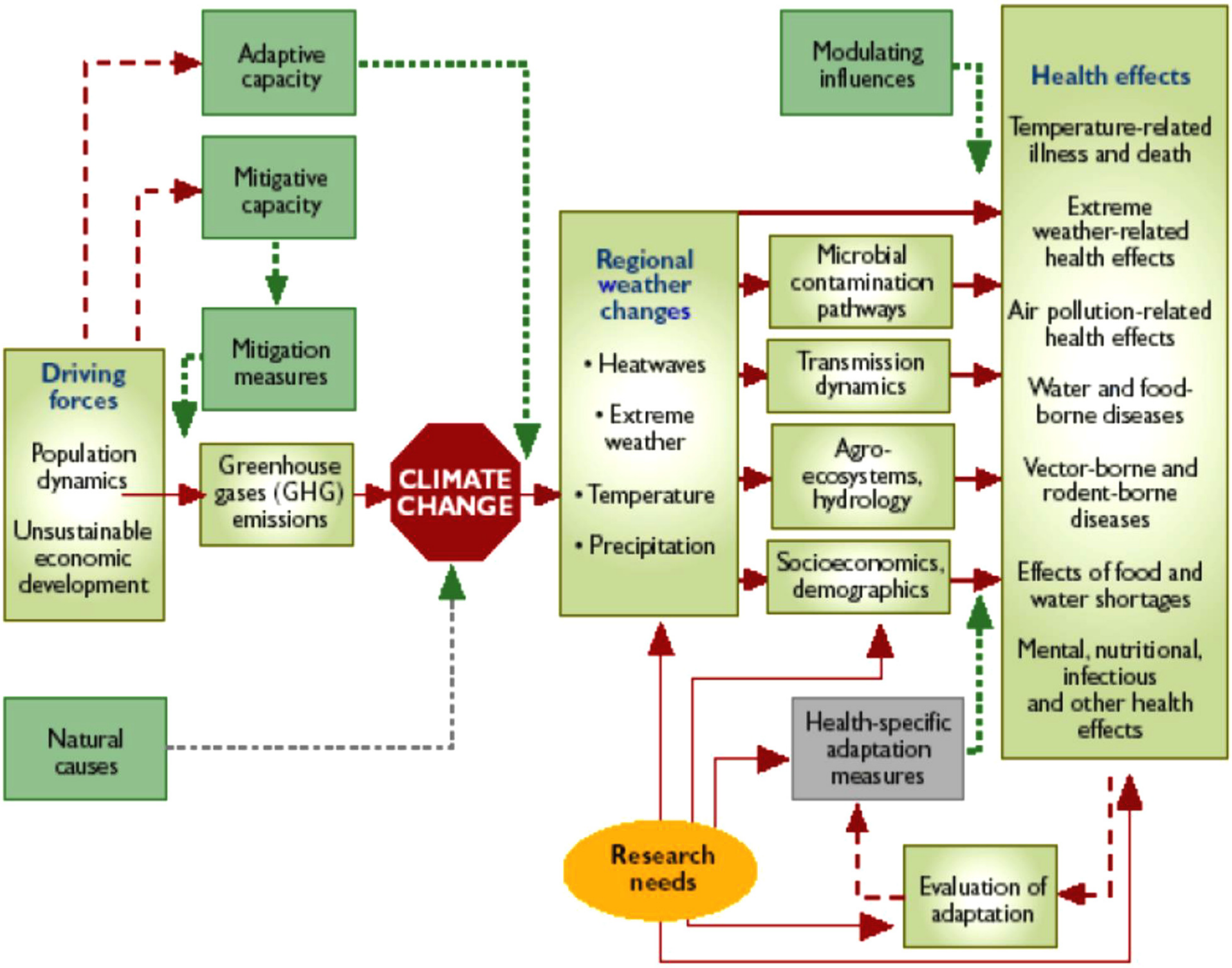


Figure 4. 6 Potential Health Effects of Climate Change (Source: IPCC, 2001)

According to the United Nations Country Assessment Report for Malawi (2010), climate change poses a serious threat to Malawi's development agenda. In the short to medium term climate change will significantly affect the functioning of natural ecosystems, with serious repercussions on weather-sensitive sectors, particularly agriculture, forestry, water resources, energy, fisheries, and wildlife; and human systems such as human health, human settlements, and gender (GoM, 2002; GoM, 2006; GoM, 2007; GoM, 2010; GoM, 2011a; GoM, 2011b; Oxfam, 2009).
It is envisaged that in the long-term, climate change will undermine the attainment of the Sustainable Development Goals (SDGs), Vision 2020, and the Malawi Growth and Development Strategy (MGDS III: 2017-2022) thereby exacerbating poverty in the country.

The Ministry of Health (MoH) is taking new steps to address climate change risks to human health in Malawi as attested by the Ministry's participation in the Africa Adaptation Program of the Global Framework for Climate Services (GFCS). The Ministry plans to work with multiple sectors to improve understanding and readiness for the health risks of climate change and variability. An initial activity of this project involved conducting a nationwide assessment of the potential impacts of climate change on human health in Malawi. The assessment was funded by GIZ of Germany.

The Malawi Growth and Development Strategy III (GoM, 2017) is the overarching medium term strategy designed to attain Malawi's long term aspirations as spelt out in the Vision 2020. The National Health Bill is under review to replace the Public Health Act of 1948 while the National Health Policy is still in draft form.

The country's Health Sector Strategic Plan II (HSSP II) covering the period 2017-2022 has been formulated to align with the MGDS III (2017-2022) and the global Sustainable Development Goals (SDGs), particularly Goal No.3:"Ensure healthy lives and promote well-being for all at all ages". The Health Sector Strategic Plan II guides the implementation of the health interventions and emphasizes increasing coverage of high quality Essential Health Package (EHP) services and strengthening performance of the health systems to improve equity, efficiency and quality of EHP services in Malawi. Essentially, the objectives of the HSSP II focus on two main aspects, namely: strengthening health systems for the delivery of an essential health package, and tackling social determinants of health. They are as follows:

(a) Increase equitable access to and improve quality of health care services;
(b) Reduce environmental and social risk factors that have direct impact on health;
(c) Improve the availability and quality of health infrastructure and medical equipment;
(d) Improve availability, retention, performance and motivation of human resources for health for effective, efficient and equitable health service delivery;
(e) Improve the availability, quality and utilization of medicines and medical supplies;
(f) Generate quality information and make it accessible to all intended users for evidence-based decision-making, through standardized and harmonized tools across all programs;
(g) Improve leadership and governance (particularly setting direction and regulation) across the health sector and at all levels of health system; and
(h) Increase health sector financial resources and improve efficiency of their allocation and utilization.

The health care delivery system in Malawi mainly consists of government facilities (63%), Christian Health Association of Malawi (26%) and some private for-profit providers (Table 4.11).

Table 4. 11 Health Facilities in Malawi (Source: UNICEF, 2016)

Type of Health Facility	CHAM	Government	NGO	Private	Total
Dispensary	4	49	4	30	87
Health Centre	107	413	4	18	542
Health Post	18	132	2		152
Hospital (Central and District Hospitals)	38	45	1	1	85
Outreach	968	4,008	43	71	5,090
Village Clinic		3,542			3,542
Total	**1,135**	**8,189**	**54**	**120**	**9,498**

This study builds on the uncoordinated studies conducted in the past and provides an appropriate platform to articulate critical issues linking the two areas: climate change and human health in the Malawi context.

UNDP Human Development Report 2014 ranks Malawi as number 174 out of 186 countries that were assessed.

In addition, traditional healers and herbalists play an important role in the delivery of health services in the country. The Herbalists Association of Malawi has about 75,000 members. Despite this well- established network of health facilities, the health delivery services have remained poor due to limited financial and human resources. The 2013 Malawi health profile indicated that the ratio of medical personnel to patients is still very low: 0.2 physician to 10000 patients and 3.4 nurses/midwifes to 10000 patients. Thus, improvements in health indicators have been rather slow. In addition to the mainstream challenges such as shortage of financial and human resources, as well as poor infrastructure capacity, climate change is exerting an additional strain to the already loaded system. Thus, if appropriate steps are not taken to develop specific strategies to respond to impacts of climate change on human health, the current health management initiatives will not cope and therefore fail to yield desired results.

This study builds on the uncoordinated studies conducted in the past and provides an appropriate platform to articulate critical issues linking the two areas: climate change and human health in the Malawi context.

4.3.1 Importance of Human Health

As stated in the Malawi Growth and Development Strategy III (GoM, 2017), human health is the lynchpin of economic development. Improving health outcomes is an essential prerequisite for increased national development, increased economic growth and poverty reduction. Thus, improvements in the health sector have a social economic trickledown effect on other key elements of development including human population growth, education, agriculture, industry, among others. For example, the health status of any country influences all component of population change, as it directly and indirectly affect levels of mortality, fertility, and migration. And conversely, a high population growth rate contributes to increased demand for basic necessities of life such as food, health and shelter.

4.3.2 Vulnerability of Human Health

Generally, vulnerability assessments of impacts of climate change on various sectors of the economy begin with the generation of climate change scenarios for temperature and precipitation using GCMs, Regional Circulation Models, or Down Scaled GCMs. These data are then used as inputs in sector specific models, e.g. water balance models for water resources, crop models for agriculture, etc. Outputs from sector specific models are used as inputs in economic models in order to assess potential impacts of climate change on the GDP. But considering that models for the health sector are still being developed, the WHO has developed guidelines for assessing the vulnerability of the sector to climate change, Figures 5 to 8. And most of the assessments are done using statistical models.

As stated in the preceding discussion, the changing climate is linked to increases in a wide range of non-communicable and infectious diseases (Manangan *et al.*, undated), Figure 1. There are complex ways in which climatic factors can directly or indirectly affect the prevalence of disease. Identification of communities and places vulnerable to these changes can help health departments assess and prevent associated adverse health impacts. The Climate and Health Program at the Center for Disease Control and Prevention (CDC) has developed the Building Resilience against Climate Effects (BRACE) framework to help health departments prepare for and respond to climate change. The BRACE framework is a five-step process that helps health departments to understand how climate has and will affect human health, and enables health departments to employ a systematic, evidence-based process to customize their response to local circumstances. Listed below are the five steps:

a) Determine the scope of the climate vulnerability assessment by firstly, identifying the area of interest and the projected change in climate exposures at the smallest possible spatial scale, and secondly by identifying the health outcome(s) associated with these climate exposures;
b) For these health outcomes, identify the known risk factors (e.g., socioeconomic factors, environmental factors, infrastructure, pre-existing health conditions);
c) Acquire information on health outcomes and associated risk factors at the smallest possible administrative unit (e.g., census block group, census tract, county) in accordance with data privacy regulations and availability;
d) Assess adaptive capacity in terms of the system’s (e.g., communities, institutions, public services) ability to reduce hazardous exposure and cope with the health consequences resulting from the exposure; and

e) Combine this information in a Geographic Information System (GIS) to identify communities and places that are vulnerable to disease or injury linked to the climate-related exposure.

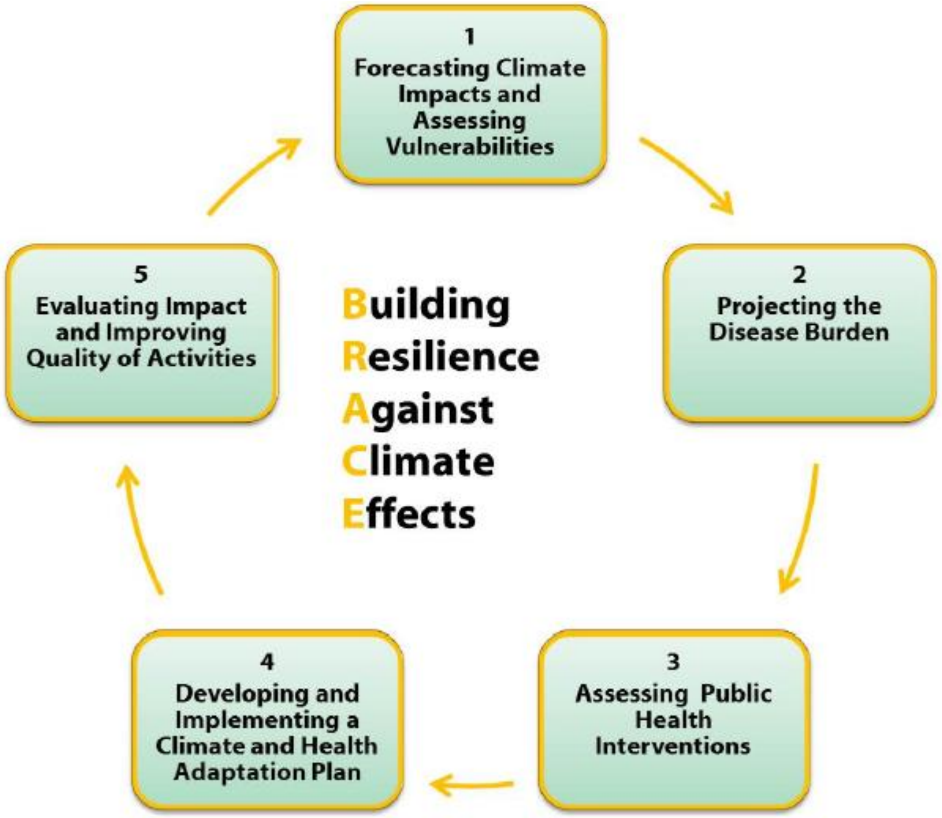


Figure 4. 7 Framework for Building Resilience against Climate Change Effects (Source: CDC, Undated)

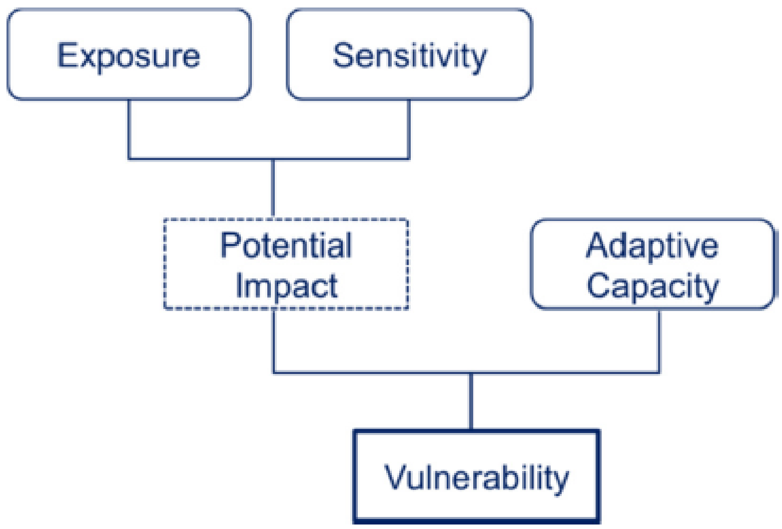


Figure 4. 8 Factors that determine vulnerability (Source: CDC, Undated)

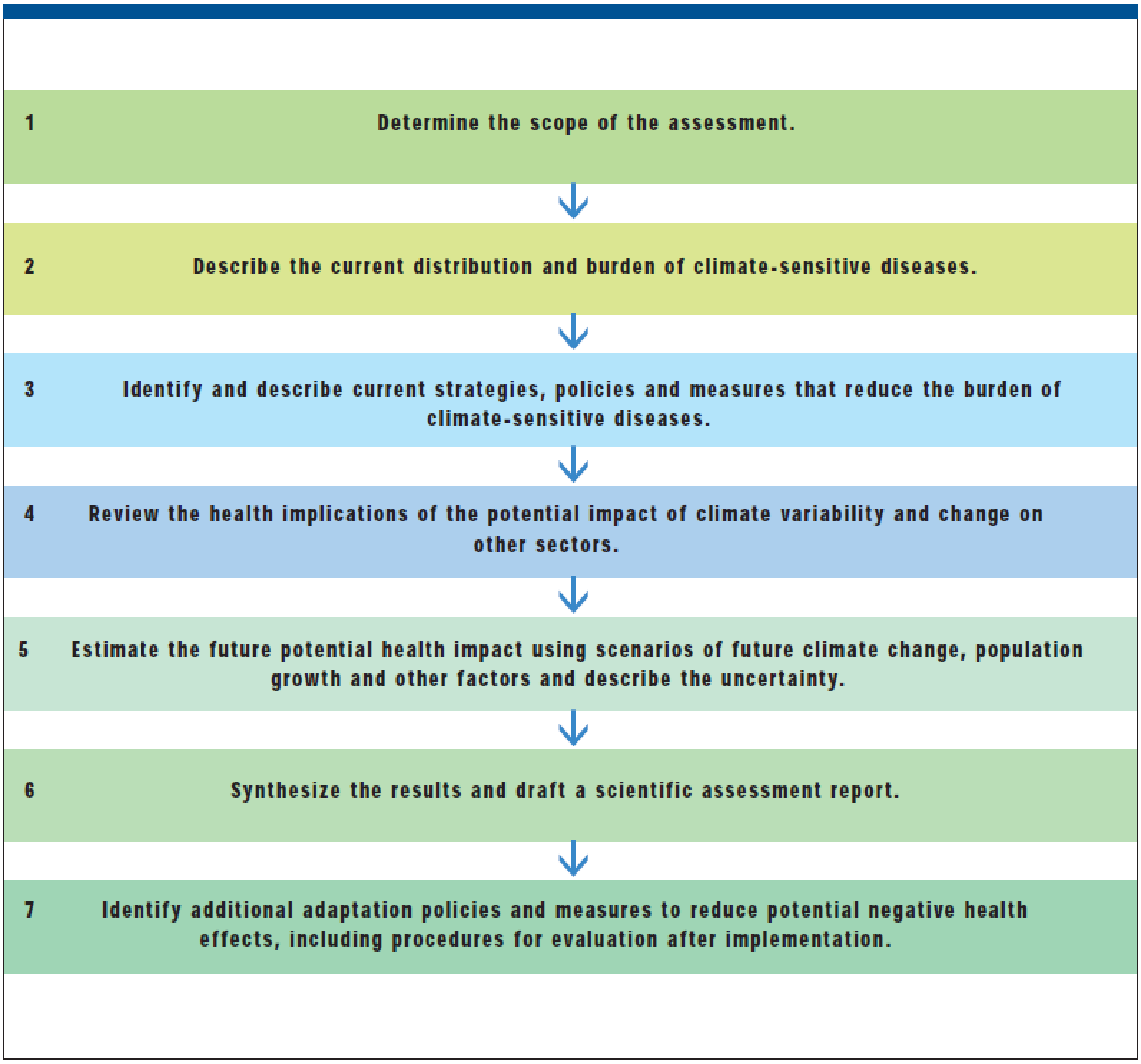


Figure 4. 9 Steps in assessing vulnerability and adaptation (WHO, 2003)

The vulnerability assessment of the health sector in Malawi to impacts of climate change was conducted by using two approaches, and these are: statistical analysis of the scenarios data generated using IPCC's Fourth Assessment Report (AR4) method as described in Malawi's Health NAPA of 2015, complemented with climate scenarios data for temperature and rainfall generated using statistically downscaled General Circulation Models following the Intergovernmental Panel on Climate Change (IPCC) procedure reported in Fifth Assessment Report or AR5 (IPCC, 2013). The Fifth Assessment Report is premised on two Representative Concentration Pathways (RCPs) in respect of emissions of Greenhouse Gases (GHGs), namely: RCP 4.5 (Intermediate Emission) and RCP 8.5 (High Emission) as described by Moss *et al.* (2013). In the first approach, data on climate change projections for temperature and rainfall were applied in the statistical modelling of future impacts of the three selected diseases: malnutrition, malaria, and diarrhoea.

The task of generating climate change scenarios of temperature and precipitation involved the application of an ensemble of General Circulation Models (GCMs) for the entire country

(GoM, 2011; GoM, 2002). This was complemented by results presented by the IPCC in its Fourth Assessment Report (IPCC, 2007), the UNDP Report (McSweeney *et al*., (2008); Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre) report of 2007).

After generating climate change scenarios of temperature and rainfall, univariate analysis was conducted for each of the selected disease and climatic variables with cross-correlation analysis in order to assess associations between malaria, malnutrition, dysentery, cholera and climatic variables, together with other covariates over a range of time lags. The time lags chosen for the final model simulation were outcomes of cross-correlational analysis using seasonally differenced data.

A dynamic linear model (DYLM) model, which is equivalent to the seasonal autoregressive integrated moving average (SARIMA), was then applied to examine independent contributions of malaria, dysentery, or cholera transmission covariates. The number of terms for SARIMA were determined using the autocorrelation function (ACF) and partial autocorrelation function (PACF). When fitting the SARIMA model, the outcome variables were transformed using Johnson and Wichern (1998) approach. For the cholera outcome, a square root transformation to account for zero-inflation was used while logarithmic transformation was employed for malaria, malnutrition and dysentery.

To create an appropriate stationary time series for the analysis, all dependent and independent variables were differenced at an appropriate lag periodicity. For malaria and dysentery, lags at month 1 and 2 were created while for cholera constructed seasonally adjusted lags of 12 months were applied. For malnutrition, lags at 6 and 12 months were created, guided with the prior belief that most of malnutrition cases in Malawi might be due to chronic under-nutrition (stunting) and seasonal under-nutrition (wasting).

Data on climatic variables (temperature and rainfall) and number of cases of key diseases were collected from the Department of Climate Change and Meteorological Services (for Chikwawa, Makoka, Chitedze and Salima meteorological stations) and the Ministry of Health's Health Management Information System (HMIS), respectively. These data were then correlated with a view to exploring exiting relationships.

Furthermore, future projections of climate change scenarios obtained from the IPCC Fourth Assessment Report (2007) were used to determine the future impacts on the key diseases using statistical modelling for the periods 2030 and 2050 (McSweeney et al., 2008).

Annual excess incidence of disease attributable to future climate-related changes in temperature and precipitation was estimated by the following formula:

$$\Delta inc = inc_0(e^{\beta\Delta X} - 1)$$

whereΔinc is the expected incidence change due to future climatic change ΔX, while inc_0 is the baseline incidence at the present time. Here, the relative risk captures the expected change in disease risk following a 1 ^{o}C change in temperature or 1% change in rainfall. The average incidence in 2007 was used as a baseline incidence to calculate future incidence.

This involved the identification of key indicators for use in tracking the disease burden (e.g. proportion of disease cases) and their spatial distribution, as well as noting the frequency and magnitude of flood and drought disasters. The vulnerability assessment described above assisted in the identification of some indicators that can be used in tracking climate change impacts.

Risk factors for tracking climate change were identified using literature review and questionnaires that were administered to stakeholders.

The baseline assessment focused mainly on information on three key climate sensitive diseases and the relationship between the occurrences of these diseases and climatic variables. The study findings show that malaria, diarrhoeal diseases and malnutrition are among the main causes of illnesses and deaths in Malawi (Tables 3 to 7; Figures 9 to 16). Furthermore, study findings revealed that the average number of diarrheal cases in Chikwawa was 1242 while malaria was 7098 and malnutrition was 272.73.

The results show that diarrhoea, malaria and malnutrition are weakly correlated with climatic variables (correlation $r<0.2$), except for rainfall and diarrhoea ($r=0.54$). In Zomba, the mean number of diarrheal cases of 1096.4 was slightly lower than in Chikwawa district. The mean number of malaria and malnutrition cases were 9825 and 213.7 respectively. The correlation of malaria with rainfall and minimum temperature was moderate ($r=0.5$), but weak for malnutrition and diarrhoea. During the period of study, Lilongwe posted slightly higher number of cases of all disease types. The mean cases of diarrhoea was 3516 while malaria and malnutrition were 22194 and 783.4 respectively. For all diseases, the highest correlation with climatic variables was observed between malaria and rainfall and minimum temperature, otherwise for other diseases this was estimated at $r<0.3$. In Salima, the mean cases were 585, 5259, and 162.7 for diarrhoea, malaria and malnutrition respectively.

4.3.3 Trends and Seasonality of Disease Incidence

The box plots (Figures 9 to 12) present the observed incidences of diarrhoea, malaria and malnutrition in the four districts under study. These plots display the long-term trend (years) in disease incidence, and seasonality of disease using month. Figure 9 illustrates monthly average variations in disease incidence in Chikwawa district, and provides evidence of strong seasonality of diarrhoea while for malaria, highest average incidence are generally in the first months of the year, which coincides with the hot and rainy season. The trend shows the average incidence of diarrhoea has been increasing while that of malaria and malnutrition has been decreasing.

Table 4. 12 Summary statistics of disease incidence and climatic variables in Chikwawa, Zomba, Lilongwe and Salima districts

District	Variable	Number (months)	Mean	Median	Standard deviation	Minimum	Maximum
Chikwawa	Diarrhoea	84	1242.0	1135	400.67	706	2701
	Malaria	84	7098.0	7618	2952.86	1799	14764
	Malnutrition	84	272.7	217	221.33	39	1261
	Rain	84	59.6	22.20	86.87	0	391.60
	Minimum Temperature	84	20.3	21.20	3.50	12.00	25.90
	Maximum Temperature	84	32.9	32.90	3.11	25.20	38.60
Zomba	Diarrhoea	96	1096.4	1078.0	406.01	479.0	2986.0
	Malaria	180	9825.0	9286	4075.68	3260	25893
	Malnutrition	132	213.7	173.0	125.75	100.0	1127.0
	Rain	180	82.3	18.65	110.64	0	439.10
	Minimum Temperature	180	15.9	16.75	2.86	10.40	20.80
	Maximum Temperature	180	26.6	26.80	2.39	21.60	31.60
Lilongwe	Diarrhoea	84	3516.0	3178	1640.02	40	7919
	Malaria	84	22194	20013	12229.1	306	51999
	Malnutrition	84	783.4	781.5	423.68	0	1943.0
	Rain	84	69.77	15.95	98.41	0	407.80
	Minimum Temperature	84	15.14	15.60	3.25	9.00	19.60
	Maximum Temperature	84	27.21	27.00	2.18	22.70	32.00
Salima	Diarrhoea	132	585.8	643.0	491.14	11.0	2760.0
	Malaria	132	5259	5798	3271.64	393	14643
	Malnutrition	132	162.7	127.0	159.14	5.0	945.0
	Rain	132	96.24	8.50	153.95	0	760.70
	Minimum Temperature	132	20.51	20.86	2.34	15.70	24.60
	Maximum Temperature	132	29.56	29.40	2.17	24.60	34.50

Table 4. 13 Regression coefficients for Chikwawa and Zomba districts

		Chikwawa			Zomba		
Variable		Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)	Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)
Climatic	Rainfall (Lag0)	1.001 (1.000-0.002)	1.001 (1.000-1.001)	1.000 (1.0001-1.0004)	1.0006 (1.0005-1.008)	1.0003 (1.00031-1.00037)	1.001 (1.0004-1.002)
	Rainfall (Lag1)	1.005 (1.004-1.006)	1.001 (1.001-1.002)	1.000 (1.0000-1.0003)	1.0005 (1.0004-1.0006)	1.000 (1.0002-1.0003)	1.000 (1.0003-1.0009)
	TMin (Lag1)	1.004 (1.002-1.005)	0.967 (0.994-0.999)	1.037 (1.01-1.04)	0.988 0.97-0.99)	0.953 (0.94-0.97)	1.016 (1.01-1.02)
	TMin Lag2)	1.031 (1.001-1.004)	1.027 (1.011-1.068)	0.984 (0.98-1.01)	1.004 (0.99-1.007)	0.935 (0.92-0.94)	0.873 (0.84-0.89)
	TMax (Lag1)	1.031 (1.000-1.004)	1.04 (1.02-1.005)	0.953 (0.94-0.99)	1.042 (1.03-1.047)	1.013 (1.01-1.03)	0.983 (0.93-1.01)
	TMax (Lag2)	1.019 (1.000-1.002)	0.987 (0.971-0.999)	1.046 (1.03-1.06)	1.076 (1.07-1.088)	1.071 (1.035-1.11)	1.09 (1.02-1.13)
Year	2007	1.000	1.000	1.000	1.000	1.000	1.000
	2008	0.856 (0.822-0.878)	1.150 (1.12-1.18)	0.668 (0.64-0.72)	1.474 (1.44-1.49)	1.047 (1.03-1.045)	0.980 0.96-0.99)
	2009	0.873 (0.814-0.929)	1.052 (1.03-1.08)	0.586 (0.55-0.64)	1.586 (1.55-1.61)	1.157 (1.13-1.19)	1.176 (1.15-1.195)
	2010	0.864 (0.855-0.877)	0.970 (0.96-0.99)	0.643 (0.62-0.69)	1.837 (1.62- 2.01)	1.248 (1.21-1.26)	1.457 (1.13-1.61)
	2011	1.005 (1.002-1.008)	0.647 (0.62-0.66)	0.236 (0.22-0.25)	2.135 (2.08-2.21)	1.380 (1.33-1.42)	1.037 (1.01-1.05)
	2012	1.163 (1.141-1.190)	0.434 (0.42-0.44)	0.197 (0.18-0.22)	2.028 (1.93-2.11)	0.923 (0.91-0.95)	0.951 (0.89-0.98)
	2013	1.184 (1.178-1.197)	0.488 (0.47-0.50)	0.214 (0.201-0.23)	2.343 (2.16-2.55)	0.936 (0.91-0.96)	1.186 (0.16-1.21)
	2014	1.075 (1.057-1.091)	0.624 (0.61-0.64)	0.197 (0.188-0.22)	2.620 (2.51-2.74)	1.488 (1.42-1.57)	2.459 (2.22-2.64)

Table 4. 14 Regression Coefficients for Lilongwe and Salima Districts

		Lilongwe			Salima		
Variable		Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)	Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)
Climatic	Rainfall (Lag0)	0.998 (0.9983-0.9988)	0.99 (0.992-0.994)	0.998 (0.982-0.990)	1.000 (1.0003-1.0005)	0.999 (0.9987-0.9998)	1.001 (1.0008-1.0011)
	Rainfall (Lag1)	0.999 (0.9990-0.9994)	0.98 (0.981-0.986)	0.998 (0.980-0.999)	1.000 (0.999-1.0001)	0.999 (0.9986-0.9998)	0.999 (0.9985-0.9998)
	TMin (Lag1)	1.000 (0.991-1.002)	1.051 (1.02-1.07)	1.105 (1.05-1.12)	0.875 (0.87-0.89)	0.972 (0.962-0.986)	1.059 (1.02-1.071)
	TMin (Lag2)	0.995 (0.991-0.999)	1.136 (1.11-1.15)	0.961 (0.94-0.98)	1.042 (1.03-1.06)	0.948 (0.942-0.952)	0.995 (0.96-1.01)
	TMax (Lag1)	1.021 (1.015-1.022)	0.99 (0.995-0.996)	0.884 (0.85-0.91)	1.120 (1.09-1.15)	1.048 (1.02-1.06)	1.084 (1.04-1.10)
	TMax (Lag2)	1.036 (1.025-1.042)	0.904 (0.89-0.91)	0.959 (0.94-0.96)	0.987 (0.96-1.001)	1.043 (1.02-1.05)	1.033 (1.02-1.07)
Year	2007	1.000	1.000	1.000	1.000	1.000	1.000
	2008	1.138 (1.12-1.15)	1.350 (1.32-1.37)	1.007 (1.004-1.10)	2.045 (2.02-2.06)	1.62 (1.30-1.89)	2.984 (2.84-3.14)
	2009	1.268 (1.22-1.28)	1.639 (1.59-1.67)	0.614 (0.59-0.63)	2.409 (2.20-2.71)	1.57 (1.39-1.78)	1.963 (1.81-2.12)
	2010	1.641 (1.57-1.72)	1.979 (1.97-1.99)	0.817 (0.80-0.82)	2.72 (2.41-2.92)	1.874 (1.84-1.95)	2.343 (2.23-2.44)
	2011	1.060 (1.03-1.08)	1.234 (1.20-1.26)	0.479 (0.43-0.51)	2.21 (2.20—2.23)	0.968 (0.94-0.98)	1.01 (1.004-1.012)
	2012	1.324 (1.28-1.36)	0.713 (0.66-0.75)	0.314 (0.28-0.33)	2.98 (2.87-3.12)	1.058 (1.02-1.07)	0.892 (0.74-0.96)
	2013	2.025 (2.02-2.03)	0.825 (0.80-0.84)	0.301 (0.28-0.32)	4.083 (4.03-4.11)	1.487 (1.34-1.56)	1.742 (1.66-1.89)
	2014	2.271 (2.24-2.29)	1.056 (1.03-1.07)	0.628 (0.60-0.64)	3.538 (3.31-3.76)	1.947 (1.82-2.01)	2.904 (2.80-2.98)

Table 4. 15 Composite projected change in mean annual temperature and rainfall by 2030 and 2050 in four study district

1 Climatic variable	2 District	3 Expected Change in Year 2030	4 Expected Change in Year 2050
5 Temperature	6 Chikwawa	7 1.1	8 2.0
	9 Zomba	10 0.9	11 1.6
	12 Lilongwe	13 0.9	14 1.7
	15 Salima	16 0.9	17 1.7
18 Rain	20 Chikwawa	21 -1.4	22 -2.6
19	23 Zomba	24 -0.4	25 -1.1
	26 Lilongwe	27 3.3	28 6.2
	29 Salima	30 3.3	31 6.2

Table 7 : Dise ase incidence change in 2030 and 2050 based on projected climatic change

1 District	2	3 Diarrhoea		4 Malaria		5 Malnutrition	
6	7	8 Year 2030	9 Year 2050	10 Year 2030	11 Year 2050	12 Year 2030	13 Year 2050
14 Salima	15 Rain	16 0.12	17 0.22	18 0.01	19 0.02	20 0.41	21 0.76
22	23 Tmin	24 -9.71	25 -17.54	26 -4.20	27 -7.79	28 6.65	29 12.92
30	31 Tmax	32 9.66	33 19.21	34 6.68	35 12.98	36 8.95	37 17.58
38	39 Overall	40 -0.88	41 -1.67	42 2.14	43 4.02	44 14.34	45 25.45
46 Lilongwe	47 Rain	48 -0. 09	49 -0.17	50 -0.31	51 -0.58	52 -0.49	53 -0.92
54	55 Tmin	56 1.29	57 2.46	58 6.69	59 13.02	60 4.85	61 9.36
62	63 Tmax	64 2.21	65 4.20	66 -2.46	67 -4.53	68 -9.14	69 - 16.57
70	71 Overall	72 3.32	73 6.16	74 3.63	75 6.73	76 -5.47	77 - 10.53
78 Zomba	79 Rain	80 -0.02	81 -0.04	82 0.01	83 0.003	84 -0.04	85 -0.12
86	87 Tmin	88 -0.65	89 -1.14	90 -6.19	91 - 10.74	92 -2.33	93 -4.09
94	95 Tmax	96 4.04	97 7.29	98 2.91	99 5.24	100 0.97	101 1.74
102	103 Overall	104 3.24	105 5.68	106 -3.58	107 -6.45	108 -1.44	109 -2.61
110 Chikwawa	111 Rain	112 -0.08	113 -0.16	114 -0.11	115 -0.18	116 0.03	117 0.06
118	119 Tmin	120 0.41	121 0.75	122 -3.34	123 -5.96	124 3.50	125 6.46
126	127 Tmax	128 0.03	129 6.24	130 -1.18	131 -2.14	132 -4.85	133 -8.65
134	135 Overall	136 3.59	137 6.41	138 -4.76	139 -8.81	140 -1.51	141 -2.76

Table 4. 16 Disease incidence change in 2030 and 2050 based on projected climatic change

In Zomba, all diseases show a strong seasonality variation (Figure 10). High average numbers of cases coincide with the hot and rainy season (November-March) while average low incidences were recorded in the cold season. The trend presented displays an increasing average number of diarrhoea and malaria, but a nearly constant pattern with regards to malnutrition. The variability of malaria within each year is relatively higher than for the other two diseases.

The trends in average incidence of diarrhoea, malaria and malnutrition in Lilongwe are presented in Figure 4.9 below. The three selected diseases show seasonality variations. High average numbers of reported cases were recorded in January and February, and also in November-December, which is a rainy season, while low average incidences were recorded in the second or third quarters of the year. The increase in trend was visible in diarrhoea incidence while for malaria this increased for four consecutive years (2007-2010) and decreased in subsequent years only to increase again in the year 2012.

Figure 4.9 shows the distribution average incidence of diarrhoea, malaria and malnutrition in Salima. All box plots show that in general no disease displays seasonal variation, although diarrhoea and malnutrition depict some peaks towards the beginning and end of the year. As in other districts, the average incidence of diarrhoea and malnutrition has increased since the year 2007. For malnutrition, the trend of incidence is somewhat constant.

4.3.4 Relationship between disease incidences and climatic variables

The findings on the relationship between diseases and climatic variables are presented in Figure 4.6 to 4.9. The top panel shows a plot of diarrhoea against each climatic variable while presented in the middle panel is the relationship between malaria and climatic variables and bottom graphs are showing the relationship between malnutrition and climatic varables.

Regression analysis was used to determine the relationship between climate variables and disease incidences. The root mean square error was used to validate the model. The best fitting model was identified and used. Summary of results are presented in Tables 4.15 and 4.16.

For Chikwawa district, it was noted that the effect of rainfall was positively related to all diseases at both lag of 0 and 1 month. There was approximately 0.1% increase in diarrhoea, malaria and malnutrition per unit percentage increase in rainfall in the current month, and 0.5% increase in diarrhoea per percentage increase in rainfall in the previous month. Both minimum and maximum temperatures were associated with diarrhoea, malaria and malnutrition. For malaria and minimum temperature, results show a 4% reduction in malaria when temperature increases by 1 degree in the previous month, while malnutrition decreases by 2% in 1 degree increase in temperature in the past 2 months (Table 4). Across all years in Chikwawa, compared to the year 2007, the incidence of diarrhoea has increased, however, a reduced risk of malaria and malnutrition was estimated.

In Zomba district, rainfall was the main driver of all diseases, but the effect was relatively small (0.06%, 0.03% and 0.1% increases for diarrhoea, malaria and malnutrition respectively, for every 1% increase in rainfall). Minimum temperature at a lag of 1 month was negatively associated with the incidence of diarrhoea, and malaria, but positively related to the incidence of malnutrition. However, at lag of 2 months, a positive relationship was noted with the incidence of diarrhoea, at the same time negatively associated with the incidence of malaria and malnutrition. Maximum temperature also positively affected diarrhoea and malaria incidence, but negatively with malnutrition. Overall, the incidence of all diseases has increased since 2007.

Table 4.16 shows regression estimates for Lilongwe and Salima districts. Results show that the incidence of diarrhoea has been increasing in both Lilongwe and Salima. Diarrhoea was negatively associated with rainfall in Lilongwe, but was positively related to rainfall in Salima. A one degree change in maximum temperature at lag of 1 was associated with a 2% increase in diarrhoea in Lilongwe and 12% increase in Salima. Similarly rainfall was negatively associated with malaria and malnutrition in Lilongwe. A unit increased change in rainfall was associated with about 1% reduction in malaria or malnutrition in Lilongwe. Current rainfall levels were associated with increased malnutrition in Salima, with a 0.1% increase for a 1 unit increase in rainfall. Minimum temperature at lag of 1 month was likely to increase malaria and malnutrition risk by 5% in Lilongwe, and 13% at lag 2 for malaria only in Lilongwe. The same margin of association of 5% was observed between minimum temperature and malnutrition in Salima. Maximum temperature at lag 1 was also associated with a 4.8% and 8.4% increase in malaria and malnutrition respectively.

Recent climate trends in Malawi show a temperature increase of 0.9^{o}C between 1960 and 2006, an average rate of 0.21^{o}C per decade. The increase in temperature has been most rapid in December-January-February (DJF) and slowest in September-October-November (SON). Daily temperature observations show an increase in the frequency of hot days and nights in all seasons. The frequency of cold days and nights has significantly decreased in all seasons except in SON. Observed rainfall over the country does not show statistically significant trends. Also, there are no statistically significant trends in the extremes indices calculated using daily precipitation observations (McSweeney *et al*., 2008).

Based on the energy situation in Malawi, the A1B scenario was selected for the generation of climate change predictions as described in the 4th Assessment Report or AR4 (IPCC, 2007). The future climatic changes in temperature and rainfall are presented in Figures 14 and 17 respectively, for the year 2030 and 2050.

In summary, mean annual temperatures are expected to rise by 0.9 to 1.1 degree in 2030, and a further 1.6 to 2.0 degrees in 2050 (Table 6). Mean annual precipitation is projected to change by -1.4% to 3.3% in 2030, while in 2050 this will change by -2.2% to 6.2%. The respective expected changes in Lilongwe, Salima, Zomba and Chikwawa are presented in Table 7.

Figures 14 to 17 show the percentage change in disease incidence for each district under climate change scenario.

Figure 14 shows the projected change in incidence of diarrhoea, malaria and malnutrition for Salima district. The highest increase is estimated in malnutrition, projected at 14.3% in the year

2030 and 25.4% in 2050. Diarrhoea was estimated to decrease by 0.9% and 1.7% in 2030 and 2050 respectively.

In Lilongwe, both diarrhoea and malaria incidences are expected to increase (Figure 15). In 2030 and 2050, diarrhoea incidence are expected to increase by 3.32% and 6.16% respectively while malaria in the same periods will increase by 3.36% and 6.73% respectively. On the other hand, malnutrition will decrease by about 5% in 2030 and by 6% in 2050.

Figure 16 shows the anticipated changes in incidence of malaria, diarrhoea and malnutrition in Zomba. By 2030 and 2050 diarrhoea incidence is estimated to increase 3.2 % and 5.7%respectively compared to the present period (2007-2014). Future malaria incidence will decrease by about 4%, in 2030, and 6.5% in 2050, whereas malnutrition will decline by 1.4% and 2.6% in the two future projected periods.

A similar pattern of projected change in disease incidence for Chikwawa is depicted in Figure 17. Diarrhoea incidence will increase by 3.6% in 2030 and 6.4% in 2050. At the same time, malaria incidence will decrease by 4.8% and 8.8% in 2030 and 2050 respectively, while malnutrition will decrease by 1.5% and 2.8% for both 2030 and 2050 respectively.

A similar pattern of projected change in disease incidence for Chikwawa is depicted in Figure 17. Diarrhoea incidence will increase by 3.6% in 2030 and 6.4% in 2050. At the same time, malaria incidence will decrease by 4.8% and 8.8% in 2030 and 2050 respectively, while malnutrition will decrease by 1.5% and 2.8% for both 2030 and 2050 respectively.

Study findings by Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre) of 2007 (IDGAD, 2007) show that temperatures in Malawi will increase with climate change while rainfall will decrease in the southern region and increase in the central and northern regions (Figures 18 and 19).

In 2019, projections of temperature and rainfall were developed for Malawi using statistically downscaled General Circulation Models (GCMs) following the procedure recommended by the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report or AR5 (IPCC, 2013), resulting in the demarcation of Malawi into five climatic zones, namely: Shire Valley, Shire Highlands, Central Areas, Lake Shore Areas, and Northern Areas.

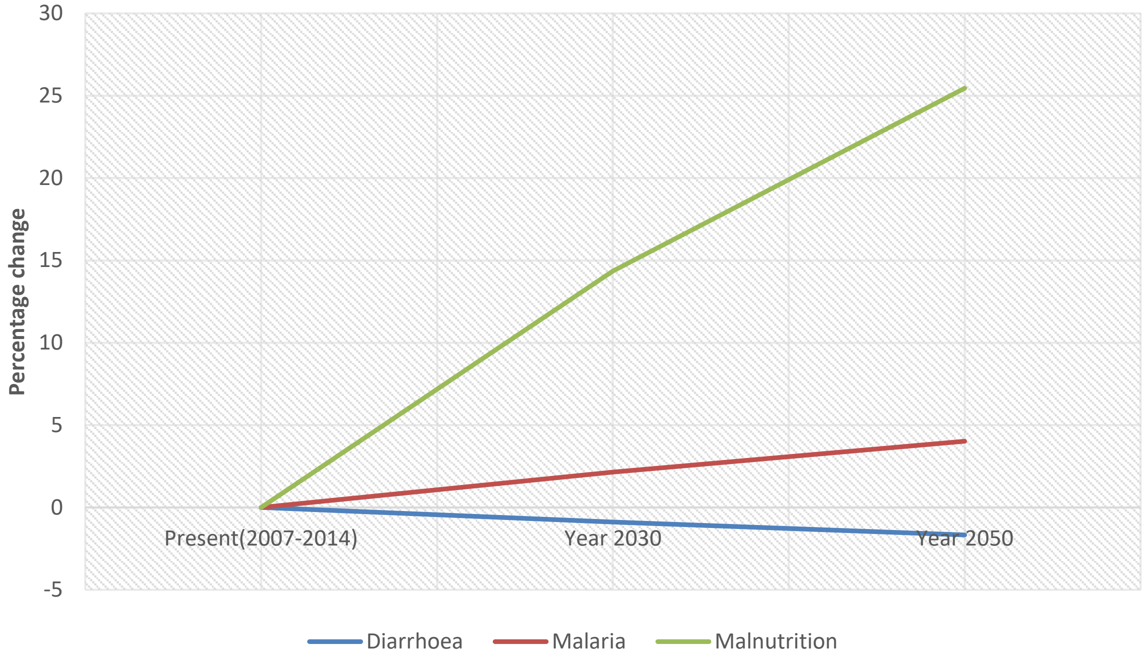
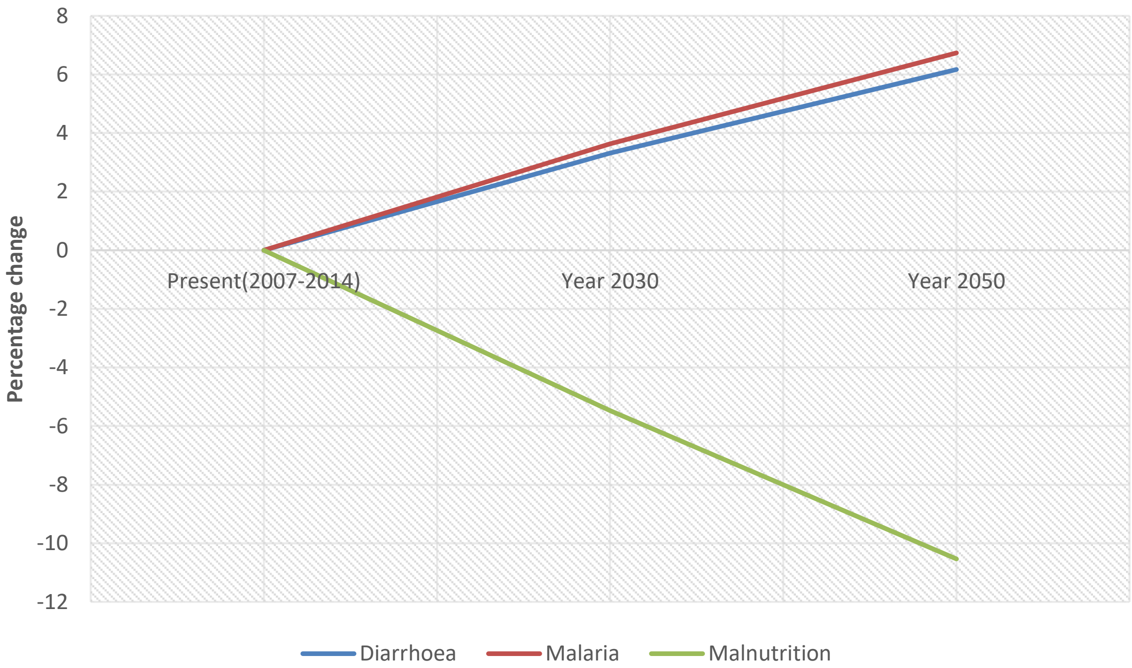


Figure 4. 10 Projected change in incidence of diarrhoea, malaria and malnutrition in Salima district



.

Figure 4. 11 Projected changes in incidence of diarrhoea, malaria and malnutrition in Lilongwe district

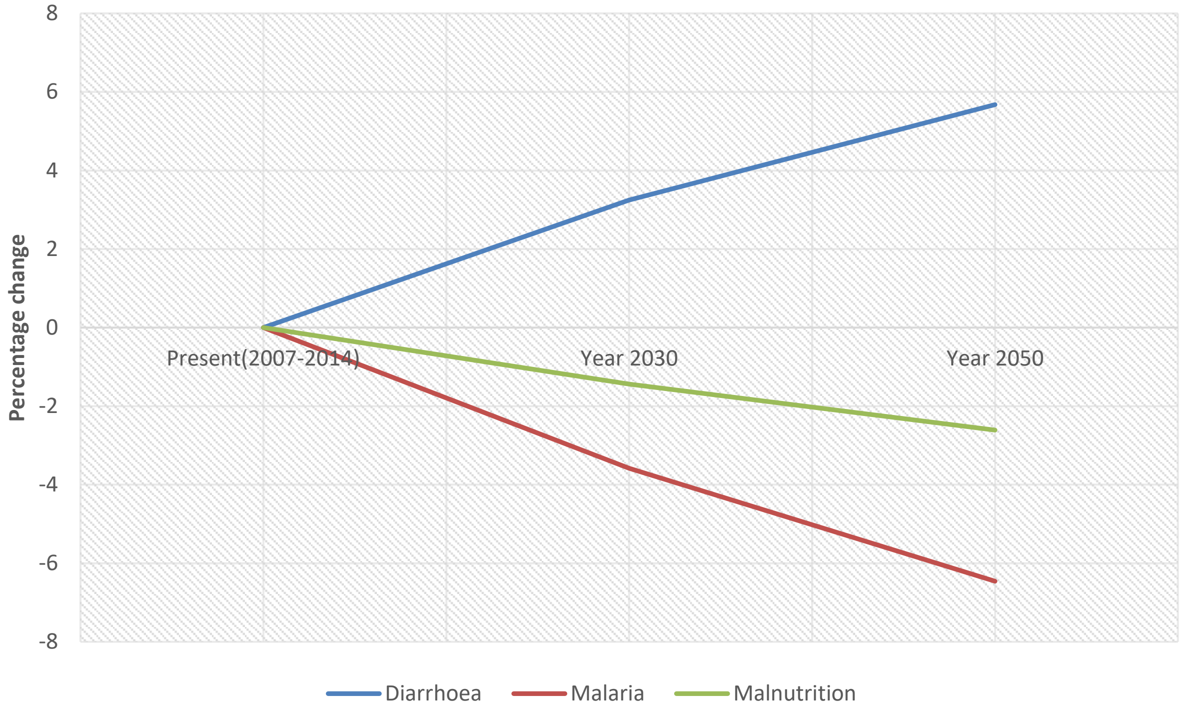


Figure 4. 12 Projected change in incidence of diarrhoea, malaria and malnutrition in Zomba districts

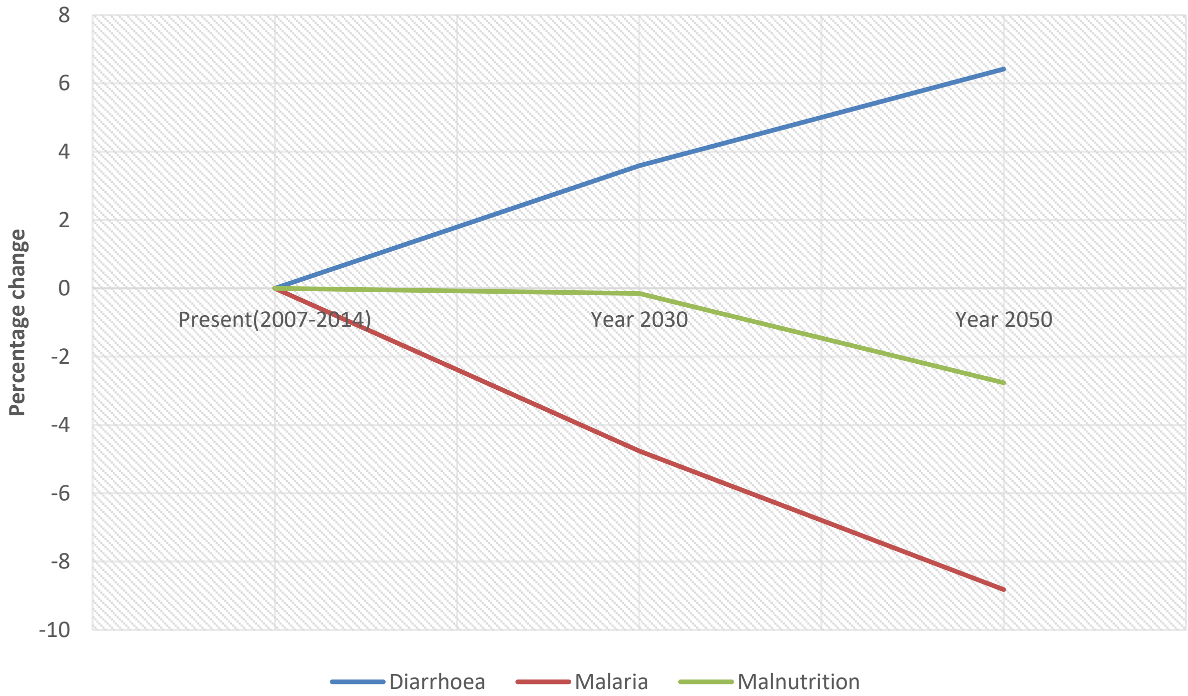


Figure 4. 13 Projected change in incidence of diarrhoea, malaria and malnutrition in Chikwawa district

4.3.5 Indicators for Tracking Climate Change Impacts on Human Health

Based on the results of the baseline assessment for the Health NAPA study, the following indicators were proposed for monitoring and tracking climate change impacts on health:

- Proportion of malaria cases;
- Proportion of diarrhoeal cases;
- Proportion of malnutrition cases;
- Rainfall (mm);
- Maximum and minimum temperatures; and
- Humidity.

These indicators will be captured by the Ministry of Health and Department of Climate Change and Meteorological Services through HMIS and CLIMSOFT respectively.

4.3.6 Potential Adaptation Strategies

Possible strategies and measures to adapt to the adverse effects and impacts of climate change in the Human Health Sector mainly address three diseases, namely: malaria, diarrheal diseases (cholera and dysentery) and malnutrition, which are a major problem in Malawi.

4.3.7 Malaria

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 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).

Since 1995, the National Malaria Control Programme 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. Currently, Malawi is one of the countries in Africa that is participating in the malaria vaccine testing programme.

4.3.8 Diarrhoea.

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) homemade 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.

4.3.9 Malnutrition.

Some of the current adaptation measures for malnutrition 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.

4.3.10 Additional adaptation policies and measures.

Prevention of diseases through the 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, crosscutting 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.

4.4 Energy

Malawi’s Energy Sector comprises ten main sub-sectors, namely: (i) electricity from renewables and non-renewables - both on grid and off-grid, (ii) wood fuel (biomass), (iii) petroleum products, (iv) Bio-ethanol and other bio-fuels (v) coal, and (vi) Liquefied Petroleum Gas, (vii) Biogas and Natural Gas, (viii) Coal, (ix) Nuclear energy, and (x) Energy Efficiency/Demand side Management. Beside the global agenda in the name of Sustainable Energy For all (SE4All) Initiative as well as Sustainable Development Goal number 7 and the National Development Strategy (MGDS III), the sector has put in place a series of legislative frameworks, policy and strategies to promote and consolidate environmental protection, curb adverse climate change effects and promote other socio-economic developmental activities in Malawi. These include: National Energy Policy 2018, Malawi Renewable Energy Strategy 2017, Malawi Integrated Resource Plan (IRP) 2017, Malawi Sustainable Energy For All (SE4All) Action Agenda 2017, and Charcoal Strategy among others. In all these policy and related documents climate change and its mitigation has been mainstreamed.

Malawi has large quantities of energy resources that include: (i) biomass, (ii) coal, (iii) fast flowing perennial rivers, (iv) solar energy, (v) wind energy, (vi) geothermal, and (vii) uranium deposits. Malawi's energy mix comprise of: Biomass-80.5%, Liquid Fuels and Biofuels-9.9%, LPG, Biogas and Natural Gas-0.1%, Electricity from Renewable Sources-6.9%, Electricity from Non-Renewable Sources-0.3%, Coal-2.3%, and Electricity from Nuclear Energy-0.0%.

Table 4. 17 Malawi's Energy Mix (Source: GoM, 2018)

Supply							
Energy Source		**2008**	**2015**	**2020**	**2025**	**2030**	**2035**
Biomass	%	88.2	80.5	70.3	57.6	44.8	33.5
Liquid Fuels and Biofuels	%	6.4	9.9	11.6	13.0	14.2	14.8
LPG, Biogas and Natural Gas	%	0.0	0.1	2.0	3.7	6.0	9.0
Electricity from Renewable Sources	%	2.6	6.9	10.7	16.0	23.0	28.9
Electricity from Non-Renewable Sources	%	0.0	0.3	1.8	5.7	7.5	8.0
Coal	%	2.8	2.3	3.6	4.1	4.5	4.9
Electricity from Nuclear Energy	%	0.0	0.0	0.0	0.0	0.0	1.0
Total		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

National Energy Policy 2018

In terms of Energy production, Malawi has an installed hydropower capacity of 361 MW. Further, there is also an installed capacity of 124 MW of diesel peaking plants. Over 85% of the hydro electricity generated in Malawi is derived from hydropower plants installed in the middle reach of the Shire. In order to meet with the growing energy demand, the Government of Malawi is planning to expand its hydro generation capacity both in the shire river and other rivers in the country, and to introduce into the generation system the grid connected Solar Power, Coal and Gas fired Power plants as well as Nuclear energy as stated in the country's IRP 2017.

In terms of energy usage and demand, currently 11.4% of the Malawi National population is connected to grid electricity and 6.6% is connected to off-grid Solar systems; and the current electricity demand is 621 MW. Other sources of energy that are in use for lighting in Malawi include: batteries at 52.9%, kerosene (paraffin) at 1.7% and biomass at 6.5%.

In terms of cooking energy, biomass dominates other energy sources at around 95% of Malawi's households. Other important cooking energy sources in Malawi include electricity (at 2%) and Gas (at 0.4%). In Malawi's rapidly growing urban centres, biomass energy remains the primary cooking and heating fuel for 88% of the population, and charcoal is now the primary source of fuel for the majority (54%) of urban households. In rural areas, households continue to rely extensively on firewood.

The National Energy Policy of 2018 clearly highlights Malawi's overdependence on wood-fuel (i.e., charcoal and firewood), which accounts for nearly 80.5% of the country's aggregate energy demand. The high dependence on wood-fuel results in increased deforestation in the form of uncontrolled felling down of natural woodlands. As more prime forest areas continue to dwindle, there is an increase in the expanse of fragile ecosystems, resulting in erosion, flash floods and river bank siltation, which in turn affect hydro-electric power generation. Inevitably, the Energy Sector is also affected by extreme weather events, such as droughts and floods, which negatively impact hydro-electric power generation capacity along the Shire River, a major source of energy for Malawi. The water flow disruptions are generally exacerbated by siltation caused by poor and unsustainable agriculture practices, deforestation, and noxious weeds, including water hyacinth.

4.4.1 Importance of Energy

Energy is the lifeblood of the economy as it serves as a crucial input into all economic and social activities or services. A well-developed and comprehensive energy sector can improve service delivery and increase outputs in industries such as manufacturing, trade, tourism, and other services, Access to clean, reliable, affordable and sustainable energy supply is central to maintaining and improving the living standards of people. It enables communities to power homes, schools, health facilities and support productive businesses. It is for these reasons that Malawi has ranked the energy sector as its key priority area number three (3) in its Malawi Growth and Development Strategy (MGDS) III.

Constitution of Malawi in section 13 states that the country should develop policies (including Energy sector Policy) that will prevent the degradation of the environment. The constitution therefore mandates the energy sector to embed environmental protection, mitigation and climate change adaptation as well as mitigation in its energy service delivery.

Without implementing climate change adaptation strategies in the energy sector the Malawian economy as well as social services delivery systems can dwindle, and people’s living standards can deteriorate.

For example, if biomass usage and dependence is not made sustainable and efficient by use of more efficient biomass technologies and its heavy dependency reduced by promotion of biomass alternative technologies, hydro power supply will be poorer due to degradation of forest cover in the catchment of hydro power generating rivers. This would result into low production in factories and other essential service delivering institutions and companies.

Furthermore, continued heavy dependence on firewood and charcoal for cooking means more indoor air pollution, which harms both the environment and causes lung-related diseases amongst women and children. If alternative cooking fuels are promoted, this could eventually be avoided.

Similarly, promotion of biofuels would reduce the emission that come from utilisation of petroleum fuels, and promotion of energy efficient technologies and appliances such as LED bulbs would decrease pressure on the national grid.

4.4.2 Vulnerability of Energy

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 supplyhas hindered growth and development of many socioeconomic 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 Generation Company of Malawi (EGENCO) spends more than MK 3.5 million every month to clear the weeds and remove the trash above the Kamuzu Barrage at Liwonde. 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 biomassenergy 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 utilization 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 neighboring 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 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. However, this study has considered recent trends in population growth rate of 2.9% per annum with prospects of doubling the 2018 figure by 2042. This trend, when married to the dominance of trend of biomass-charcoal in urban areas and firewood in rural areas for cooking and heating, implies that in future biomass will still remain a major driver for deforestation and forestry degradation in Malawi. It will also undermine agricultural productivity and food security, water security, and hydroelectric generation capacity, leaving the country more vulnerable to climate shocks.

Considering the vulnerability and adaptation assessments undertaken as part of previous National Communications, a projected temperature increase of between 1.0 C and 3.0 C is predicted 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. This presents a future picture with continued water problems in Lake Malawi and Shire River due to low rainfall and high evaporation. This will constraint the capacity of our hydro-electricity generation to meet the growing electricity demand, which is predicated to rise to 719MW by 2020, 1,873 MW by 2030, 3,566 MW by 2037 and 4620 MW by 2040 according to IRP 2017.

4.4.3 Potential Adaptation Strategies

In the short-run, the Government of Malawi, through EGENCO, installed 46 MW of diesel generation plants, and through ESCOM, Aggreko was engaged to supply 78 MW of the same for peaking. The more these diesel generators are used, the more emission are released into the atmosphere thereby compounding the problem of climate change. The Government, through ESCOM, also procured three IPPs to develop and supply 118 MW of grid connected solar PV from four different locations in Malawi. The development of these Solar Plants by IPPs is underway and represents positive adaptation efforts by the Government of Malawi.

There are also other off-grid renewable energy systems being promoted with various decentralised energy sources. The sources vary from solar, small hydro and wind energy, though most are still in the infant and pilot phase. 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.

On the other hand, Malawi is obliged to import refined petroleum products since it lacks domestic refining capacity. On average, Malawi uses between 35 and 40 million litres of petroleum fuels per month which translate into an average national consumption of 1 million litres per day. Malawi has now over 75 million litres fuel holding capacity meaning that the available fuel in the storage facilities can sustain the country for at least 75 day. This falls short of the international fuel holding requirement of 90 days. The deficiency in storage capacity for imported petroleum 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.

On demand side management, the government of Malawi through National Steering Committee on Cook stoves is promoting improved cook stoves with thermal efficiency of not less than 20%. The government has set itself a target of disseminating 2 million improved/efficient cook stoves by 2020 and 5 million improved cook stoves by 2030. Currently, about 1.4 million efficient cook stoves have been disseminated, each with between 2-3 tons of carbon (CO_2 equivalent) saving per year. These stoves have got huge actual wood fuel saving thereby encouraging forestry regeneration in the areas where these are used.

Furthermore, Malawi is also promoting use of other energy efficient technologies and appliances. One example is LED bulbs. Malawi through its utility company ESCOM started selling subsidised LED bulbs in 2017. For this period of three (3) years ESCOM has sold about 1.8 Million LED bulbs saving about 42 MW of electricity thereby relieving the National generation capacity which is very low compared to the current electricity demand. This programme for promotion of LED bulbs is ongoing.

As a Demand Side management measure, Malawi target is to disseminate 40,000 solar water geysers/heaters by 2030 from the current 2000 (SE4All Action Agenda for Malawi 2017), which is also energy saving technology.

Most of the energy sector interventions that have been put forward as mitigation activities have adaptation co-benefits (Table 4.18). The vulnerability of energy production is related to the sources being affected by floods and droughts in terms of damage to machinery, loss of biomass productivity and availability of appropriate alternative technologies. For instance, solar PV is an alternative energy source for lighting when there is load shedding resulting in generation outage, but the technology is currently unaffordable without international support. Biomass briquettes and biofuels provide alternative energy sources in place of charcoal and firewood as the national forest stand is simultaneously under pressure from unsustainable wood extraction and climate change effects.

Table 4. 18 Adaptation Strategies

STRATEGIES	IMPLEMENATATION PERIOD			POTENTIAL IMPACT		
	Short term	Medium term	Long term	Low	Medium	High
Promote use of biomass briquettes as substitute for firewood and Charcoal	X			x		
Promote an energy mix that moves people away from use of biomass(LPG, Natural Gas, Gell Fuel, Biogas, etc)		x				x
Support an expanded programme of briquette production and use	X			X		
Construct storage dams for hydropower generation			X			X
Promote solar PV and use of energy efficient bulbs	X					X
Promote use of bio-fuels for lighting and cooking replacing fossil based fuel		X			X	
Diversification of energy generation away from hydro and diversification of hydro generation to other rivers apart from Shire River.			X			X
Instituting appliance testing, labelling and standards, which will include minimum energy performance standards (MEPS);		X			X	
Encouraging regular energy audits conducted by certified auditors in public, industrial, and commercial buildings.		X			X	
Promoting use of multiple sources of energy and energy efficiency in		X			X	

buildings (a limit can be set as to the size of the buildings).						
Encouraging research and development in energy efficient equipment, buildings etc.			**X**		**X**	
Reducing or eliminating import duty and taxes on energy efficient products	**X**				**X**	
Programs for upgrading standard burnt motors, gear boxes and conveyors with energy efficient replacements;		**X**			**X**	
Installation of variable speed drives on large motors operating under fluctuating loads;		**X**			**X**	
Mandatory energy audits for large users;		**X**		**X**		
Mandatory regular examination and maintenance of large motors;		**X**		**X**		
Automation of steam generating boilers;			**X**		**X**	
Installation of combined heat and power generators, where applicable; and		**X**		**X**		
Promotion of sub metering in complex industrial and manufacturing processes		**X**		**X**		
Interconnecting with other countries to allow Malawi buy power from SAP and other regional power polls.		**X**				**X**
Dissemination of 500 million improved cook stoves By 2030		**X**			**X**	

GoM, 2018, National Energy Polic

4.5 Infrastructure (Transport and Buildings)

The climate change debate has moved away from whether or not there is evidence of climate change to what must be done to reduce the magnitude of further changes and minimize the associated deleterious impacts. There is now an overwhelming body of scientific evidence highlighting the serious and urgent nature of climate change due to emissions of greenhouse gases resulting from anthropogenic activities. Thus, it is now unequivocal that warmer temperatures resulting from climate change, and the occurrence of more frequent and severe extreme weather events such as floods, droughts, and strong wings, as well as the decreased availability of natural resources, will increase pressure on a number of social economic sectors to adapt to changing climatic conditions, along with threats to assets and the integrity of various types of infrastructure, including buildings and transport. Climate change poses a critical threat to future development, particularly in areas where poverty is widespread and key assets such as infrastructure are underdeveloped for even current needs. It is therefore absolutely necessary to protect current and future infrastructure investments and the economic, social, and other functions they serve. It is in light of the above that the discussion in this chapter is centered on exploring potential climate change adaptation strategies for buildings and transport infrastructure, particularly roads, rail lines, water, and airports in Malawi as a measure for building climate change resilience.

4.5.1 Transport Infrastructure

In rural areas, particularly those in low-income countries, roads represent a lifeline for economic and agricultural livelihood, as well as a number of indirect benefits including access to healthcare, education, credit, political participation, and more. Extreme events pose a costly hazard to roads in terms of degradation, necessary maintenance, and potential decrease in lifespan due to climatic impacts. Climate change has adverse and costly impacts on the transport sector in terms of maintenance of roads, their repairs and lost connectivity; yet many of these impacts can be mitigated and avoided by implementing pro-active adaptation measures.

The transport sector is an important and necessary enabler of business, encompassing road, rail, air and maritime transport. It underlies virtually all other sectors and relies on extensive infrastructure. At the same time, the transportsector is a significant and growing contributorof greenhouse gas emissionsthat lead to climate change, particularly CO_2 emissions from exhaust fumes. Hence an efficient, effective and climate-resilient transport sector is crucial to the lowering of cost of doing business, and to increase competitiveness.

Malawi's transport system is dominated by roads which carry more than 93% of internal freight and close to 90% of international freight, with the modal share similar in both urban and rural areas (GoM, 2017a; GoM, 2017b). The road network provides access to only about 26% of Malawi's population; and they are the only means of accessing and travelling within most urban and rural areas in the country, and there is no indication that this will change soon. Transport infrastructure is pivotal in accelerating growth and acts as an enabler for poverty reduction and wealth creation.

The MDGS III (GoM, 2017b) highlighted six major outcomes which will result from improved transport sector in Malawi, namely: (a) reduced travel time and costs for persons and goods; (b) improved transport reliability, levels of service and service efficiency; (c) enhanced access to local and international markets; (d) improved access to inclusive social and public services; (e) reduced accidents and their effects on human life and economies in general; and (f) increased private sector investment in the operation and management of transport infrastructure.

In 2017, the Government of Malawi developed the National Transport Master Plan (GoM, 2017c) where development of transport infrastructure from 2017 to 2037 is outlined, see Table 1. It is imperative that the development of this infrastructure has to take into account potential impacts of climate change.

Table 4. 19 Infrastructure Investment for Malawi for the period 2017-2037 (Source: GoM, National Transport Master Plan).

Subsector	Main Plan Components
Roads	• Maintenance of the road network; • Rehabilitation of all failing sections of the road network; • Upgrading 1,418 km of rural roads to assist agricultural production and improve rural accessibility; • Introduction of over 500 km of segregated cycle/pedestrian facilities on high trafficked roads.
Rail	• An extension of the railway line from Beira Port in Mozambique northwards from Mutarara into Malawi, in stages (313 km); • A spur line from Mbeya to Chilumba (234 km).
Inland Water Transport	• Improved port facilities at Nkhata Bay and roll-on roll-off freight services to Mbamba Bay on the Mtwara Corridor; • Introduction of a regular freight service between Chilumba and Liwonde; • Construction of a wet port at Liwonde.
Civil Aviation	• Measures to improve safety and security to world class standards; • Runway and apron improvements at Chileka and Kamuzu International Airport to accommodate larger aircraft, and terminal capacity increases; • Developing some rural airfields for tourist use; • Handing over unused airfields to local authorities and the private sector.
Urban Transport	• Concession bus routes in high patronage corridors to large buses; • Construction of Lilongwe eastern and western bypasses; • New urban expressway in Blantyre; • Major programme of improved pedestrian and cycle facilities in Lilongwe, Blantyre, Zomba and Mzuzu; • Improved traffic management and traffic signal provision in Lilongwe and Blantyre; • Bus Rapid Transit scheme in Lilongwe.

Source: GoM 2017, National Transport Master Plan

Road Transport

The national road network in Malawi comprises 15,451 km (Table 2), of which about 26% are paved while the rest of the road network (74%) is of earth/gravel surface (GoM, 2017a). Studies carried out in 2005 identified about 10,000 km of undesignated road network that serve rural communities. Hence the total public road network in Malawi will be approximately 25,000 km once the new classification has been gazette.

Table 4. 20 Malawi's Road Network (Source: GoM, 2017a)

Road class	Paved			Unpaved			Total		
	km	%*	Asset value (US$ million)	km	%	Asset value (US$ million)	km	%	Asset value (US$ million)
Main	2,809	69	2,827	548	4.8	114	3,357	21.7	2,942
Secondary	442	10.9	385	2,683	23.6	653	3,125	20.2	1,038
Tertiary	44	1.0	29	4,077	35.8	815	4,121	26.7	844
District	8	0.2	4	3,492	30.7	524	3,499	22.7	527
Urban	770	18.9	386	578	5.1	115	1,349	8.7	501
Community [undesignated]	0	-	-	9,478	100	unknown (u/k)	9,478	100	u/k
Tracks	0	-	-	u/k	u/k	u/k	u/k	u/k	u/k
Total classified rural (non-urban) roads	**3,304**	**-**		**10,800**	**-**		**14,102**	**-**	
Total classified	**4,074**	**-**	**3,630**	**11,378**	**-**	**2,222**	**15,451**	**-**	**5,852**

*u/k stands for unknown.

According to the Public Roads Act of 1962 and the Local Government Act enacted in 1998, the road network in Malawi may be grouped into five categories as shown in Table 1 and Figure 1 (GoM, 2017a), namely: (a) main roads - these are inter-territorial roads located outside cities or towns and are unilaterally designated by Government. They provide a high degree of mobility and connect provincial capitals and/or serve as international corridors; (b) secondary roads - these are roads located outside cities or towns, unilaterally designated by Government. They provide a high degree of mobility, and link main centers of population and production, and connect to the main road network; (c) tertiary roads - roads outside cities or towns, unilaterally designated by Government, link collector roads to arterial roads, accommodate shorter trips, and feed the arterial road network; (d) district roads - roads located outside cities or towns, designated by Government after consultation with the district authorities, provide intermediate level of service, connect local centers of population, and link districts, local centers of population and developed areas with the principal arterial system; and (e) urban roads - any other road in an urban area other than a designated road, they include arterial and collector roads, and cross city boundaries. The main function of roads is to provide accessibility over relatively short trip lengths at low speeds and to provide services to smaller communities (GoM, 2017a). Figure 1 shows main and secondary roads in Malawi, which constitute a comprehensive network. The national highway, M1, spans the entire length of the country, from Nsanje in the south to Chitipa in the north. Malawi's classified road network is complemented by undesignated community roads. The length, nature and value of the road network is summarized in Table 4.20

The extent of the road network in Malawi is generally considered sufficient; but the capacity of some links, particularly in rural areas, is inadequate. A number of community roads, for example, are too narrow to accommodate bicycles along with other both motorized and non-motorized vehicles. Furthermore, the number of bridges at numerous locations in districts is inadequate. The main concern is the potential for conflict among road users, which has implications for road safety, particularly given the lack of dedicated provision for non-motorized transport (NMT).

Almost 84% of Malawi's road network, for example, is unpaved with either an earth or gravel surface. This includes all of the 9,478 km of undesignated community roads and 74% of its classified road network (Table 2). In 2010, it was estimated that the majority of Malawi's rural population lives more than 2 km away from an all-weather road (World Bank, 2010). It is essential not to disregard or underestimate the importance of undesignated roads. The main and secondary roads are not typical of rural areas, rather they are corridors that form part of the country's hub-and-spoke system. A number of recent programmes have upgraded, rehabilitated and sought to improve the maintenance of rural roads in Malawi. In 2014, 22% of the classified road network was in a 'poor' condition; and while some of this network will have since been upgraded and maintained, there is also the potential for deterioration – approximately 60 km of paved highway is either rehabilitated or resealed annually. Without more frequent rehabilitation and periodic maintenance, the condition of paved roads in the country is likely to get worse. This information is based on the International Roughness Index (IRI), and do not take into account other factors such as shoulder condition, which are important for non-motorised transport on rural roads.

The road transport in Malawi may be grouped into two major categories: passenger public and freight transport. Road-based passenger public transport, in the form of minibuses, buses, coaches, taxis, bicycles, and motor-cycles, is operated by private companies and individuals who collect fares and retain the revenue. Details regarding the relationship between the amount of revenue collected and the relationship with operating costs are not known; although fares, which are set by operators, tend to be relatively high by international standards. This is largely attributed to the country's relatively high fuel prices and the absence of Government fare subsidy programmes. Public transport operators are bound by a regulatory framework, and many are members of minibus or Kabaza Associations. Commercial road freight transport services in Malawi comprise: (a) domestic road freight haulage, including local and regional movements in addition to movements to the national border points; and (b) cross-border and international road freight haulage. The operation of these services generate GHG and so have to be regulated to minimize emissions. And a Bill has just been passed in Parliament during its October 2019 sitting authorizing the transport sector to collect carbon tax on freight transport.

The Rail Transport is another vital mode of transport in Malawi as it provides cheaper means of transportation of goods and people and complements other modes of transport. The rail mode carries 7% of the freight in the country. The total rail network within Malawi is 926.5 km. However, the Malawi National Transport Master Plan (MNTMP) indicates that there are proposals for an additional 1,060 km of new rail to be invested.

The effects of climate change have already started being felt in the rail transport as evidenced by the collapse/wash-away of the Lupanga bridge in Balaka in 2002 and frequent flooding of the rail line in Makhanga and Bangula. The rebuilding of the Lupanga bridge took over three years to complete as a result of which rail transport almost became non-existent. The Chiromo bridge is another example of the consequences of extreme weather events affecting rail infrastructure. Figure 4.13 shows the current rail line situation in Malawi.

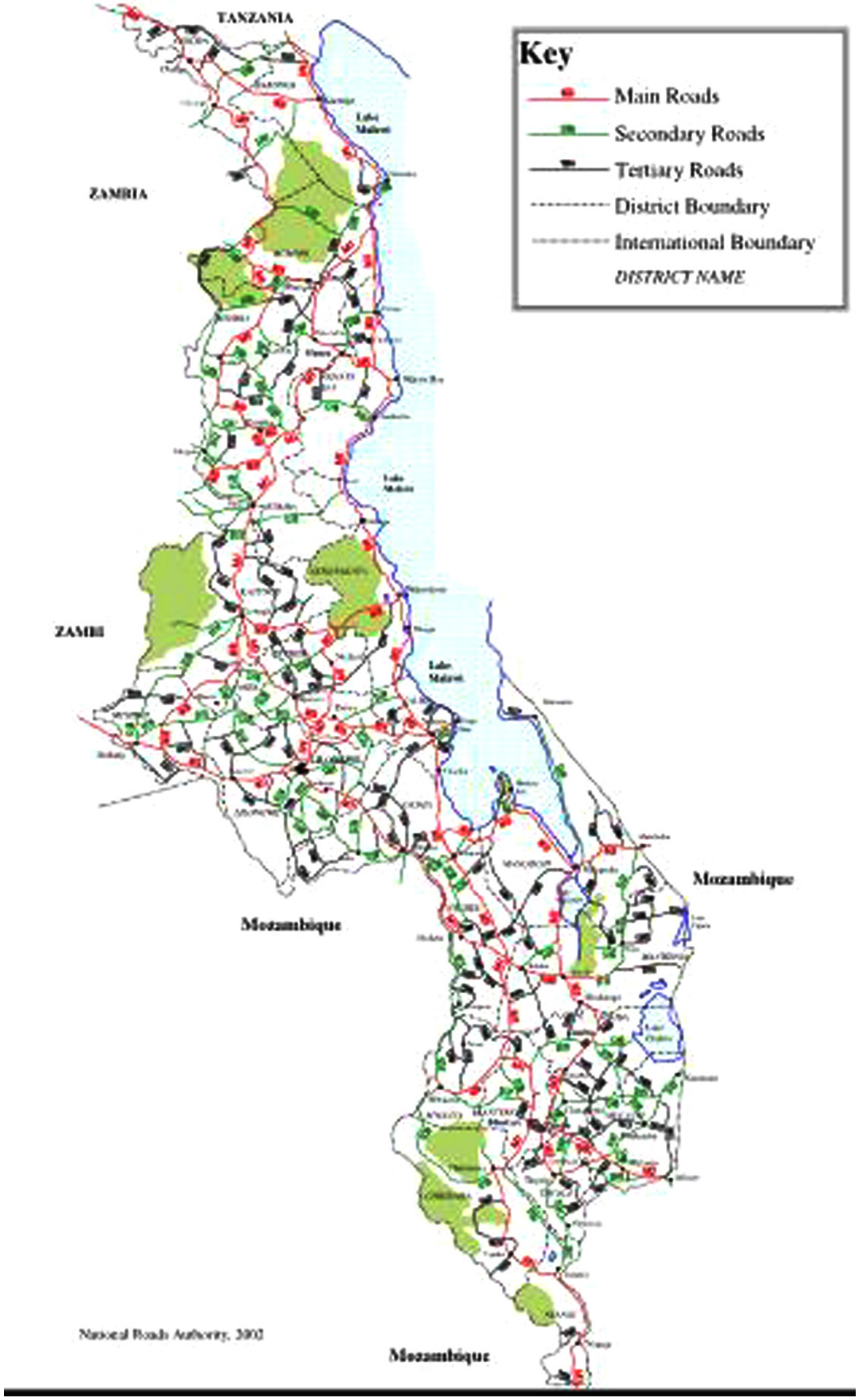


Figure 4. 14 Malawi Road Network Map (National Roads Authority, 2002)

Rail Transport

Water Transport

Water Transport in Malawi has so far been restricted to Lake Malawi. The main ports being Nkhata Bay and Chipoka, and others are: Liwonde, Monkey Bay, Chilumba, Nkhotakota and Likoma. However, the Government of Malawi has been investing in the Shire-Zambezi Waterway Project for some years now. These ports and new port facility investments need to be designed and maintained with climate resiliency taken into consideration, in order to avert situations that the country is facing now where some of the ports are experiencing siltation which requires frequent dredging to enable lake vessels to dock.

Air Transport

The country has two main airports, namely: Kamuzu International Airport in Lilongwe and Chileka International Airport in Blantyre. There are, however, a number of small airports which provide strategic mobility of passengers but also assist in delivering emergency suppliers during disasters. These small airports have earth surfaced runways. The main hazards to air transport are stormy weather, heavy winds and the flooding of runways.

4.5.1.1 Importance of Transport Infrastructure

As a land-locked country which depends on the transport sector to export its agricultural products, reliable road access is crucial for Malawi's social economic development and prosperity.

Figure 4. 15 Existing and proposed rail line (Source GoM, 2017).

The country is heavily dependent on links to regional and overseas markets for the transfer of goods; and while linked to such markets by rail and air transport, market access is predominantly via roads. In 2015, road transport accounted for the movement of 87.2% of imported and exported goods by tonnage, with rail transport taking 12.3%, and air transport 0.5%. Thus, poor performance of the transport sector is bound to stagnate Malawi's already fragile agro-based economy.

As pointed out in the preceding discussion, more than 93% of internal freight is transported by road. The agriculture sector generates a third of the country's GDP and employs 80% of the country's population, and as with other industries relies heavily on the road network for its inputs, such as access to and distribution of fertilizer, and trading of its outputs. Malawi's high transport costs are said to be the main component of the price of commodities traded by subsistence farmers in districts across the country; hence access to the road network and ease of travelling on it impacts profitability, which has a knock-on effect on social welfare.

The growth of the tourism sector is also dependent upon roads. And the same is true of the mining sector, which is expected to experience considerable growth over the period 2016 to 2036. The road network has a direct impact on social as well as economic outcomes. They are the primary means of accessing employment, health, education and other social services in Malawi. As such, any change in the time, cost and effort required to access these facilities affects social welfare and life opportunities for the citizenry. Difficulties experienced in a\ccessing educational facilities by road, for example, manifest themselves in high absenteeism and drop-out rates in schools, pupils attending school from a higher age than recommended, children having insufficient energy to concentrate on lessons during classes, and children experiencing physical attacks on their journey to or from school. This can resulted in some children choosing not to attend school, or parents opting not to send their children to school. This has negative impact on the population's life opportunities; and by extension, the future of the country. At a superficial level, the value of Malawi's road network is also linked to its asset value, which exceeds 30% of GDP. The value of road network asset is valued at US$ 6.2 billion (GoM, 2017a).

4.5.1.2 Vulnerability of Transport Infrastructure

The transport sector will need to adapt to impacts of climate change. Lake level rise, storms, rain, flooding and higher temperatures pose several immediate and long-term risks and impacts for the transport sector's day-to-day operations. As stated by KEPSA (2014), some specific risks that could affect the transport sector include:

(a) Risk of damage to port facilities from increasingly severe storm events and lake level rise;
(b) Destruction of infrastructure, including roads and bridges during storms,which is increasingly becoming a commonphenomenon during extremeweather events;
(c) Flooding, contributed to by periodic torrential rainfall, poses a risk to maritime, road, rail and air networks;

(d) Higher temperatures can cause pavement to soften and expand, creating rutting and potholes; as well as warping of rail tracks, requiring track repairs or speed restrictions to avoid derailments;
(e) Extreme weather may interrupt supply of raw materials (such as metal and rubber), pose a threat to drivers, create delays and increase costs;
(f) Drought and changes in water availability can increase transportation costs.;
(g) Disruptions to service operations - Supply chain disruptions due to extreme weather events, rising lake levels, and changes in temperature can harm a supplier's assets, leading to service delays or temporary shutdowns. This can result in loss of business, contracts, and customers. Also, consistent disruptions in service due to supply chain issues, operations issues, and extreme weather may result in loss of customers
(h) Threats to assets and infrastructure - The location, equipment, and infrastructure that the transportation sector is reliant upon require adaptive investments to not only safeguard against climate change, but also to improve upon existing networks. Since transportation infrastructure is used over a span of 10 years or more, strategic investments are critical to make transportation systems secure and climate resilient. Airplanes and rail lines and other equipment prone to weather impacts have an increased risk of malfunctioning and/or being damaged.

4.5.1.3 Potential Adaptation Strategies

Some of the adaptation strategies for the infrastructure sector are listed below and in Table 2, with their associated climatic variable.

Increased Temperature

(a) Using more resistant materials and processes which have heat-resistant properties;
(b) Increased use of heat resistant materials.

Increased Wind Strength

(a) Modify the design of supports and anchorages;
(b) Increased frequency of gulley maintenance activities;
(c) Improved communication systems and warnings for network users;
(d) Structural assessment of suspension bridges, sign posts, and tall structures;

Increased Precipitation

(a) Applying a safety factor to design assumptions;
(b) Reducing the gradient of slopes;
(c) Increasing the size and number of engineering structures, e.g., culverts;
(d) Raising pavements and adding additional drainage capacity;
(e) Realigning natural water courses;
(f) Updated design standards for drainage systems;
(g) Implementation of emergency warning systems in the event of flooding;
(h) Improved communication methods for network users in the event of an emergency;
(i) Improved coverage of street lighting due to reduced visibility;

(j) Conduct slope stability studies in an attempt to minimize incidents of landslides as a result of increased precipitation;
(k) Soil moisture removal techniques to prevent the deterioration of the structural integrity of roads, bridges and tunnels.

Reduction in Rainfall, and Increase in Drought

(a) Using flexible pavement structures;
(b) Using matting/erosion control blankets;
(c) Applying granular protection;
(d) Ensuring the selection of materials with high resistance to dry conditions.

Lake Level Rise and Storm Surges

(a) Raising road and pavement levels;
(b) Road realignment;
(c) Construction of offshore breakwaters, groins to protect shorelines from coastal erosion;
(d) Replacing metal culverts with reinforced concrete;
(e) Developing flood risk management plans.

Table 4. 21 Climate Change Impacts and Adaptation Strategies for Infrastructure (Source: GoM, 2017)

Aspect	Impact: precipitation (increasing)	Impact: precipitation (decreasing)	Impact: temperature (increasing)	Impact: wind	Adaptation
Road					
Un-engineered earth roads **Engineered earth roads** **Gravel roads**	▪ Flooding ▪ Softening of material ▪ Impassability ▪ Erosion of surface ▪ Loss of shape ▪ Traffic disruption and congestion	▪ Increased wear and loss of gravel ▪ Increased dust emissions over longer periods ▪ More rapid deterioration of gravel ▪ Increased development of loose material and roughness	▪ Cracking, development of roughness and generation of loose material ▪ Reduced visibility and operational disruption (fires)	▪ Deterioration ▪ Accumulation of sand	▪ Higher degree of compaction ▪ Appropriate material selection and construction ▪ Accounting for climate risks in maintenance regimes ▪ Raise riding surface and appropriate drainage ▪ Upgrade to engineered, gravel or paved standard

Paved roads	• Loss of strength of layer materials • Damage to structure and surfaces • Erosion of unpaved shoulders • Traffic disruption and congestion	• Damage to thin surfaces and asphalt • More rapid binder deterioration	• Ageing of bituminous binders • Softening, deformation and damage to bitumen in asphalt • Expansion and buckling of concrete roads and structures • Reduced visibility and operational disruption (fires)	• Accumulation of sand • Wind-loading of structures	• Appropriate structural designs, surfaces and construction • Use different (harder) binders in asphalt • Changes to concrete mixes and reinforcing • Accounting for climate risks in maintenance regimes

Aspect	Impact: precipitation (increasing)	Impact: precipitation (decreasing)	Impact: temperature (increasing)	Impact: wind	Adaptation
Port					
Port infrastructure	• Damage to structure and surfaces • Flooding of stacking and stockpiling yard • Closure of supporting transport network • Operational disruption	• Lowering of water levels and consequential impacts on operations	• Expansion and buckling of structures and surfaces • Increased energy consumption for cooling • Damage and disruption (fires)	• Wind-loading of structures • Closure of supporting transport network • Toppling of containers in stacking yard • Delays to unloading/ loading • Damage to equipment • Power disruption	• Appropriate structural designs, surfaces and construction • Accounting for climate risks in maintenance regimes • Appropriate drainage • Paved surfaces • Energy efficiency measures • Changing work regimes • Insurance • Automation of logistics • Locking positions for equipment • Re-organisation of storage and reduced stacking height of containers • Underground power supply • Warning systems • Green infrastructure

Airport infrastructure	• Loss of strength of layer materials • Damage to structure and surfaces • Traffic disruption and congestion • Flooding (damage and disruption) • Electronic equipment failures	• Damage to thin surfaces and asphalt • More rapid binder deterioration	• Ageing of bituminous binders • Softening, deformation and damage to bitumen in asphalt • Expansion and buckling of • concrete surfaces and structures • Reduced visibility and operational disruption (fires) • Increase demand on air conditioning and ventilation systems • Decreased reliability of air conditioning and ventilation systems • Reduced passenger and worker discomfort • Overheating of electrical equipment • Damage and disruption (fires)	• Wind-loading of structures • Operational impacts • Damage to buildings, assets and equipment	• Accounting for climate risks in operational planning and maintenance regimes • Appropriate structural designs, surfaces and construction • Automation of logistics • Changes to concrete mixes and reinforcing • Changing work regimes • Energy efficiency measures • Green infrastructure • Insurance • Locking positions for equipment • Passive design • Strategic placement of buildings, equipment and assets • Temperature stabilising design • Underground power supply • Use different (harder) binders in asphalt • Warning systems

Aspect	Impact: precipitation (increasing)	Impact: precipitation (decreasing)	Impact: temperature (increasing)	Impact: wind	Adaptation
Construction	• Difficult working conditions • Excessive moisture in materials • Reduced working periods and increased delays • Water damage	• More dust • Evaporation of construction water	• Enhanced reactions when cement stabilising and drying of concrete • Difficult working conditions • Damage and disruption (fires)	• Difficult working conditions • More dust • Evaporation of construction water	• Construct in dry season • Greater use of unslaked lime • Modified and innovative construction techniques • Water efficiency measures • Dust management plan

Operation and maintenance	▪ Additional damage and maintenance requirement ▪ Reduced opportunities maintenance ▪ Operational disruption	▪ Adequate resources and capacity in place ▪ Local community maintenance programmes ▪ More regular maintenance and preventative action ▪ Underpinning the efficiency and effectiveness of incorporated climate change adaptation measures ▪ Emergency planning for climate impacts ▪ Early warning systems ▪ Monitoring and evaluation of asset resilience to inform climate change adaptation decision-making ▪ The incorporation of adaptation measures to existing assets during planned maintenance and repairs ▪ Water efficiency measures

4.5.1.4 Study Limitations

In this study, models were not applied in conducting vulnerability assessment of road infrastructure to impacts of climate change. As such, the formulation of adaptation strategies outlined in the report was done sorely based on climate change scenarios developed by the Scenarios Group.

4.5.2 Building Infrastructure

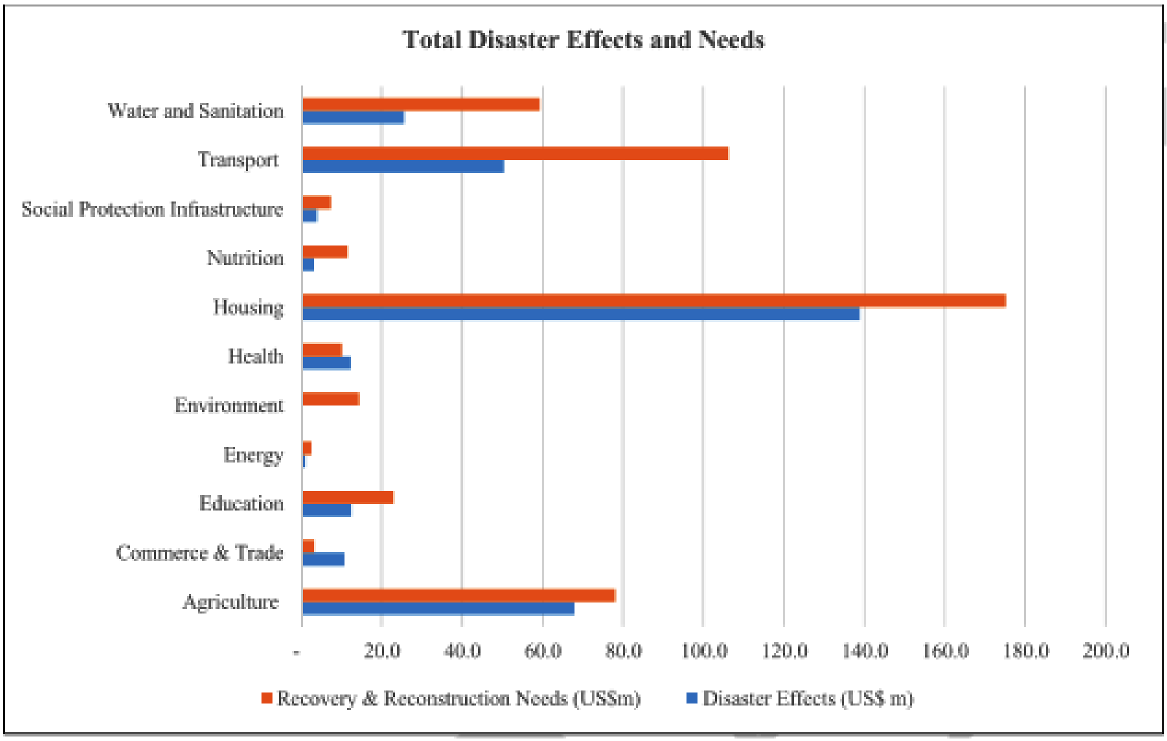
One of the fundamental requirements of buildings is the protection of the people who live and work within them from adverse weather conditions. And hence the successful design and construction of buildings relies on an appropriate understanding of the climate. With the advent of climate change, the built environment will be vulnerable to five major hazards, namely: (a) excess heat; (b) flooding; (c) subsidence; (d) drought; and (e) wind.

More and more frequently in recent years, the perception that the earth's climate is altering has been growing in public consciousness. The one thing that cannot be disputed though is that the majority of buildings are not well-suited to changes in weather patterns beyond a very narrow range. As such, they are not well-suited to changes in weather patterns anticipated to result from climate change. In light of the above, it is an absolute necessity that buildings should be designed by taking into consideration future climate change scenarios in order to avoid potential risks such as building collapse, declining health, damage from land subsidence, water encroachment, deteriorating indoor climate, and reduced building lifetime. In the short term stronger storms are the greatest challenge. They will constitute a safety risk in those parts of existing buildings that do not meet the building code's safety requirements. In the longer term, more and longer-lasting heat waves could have health-related consequences, especially for the elderly and the weak, particularly those in nursing homes, for example.

The majority of houses in Malawi are of poor quality, and are mainly found in rural areas and urban unplanned settlements (GoM, 2010). According to the Population and Housing Census report of 2008, about 28% of the houses were traditional houses, 44% semi-permanent structures, and 28% permanent buildings. Materials used for constructing permanent houses include: burnt bricks, concrete/quarry stones, cement, sand, tiles, and iron sheets for the roof. Semi-permanent houses are built of sundried bricks and grass thatch while traditional houses are built of mud walls, with a thatched roof. Ventilation, and hence air circulation, in traditional houses is generally poor, although the thatch tends to cool the houses. There have been efforts to improve the standard of construction by developing Safer House Construction Guidelines (Bureau TNM, 2016). The University of Bristol and University of Malawi have been studying the performance of masonry buildings so that building materials and form of construction are capable of overcoming different type of loads (Ngoma *et al*, 2018). Furthermore, the Government of Malawi is developing National Building Regulations as well as Building code. The population of Malawi currently stands at 18.7 million (GoM, 2018).

4.5.2.1 Importance of Building Infrastructure

The benefits of services derived from buildings are mostly social in nature. And hence climate change impacts would have a direct bearing on the survival of human beings, human health and economic development. Buildings are what identify settlements as a result of which households are identified by a housing unit. In light of the above, the building sector is very important. The role of the building sector to social economic development cannot therefore be overemphasized as it covers homes, hospitals schools, offices, shops and recreation facilities without which life stops. Notwithstanding the benefits that we derive from the sector, it is important to bear in mind that the sector is greatly impacted by floods and other climate change related hazards as shown in figure 3. The effects and recovery needs can be more than double the other sectors. There are many reasons for this situation.



Source: GFDRR, 2015.

Figure 4. 16 Total Damage, Loss, Recovery and Reconstruction Needs after 2015 Floods

4.5.2.2 Vulnerability of Building Infrastructure

Increases in temperature arising from global warming with climate change has the potential to cause heat stress. Heat stress can prove fatal. Heat stress is caused by an inability of the human body to maintain its core temperature at 37°C. As well as being determined by temperature, heat stress risk is affected by high relative humidity which limits the ability of the body to lose heat through perspiration. No upper limit on acceptable building temperatures is presently specified in health and safety guidance or building regulations. Guidance from the American Society of Heating, Refrigeration and Air-conditioning Engineers recommends that 35°C is the heat stress 'danger line' for healthy adults when relative humidity is 50%. This danger line temperature decreases by several degrees for higher humidity levels and for more vulnerable groups such as the elderly.

Flooding is an emotive subject due to the degree of devastation it can cause. Not only can severe flooding endanger life, but even at moderate levels it can lead to substantial damage and disruption to normal patterns of life. Water source contamination and inhibited access are significant problems, coupled with the ease with which internal fixtures and decorations can be damaged irreparably: a flooded house can be uninhabitable for months, and subsequent insurance costs can rise considerably as a result. Flooding is currently seen as the biggest climate change risk at present, both immediately and in the short term. Flooding may occur from three primary sources:

(a) Coastal (sea) flooding;
(b) Fluvial (river) flooding; and
(c) Pluvial (rain) flooding (e.g. surface water run-off).

Coastal flooding is primarily due to tidal variations in particular at spring tides, and these can be exacerbated by stormy weather conditions. In such circumstances it is coastal areas, obviously, which are greatest affected. Rising sea levels pose a risk to existing defences. Fluvial flooding occurs due to periods of excessive rainfall and the subsequent drainage into the river system which makes its way downstream, swelling river channels. Pluvial flooding is generally due to excess rainfall falling onto ground which cannot absorb it, whether it is saturated, frozen or covered in an impermeable surface.

Floodwater is invariably contaminated in some form and these contaminants can cause further damage to buildings and services, besides posing a threat to public health. Contaminants can include sewage, hydrocarbons, silt, salt and other biological or chemical substances, depending on the location of the flood and any unsecured hazards that may be present in the vicinity. Hydrocarbons are perhaps most commonly present in this manner in the form of petroleum, although asphalt and wood preservatives such as creosote are other sources for hydrocarbon pollution.

Apart from the obvious routes, water can enter buildings through many places. The wall and floor materials themselves can be permeable; concealed voids such as wall cavities and party walls; at junctions between, for example, suspended timber floors and walls; air bricks and other ventilators; inadequate or broken seals around window and door frames (including thresholds); weepholes in facing brickwork; services entry points; cracks in mortar or render; subfloor voids; inadequate or defective damp-proof membranes or tanking; and through sanitary or washing appliances via drainage backflow.

Unpredictable weather patterns include the occurrence of storms. Extreme low pressure areas generate high wind speeds, particularly during the traditionally-stormy season of autumn. Wind speeds of 90km/h can have impact on human safety and speeds of 126km/h can cause damage to buildings, which in turn can endanger human life. Uprooted trees, loosened roof coverings and unsecured walls (particularly on construction sites) can all threaten health, cause extensive damage to property and disrupt services. Power transmission cables can be brought down, water supplies contaminated and transport services interrupted. High wind gusts can cause uplift on roofing due to the drop in air pressure caused by the moving air currents; coupled with rain, then even the under-layers can be vulnerable to damage.

The incidence and prevalence of subsidence can be dated back to the earliest times, with famous historical examples including the Leaning Tower of Pisa and Venice's Campanile in St Mark's Square. But the rise in prominence of subsidence at a smaller and more local scale began in the 1970s with the introduction of insurance policy clauses, around the time of the 1976 heat-wave. Since then, subsidence has been a key feature of building surveys and ground movements, whether swelling due to excess ground water or shrinkage due to drought are the cause. Problems of subsidence can be exacerbated by the proximity of tree roots to foundations.

During periods of excessive and prolonged rainfall, ground water levels can rise and swell prone soils, particularly cohesive soils with a high clay content, which are particularly susceptible to volumetric change. Conversely, excessive and prolonged dry periods cause shrinkage. In winter, waterlogged ground can move further by frost heave. Shrinkage and swelling tends to occur within 5 m of the ground surface, and although rarely more than 150 mm either horizontally or vertically, this is obviously more than enough to cause significant damage and risk to safety. Non-cohesive soils by contrast, such as sands and gravels, can also give rise to subsidence when the fine particles are washed away during floods.

Tree-induced ground movement occurs when either there is a period of drought, in which case the tree removes moisture from the soil at a faster rate than it is replaced by natural rainfall (mature deciduous trees can remove 50,000 litres of water per year!), or due to ground swelling if a mature tree is removed suddenly and hence the water depletion rate drops. Similarly, extensive pruning can have a significant effect on the amount of water uptake that the tree exhibits. The proximity of trees to a building is therefore likely to impact on the degree of risk of subsidence.

Subsidence can also occur due to human intervention, on old in-filled sites such as excavation workings where the fill can consolidate, degrade or decompose over time. In addition, subsidence can also occur due to other problems, including cracked and broken drains or water supply pipes, which should all be investigated and ruled out before concluding that problems are due to shrink-swell. Finally, shrink-swell only occurs due to changes in water content – a constantly-wet or constantly-dry soil should not exhibit such unstable tendencies.

Perhaps the most synonymous with rising temperatures, droughts are a common phenomenon, but their magnitude and frequency of occurrence could be enhanced by climate change. Falling ground water table levels can lead not only to soil shrinkage and subsidence, as discussed above, but also to deplete supplies of potable water in reservoirs. As households become progressively more affluent, and as population levels increase, so to the demand on the country’s water resources rises. Hosepipe bans are imposed by the water supply companies, and irrigation of food crops becomes the priority over motor vehicle cleanliness. Besides domestic and agricultural users, other major abstractors of water include power stations and fish farms. Not only do droughts impose physical constraints, but economic impacts are also felt.

Houses will be impacted by higher wind speed. A roof blown off by strong winds (Bangula)

Subsidence of building due to moisture variation

Figure 1. 2 impacts on infrastructure

4.5.2.3 Potential Adaptation Strategies

Presented in this discussion are measures for averting excess heat, flooding, strong winds, subsidence, and droughts.

For new construction, there are numerous measures available to militate against the effects of overheating. At the earliest stages of a building project, a detailed site analysis should be undertaken which identifies the optimum positioning and orientation of the building on the site. Features should be noted including:

(a) The presence of any existing vegetation (particularly deciduous), and if it can be utilised to provide shading;
(b) Shading provided by existing buildings around the site; and
(c) The aspect of the site, i.e. the sun-path.

Building orientation is particularly important for windows and window sizes – the peak time of day for solar gain is mid-afternoon to mid-evening (in the summer). South-west to west orientation is consequently worst, as the sun angle is lower as sunset approaches, whereas temperatures are at their peak still; south is better as the sun is still higher (being earlier in the day), so the angle of incidence on the glass is more acute. However, it should be borne in mind that the opposite of this advice is desirable for winter solar gains.

Passive cooling measures can be surprisingly effective, and it is possible to learn valuable lessons from traditional design in hot countries. For example, high thermal mass, and stack-effect ventilation (drawing air over a pool of water to increase its humidity) have long been features in arid countries such as Egypt. For thermal mass to be utilized effectively in avoiding overheating, the wall and floor elements should be exposed to the interior (but not to direct sunlight). This is for the same reason that underfloor heating is most effective when used under hard floor surfaces, i.e. the heat is able to be radiated into the room, and not absorbed by soft coverings which act as insulators. In the same way, the use of a built-up (or spray-applied) wet plaster finish is better than plasterboard on dabs, which de-couple the heat transfer. Plasterboard drylining has replaced wet plaster in recent years, due to speed and cost advantages. However, the disadvantage of this technique is a poorer level of thermal comfort in winter than is achieved with lightweight, highly-insulated construction, since the thermal mass of the substrate is rendered useless. Also, it needs to be used in conjunction with effective night ventilation to expel the heat absorbed during the day; otherwise heat will build up during prolonged hot periods.

Ventilation and cooling strategies can include the use of passive stack-effect ventilation; stairwells and atria can be used as thermal chimneys, with clerestory or roof windows to expel exhaust air in conjunction with low-level inlets on shaded elevations to draw in cooler, fresh air. Openable windows (particularly with top and bottom opening lights in large glazed areas, to generate stack-effect ventilation) are vital, with the focus being on over- rather than under-provision. Where security is an issue, louvred side vents to windows (with a hinged insulated panel behind) can be incorporated. Ventilation positions are also critical; openings on opposing sides of a room promote cross-ventilation, while positioning openable windows on shaded elevations avoids drawing-in the hottest air. Whole-house extract ventilation systems can assist when used in a stack-effect arrangement, although the running costs need to be considered.

Placement strategies for mechanical and electrical equipment can also assist; locating appliances which generate waste heat outside the insulated envelope (for example, in a domestic garage, or communal heating systems in apartment buildings) – although again, this is obviously at the expense of being able to take advantage of winter gains.

Externally, minimizing hard landscaping materials which absorb heat during the day and re-radiate it at night will assist in counteracting the urban heat island effect. The use of reflective colors for hard materials, and the use of more ‘soft’ materials especially vegetation, together with avoiding mechanical cooling plant where possible, are all strategies which can be utilized at a larger scale.

Solar shading devices can be highly effective in reducing gains particularly through windows, and are available in many forms. Brise-soleil are good for south-facing elevations, while fixed vertical louvres and shutters are more effective in east or west-facing situations. Awnings, canopies and exterior blinds can all prevent direct sunlight incident on the building envelope, thereby giving flexibility and choice in aesthetic and other practical considerations. They can often be the best solution for most house types, typically offering a 50% reduction in overheating exposure, and don't restrict views from windows unduly. Retractable or movable devices also have the advantage of being able to avoid inhibiting the desirable winter solar gains and, particularly in the case of awnings, can be withdrawn to avoid damage in the event of high winds, or deterioration during inclement winter weather. Automation and sensors are also available, which enable use while buildings are unoccupied, albeit at increased cost. Other building features can also provide shading, such as extended roof overhangs, balconies and deep window reveals (although weather-protective detailing must be considered more carefully in these instances).

Measures to be adopted for managing residual flood risk are aimed either at resistance (keeping water out), resilience (to water damage), and/ or repair (of water damage). For resistance, barriers or bunds can be considered – either permanent landscaped features or bund walls (including, for example, around fuel storage tanks), or removable products for installation as temporary barriers across building apertures, e.g. flood boards on doors or airbricks/ service ducts. Similarly, temporary, freestanding barriers which are assembled close to, but not in contact with, buildings (such as property flood skirt systems) can be useful. Fences can be designed to include impermeable materials at the base, such as concrete planks or masonry dwarf walls. Drainage systems can incorporate double-sealed lock-down inspection chamber covers and non-return valves to prevent sewage backing-up. Sanitary and washing appliances should be sited above ground level, i.e. not in basements.

Although it can be argued that resistance measures such as those noted above have the undesirable effect of 'moving the problem elsewhere', they can of course be compensated by other measures, such as the creation of flood retention areas in places such as car parks or landscaping features.

Resilience is defined as minimizing the impact that flood water has upon entry to a building, seeking to avoid permanent damage or loss of structural integrity, maintain pre-flood dimensions (i.e. timber swell), and improve the speed and convenience of drying and cleaning to avoid rot or mould decay. Resilience measures can take many forms across many areas of the building:

(a) Floors – use ground-bearing solid concrete slabs in preference to suspended timber; specify ceramic, stone or concrete-based tiled surfaces to floors and skirtings (with cement-based adhesive and water-resistant grout), ideally draining to a floor sump pump; paint timber skirtings on the reverse before fitting; avoid concrete screeds above insulation as drying time of the insulation is increased considerably; damp-proof courses and membranes should be durable (minimum 1200 gauge for polythene) with particular attention paid to laps, and consider double-layer protection with cavity drains to retaining walls and basements; consider loose rugs in preference to fitted carpets for ease of removal and storage, as well as drying and replacement; specify closed-cell insulation to resist water absorption (but bear in mind that floor coverings will need to counteract the buoyancy of the insulant if submerged).

(b) Walls – use closed-cell insulation below predicted flood level in external walls; specify water-resistant walling materials such as pressed-face or engineering brick or rendered blockwork, use extended periscope subfloor ventilators or fit removable airbrick covers; fix plasterboard sheets horizontally rather than vertically, or split sheets mid-height with a dado rail, to reduce the extent of replacement; specify lime- or cement-based renovating plasters or renders rather than gypsum-based, with water-resistant paint finishes. The use of water-proof, water-resistant or micro-porous surface coatings on masonry should be viewed with caution – these have been seen in some instances to inhibit the drying-out of the building fabric, leading to further dampness-related problems internally..

(c) Kitchens – specify plastic, solid wood or stainless steel for cupboards and housings, in preference to particle board; mount appliances above the predicted flood height; fit non-return valves to drains from washing machines and dishwashers; seal between and behind cupboards to minimise water penetration; specify low-porosity materials for work surfaces.

(d) Doors and windows – specify PVC-U, aluminium (and aluminium-faced or foam-core door panels) or hardwood frames in preference to softwood; use loose-pin butt hinges to enable easy removal of internal doors for temporary storage above flood level; ensure that all frames are well sealed and gasketed.

(e) Services – avoid (or minimise) any wiring below predicted flood level; fit all switches, socket outlets, service panels, meters, etc. above predicted flood level; consider routing electrical ring main at first floor level with drops to ground floor; fit electrical cabling in surface trunking rather than chased-in to wall surfaces; install boilers and other heating or cooling equipment at first floor level (or as close to ground floor ceiling level as possible); protect communications wiring and other services with insulation within services ducts.

The deleterious effect of strong winds can be averted by siting and orientating buildings at the earliest planning stages of a project which can often go a long way to militate against the risk of wind damage. In addition, height, massing and roof form (avoid gables) can also play a significant part. Angling roofs so that they slope down to face the prevailing wind direction can assist in reducing uplift-related problems, and taking advantage of adjacent shielding, whether in the form of natural landscapes or other buildings, can also be prudent. Excessive roof overhangs should be avoided, particularly on elevations facing the prevailing wind direction, and the proximity of nearby hazards should be evaluated, e.g. mature trees and overhead distribution cables. In addition, ring beams should be part of all wall construction.

Consideration should be given to specifying single car-width garage doors in preference to double car-width – the increased size can enhance wind deflection and, in extreme cases, push the door out of the guide rails. As soon as the door has been blown in, the interior becomes more vulnerable and in particular the roof can be subjected to additional uplift action, thereby increasing the risk of the roof being damaged.

Adaptation strategies for subsidence of buildings may include the following remedies:

(a) Continuous mass concrete underpinning, generally installed in a hit-and-miss sequence for large areas;
(b) Beam and base underpinning;
(c) Mini-piled underpinning, including pile and beam, cantilever pile caps and piled rafts;
(d) Displacement piles;
(e) Expanding resin injection;
(f) Micro-piles;
(g) Ground bearing raft;
(h) Structural strengthening – tie rods, resin bonding, masonry stitching, corseting with reinforced concrete or post-tensioned ground beams;
(i) Jet grouting; and
(j) Geopolymer injection or fluid cement.

Governments and businesses must identify their drought vulnerabilities and improve their resilience. Actions like using water more efficiently (water demand management) and developing technologies that reduce water wastage.

Other actions that improve resilience to other stressors, like deploying green infrastructure for storm water management or increasing energy efficiency in buildings (thereby using less water-cooled power), can improve resilience to drought as a co-benefit.

These steps will be most effective if they are combined with reductions in greenhouse gases that can minimize the ultimate magnitude of climate change.

The key to ensuring that these best practices are followed is by incorporating them in the building regulations to be enforced through the local authority by laws.

4.5.2.4 Study Limitations.

In this study, simulation models were not applied in conducting vulnerability assessment of buildings to impacts of climate change. As such, the formulation of adaptation strategies outlined in the report was done sorely based on climate change scenarios developed by the Scenarios Group.

4.7 Land Resources

Land is a finite natural resource, comprising of interrelated environmental components of geology or rock type, soils and its organisms, topography and it aspect, climate (including micro climate), water (rivers, underground and lakes) and vegetation. Land and its interrelated environmental components make up land resources. Agriculture is the biggest use of land in Malawi and this affects and is affected by other land uses. Agriculture remains the backbone of Malawi's economy as it accounts for 30% of Gross Domestic Product (GDP) and generates over 80% of national export earnings. Between 2005 and 2011, over 80% of the country's total exports were agricultural commodities, primarily tobacco, sugar and tea. Agriculture employs 64.1% of the country's workforce comprising mostly the smallholder subsistence farmers. Agriculture also significantly contributes to the national and household food security and nutrition. The agriculture sector in Malawi comprises of smallholder and the estate subsectors, with more than 99% of households involved in smallholder subsectors which contribute 80% of overall production and 70% of agricultural GDP. The smallholder cultivates 65000 square kilometers of land which constitutes 85% of the total land. Malawi has a total land area of 118,484 square kilometers, of which 20% is covered by water.

In view of the above, Malawi's economy is highly dependent on the land resources. If these are depleted or degraded long term food and nutrition security and socio economic growth will be greatly compromised. It is, therefore, important to promote the efficient, diversified and sustainable use of land based resources for both agriculture and other uses in order to avoid sectoral land use conflicts and ensure sustainable and socio-economic development in the country

Land resources continue to face pressure due to natural and anthropogenic activities which are causing soil erosion, deforestation, water resources degradation and depletion and climate change. A recent estimate of the average rate of soil loss in Malawi is **29 MT/ha/yr. (Soil Loss Assessment Study, 2014)**. This is almost thrice the world soil loss tolerance standard figure of **11.2 t/ha**. This soil loss has resulted into continued declining trend in topsoil nutrients levels leading to substantial reduction in crop yields of more than four per cent per year. Since 1990s, Malawi has also witnessed significant losses in vegetative cover, heavy siltation and drying up of once perennial rivers.

4.7.1 Soil resources

Although Malawi is endowed with naturally good soils for agriculture, the soils are highly susceptible to soil erosion processes. All together the three major soil types comprise about 76% of Malawi. Due to their chemical and physical characteristics, these soil types have inherent predisposition to erosion. This implies that about three-quarters of Malawi is already predisposed to soil erosion by virtue of soil type.

The Cambisols and Luvisols that are regarded as soil with relatively good natural nutrient characteristics are quite susceptible to exploitation through agricultural activities. They are also predisposed to soil erosion due to their chemical and physical characteristics. The tendency to exploit these soils for agricultural production makes them more vulnerable to soil erosion in the absence of proper soil conservation and management practices. For Lixisols, they have low aggregate stability and slaking characteristics. These characteristics form a bad combination with high erosive rainfall and low vegetation cover that is typical of some parts of the country where these soil types may be found. In general, the major soil types in Malawi have potential threats for degradation under poor management.

4.7.1.1 Soil Loss Trend

Soil loss is one of the major threats to agricultural development in Malawi. Since Malawian economy is largely dependent on agriculture, loss of soil especially from the farmlands is conceived as a major hindrance to the overall economic development of the country. Not only does soil loss reduce the cultivable soil depth but also takes away the fertile soils from the farmlands. The net effect is loss of agricultural productivity, increased expenditure on fertilizers (that are required to maintain the yields), and a general decline in profitability of crop production. Besides the negative impact on agriculture, soil loss also affects surface water resources through loss of water quality and quantity, increased flashfloods, and siltation of rivers and irrigation canals. There are also arguments of soil loss increasing emissions of greenhouse gasses. During the soil loss process, there is potential breakdown of soil aggregates and clods into their primary particles (such as clay, silt and sand). Consequently, the carbon that is held within the soil ends up breaking and is released into the atmosphere as CO_2 (Lal, 1995). Upland soil loss also affects other key sectors of the Malawian economy such as the fishery and water resources (water supply and hydro-electricity generation) among others.

GoM through the Land Resources and Conservation Department (LRCD) commissioned a study which among other things was to establish a time-series assessment of soil loss in Malawi for the period between 2000 and 2014 (Vargas and Omuto, 2016). The study used SLEMSA model across the whole grid scenes covering the country. The model output shows the areas which had significant increasing or declining trends of soil loss rates at 5% level of significance (Figure 3 and Figure 4). The majority of areas with increasing trends of soil loss were observed in the northern region. Notably, Nkhata Bay had highest increase in soil loss rates between 2000 and 2014 while some parts of Chitipa, Keronga, Mzimba and Rumpi had slight increase in soil loss rates (Vargas and Omuto, 2016). In the south, Mulanje and Phalombe had slight increase in topsoil loss rate while the remaining majority of the districts had declining rates or no significant change in topsoil loss rates.

Vargas and Omuto (2016) quoted FAO (2012), which substantiated that the areas with increasing trends of soil loss showed the largest land cover change from natural vegetation to crop lands or other land cover types without good vegetation cover between 1990s and 2010. Nkhatabay showed increased trend of soil loss up to 39 ton/ha/yr. Similarly, areas that had declining trends in soil loss rates especially in the Rift Valley sections, the soil loss rate seemed to have declined to less than 10 ton/ha/yr towards 2014. The decline is attributed to potential increase in vegetation cover in these areas as was reported in the FAO (2012) report (Vargas & Omuto, 2016). The majority of areas with increasing trends of soil loss were observed in the northern region. Notably, Nkhata Bay had highest increase. Careful assessment of Nkhata Bay District show that it has the majority of steep slopes, fragile soil, and high rainfall, all of which could have contributed to high soil loss. However, all studies indicate that the highest levels of soil loss were from agricultural lands.

Overall, in 2014, the national average soil loss rate was 29 ton/ha/yr. The areas with high extremes of topsoil loss rates were found to have had steep slopes, shallow soil, and with low vegetation cover

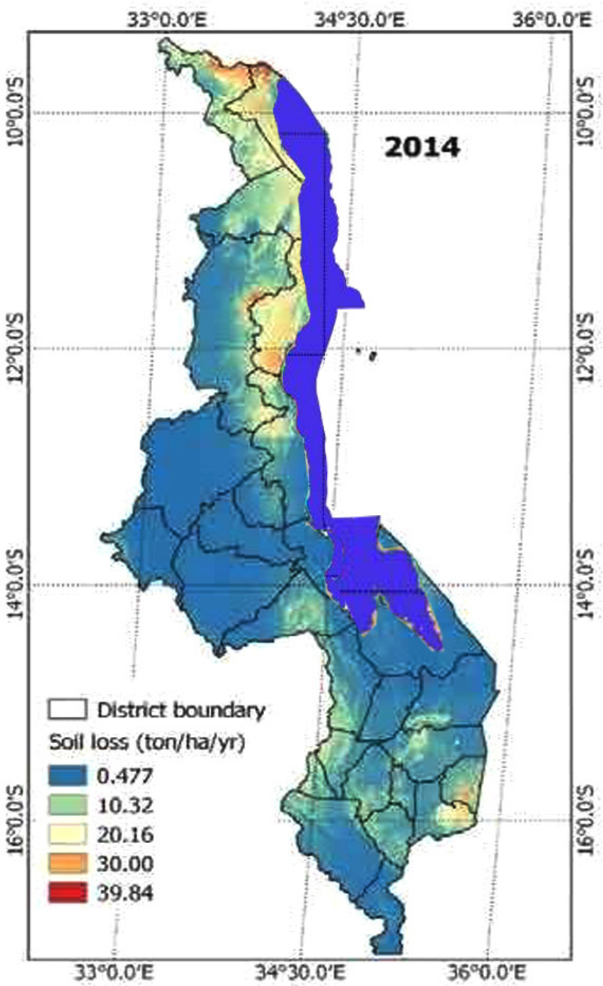


Figure 4. 17 Time-series change in tropical loss rate between 2000 and 2014 (Source: Vargas and Omutu, 2016).

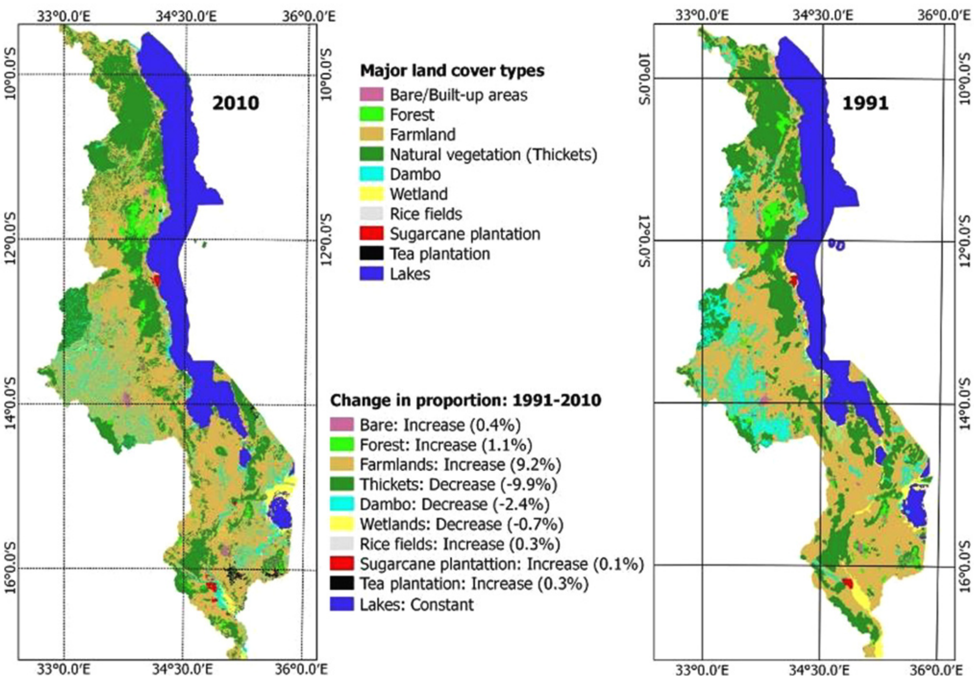
4.7.1.2 Vegetation cover

The main land use/cover types in Malawi are farmlands, natural forests, forest plantation, wetlands, and lakes. Farmlands have the highest proportion in addition to having improved its spatial coverage by 9% between 1991 and 2010 (Figure 5). Majority of the farmlands have seasonal ground/vegetative cover owing to the seasonal types of crop grown in them. They provide the agricultural produce for the country. The increase in spatial proportion shows that there was an expansion of land under agriculture between 1991 and 2010.

The natural forest is dominantly used as game parks or forest reserves. They provide the country with tourist attraction benefits, fuelwood, medicinal plants, timbre, food, water catchment areas, above-ground carbon stocks, and the ground cover that protects the soil from agents of erosion. Some parts of it have been replanted with forest plantations such as pines, rubber, etc. Altogether, the forests occur mainly in the north and upper parts of the central region. In spite of the importance of the natural forest, their cover seems to have declined between 1991 and 2010 (Figure 2.2). For the wetlands, they have been predominantly in the central and southern regions. A good fraction of the have been reclaimed between 1991 and

2010 in the central region. These were mainly those along Lake Malawi in Nkhotakota and Salima Districts.

In terms of changes in land use/vegetation cover, it was observed that the decrease in spatial coverage of the natural forests was almost corresponding to the proportional increase in areas under agriculture during the 1991-2010 period. This suggests that agricultural land could have reclaimed some parts of the natural forest. This observation was particularly evident in the southern and northern regions. Although this change positively increased the areas under agriculture, it could have brought potential negative effects to the soil in case proper soil management did not accompany the transition. Interesting attention could be drawn to the areas where changes of land use from natural forest to agricultural land occurred in the structurally unstable Lixisols in the northern region and vulnerable Luvisols and Cambisols in the south especially in Mulanje, Phalombe, and Nsanje Districts (Figure 5). These soil types have high risk of erosion if the protective vegetative cover is removed.



18 **Figure 4. Main land use/cover types in Malawi in 1991 and 2001 (*Data source: GoM and Map drawn by C. Omuto*)**

4.7.1.3 Importance of Land Resources

As pointed out in the introduction, Agriculture is the biggest user of land and its resources in the country and that Agriculture remains the backbone of Malawi's economy as it accounts for 30% of Gross Domestic Product (GDP) and generates over 80% of national export earnings. This means that land resources play big role in the country. However, Land resources are undergoing degradation due to soil erosion, deforestation, climate change and water resources degradation and depletion. Failure to introduce the mitigation and adaption measures will result into low agricultural production and productivity which will lead to food and nutrition insecurity in the country as well as the sector may contribute to the socio economic development of the country.

4.7.1.4 Vulnerability of Land Resources

Key vulnerabilities of land resources to climate change are loss of soil through erosion, and declining soil fertility. With increased frequency and magnitude of floods, exacerbated by poor land use practices, it is expected that soil loss will increase under climate change scenario, topping the current rate of soil loss of 29 tons/hectare/annum. Also, the removal of the rich topsoil through erosion will result in reduced fertility, necessitating the need to use organic fertilizer or manure in order to sustain crop production.

4.7.1.5 Potential Adaptation Strategies

The country is promoting sustainable land and water management or climate smart agriculture practices as some of the adaptation and mitigation measures. Some of the practices include: Conservation Agriculture, Agroforestry, Compost and manure making and use, rainwater harvesting and soil and water conservation.

Conservation Agriculture

Conservation Agriculture- (CA) is a cropping system that aims at conserving agriculture resources, strives to achieve acceptable profits together with high and sustained yield levels while concurrently serving the environment. Conservation agriculture is being promoted in Malawi as an ecologically sound cropping system capable of boosting crop yields and increasing resilience to climate variability and change.

CA offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resource use. CA practices increase soil organic carbon which improves both efficiency and resilience. They also improve nutrient and water intake by plants, which increases yields and resource efficiency of land. Soil erosion is reduced and water retention is increased, especially as it is often combined with added soil cover. The combination of CA practices makes the production system more resilient to variability of precipitation and to extreme weather events. Increasing carbon sinks in the soils also captures carbon, which contributes to climate change mitigation.

Minimal mechanical soil disturbance considerably reduces nitrate leaching. Largely, because, unlike mechanical tilling practices, ***zero tillage*** leaves the soil undisturbed; this decreases mineralization and the subsequent production of nitrates. Cover crops take up the nitrogen and reduce its loss from the soil. At the same time, unused mineralized nitrogen remains distributed within smaller pores and are not washed out of the soil.

Rotating and diversifying crops reduce crop pests and diseases and use leguminous species capable of hosting nitrogen-fixing bacteria in their roots to replenish soil nutrients, which contributes to optimum plant growth without increased emissions induced by inorganic fertilizer's production.

Soil Fertility Improvement

The continuous mono-cropping common in most places often with no improved inputs has led to exhaustion of soils. Soil fertility has declined to the extent that even response to mineral fertilizers is declining. The Department and other partners have been promoting integrated soil fertility management that advocates the use of both organic and inorganic sources of nutrients including nutrients from plant fixation.

On organic soil fertility initiatives the focus has been on ***compost manure making and application***. It has been demonstrated that even during years of droughts, maize applied with organic manure has performed much better than maize only applied with inorganic fertilizers. The Department continues to spearhead the national campaign on manure which in 2001 culminated in a national launch by the State President at a function in Dowa District. The national launches have since been broadened to include conservation agriculture and irrigation (optimal use of water resources) in a bid to increase awareness on adapting to changing climate and usually the Ministers of Agriculture preside over the functions every year. The Department also supports, demonstrates and promotes use of other types of manure like khola manure, Bokashi and biomass from fertilizer trees including crop residue incorporation which quickens decomposition of organic materials.

Agroforestry

Promotion of Agroforestry i.e. the use of trees and shrubs in agricultural crop and/or animal production and land management systems and it’s the deliberate use of forestry in the agricultural landscape, is a common practice in Malawi and across the globe. It is estimated that trees occur on 46 percent of all agricultural lands and support 30 percent of all rural populations (Zomer et. al 2009). Agro-forestry improves land productivity providing a favourable micro-climate, permanent cover, improved soil structure and organic carbon content, increased infiltration and enhanced fertility, reducing the need for mineral fertilizers. This way agro-forestry is important in food security.

Similarly, trees on farms or agro-forestry systems can contribute to mitigating climate change as they tend to sequester greater carbon quantities than agricultural systems without trees. Planting trees in agricultural lands is relatively efficient and cost effective compared to other mitigation strategies, and provides a range of co-benefits important for improved farm family livelihoods and climate change adaptation. Trees and shrubs can diminish the effects of extreme weather events, such as heavy rains, droughts and wind storms. In addition, an agroforestry provides alternative sources of firewood and construction timber, and new sources of income.

Farmer Managed Natural Regeneration

Farmer Managed Natural Regeneration is a popular practice which has traditional roots in many farm communities. It is probably the most widespread and successful agroforestry system. The best known system involves *Faidherbia albida* which is valued by farmers for its beneficial effects on crops, soil fertility and the micro-environment to increase and stabilize yields, especially in years of drought or low rainfall. The tree's abundant production of nutritious pods also provides a valuable source of quality feed to livestock during the dry season when the supply of quality forage is very limited. If left in the farm fields and around homestead, trees provide shade for both mankind and animals from intense sun's heat that is associated with climate change

Soil and Water Conservation

There are significant achievements in the transfer of knowledge and skills to support implementation of soil and water conservation initiatives among smallholder farmers. The department is promoting ***contour ridging***as the first line of defense against soil erosion. The contour ridging is supported by contour ***vegetative hedgerows***of vetiver grass that now dominate the landscape of most conserved areas.

These structures can provide benefits by reducing water erosion, improving water quality, and promoting the formation of natural terraces over time, all of which lead to higher and less variable yields. Such benefits extend to neighbors and downstream water users by mitigating flooding, enhancing biodiversity, and reducing sedimentation of rivers.

The soil and water conservation structures that the department is advocating produce relatively high benefits in mountainous areas (Misuku Hills, Livingstonia escarpments, Nkhata Bay, Viphya plateau, Dedza mountains, Dowa-Ntchisi ridge, Shire Highlands) where farming occurs on the slopes, where benefits to water retention are relatively great and potentially where gully and rill problems have already surfaced.

Rainwater Harvesting

Rainfall pattern in Malawi has in recent years been very variable both in amounts and distribution. This creates a problem of water shortage for a larger part of the year. In addition, the rain season is inter-spaced with dry spells, which unfortunately, coincide with critical crop growth stages resulting in crop failures that lead to critical food shortages during most parts of the year.

The Department is, therefore, promoting a number of technologies aimed at collecting and storing water from rainfall and runoff for various uses such as domestic, irrigation and livestock. With increased adoption of these technologies, it is hoped that the negative impacts of droughts will be minimized. In addition, rainwater harvesting has great potential to conserve the soil as runoff is effectively controlled.

Challenges

The department has a number of challenges in implementation of climate change adaptation interventions. These include the following:

- Low technology uptake by farmers due to inadequate knowledge of the benefits of such technologies
- Long term realization of climate change adaptation benefits from most of the sector's interventions such as agroforestry
- Financial constraints that limit greater investments in implementing adaptation interventions.
- Weak collaboration and coordination with other sectors working in the sustainable land management areas such as forestry, irrigation and environmental affairs

Possible Solutions

- Strengthening institutional capacities at all levels including farmers and communities to empower them to provide leadership in climate change adaptation
- Intensification and inclusion of early maturing fruit trees in the agroforestry dimension for farmers to realize the benefits in short or medium term periods
- Establishing and strengthen multi-sectoral platform for formal coordination and governance of climate change adaptation strategies.

4.8 Fisheries

In Malawi, the fisheries sector comprises capture fisheries and aquaculture, with the former being the dominant type. Capture fisheries includes small scale, large scale and ornamental fisheries. The small-scale fisheries is "open entry" and contributes over 90% of the total catch landings in Malawi while the large scale fisheries is controlled through licensing. At present, there are 48 large scale licensed fishing units in the country, most of which operate in the southern and central part of Lake Malawi. Nationally, a total of 62,000 people are directly employed by the sector as fishers. However, the majority of this is made up of crew members (82%) while gear owners make up 18% (Table 1). The fishery industry is dominated by male gear owners, who account for 98% of the total population while 2% are female gear owners. An analysis of the total number of fishers by water body shows that Lake Malawi has the largest number of total fishers, with 79% of the total population of fishers in the country plying their trade in this lake. To reduce issues of illegal, unreported and unregulated fishing (IUU), the Department of Fisheries has installed a vessel monitoring system (VMS) on large-scale fishing boats. This tool assists with proper estimation of fishing effort in the sector which is an important component in assessing the status of fish stocks in the lake. The fisheries sector contributes approximately 4% to the national GDP, and currently provides 60% of the animal protein consumption to the diet of the citizenry. The sector is of great importance to the country's socio-economic development because it is a source of employment, food, rural income, export, import substitution and it is important for biodiversity conservation. The sector indirectly employs over 500,000 people who are involved in fish processing, fish marketing, boat building and engine repair. Furthermore, nearly 1.6 million people in lakeshore communities derive their livelihood from the fishing industry (GoM, 2013). The sub-sector is largely artisanal in nature, except that in Lake Malawi there are also semi-commercial and commercial fisheries, made up of pair trawlers and larger stern trawlers respectively.

As pointed in the preceding discussion, fishing areas in the country include Lake Malawi, which is the biggest lake in Malawi. It has a surface area of 29,000 sq km. Lake Chilwa is the second and has an area of about 2,000 sq. km depending on seasons. Other smaller water bodies include Lakes Malombe (390 sq. km) and Chiuta (about 200 sq. km) and the Shire River system in the Lower Shire Valley. Fish production varies annually with available estimates from 2000 to 2015 averaging 90,000 tonnes per annum. Catches of the most valuable fish, Chambo (*Oreochromis* spp), however, remain low averaging 4,000 tonnes per annum. This is in contrast to the period between 1981 and 1990 when average catches of over 10,000 tonnes of Chambo were landed per annum. The aquarium trade mainly involves Mbuna fish which are exported abroad. Mbuna fish are also part of the rich biodiversity of Lake Malawi that attract tourism. The sub-sector is dominated by very few operators.

In Malawi, fishers mostly use boats fitted with engines, boats without engines, planked canoes and dugout canoes for their daily fishing operations. According to the 2018 Annual Frame Survey, a total of 18,118 fishing crafts operate in the waters of Malawi. Dugout canoes contributed 68% of the total number of boats, followed by boats without engines with 13%, boats with engines, 11% while planked canoes contributed 9%. Approximately 61% of the total number of fishing crafts operate in Lake Malawi and all the boats with engines are exclusively operated in Lake Malawi.

Table 4. 22 Summary table for fishers and fishing crafts registered during the 2018 Frame Survey

Waterbody	District	Fishers					Fishing Crafts				
		Female	Male	Number of Gear owners	Number of Crew members	Total Number of Fishers	Boat with Engine	Boat without Engine	Planked Canoes	Dugout Canoes	Total Number of Fishing
Lake Chilwa	Phalombe	1	349	350	552	902		60	81	165	306
	Zomba	7	713	720	1,915	2,635		250	110	333	693
	Machinga		381	381	715	1,096		58	30	292	380
Lake Chiuta			340	340	340	680				192	192
Lake Malawi	Dedza	2	255	257	1,721	1,978	7	158		164	329
	Karonga	5	1186	1,191	4,039	5,230	155	71	106	1,829	2,161
	Likoma	17	410	427	3,101	3,528	186	27	355	255	823
	Nkhata Bay	17	1620	1,637	7,091	8,728	436	49	155	2,544	3,184
	Nkhotakota	4	1306	1,310	5,987	7,297	276	90	409	1,209	1,984
	Rumphi	10	371	381	1,664	2,045	79	37	115	668	899
	Salima	4	742	746	4,608	5,354	249	130	60	1,163	1,602
	Mangochi	74	1820	1,894	13,200	15,094	591	836	114	2,769	4,310
Lake Malombe		2	263	265	2,058	2,323		278		1	279
Upper Shire River		3	209	212	1,883	2,095		230		34	264
Lower Shire River	Chikwawa	21	375	396	432	828		7	26	65	98
	Nsanje		804	804	1,428	2,232		9	1	604	614
Total		**167**	**11144**	**11,311**	**50,734**	**62,045**	**1,979**	**2,290**	**1,562**	**12,287**	**18,118**

Fish production in Malawi varies annually. The catch and effort data collection system established and introduced into the country by Food and Agriculture Organization (FAO) shows that production of less than 15,000 tons was recorded between 1964 and 1974. The catches increased to around 80,000 tons in the 1980s and then declined to less than 40,000 tons in the mid-1990s. However, the dominance of *Usipa* catches (estimated to account for over 60% of the total catch) has been observed from 2000 to 2018 (Figures 1 to 4). Fish catches in 2018 was estimated at around 220,000 tons.

The large-scale fisheries in Malawi comprises midwater stern trawls, bottom water stern trawls and pair trawls. Total fish catches in the large-scale fisheries shows a steady declining trend since late 1980s (Figure 3). catches have declined from an average of 7,000 tons between 1976 and 1990 to an average of 3,500 tons between 2013 and 2017.

While the fish production trend in Malawi shows an increasing pattern, the large-sized and commercially important fish like Chambo (*Oreochromis* spp.) have declined (Figure 4). During the late 1970s, production of Chambo was about 9,000 tons annually but landings declined since 2010 and have remained at those low levels with current estimates of about 4,000 tons.

An analysis of the species groups composition in the large-scale fisheries, shows a succession of species with time (Figure 4). Chambo and Chisawasawa (Lethrinops spp.) were the mainstay fisheries from 1976 up until early 1990s but have been replaced by Ndunduma (Diplotaxodon) and Utaka (Copadichromis spp.)

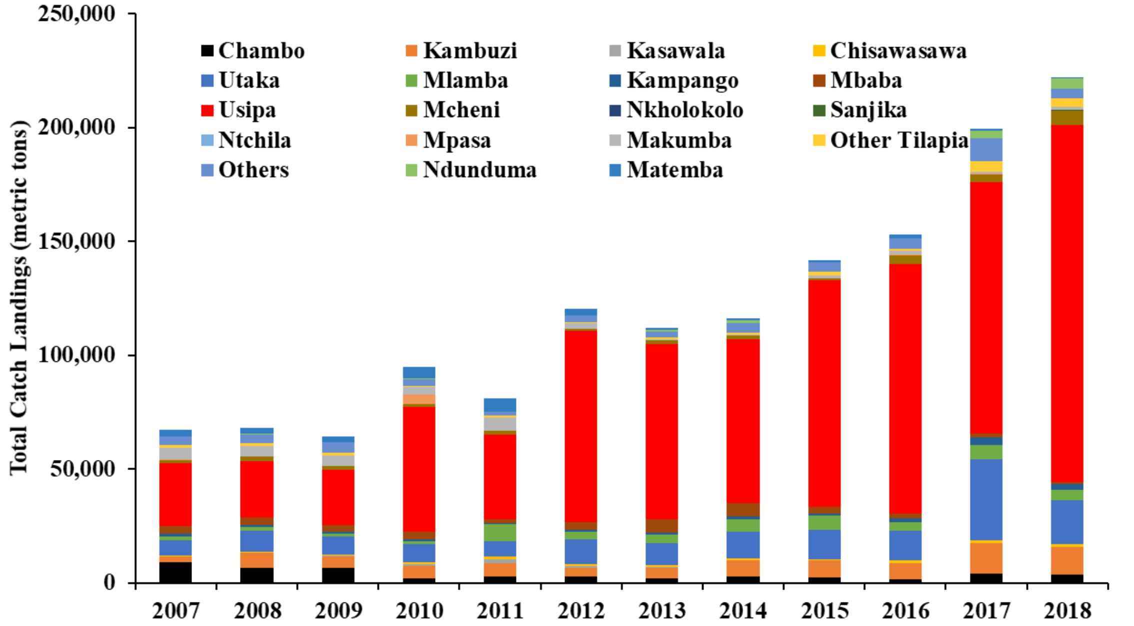


Figure 4. 19 Fish production from the major water bodies of Malawi. source (GoM 2019)

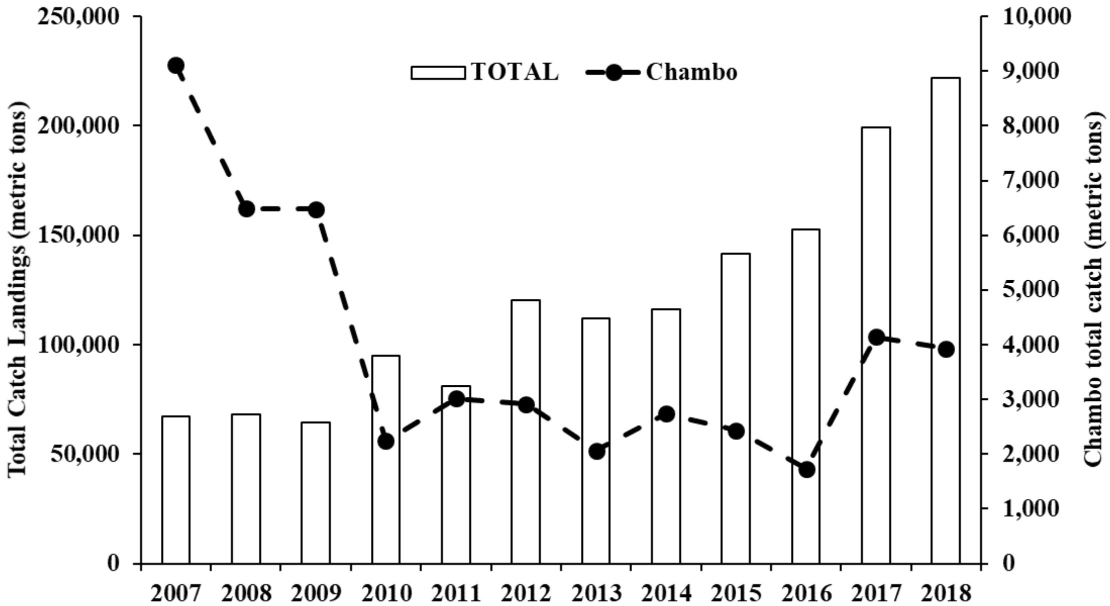


Figure 4. 20 Fish production from the major water bodies of Malawi showing trends in Chambo fishery against total catch. source (GoM 2019)

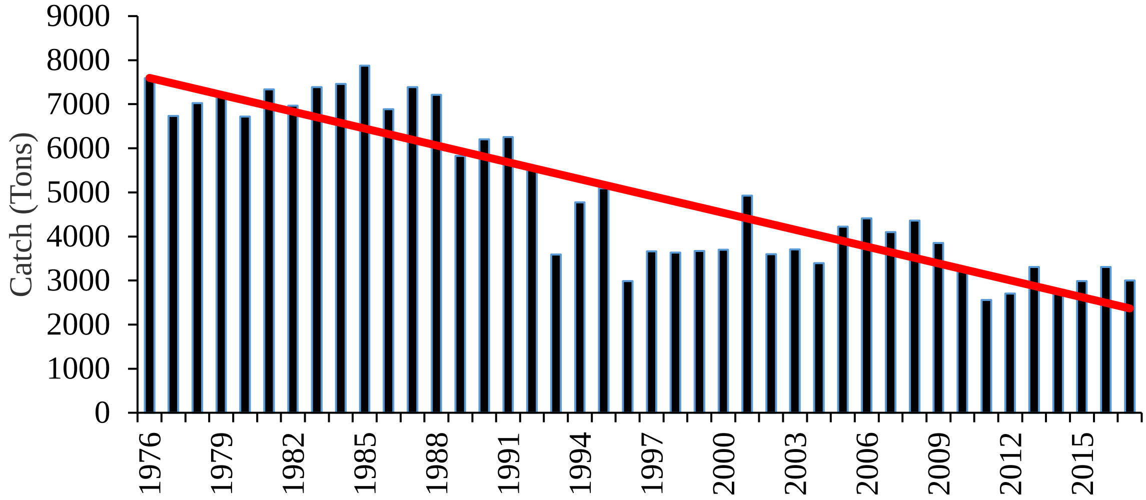


Figure 4. 21 Total fish production from large-scale fisheries in Malawi. source (GoM 2019)

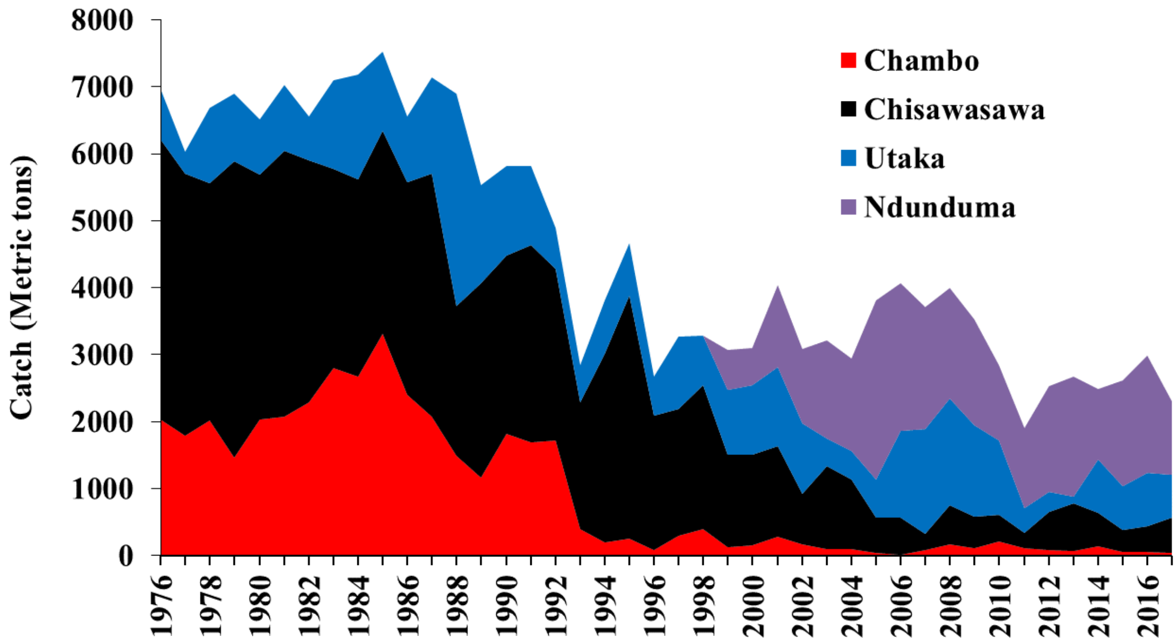


Figure 4. 22 Fish production from large-scale boats showing trends in the commercially important fisheries. source (GoM 2019)

The ornamental fish trade has become a commercial business in Malawi in recent years. The operations of ornamental fishing are currently confined to four licensees that target Mbuna fish species, the highly colored territorial cichlids commonly found within 100 m (Figure 5). The ornamental/aquarium trade thrives on the exploitation and exportation of these colored cichlids, mostly to Europe, Asia and North America. Exploitation of these fish is allowed in all waters of Lake Malawi except in National Parks.

Figure 4. 23 Fish species of the Mbuna group, the rock-dwelling coloured fish

The fishery industry faces a number of challenges that need to be addressed in order to ensure improved and sustained benefits to Malawi and the world at large. Major challenges include habitat degradation and pollution, deforestation, loss of biodiversity, overfishing and over capitalization, high post-harvest fish losses, hydropower development, oil exploration, exotic species introductions, climate change and variability, weak collaboration among stakeholders, non-commitment to global obligations i.e. Nagoya Protocol, and slow progress in aquaculture development due to poor quality feed and fingerlings. Some of the opportunities of the fisheries sector are that the sector is well recognized and supported by both state and non-state actors, including donor partners. There are both new and old infrastructure across the country that can support investments including research into the sector. There is also a strong linkage between national policies which guide national development and the fisheries policy which ensures that the sector is kept abreast of both local, regional and international developments and obligations.

The goal of the National Fisheries and Aquaculture Policy is to promote sustainable fisheries and aquaculture development in Malawi in order to contribute to the country's economic growth. It seeks to provide guidance to all stakeholders in the implementation and provision of fisheries services, as well as interventions that will continue rendering the sector as a key source of food and wealth in Malawi. The policy focuses on enhancing fish quality and value addition for domestic and export trade to create wealth, promote technology development and its transfer to the users, enhance capacity for the sector's development and promote social development, decent employment, fisheries governance and sustainable utilization through participatory resource management regimes.

Lake Malawi is not only distinguished by its old age, but it also has the highest number of fish species in the world, estimated at over 800 fish species. Although eleven (11) fish families exist in the lake (Table 4.23), the Cichlidae family is by far the most speciose (in terms of species richness, diversity and numerical abundance), contributing over 90% in the lake and all of it is endemic to the lake. According to Ribbink et al (1983), in the rocky near shore of the lake, more than 500 individual fish types belonging to over 22 species can be found is a 50 m^2 area.

Table 4. 23 The riverine and lacustrine fishes of Lake Malawi (adapted from Ribbink 2001)

Family	Genera	Species
Anguillidae	1	1
Aplocheilidae	1	2
Bagridae	2	4
Characidae	2	2
Cichlidae	41	Over 750
Clariidae	2	17
Cyprinidae	5	26
Mastercembelidae	1	2
Mochokidae	2	3
Mormyridae	4	7
Protopteridae	1	1

The aquaculture sub-sector has potential to increase fish production in the country. Enhanced aquaculture production especially at commercial level would improve supply of fish protein in rural areas far away from the major fish production sources and also creation of wealth and employment in such areas. The aquaculture subsector can also be one of the major sources of fish product exports, thereby contributing to Malawi's economic growth. There are 6,000 fish farmers with varying sizes of ponds in the aquaculture subsector. Fish production in the sub-sector has been increasing from 800 tonnes per annum estimated in 2006 to 3,600 tonnes per annum by 2015. However, one of the major problems identified with commercial aquaculture is that the species cultured are slow growing and have a poor feed conversion, making the products of aquaculture expensive to produce.

4.8.1 Importance of Fisheries

Apart from other water bodies found in Malawi, Lake Malawi alone harbours extraordinarily high diversity and endemism of freshwater fish species (Sayer et al 2019). The Lake is globally the most fish species rich contributing about 4% of the fish species and 14% of the freshwater fish and it is estimated to contain over 1000 fish species (Stauffer et al 1997). The greatness in diversity is important for evolutionary studies where the species occupy different habitats which can respond differently to climate and environmental changes. Furthermore, it is a source of animal protein to the human diet by providing about 60% of the total animal protein consumption by the citizenry; it is a source of employment and it is estimated that in 2016 there were 61,143 fishers with more 500,000 people working in auxiliary services such as fish marketing, engine repair, boat building and fish processing; it support the economic growth and contributes 4% to the national GDP; and it attracts tourists where they visit the lake and take part in water activities, including snorkelling and diving to see the colourful rock-dwelling cichlid fishes, the rapid and extensive fish species radiation has attracted a lot of researchers from all over the world.

4.8.2 Climatic influence on water bodies

Most of the water bodies are influenced by rainfall, temperature and wind in one way or the other. Malawi has a dry and a wet season. The water level for most water bodies rises during the wet season and for Lake Malawi, it fluctuates between 0.8–1.4 m (Weyl et al, 2010). It shows that the hydrological regime in Lake Malawi is dominated by precipitation (41 km3 per year) and evaporation (54 km3 per year), with river inflow and outflow only at 29 km3 per year and 12 km3 per year, respectively (Weyl,et al 2010). Furthermore that the water bodies in Malawi are susceptible to climate changes for instance Chavula 2016 sited a record where the Lake Malawi was closed, no outflow of Shire River between 1915-1935 and Kidd 1983 noted that the Lake nearly became closed in 1997 as a result of low precipitation.

Lake Malawi is known to be permanently stratified where it is anoxic below depths of about 170–200 m. Temperature has a great influence on the processes in the lake, for instance at shallower depths, water temperatures and lake stratification follow seasonal patterns. In the months between September and December there is a warming of the surface waters and stratification intensifies. By May the upper 60–80 m is homothermal at about 27◦C; during the cool windy season the thermocline weakens so that by July it is poorly defined and there is a gradual temperature gradient of 23◦C at the surface to 22.5◦C at 250 m (Weyl et al, 2010).

Wind causes upward flux of nutrient rich waters from hypolimnion and metalimnion to the surface during southeast trade winds (Mwera winds). The upwelling can occur in parts of the lake during cool season. The lake shape result into strongest upwelling in Southeast arm. The upwelling causes high plankton production in southeast arm during and shortly after windy season (Bootsma 1993a, Patterson and Kachinjika 1995). In the recent decade it has been observed that there is no specific wind pattern where Mwera winds can occur in November in contrast to the past experiences. This can be associated to climate change. Increased occurrence of storms (associated with Mwera or south-easterly winds, and mpoto or north-easterly winds) is one of the factors that constrain fishing activities: Fishers are reluctant to venture far from shore as they are concerned about the risk of capsizing and possibly drowning, which they described as becoming an increasingly common occurrence, especially for fishers operating with canoes or planked boats, and without life jackets.

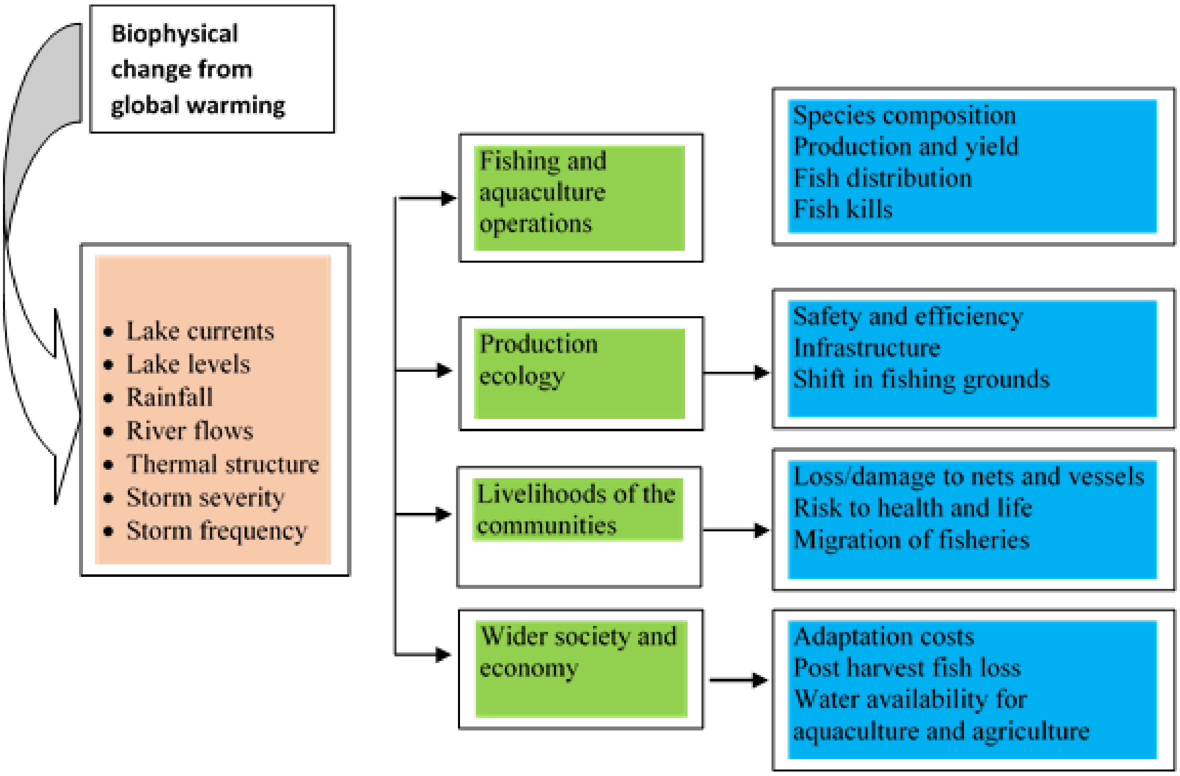


Figure 4. 24 Conceptual framework of the climate change effects and impacts on fisheries and aquaculture systems (Adapted from Badjeck et al. (2010) and De Silva, et al (2009)

4.8.3 Vulnerability of Fisheries

The fishery industry faces a number of challenges, including: overfishing; climate change and climate variability, resulting in floods and droughts; siltation; weed infestation; and eutrophication. Hydrological variabilities in some major water bodies such as Lakes Chilwa and Chiuta, including aquaculture systems, caused the water bodies to dry up completely, resulting in dramatic losses in fish stocks.The changes in fish catches especially when the lakes dry-up have resulted in loss of livelihoods for many people that depend on the fisheries, considering the limited alternatives available to them to cope with such shocks.

The predicted increase in temperatures and shortened rainy season will likely lead to decreased water levels in water bodies mainly as a result of evaporation, transpiration, low water table and reduced inflows from streams and rivers feeding into main water bodies. Reduced water levels will adversely affect utilization of water bodies and productivity of fisheries and aquaculture establishments in a number of ways. Reduced water levels in the water bodies, coupled with increased temperatures, will favour rapid growth of invasive aquatic weeds such as Water Hyacinth *(Eichornia crassipes)*, Azolla *(Azolla nilotica)*, among others, which will result in colonization and choking of water bodies. The most vulnerable areas include bays, shallow lakes, reservoirs, pools, deltas, estuaries, fish landing points, water abstraction points, hydro-power schemes and fish ponds. Colonisation of water bodies, water ways and channels by invasive aquatic weeds will further result intointerference with primary production in water bodies, including fish ponds because of reduced sunlight which will not penetrate the water below the weeds. The water underneath the weeds will also have low dissolved oxygen (DO) because of increased Biochemical Oxygen Demand (BOD) due to decomposing biomass. Also, the weeds will cause obstruction to navigation and fishing in choked water bodies and waterways; create a conducive environment of increased risk of attacks from crocodiles, snakes, leeches and Hippos; increase the risk of water-based diseases such as bilharzia due to favourable conditions for vectors, among others; and an increase in the acidity of the bays due to the reduction of pH resulting from decomposed biomass.

Secondly, the predicted increase in rainfall variability will further increase the frequency of severe droughts which have already wreaked havoc in the fisheries and aquaculture sectors in the country. Some water bodies such as Lakes Chilwa and Chiuta have undergone more frequent droughts in the recent past. Data shows that Lake Chiuta dried up in 2017 whereas Lake Chilwa dried up in 1914 - 1915, 1966 – 1967, 1993 – 1994, 1995 and recently in 2018. Drought adversely affects fish production in both capture fisheries and aquaculture. In capture fisheries low water levels result in habitat loss especially shallow areas where breeding, feeding, nursing and foraging occurs. In aquaculture, low water levels result in increased predation levels and shortened rearing period where a farmer is forced to harvest while the fish have not reached the desired size. Low water levels also result in deterioration of water quality. Among others, increased water column temperatures, reduced dissolved oxygen concentration, proliferation of harmful and toxic bacteria, reduced pH all pose serious threats for the survival of aquatic life including fish. Persistent droughts also lead to drying up or reduced river flows affecting fish migration upstream or downstream. Some fish species such as Mpasa- (*Opsaridium microlepis*), Sanjika (*Opsaridium microcephalum*), Ntchira (*Labeo mesops*), Mlamba (*Clarias* spp) among others move upstream to breed or deposit young ones. After breeding, these fish migrate downstream to larger water bodies where they find refuge and are assured of abundant food resources. As such loss of riverine habitats due to drying up of rivers or streams results in spawning failure which consequently leads into decline of fish populations raising the probability of extinction for those species with narrow distribution ranges.

Besides the increased frequency of severe droughts, the models also project a shortened rainy season with highly intense rainfall. The high-intensity rainfall will pose increased risks of severe flooding (Figure 6), flash floods and landslides which will destroy fish ponds, farmlands, homes and infrastructure key to sustainable fisheries and agricultural production. This will also lead to increased sedimentation with attendant eutrophication as has recently been experienced in Lake Malombe. Such scenarios will negatively impact livelihoods and local economies of populations relying on fisheries and allied activities.

The increased temperatures will enhance the growth of toxic algal species such as the blue-greens which flourish in hot weather conditions. The Blue-green algae produce a highly toxic poison which is lethal to fish and in situations where algal blooms have formed, resulting in fish kills. In addition, algal blooms also produce bad odour, deplete dissolved oxygen (DO) and cause rapid deterioration of water quality, rendering the water unusable and unpalatable to most organisms, including humans.

4.8.4 Potential Adaptation Strategies

The major threat to the sustenance of the fishery industry in Malawi is overfishing. As such, enforcement of regulations regarding sustainable fishing in the country's water bodies is an absolute necessity. Also, is important to keep the numbers of fishers to manageable levels, with strict controls on the type of gear used.

The impacts of invasive aquatic weeds like Azolla and Water hyacinth can be reduced by installation of strong barriers in targeted areas of the water body to enable easy harvesting of the weeds when trapped and arresting further spread.

In the event of severe droughts where water bodies are likely to dry up and hence threatening survival of resident fish species as has happened in the cases of Lakes Chilwa and Chiuta, the plausible solution will be to move affected fish species to temporary bio-secure facilities. Fish will have to be kept in these temporary facilities until the affected water bodies naturally refill after which restocking will then have to be conducted. In the previous drought episodes where Lake Chilwa dried up, fish species from the lake had been temporarily moved to ponds at the National Aquaculture Centre in Domasi and were re-stocked after the lake filled up again.

To minimize drastic reduction in groundwater tables and degradation of water bodies, it is imperative to promote Soil and Water Conservation through the introduction of Integrated Catchment Management (ICM) practices. Enforcement of existing buffer zones along watercourses would also consolidate the gains from ICM interventions. Also, fish resource access restrictions and Community Based Systems to safeguard the fish resources should be encouraged.

Other adaptation measures may include: (a) enhancement of breeding program for affected fish species where national and private hatcheries can be introduced to produce fingerling for stocking; and (b) the use of fish cage farming to promote in situ water use. Also, there will be a need to find alternative fish species that can grow faster to cope with short duration of water in the ponds.

Other adaptation measures include the following:

Promotion of Climate Smart Aquaculture.

1) ***Deep-large ponds***

The use of deep-large ponds to store water for a prolonged length of time before drying up has proven very effective in lessening the adverse impacts of droughts on aquaculture production. In addition, the technology increases fish productivity and profits for the local farmer as it uses higher stocking densities.

2) ***Promotion of cage aquaculture***

The small scale fish farmers are likely to be impacted by climate change as a result of global warming. Water availability for fish farming cannot be guaranteed due to impacts of climate change. It is likely that some adaptive measures need to be developed particularly for inland aquaculture. Adaptive measures include the introduction of improved technologies that would withstand extreme weather conditions like cage culture.

In situations where ponds are drying up because of high temperature, cage culture would support aquaculture production (Figures 8 and 9). Most probable impacts of climate change could range from physical destruction of aquaculture facilities, loss of stock and spread of fish diseases.

Figure 4. 25 Large – Scale Circular Cages in Lake Malawi

Figure 4. 26 Small – Scale Hexagonal Cages in Lake Malawi

3) Protection of Protected Areas

Since the establishment of Lake Malawi National Park in 1982, no other lake has been subjected to such restrictions. 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.

4) Improved Coordination Among Riparian Countries

There is lack of acoordinated regional approachto the management of fish resources in Lake Malawi/Nyasa/Niassa among Malawi, Mozambique and Tanzania. Mozambique and Tanzania are the two critical riparian states with joint management programmes with Malawi of Lake Malawi aquatic ecosystem. There have been joint Lake Malawi research programs in the past, but such programmes have not been very effective.

5) Enforcement of buffer zones for Lakes and rivers

While regulations exist for the conservation of buffer zones for both rivers and lakes, enforcing the regulations has been a very big challenge. The Department of Irrigation has a 10 m buffer zone regulation for which farmers are supposed to observe. However, in many lakes and rivers, cultivation in marginal and river banks is the order of the day. The problem with not leaving a pristine buffer zone is that when the first rains come, most of the loose soil and organic matter are transported into the rivers, ending up getting dumped in the lakes. An example where this practice has negatively affected the flow and availability of water is Likangala River drains into Lake Chilwa (Figures10 to 12). Farmers have opened rice and maize gardens along the river and at the mouth of Lake Chilwa. Deep pools in Likangala Rivers have been shown to play a major role in the rebuilding of fish stocks in Lake Chilwa. Unfortunately, with the current trend, it means

Figure 4. 27 Dry Likangala River, a tributary of Lake Chilwa with a cultivated buffer zone

that most deep pools are filled with sediments. In addition, most of this loose soil is transported into Lake Chilwa which has contributed to observed drying up.

Figure 4.27: The mouth of Lake Chilwa where Likangala River flows.

4.9 Forestry

Forests play an important role in the socio-economic growth and development of Malawi. They 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. Despite the important role that forests play in Malawi, they are under threat of depletion. For instance, in 1975, 57% of Malawi was classified as forest, while in 2000, only 28 % was classified as forest, and the current (2019) stands at 23%. Other records show considerable reduction in forestland from 4.4 million hectares in 1972 to around 1.9 million hectares in 1992 (EAD, 1998; 2001).

Forests and woodlands are estimated to cover 3,237,000 ha, about 34% of the total land area of Malawi (FAO, 2010). This figure was extrapolated from the 1993 Forest Resources Mapping and Biomass Assessment for Malawi Report (GoM, 1993). The 1993 report estimated forest cover at 2,642,800 ha while the Malawi report of 2010 for Food and Agriculture Organization (FAO) gives an estimate of 3,830,00 ha for the same period. The discrepancy is due to the use of different forest classification systems. These figures are seriously outdated, and the extent of forest cover is now likely much lower. However, no comprehensive survey of forest cover has been done since 1993.

Main threats to forests in Malawi are deforestation and forest degradation. Deforestation refers to a total change in landscape and land use, typically the removal of all trees in a forested area to create land for agriculture and settlements. Forest degradation refers to deterioration in forest condition. Forest degradation is manifested in reduced crown cover (forest density) due to selective tree cutting; poor tree health due to frequent fires and debarking for medicines; and reduced biodiversity due to selective tree cutting (i.e. of timber trees). In estimating forest cover, forest reserves are assumed to be intact, although in actual fact they are often degraded due to illegal cutting of trees for charcoal, firewood and the collection of edible caterpillars.

According to the Malawi official report to FAO (2010) and FAO forest classification system, deforestation rate is estimated to be 1% per year. The 1993 Biomass Assessment Report put the deforestation rate at 2.8%. If forests were declining at the rate of 2.8% annually, Malawi's forest cover would be 1.5 million hectares. But this is not the case since protected forests alone account for about 2.2 million hectares. Therefore, it makes more sense to use the FAO forest classification system, which puts the current forest resources at 3,237,000 hectares, representing 34% of land area. Actions that directly cause forest decline are called 'direct or immediate causes' while factors that influence actions are called 'underlying' causes (CIFOR, 2000).

Deforestation increases soil erosion which leads to reduced agricultural production. According to the Economic Study (GoM, 2010), Malawi lost MK7,540 million in the agriculture sector in 2007 due soil losses. This was 1.6% of the GDP at the time and 6.3% discounted over 10 years. Deforestation and forest degradation have contributed to reduced electricity generation. Siltation and water weeds blockages reduce the water flow in the river resulting into high cost of electricity generation. As a result power cuts and fluctuating power levels are a major problem. Forest degradation affects livelihoods, especially that of women and children. Women and children spend more time searching for firewood and forest foods. Forest resources have an important safety net and income equalizing effect across rural households, particularly those from poorest segments who earn their

Malawi's forest cover 25% (23,677 km^2) of the total land area. Miombo woodlands cover 22,857 km^2 while plantation forests cover 820 km^2. Pine and Eucalyptus are the most common trees in the plantations while Brachystegia is the most prevalent tree genus in miombo woodlands.

Malawian forests are either classified based on land tenure or by type. When defined by type, forests are grouped into natural/indigenous or plantation forests. When classified by land tenure, forests in Malawi may be classified as Public, Customary or Private according to the Malawi National Land Policy (2002). Over 70% of the land under the Protected Areas network was gazetted before independence in 1964. Land under protected areas has increased steadily from 1897, when Lake Chilwa and Elephant Marsh game reserves were created. In 1998, Malawi had a total of 94 protected areas (comprising 85 Forest Reserves, five National Parks and four Wildlife Reserves) which occupied a total of 1,869974 ha. Data from Forestry Department shows that the number of forest reserves has now increased to 88, for a total of 97 protected areas that occupy about 2,018,198 ha. This means that land under protected areas has increased by 148,224 ha (8%). Currently, three forest reserves are proposed for protection: if approved, this will bring the number of protected areas to 100. In addition, there are over 240,000 ha of ungazetted land that is being considered for formal protection.

The primary reason for forest reserves is catchment protection. In addition to this function, forest reserves are crucial for biodiversity conservation, protection of sources of water supply, erosion control, nutrient recycling, carbon capture and storage. The Public Lands Utilization Study (PLUS) of 1998 reported that the initial three forest reserves in Malawi were created for conservation of biological diversity (Orr *et. al.*, 1998).

4.9.1 Importance of Forests

According to the Economic Valuation of Sustainable Natural Resources Use in Malawi of 2011, forests contribute 6.2% to the GDP. Forests and trees are important for environmental protection and provision of environmental goods and services. Forest supply more than 96% of the country's energy need. Apart from energy, trees provide timber and non-timber forest products.

The importance of forests and trees to Malawian livelihoods cannot be over emphasized. People depend on forests for provision of construction materials (poles and timber for construction); health (food and medicinal herbs), financial capital through sale of forest products (timber and non-timber); cooking (96.7% of people use firewood or charcoal (GOM, 2005) and for religious ceremonies. Managing forest resources in a sustainable manner therefore has enormous benefits for the people that depend on forest resources for a living. The Department of Forestry employs about 6,400 people. Forests play several roles in the maintenance of healthy ecosystems. They provide a habitat for diverse flora and fauna, protect watersheds, regulate climate by sequestering (capturing) carbon dioxide and are important for eco-tourism. Another environmental function of forests is that of preventing land degradation and controlling soil erosion and water loss. These functions are essential for the continued productivity of the agricultural sector in Malawi.

Forests have experienced high deforestation rate estimated at 2.8% representing an annual average loss of 250,000ha of forest cover. The direct causes of deforestation include agricultural expansion; human settlement; uncontrolled fires; unsustainable harvesting for energy (charcoal and firewood) and timber requirements.

4.9.2 Vulnerability of Forests

Past vulnerability assessments of the forest sector in Malawi to impacts of climate change used both the Holdridge and Gap Models. 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. 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) biotemperature. 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. The change in Malawi reflects increasing dry conditions, with forest types progressively changing to drier forest types. The implication of this scenario is that there will be species change in favor of tree species which are better adapted to drier environments. These changes in forest types have implications on the biodiversity composition of the forests. The Gap Model was used to analyze the performance and behavior of six tree species only, out of 100 known species from Dzalanyama Forest Reserve in Lilongwe district, Central Region. 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 show that climate change will lead to a decline in wood productivity over time. An assessment using the Holdridge Model shows that the Dzalanyama 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 impact of climate change in the forestry sector was assessed in the whole country. The assessment was conducted based on five climatological zones (Figure 4.29). The following National Forest Inventory (NFI) data for different climatological zones were used:

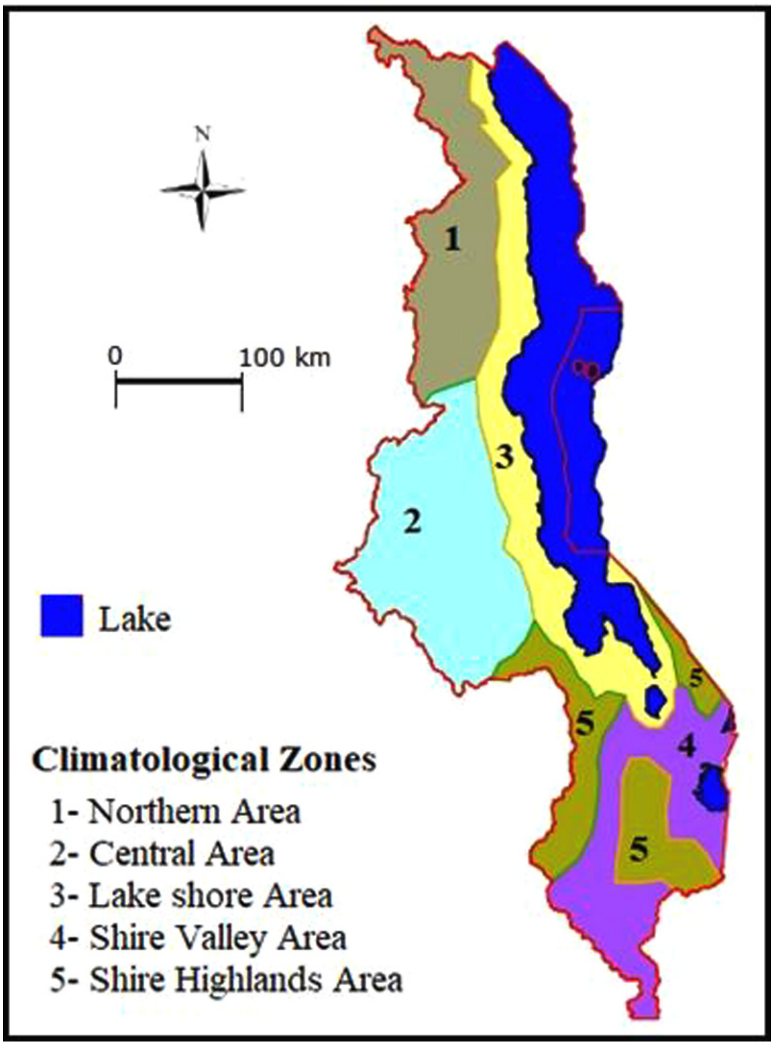


Figure 4. 28 Malawi's five climatological zones

a) Northern area – Misuku and Perekezi forest reserves, Chileta and Chowe village forest areas in Rumphi and Chitipa, respectively;
b) Lake shore area - Chinyakula village forest area in Nkhata Bay
c) Central area – Dzalanyama and Ntchisi forest reserves
d) Shire highlands area – Chongoni and Dzozi-Mvai forest reserves
e) Shire valley – Liwonde national park, Lengwe national park and Mwabvi wildlife reserve.

Three scenarios were used in the assessment. These include: Near century (2011-2040), mid-century (2041-2070), and end-century (2071-2100). The projected temperatures and precipitations for the three scenarios were obtained from Department of Climatic Change and Meteorological Services, Malawi. In the assessment, Holdridge Life Zone (HLZ) model was used to assess climate change impact on forest type while QGIS3.2 was used to produce the forest type maps. In addition, GAP-Formind modified model was used to assess the impact of climate change on forest living biomass, tree basal area and tree numbers. The current forest living biomass (above and below ground biomass) was estimated using the models developed by Kachamba et al. (2016).

Climate change projections indicate that some forests would significantly change while others would not (Figure 4.30).

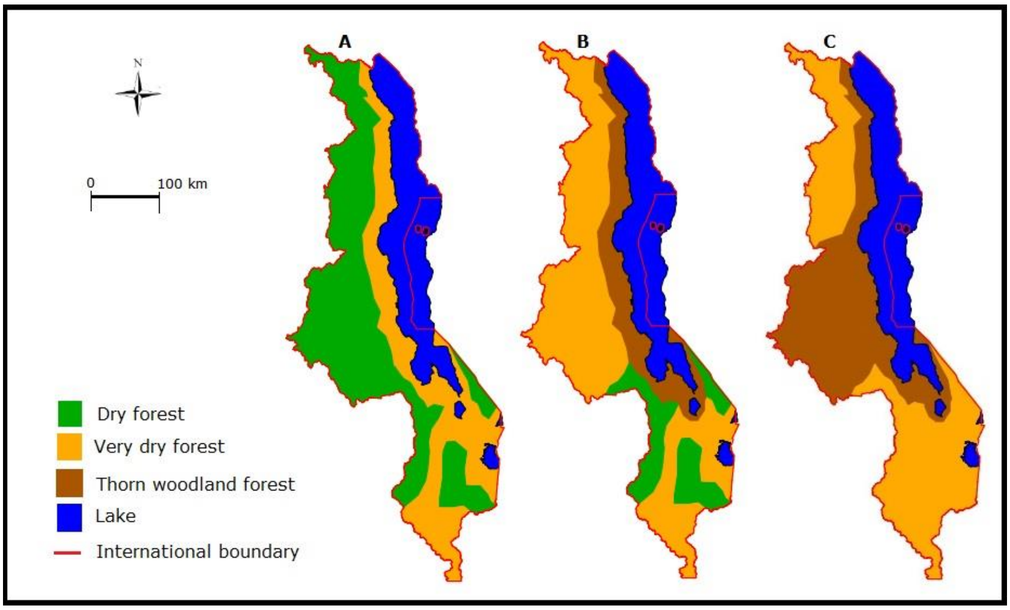


Figure 4. 29 Impact of climate change on forest types using Holdridge Life Zone (HLZ) model under three scenarios, A: Near century (2011-2040); B: Mid-century (2041-2070); and C: End-century (2071-2100)

For example, the northern area and central area forests would change from dry forest in near century to very dry forest in mid-century. The central area forests would further change from very dry forest in mid-century to thorn woodland forest in end-century. The lake shore area forests would change from very dry forest in near century to thorn woodland forest in mid-century. The shire highlands forest would change from dry forest in mid-century to very dry forest in end-century. However, the shire valley forests would not be affected by climate change.

4.9.3 Impact of climate change on forest living biomass, tree basal area and tree number

Summary of the results on the impact of climate change on forest living biomass, tree basal area and tree number are presented in Figure 3. The results show a significant decrease in forest living biomass for northern area forests (2,300 kgha^{-1}yr^{-1}) and lake shore area forests (1,200 kgha^{-1}yr^{-1}) from near-century to mid-century. Similarly, projections show a significant decrease in forest living biomass for central area forests (1,000 kgha^{-1}yr^{-1}) and shire highlands forests (1,600 kgha^{-1}yr^{-1}) from mid-century to end-century. On the other hand, the projections show that forest living biomass for shire valley area forests would not be highly affected by climate change.

The projections further show a significant decrease (40%) in tree basal area for northern area forests from near-century to mid-century. Similarly, the results indicate a significant decrease (32%) in tree basal area for shire highlands area forests from mid-century to end-century. Conversely, tree basal areas for shire valley, lake shore and central area forests would not be highly affected by climate change.

In addition, the projections show a significant increase in number of stems for northern area forests (13 stemsha^{-1}yr^{-1}) from near-century to end century and a significant increase in number of stems for lake shore area forests (8 stemsha^{-1}yr^{-1}) from near-century to mid-century. Equally, the projections show a significant increase in number of stems for shire highlands area forests (8 stemsha^{-1}yr^{-1}) from mid-century to end-century. On the other hand, number of stems for shire valley and central area forests would not be highly affected by the climate change.

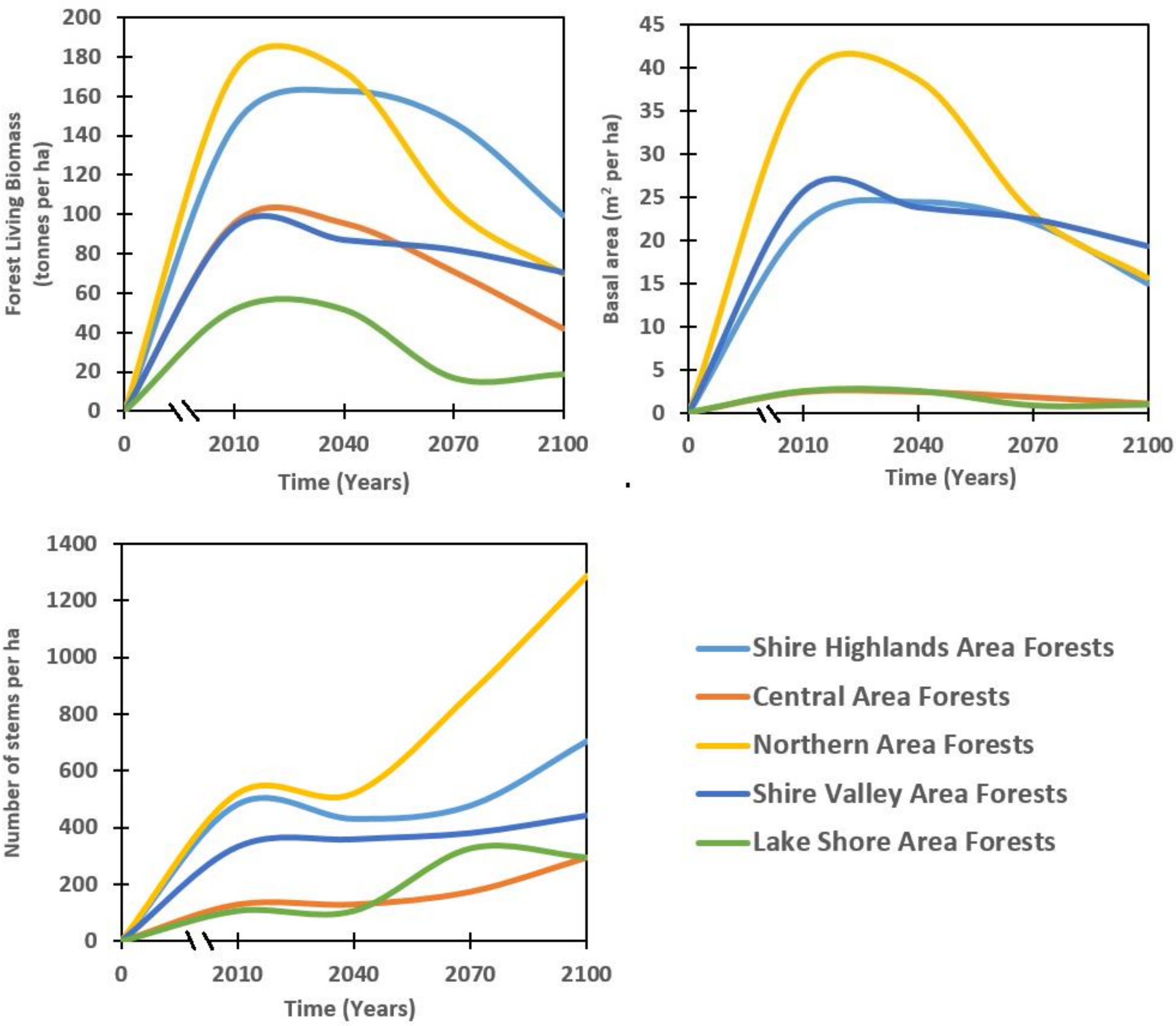


Figure 4. 30 : **Prediction on the impact of climate change on forest living biomass, tree basal area and tree number for different climatological zone forests in Malawi**

4.9.4 Potential Adaptation Strategies

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 Organizations (CSOs). The proposed adaptation measures include the vollowing: (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.

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 conditions (more than 36 weeks). The indigenous tree species adapted to such environments include: *Cordyl Africana, Sclerocarya birrea, Steculia appendiculate, Albizziaharveyi, Bosca salicifolia, Dalbergia melanoxylon, Tamarindes indica, Loncocarpus capassa,Adansonia digitat, Acacia negrescens, Acacia tortilis, Combretum imberde, Ficus spp, Ziziphusmauritania, 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, Acaciakarro, Azadrichta indica, Eucalyptus camadulensis, E. teretoconis, Gliricidia sepium, Sesbaniasesban, 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 under climate change scenario. 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. Other adaptation measures to be considered are: (a) promotion of natural regeneration of tree species; (b) promotion of participatory forest management; (c) promotion of tree site matching; (d) produce and promote new tree seed varieties; (e) promotion of biological control on new pests; and (f) seed bank for drought resistant tree species

4.10 Tourism

Tourism is the world's third largest export sector after chemicals and fuels ahead of automotive products. According to the World Travel and Tourism Council (WTTC), in 2018, tourism contributed USD8.8 trillion to global GDP. One in every ten (10) jobs (319 million) in the world was in the travel and tourism industry and 1 in every 5 new jobs created in the global economy in the past five year was in tourism. A total of 1.326 billion tourists, 28.8 percent of which were domestic and 71.2 percent international, travelled globally generating over USD1.34 trillion in revenue.

In terms of purpose of visit, 55 percent of the tourists travelled for leisure, recreation and holiday; 13 percent for business and professional reasons; 27 percent travelled Visited Friends and Relatives (VFR), health and religion and 6 percent did not specify reason for travel. On mode of transport used, 57 percent of global tourists travelled by air, 37 percent by road, 4 percent by water and 2 percent by rail. Africa accounted for 8.5 percent of global tourist arrivals and generated USD194 billion in receipts. For most developing countries, tourism is in the top export category. The SADC region tourism sector contributed 8.4 percent to the regional economy and 6.8 million jobs. In 2017, Malawi received 837,000 tourists generating over MK26.8 billion in visitor exports. In 2018 tourism contributed MK403 billion to GDP representing 7.7 percent. Over 233,000 were directly employed in the sector representing 3 percent of total employment and 524,500 were indirectly employed by the sector representing 6.7 percent of total employment.

Tourism is a highly seasonal sector which is vulnerable to climate change. Research shows that climate change is one of the major factors that affects global tourist flows. One of the major reasons people leave their countries as tourists, especially in the developed world, is to have temporary relief from adverse climatic conditions and experience favourable weather conditions in developing countries which are mostly located in tropical regions. In tourist originating countries factors such as heat waves or extreme cold conditions force people to travel to warmer regions.

However, climate change, which is characterised by extreme weather conditions such as severe floods, storms, and droughts, has over the years reduced the fair weather advantage developing countries have had over developed regions. Studies show that more people, especially in Europe, are now preferring to take holiday's closer home in countries that have similar favourable weather conditions to developing countries such as Spain, Portugal, France, Egypt, Tunisia, among others.

Malawi is endowed with a wide variety of flora and fauna and has varied topography ranging from mountains, valleys, plains, lakes and rivers. The country's tourist product base is predominantly nature and culture based and is evenly spread across the length of the country. Lake Malawi, which is the life blood of Malawi's tourism sector, claims a large part of the country's landscape, and together with the country's other water bodies, makes up 20 percent of the country's total land area. The Lake is susceptible to unpredictable changes is water levels due to alternating flood and drought conditions caused by climate change. This affects utilization of most of Malawi's tourism facilities which are concentrated along the shows of Lake Malawi. Malawi currently promotes five tourist products lines namely; Lake Malawi and water; Nature; Wildlife; Culture and People; and Meetings, Incentives, Conventions & Exhibitions (MICE).

The recently approved Malawi National Tourism Policy acknowledges climate change as a emerging issue which is exerting pressure on tourism resources. The Policy identifies climate change as one of the key cross-cutting issues that impacts on tourism sector development and therefore provides direction for development of strategies to mitigate against effects of climate change on the sector.

The tourism sector has not conducted a sector climate change vulnerability and adaptation assessment study. However, based on observations the following are some of the climate change issues impacting on the sector:

- Reduced visitations to some national parks and wildlife areas due to reduced probability of viewing game due to drying up of water holes. Examples include Mwabvi wildlife Reserve which has been neglected by Wildlife authorities;
- Unsustainable harvesting of trees in places of outstanding tourist beauty such as Zomba plateau, Chikangawa forest and Mount Mulanje which has affected the aesthetic beauty of tourist resources and made them more vulnerable to climate change;
- Disregard of 35 m limit to development along the lakeshore by tourism business operators which puts tourism infrastructure at a risk;
- Unsustainable clearing of natural forests by Tourism operators to construct tourism facilities and infrastructure;
- Use of fossil energy (generators) during power blackouts and limited use of solar energy;
- Lake debris washing up to the beach when Lake water level run low especially around Sunbird Nkopola Beach;
- Reduction in beach area size due to rising water levels in the lake especially at SunNSand Beach resort where beach was reclaimed from the Lake;
- Absence of a climate change impact risk map in disaster prone areas to guide tourism development;
- Little enforcement on green tourism which minimizes water usage, not using environmentally friendly laundry detergents and bath soaps;
- Poor waste water management in tourist areas;
- Wanton cutting of trees and environmental degradation in major tourist resource area such as Mount Mulanje, Viphya Forest, Zomba plateau

The country's tourism high dependence on nature and cultural attractions, which are mostly in the open environment, makes it vulnerable to climate change effects. Research has shown that Malawi is highly vulnerable to effects of climate change and variability such as severe droughts and devastating floods due to its location along the Great Rift Valley. Further, due to increasing pressure on natural resources by a fast growing population the country continues to experience environmental degradation of massive proportions. Studies show that over the past 50 years Malawi has experienced over 19 major floods and 7 droughts, most of which have been experienced in recent years.

Recently, effects of Cyclone Idai and Cyclone Kenneth from the Mozambique region in the region in general and Malawi in particular greatly affected infrastructure and displaced communities in Malawi’s major tourist districts of Mangochi, Zomba, Machinga, Mulanje, Thyolo and the city of Blantyre. According to reports, the cyclone damaged major tourism support infrastructure such as roads, bridges, electricity poles and water supply resulting in disruption of the tourism supply chain and tourism businesses. Further, as a result of the adverse weather condition in 2016, for example, a bridge to Majete Wildlife Reserve which is one of Malawi’s finest wildlife reserve, was washed away and a pool in one of the lodges flooded making it inaccessible to tourists.

The persistent and cyclic drying up of Lake Chilwa, whose wetland protects up to 4,000 animal plant species and rare bird species, due to erratic rainfall patterns and environmental degradation along rivers that bring water to the lake, has affected birding tourism in the area. Climate change has also put the Malawi tourism resource base under great risk and in some cases has reduced the aesthetic appeal of tourist attractions due to alternating extreme flooding and drought conditions. Studies show that climate change have impacted on ecosystems of Mount Mulanje, Nyika and Vipya plateaus which forms the spine of Malawi’s tourist resource base.

Climate change in the region also continue to affect the over 70% of Malawi’s international tourists who come from the SADC region with Mozambique, Zambia, Zimbabwe, South Africa and Tanzania contributing a bulk of the regional arrivals. Overseas tourists, who are also sensitive to climate change perceptions, constitute under 30 percent of total international arrivals and from Malawi’s main markets of United Kingdom, United Sates of America, Germany, The Netherlands and China.

4.10.1 Importance of Tourism

Globally, tourism has been adopted by both developed and developed countries as a means for generating much needed foreign exchange, creating employment and businesses, and a tool for inclusive economic growth. Research shows that 46 out of 50 Least Developed Countries (LDC) rely on tourism for generating foreign exchange. Tourism is also the only sector most developing countries experience a surplus over developed countries in their Balance of Payments (BoP). The tourism sector, by its nature, cuts across several sectors of the economy such as agriculture, transport, health, culture, among others and acts as a catalyst for deriving benefits from these sectors. For example preserving and conserving wildlife, forests and cultural sites alone cannot produce direct benefits to a country unless tourism develops and promotes them for economic benefit. Tourism therefore helps a country to optimally utilize its available resources.

The Tourism sector is one of the key sectors a country can use to build its international brand value as tourists travelling to countries form own perceptions about countries. Most countries promoting trade and investment opportunities have successfully utilized their existing tourism brand capital to promote themselves as favorable destinations for trade and investment. Countries have also used tourism to build a social structure that demand a better quality of life thereby expanding the economy by creating local demand for non-basic products and services. This also creates a sense of patriotism to citizens and also improves how they view their country as a desirable nation that has capacity to fulfil needs of the demanding international visitor.

Further, tourism, which is "an industry of industries" encompasses several sub-sectors, such as transport (air, rail, water and road); tourist accommodation sector; catering sectors; recreation sector; tour operating and travel agency, among others thereby creating opportunities for economic diversification. Because of its complexity and overlapping nature, the tourism sector has a higher multiplier effect than most industries which can accelerate economic growth.

In Malawi, under the Malawi Growth and Development Strategy (MGDS) III, Government has prioritized tourism as one of the key sectors to drive economic development. Further, tourism also features under Sustainable Development Goals (SGDs) number 8, 12 and 14 and has been identified as one of the sectors through which to achieve these goals. Due to Malawi's major tourist resources and attractions being located in remote and underdeveloped areas, tourism development has taken development such as good roads, electricity, piped water to these areas thereby benefitting once marginalized communities. Tourism businesses that have developed in these areas have also stimulated development of small businesses downstream within local communities that supply them with agricultural produce, curios, local clothing, among other items, some of which are sold to tourists. This has in turn stimulated growth of "rural industries" around tourist facilities.

Tourism also provides a strong case and motivation to countries to preserve their nature, environment, wildlife and culture due to their utility value to generate income from tourist spend. For example, Lake Malawi National Park, within Lake Malawi was declared a World Heritage Site by UNESCO in 1984 and also declared the World's first fresh water marine park because it protects over 1,000 species of cichlids fish 350 of which are endemic to Lake Malawi. However, research shows that the cichlids, *mbuna*, which are a draw card to tourists into the country, are increasingly at risk from the effects of climate change and environmental degradation. Malawi's rainfall pattern is also increasingly becoming less and less reliable. Primarily, the tourism sector exits because of the tourists attractions which Government decided to protect. Failure to protect these resource will result in the collapse of the tourism sector. It is therefore essential that the tourism sector, both public and private, take a keen interest in climate change issues and ensure the sector puts in place adaption strategies for the sector to mitigate against the effects of climate change.

The tourism sector is both vector and victim as it is a contributor to and a victim of climate change. Along the Tourism value chain there are a number of activities responsible for greenhouse gas emissions such as transportation and tourism facilities. Failure to implement adaptation measures in the Malawi tourism sector could have a severe impact on tourism businesses, tourists, Government, the destination, communities and the economy at large. For tourism businesses, not adapting to climate change would result in increased energy costs especially when rainfall patterns are erratic and enough hydroelectric power is not generated. In cases where temperatures rise they would also increase cooling costs in tourist accommodation and facilities and also reduce patronage of tourist activities, due to heat stress it causes to tourists, which generate revenue for the business.

Warm conditions also create a conducive environment for increase in pests populations and disease outbreaks. In case of flooding it can also increase risk to infrastructure constructed very close to the Lake or a river as it may cause damage. It is also costly to restore a beach submerged by water due to rising levels of the Lake. In island resorts on Likoma and Mumbo on Lake Malawi, a rise in lake levels due to floods can completely swallow up the beach, rendering the islands unattractive to tourists.

Given the wide choice of destinations around the world, tourists are usually not keen to visit countries that are prone to adverse weather patterns such as storms, flooding or drought. Tourism is a highly seasonal industry and extended or unexpected rainy season can easily shorten the leisure season. High temperatures may make experiencing outdoor activities uncomfortable for tourists. When tourists do not visit an area due to adverse effect of climate change, tourism businesses suffer. Struggling business are prone to lay off their staff, pay less taxes to Government which affect in turn affect the national economy. Furthermore, communities will not find a market for their produce or tourists to buy crafts they produce.

4.10.2 Vulnerability of Tourism

Tourism regards climate as a mixed bag as the sector contributes to and also suffers greatly from the effects of climate change. The sector benefits from climate as a resource especially to tourists from very cold regions that are looking for a destination with all year round sunshine. Studies show that tourism is very sensitive to external conditions such as climate change. Slight change in weather can result to cancellation of flights thereby inconveniencing tourists that are eager to get to a destination or return home after a holiday. Examples abound where massive cancellations of flights, car hire and hotel accommodation bookings and activities have occurred and resulted in massive loss of business. Transport and tourist facilities contribute 95 percent of the greenhouse gas emissions. Air, water, road and road are modes of transport used by tourists to get to their destinations, utilise a lot of fossil fuel which in turn produces greenhouse gasses.

Extreme Dry Weather Conditions

In Malawi, the tourist calendar places the best time to visit the country, or the tourist season, between the months of April and November, just after and before the onset of the first rains. Of late, due to climate change long spells of drought, even extending to over a month, have been experienced in the middle of the rain season, that is, in January and February. This creates challenges for outdoor activities such as game viewing in National Parks and cultural events such as the world famous Lake of Stars Music Festival. Dry Research has shown that Malawi’s rainfall patterns is one of the most unpredictable in Africa. For example, Lake Chilwa, one of

Malawi's international wetlands which protects a waterfowls and supports birdlife and is famous with bird watchers, has dried up several times in the past five or so years due to erratic and cyclic change in rain patterns. When there is drought condition in the country, the price of food goes up due to crop failure as even basic food stuffs have to be imported for the tourism sector. Further, livelihoods of people in communities around the tourist business would be greatly affected either through loss of business or employment. Dry weather conditions also reduce the quality of natural vegetation in wildlife and forest areas. This in turn affect game viewing and birdlife in the protected areas reducing the value of tourist experience.

Severe Flooding and Storms

Unexpected and severe flooding has also affected tourism in the country especially when road network, bridges, water supply and electricity infrastructure is damaged and in some cases the State President of the country had to declare a *State of Disaster* in affected areas. This makes it difficult for tourists, especially those that have already paid for their accommodation, transfers and activities having to fail to access tourist destinations such as the lake and national parks. Studies have shown that rains and cold weather spells have even occurred in tourism peak months of September and October when the weather is expected to be dry and warm thereby shortening the tourism season.

In addition, running tourism business operations become more costly, when electricity generating infrastructure is damaged by flooding. Use of off grid energy sources such as diesel generators increase operational costs and reduce profitability of tourism businesses. Furthermore, climate change impacts lead to damage to the destination reputation and to tourist facilities which may be costly to repair or restore. Persistent power outage in the past year has greatly affected Malawi's image as a tourist destination.

Increasing risks from climate change could also lead to rising in insurance premiums. Heavy floods increase levels of the Lake where most of the country's tourist facilities are located. This can lead to damage to tourism infrastructure that is located too close to the beach where a slight rise in water levels in the lake can swallow up the beach and infrastructure such as beach huts.

Table 4.24 below summarizes some of the impacts of climate change to tourism in Malawi.

Table 4. 24 Impact of climate change to tourism in Malawi

Impact	Implication for Tourism
Warmer climate and drought conditions	Prolonging tourism season crowds out domestic tourism, increase discomfort for tourists; increase cooling costs for tourism businesses especially during workshops; increase populations of disease parasites such as mosquitos (malaria) and tsetse fly (sleeping sickness) in wildlife protected areas

	such as Nkhotakota Wildlife Reserve and Kasungu National Park
Increased rainfall and flooding across the country	Damage to tourist facilities and support infrastructure such as road networks, bridges water supply, electricity, telecommunication making tourist facilities inaccessible and increase costs of tourism business operations. Affect hydro-electric power generation due to flooding of turbines and/or increased debri thereby increasing operational costs due to alternative energy supply costs Damage to tourist attractions such as flooding of wildlife areas and game viewing infrastructure and cultural sites and monuments resulting in reduction of their aesthetic value to tourism. Increased risks of landslide on tourist facilities at the foot of Mulanje mountain and Zomba plateau due to flooding
Cyclic rise / drop in Lake Malawi levels	Damage or reduction of beach size during rising lake levels. Increased costs of restoring damaged beach. Damage to facilities near beach such as beach huts, sporting activities such as beach volleyball. Poor visibility of lake waters making diving and snorkeling not viable. Drop in lake levels reduce habitats of cichlids which breed and occur in rocky areas especially in islands. Threat to swallowing up of Lake Malawi islands beach fronts due to rises in lake level

4.10.3 Potential Adaptation Strategies

Since climate change can have a devastating impact on the tourism sector, it is imperative for the sector to develop adaptation strategies to mitigate against these impacts. In general, climate change affect decision making in the planning of tourism development and investment, and destination marketing.

Research has shown that Malawi as a country in general is vulnerable to extreme weather patterns, floods and droughts, owing to its location along the Africa Great Rift Valley. This places most of the country's major attractions in extreme conditions. For example, Malawi's key national parks, that is, Liwonde National Park and Majete, and Nkhotakota Wildlife reserves are vulnerable to both drought and flooding of the Shire river and Bua River respectively; Lengwe National Park and Mwabvi Wildlife Reserve subsists in predominantly extreme and harsh semi-arid conditions putting pressure on both wildlife water resources and making the areas susceptible to wild bush fires. Flooding or drought has destroyed wildlife habitats and delicate ecosystems resulting in migration of game important to tourist out of protected areas therefore affecting the sustainability and competitiveness of wildlife and Malawi as a tourist destination.

In the past investment and planning of siting of tourist facilities has not taken into account climate change. A case in point is the construction of most resorts along the shores of Lake Malawi very close to the beach which in most occasions has been affected by extreme fluctuation of the lake levels due to extreme weather conditions. Lake Malawi is also the main source of water used to power electricity generation for the country. A rise or fall of lake levels has affected electricity generation for the country whose source is mainly hyro along the Shire river, the sole tributary of Lake Malawi. Adverse climatic conditions have also greatly affected the state of tourism support infrastructure such as road networks, bridges, water supply and electric poles rendering tourist destination, which are situated in remote areas, inaccessible and without supply of essential utilities. The has affected tourism business operations and their profitability considering that tourism is a highly seasonal industry.

Extreme climate change has also affected the tourist arrivals to Malawi over the years. Research shows most Malawi dry spells have occurred in *El Nino* years. An analysis of annual international arrivals to Malawi between 2008 and 2017 (Table 4.25) shows that tourists arrivals to Malawi went down during years Malawi had floods or drought.

Table 4. 25 climate change imoact on Malawi international tourist arrivals (2008-2017)

Year	**Climate Change Impact**	**International Tourist Arrivals**	**Change in arrivals from previous year**	**Average Length of Stay (Nights)**	**Impact on tourism by climate change**
2008	Dry spell	742,000		N/A	Low agriculture production leading to rise in food prices, increased business costs, limited game viewing by tourists
2009	Dry spell	755,000	13,000	N/A	
2010	Dry spell	746,000	(9,000)	8.5	
2011		766,900	20,000	7.6	
2012	Dy spells	770,000	4,000	7.1	
2013		795,000	25,000	7.6	

2014	Devastating Floods	819,200	24,000	10.1	Damage to tourism and support infrastructure and attractions, high energy costs due to low electricity generation
2015	Dry spell	804,912	(15,000)	8.8	
2016	Dry spells	823,471	19,000	13.6	
2017		837,223	14,000	10.8	

Source: compiled by Author

Table 4.25 above, all things being equal, shows that international tourist arrivals figures to Malawi generally fell in most years that experienced a dry spell or drought. Between year 2008 and 2013 international tourist arrivals to Malawi only increased by 7.1 percent, that is, 53,000 tourists over a period of 5 years. During the same period the Average Length of Stay (ALOS) of tourists in the country, was lowest between 2011 and 2013 hovering between 7.1 and 7.6 nights. Later years experienced higher ALOS of between 10.8 and 13.8 from year 2014 to 2017.

In 2012, dry spell may have also contributed to the lowest annual increase in tourist arrivals in the period between 2008 and 2017 of 4,000. Further, devastating floods of 2014 and dry spells of 2015 led to a decline in tourist arrivals by 1.8 percent, that is, 15,000 tourists.

Whilst the tourist arrivals to Malawi might have been impacted upon by other factors, it is also evident that during the years Malawi experience adverse climatic conditions, tourist arrivals fell.

Since climate change in Malawi has a huge impact on tourism in Malawi, Table III summarizes short term, medium term and long terms measures are being recommended to mitigate against the impact of climate change on tourism in Malawi:

Table 4. 26 Proposed climate change adaptation strategies/measures for the Malawi tourism sector

Scope	Adoption Strategies / Measures	Relevance to Tourism	Barriers to Implementation	Measures for Removing Barriers
	Tourist Evacuation plan in affected areas	Many tourists visiting Malawi are vulnerable to climate change risks e.g.	Communication problems during disaster and lack of coordination / lack of incentives to	Mandatory development of climate risk & disaster management

Short term		flooding, drought & storms	develop plans at business level	plan at business level. Requirement for licencing
	Climate Adaptation sensitization to tourism operators and public	Tourism business operators in Malawi are exposed to climate change risks due to Malawi's high vulnerability	Tourism business not believing mitigation measures will directly benefit operations. No data exists in Malawi on impact of climate change on tourism. No Government incentives available to motivate businesses to adopt climate change mitigation measures	Provision of climate change impact to tourism statistics by Government to convince operators to change. Optional certification of tourism businesses complying with climate change mitigation standards
	Improved insurance cover	Insurance cover reduce financial burden and obligation of businesses arising from climate change impact on tourists and business arising from injury or damage to property	Few operators offering competitive insurance products and cover for tourist sector. Insurance cover considered costly by small tourism businesses.	Negotiations with insurance companies for competitive premiums. Sensitization of operators to take up insurance cover to reduce premium.
	Early warning weather communication to operators	Extreme weather affect tourism activities, accessibility & operations	Some operators in very remote areas may not be reachable due to lack of communication	Develop special communication platforms and tools to reach affected areas. Provision of

			infrastructure in remote areas	comprehensive weather forecast to tourism sector
	Energy saving measures	Tourism businesses have an interest to cut energy costs as they impact profits	Off grid energy sources costly for small tourism business	Promote use of energy saving bulbs, switching of lights, solar heating
	Tourism investment plan submissions / approvals to include climate change mitigation plan	Tourism facility vulnerability to climate change effects can be reduced if these are integrated at development stage	Lack of active enforcement of climate change legislative framework by relevant institutions such as Department of Environment	Increase enforcement of provisions / climate change mitigation compliance in relevant legislator frameworks
	Visitor management	Damage to climate change ravaged tourist areas can be exacerbated by uncontrolled visitor numbers and also increase risks to tourists	Business operators may not want to control / reduce visitor numbers for fear of losing profits	Visitor education, planned tourism development and improved visitor management
	Weatherproofing tourism activities	Most tourist activities are conducted out doors	Costly for small businesses to provide additional infrastructure for shading or weather proofing for tourists	Opportunity for communities to provide indoor venues built from local material such as wood and grass
	Use of non-motorized sporting equipment for tourism activities	Motorized sporting equipment like ski-boats cause pollution. Tourists are more health conscious and	Resistance by tourism operators as motorized sporting facilities	Encourage use of non-motorized equipment by providing

		want to use manual equipment	make them look more up-market	incentives. Use of biofuels in motorized sporting equipment
	Tree planting program for tourism operators	Trees help reduce carbon dioxide emissions and storm damage to facilities	Costs of exercise may deter smaller businesses from participating in the program	Include in country carbon trading schemes.
	Utilization of local materials and designs in tourism buildings / facilities (e.g. wood, grass)	Use of locally available materials help create unique & attractive ambience of facilities	Tourism businesses feeling use of local materials not good enough preferring imports	Recruitment of more tourism operators in the Best Buy Malawi Strategy and increased sensitization on relevant to climate change mitigation
	Improved water and waste management	Treated fresh water is essential for tourism hospitality business operations and is in short supply	Reluctance by operators to use recycled water or capture rainwater. May to pass on cost to consumer making stay more expensive	Enforce water and wastewater management as a condition and requirement for Tourism operator licensing
	Membership to climate change crisis committee	Tourism private and public sector are equally impacted by climate change, both as a contributor and victim	Lack of local resources and developing partner support for mitigating climate change issues in tourism	Strengthen private sector operators representation in relevant climate change steering and

				technical committees
Medium term	Enhance tourism facility designs and planning	Poor planning and siting of tourist facilities and amenities can make them vulnerable to climate change impact	Lack of a harmonized framework for enforcement of climate change issues across sectors	Develop a framework for enforcing minimum standards. Mapping of disaster prone areas around tourist attractions
	Climate Adaptation training to tourism operators	Tourism public and private sector operators lack information on climate change adaptation	Lack of interest by tourism sector in climate change adaptation which may be seen as increasing costs and affecting profitability	Training and provide technical support to ensure operators are implementing mitigation measures
	Tourism support infrastructure development plan	Public tourism support infrastructure such as roads, bridges, water and electricity supply essential to tourism operations	Resistance or reluctance of relevant government MDAs to implement / enforce climate change issues in public infrastructure development	Mapping of tourist areas prone to climate change impacts. Mainstream climate change issues in tourism support infrastructure design and construction
Long term	Increase tourism sector compliance of issues of climate change	Tourism climate change mitigation Strategies and legislation will formalize implementation	Absence of specific climate change mitigation strategies and weak tourism law	Develop and implement climate change mitigation strategies and include issues

				in new Tourism law
	Sustainable utilization of natural resources	Tourism largely depend on natural resources	Resistance by Forest authorities to harvesting planted forests in tourist areas. Granting tourism concessions to operators by Wildlife authorities without consulting tourism	Strengthen of inter-ministerial liaison on natural resource management
	Improve tourist facility / buildings designs standards	Tourism infrastructure affected by climate change	Lack of clear monitoring mechanism for tourism investment following approval of plans	Set up inter-institutional Task Team to monitor construction of approved tourism facilities
	Product diversification	Tourism resource is nature and culture based making it vulnerable to climate change	Resistance and reluctance by MDAs to cooperate with tourism on product development issues	Develop a multi-sectoral Product Diversification Strategy which would include issues of climate change in tourism
	Development of Tourism crisis Management strategy and Plan	The Tourism is vulnerable to external crisis including climate change	Tourism not mainstreamed in key sector such as wildlife, culture, environment	Mainstreaming climate change adaptation issues in tourism

Source: Compiled by Author from various sources and experience

4.11 Industry

Manufacturing Industry refers to industries belonging to International Standard Industrial Classification (ISIC) divisions 15 – 37 and it is defined as the physical or chemical transformation of materials of components into new products, whether the work is performed by power driven machines or by hand, whether it is done in a factory or in the workers home, and whether the products are sold at wholesale or retail. Included are assembly of component parts of manufactured products and recycling of waste materials.

Industrial development plays a key role as a prime provider of goods. Central to the process of demand diversification is the growth of the manufacturing sector. Manufacturing firms are key providers of new goods and increased variety within any economy. People's lives have been radically transformed by successive waves of technological revolutions all initiated in the industrial sector. These waves significantly increased the set of goods available for consumers and continue to do so today.

All countries, including Malawi, acknowledge the fact that industrial development is central to diversification of their economies; development of the productive capacity; and the creation of employment in order to reduce poverty and set their economies on a sustainable growth path. All developing countries that have been able to make a transition from low income to upper middle income and high income status, primarily Asia, have relied on the manufacturing sector as the main source and engine of growth.

According to the World Factbook, in 2018, industry sector contributed a share of 30% of total global GDP. However in all SADC Member States, the manufacturing sector's contribution was less that 20%.

Growing concerns about climate change present immense challenges for industrial development especially in view of industry's reliance resource based output, calling for countries like Malawi to grab opportunities presented by the use of green interventions in the form of low energy intensity, low carbon emissions and clean and efficient technologies.

The development of industries is an integral part of Malawi's economic growth and development agenda. This is crucial to the attainment of the country's aspirations of transforming from a predominantly importing and consuming to a predominantly producing and exporting economy. Currently the manufacturing sector contributes about 9% to GDP due to low value addition, but has high potential to contribute more. Consequently, industrial intensity is low with industrial output heavily concentrated on low technology resource based products such as food, beverages, textiles, clothing and footwear. According to the International Labour Organisation, employment in industry (% of total employment) in Malawi was 4.8% as of 2017. This offers scope for creating more employment opportunities in order to satisfy the national agenda.

A variety of products that are currently manufactured are from the following sectors: chemicals, building materials, beverages and food products, cosmetics, medical products, animal feed, agriculture implements, textile and garments, leather and leather products, packaging materials, plastic products, furniture, and metallurgical products among others.

An increase in industrial activities has the potential to contribute to job creation which would in turn catalyse wealth creation through backward and forward linkages and spill over effects on the economy. Considering that 85% of Malawi's population is rural based and dependent on agriculture, special attention is being given to rural industrialization and agro-processing. Numerous opportunities exist in production of farm implements and inputs, textiles and garments manufacturing, assembly of various items, furniture production, building materials manufacturing, food products, sugar cane products, beverages, dairy products, plastic products and other manufactured non-traditional products.

Currently, in order to maximise beneficiation of local resources the industrial cluster strategy is being actively pursued in order to benefit from the potential for value addition that would in turn optimise investment in new and high-value products with the aim of capturing the local, regional and continental demand. In addition, new opportunities in the extractive industry are being promoted as a way of enhancing investment in pursuance of the national economic growth agenda espoused in the Malawi Growth and Development Strategy III, the Buy Malawi Strategy and the National Export Strategy.

It is also important to note that increased industrial activities creates a resultant impact on the environment and consequently impinges upon climate change. Both the SADC Industrial Development Policy Framework and the National Industry Policy for Malawi recognise the impact of the environment and climate change on the growth and structural transformation of the industrial sector. Some of the key constraints and challenges highlighted are:

- Unsustainable harvesting of forest product for use in the construction of industrial infrastructure leading to depletion and hence climate change;
- Unplanned and unsustainable clearing of natural forests to pave way for agricultural activities necessary for production of raw materials required by industry;
- Noise pollution from generators during power blackouts arising form effect of massive deforestation related to industrial activities;
- Absence of a climate change impact risk mapping in disaster prone areas to guide industry and industry related developments;
- Little enforcement on green industrial investments;
- Poor waste management in industrial areas;
- Lack of appropriate industrial waste management systems and social sustainability of the environment;
- Ecologically unsustainable production of industrial input;
- Unsustainable exploitation of natural resources used as industrial inputs.

4.11.1 Importance of Industry

Malawi's development agenda is centred on nationwide poverty reduction, economic empowerment and ensuring food and health care security for the population. In 2006 Malawi launched the Malawi Growth and Development Strategy (MGDS) to serve as the over-arching development blue print. This was succeeded in 2012 by MGDS II with the objective of continuing to reduce poverty through sustained economic growth and infrastructure development. In 2017 the Malawi Growth and Development Strategy III was launched focusing on building a productive, competitive and resilient nation. It should be noted that in all three successive growth strategies, Industry occupies a vital and central position on the backdrop of the desire to significantly increase the sector's contribution to the economy's gross domestic product.

Since independence in 1964 the manufacturing industry has remained an important driver for the economic development and growth of Malawi. From 1980 to 2000 manufacturing has acted as an engine of growth despite the general decline of its contribution to GDP since 2010 by directly measuring the relationship between manufacturing value added (MVA) share and GDP; creation of employment opportunities due to the labour intensive nature of industry; expansion of trade and commerce through forward and backward linkages; expansion of agriculture as a source of inputs for the manufacturing industries; modernisation of the agriculture sector due to the need to produce increased quantities and high value inputs demanded by the manufacturing industry; contribution towards foreign exchange earnings through exports of high value products; providing a variety of choice to consumers through innovations in products available to consumers; the manufacturing industry has led to the creation of parallel and supporting sectors such as the tool and machine sub-sector, engineering, repairing and maintenance facilities, packaging services, logistical and supply services, wholesale and retail services; imports and export services; and general improvement in the country's welfare as a result of wealth created.

MGDS III underlines the importance of industrialisation of the economy noting that it is essential to maintain the long term economic growth of the country, and that it is needed to raise per capita income, create rural and urban jobs and viable entrepreneurship opportunities for both men and women, widen the tax base to finance Malawi's welfare requirements and address an unsustainable trade deficit. It also notes that industrialisation also benefits sectors such as tourism, health and education all of which rely on industrial development.

4.11.2 Vulnerability of Industry

Industry is vulnerable to effects of climate change as a direct consequence of activities caused by industry itself as well as effects arising from activities of other sectors of the economy. The impacts of climate change on industry are derived from five focal areas, which are at the same time also five dimensions of vulnerability.

The first focal area is the impact of climate change on the availability of resources and, by extension, on suppliers, in other words on the upstream production process. For instance, regarding a water management activity, the potential reduction in the availability of water including its quality is a factor of vulnerability. The same example can be applied to other industrial inputs whose quantity and quality is affected by environmental degradation.

The second area concerns the standards used in the design of infrastructure regarding whether they are robust enough in the face of climate change. In this case designers often use climate standards that are based on the past to determine the dimensions of infrastructure or production tools and "habit" has often hidden them behind figures whose climate origin has been forgotten.

The third focal area is the impact of climate change on the management of the industrial process; are there certain elements or characteristics of this process that are sensitive to the climate in general and to climate change in particular? For instance, power plant cooling using river or lake water is a case in point that is sensitive to climate variables. If the temperature of the water rises beyond a certain level, it can no longer be used for cooling.

The fourth area is that of demand and its climate sensitivity. This is a case for instance, of heating or air conditioning and its impact on electricity generation.

The fifth and final area concerns the occurrence of industrial climate incidents, in other words, climate disasters including violent storms, floods, droughts that cause direct and indirect damage to the industrial base.

The development of potential vulnerability indicators should be structured around these focal areas for practical reasons. What remains an issue in this respect are the differences among industry participants in their willingness or capacity to integrate climate issues into their decision-making and investment processes.

4.11.3 Potential Adaptation Strategies

In light of the foregoing discussion related to constraints, challenges and vulnerability arising from climate change we propose some priority actions as adaptation strategies or actions to mitigate climate change based on the recommendations of the 5th intergovernmental panel on climate change and the UN Framework Convention on Climate Change:

Table 4. 27 potential adaptation startegies in industry

	Issue	**Adaptation Strategy**	**Scope**	**Impact Potential**
1.	Energy	Reduction of energy intensity of industry by around 25% through upgrading, replacement and of the best available technology as well as through innovations.	Medium to long term.	Medium
2.	Greenhouse gas emissions	Improvements in emissions through efficiency in raw material use, recycling	Short to medium term	Medium

		and reuse of materials and products.		
3.	Other gases e.g. carbon dioxide	Explore opportunities in the reduction of other gases e.g. methane, nitrous oxide, fluorinated gases.	Medium term	Medium
4.	Crosscutting technology	Application of crosscutting technologies and measures can improve process performance and plant efficiency. Cooperation between companies e.g. in industrial zones could include sharing infrastructure, information and waste heat utilisation.	medium	medium
5.	Waste reduction	Increased attention on waste reduction coupled by reuse, recycling and energy recovery.	Short term	High

In addition to the forgoing proposals, the following multiscale strategies can be considered in climate change mitigation in the industry arena:

- Promotion of industrial clusters to minimise emissions associated with logistics and to facilitate the sharing of facilities and services and to couple waste to input;
- Add value to natural resources to ensure stabilisation of those natural resources, rural communities and biodiversity;
- Promotion of direct digital manufacturing to reduce waste, and minimise energy and emissions;
- Colour coding of materials used in multi-material products to facilitate easy recycling;
- Promote renewable energy generation (e.g. solar) by industry utilising the vast rooftop space of factory buildings.
- Promotion of the use of biodegradable materials such those for packaging.

4.12 Wildlife

Malawi has a wide variety of wildlife that is ecologically and socio-economically important to the country's economy. 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 four game reserves (Vwaza Marsh, Nkhotakota, Mwabvi and Majete), and these cover approximately 11.6% (22%?) of the total land area (Table 4.28). In addition, there are several private wildlife Ranches such as Kuti Community Wildlife Ranch, Nyala Park, Game Haven, Kaombe Wildlife Ranch among others. Malawi has a wide diversity of animal species: 207 mammal species, 658 bird species, 108 reptile species, 56 amphibians and over 500 fish species occur in Lake Malawi National Park (LMNP) (REF). But the rate at which some of the protected mammal species are being depleted has devalued most of the protected areas in Malawi to the point that they are unable to attract significant tourism, thereby making the country less competitive in the region. For example, the population of elephants during the 1970s and 1980s was estimated at over 4,000 while currently the population is slightly over 1,000. Black Rhinos became locally extinct in the 1980s but were reintroduced in Liwonde National Park and Majete Wildlife Reserve where the population has been increasing steadily. Ivory trafficking, hunting for bush meat and illegal wildlife trade has been escalating, with recent evidence that organized international crime syndicates are targeting and exploiting Malawi as a source and transit route for illegal wildlife trade. One of the contributing factors to the flourishing of this illegal trade include: increasing consumer demand in south east Asia (particularly China) for products made from ivory, rhino horn and other animal derivatives (e.g., turtle shells).

Table 4. 28 Area covered by National Parks and Game Reserves

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)

Main challenges in the wildlife sector include increased poaching, both subsistence and commercial; trafficking of wildlife products due to low risk but high returns; increase in human pressure; inadequate field resources; weak legislation and sometimes failure to use multiple legislation during prosecution; encroachment, particularly in the National Parks of Kasungu, Lengwe, and Nyika due to increased demand for land for human settlements and agriculture production.

4.12.1 Importance of Wildlife

Wildlife resources provide the much needed ecosystem services and goods for Malawi's socio-economic development, particularly the interest they generate in tourists to view the "Big Five", namely: Elephant, Black Rhino, Buffalo, Lion and Leopard. The wildlife sector plays an important role in the conservation of biodiversity and the promotion of tourism in the country. Also, important rivers in the country arise from areas designated as National Parks and Game Reserves, hence the sector is key in water resources conservation. It is in light of the above that the Malawi Growth and Development Strategy III (MGDS III) identified wildlife as one of the sectors that could potentially contribute to the sustainable economic growth of the country. The MGDS III further calls for the conservation and prudent management of wildlife in protected areas and outside natural habitats

4.12.2 Vulnerability of Wildlife

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 entails the determination of the Habitat Suitability Index (HSI). The HSI relates the suitability of habitat variables of landscapes to species of interest. In the compilation of Malawi's Initial and Second National Communication reports, the Habitat Suitability Index (HSI) method was adopted in assessing whether habitats in the Lengwe and Kasungu National Parks would change positively or negatively under climate change scenario or not. The findings showed that in Lengwe National Park the projected climatic conditions would impact adversely on the nyala population, such that the degraded habitat would not support large mammal populations. In Malawi, wildlife resources are mostly vulnerable to droughts, diseases and poaching. During the severe droughts of 1979/80 and 1991/92 rainy seasons, high mortality of Nyala (Tragelaphus angasi G), a key species in Lengwe National Park, was one of the observed negative impacts besides overcrowding at water holes, and poor regeneration of vegetation and over-browsing. The recurrent and frequent droughts experienced over the last four decades, exacerbated by environmental degradation, has led to the drying up of many rivers and streams in Malawi, especially during the dry season. As such, it very common to find animals congregating at large pools along big rivers during the dry season, rendering them vulnerable to poachers. Also, drought conditions promote forest fires, which are a serious hazard to wildlife.

In previous studies (GoM, 2011), the vulnerability of elephants to climate change was evaluated through the use of critical environmental, biophysical and socio-economic variables that affect animal populations, which include: (i) nutrients, (ii) soil moisture, (iii) forest fire, and (iv) herbivores. Human - Elephant Conflict (HEC) and poaching are additional underlying environmental drivers that directly impact elephant populations. Thus, climate change has a profound impact on wildlife resource management, including direct physiological impacts on individual species, and changes in reproduction and interactions among species. Adverse impacts of climate change are already being experienced in this sector, including prolonged drought periods, erratic rain fall, habitat degradation and loss, and excessive storms and floods. Although the National Wildlife Policy was reviewed in 2018 to provide policy guidance in addressing the vulnerability of wildlife in general and of protected areas and wetland biodiversity to climate change and development of adaptive strategies and tools, enforcement is still weak. Also, there is inadequate data on the impacts of climate change on biodiversity due to inadequate of knowledge and capacity among staff about climate change impacts on the sector.

Future climate risks of the Wildlife Sector in the Second National Communication of Malawi was evaluated with regard to habitat suitability, nutrient availability, land degradation, and elephant damage. The study areas were Kasungu and Liwonde National Parks, and the assessment projected that the mean annual temperatures would rise by 2.2^0 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. Although, there were no significant differences in the Habitat Suitability Index between the two national parks, Kasungu National Park had a slight advantage over Liwonde National Park because of its larger size and the smaller population size of elephants. This scenario coupled with decreasing rainfall, low nutrient availability and increasing drier conditions for Liwonde would lead to loss of wildlife and some plant species.

4.12.3 Potential Adaptation Strategies

In the case of extreme changes in climate, compounded by animal populations that are at or near carrying capacity, conventional wildlife management techniques such as translocation, provision of artificial water supplies, and culling could be used. These measures have neither been prioritized nor costed in the present report due to lack of financial support.

Considering the vulnerability of Lengwe National Park, especially the Nyala Antelope species, a total of 10 solar powered waterholes were drilled in the Old Lengwe in 2017 which is the principal ecosystem for the animal species. The distribution of the waterholes in the park has also resulted in the wide distribution of animals that were at first overcrowding only around the main hide and lodge waterholes due to availability of water. This is a medium to long term strategy with high impact potential. It is anticipated that regeneration of vegetation will be enhanced with reduced over browsing and grazing due to wide distribution of the animals and water availability throughout the year.

In Liwonde National Park in order to improve the park ecosystem ecology in relation to the projected threat of climate change, a total of 261 elephants were translocated in 2016 to Nkhotakota Wildlife Reserve. Prior to the translocation, the estimated elephant population was at 830. The aerial census undertaken in August 2016 after the translocation estimated the elephant population at 578. In order to maintain healthy populations of animals and plant communities, it was recommended to reduce the elephant population and to maintain a density of no more than 0.5 animals/km^2 for the entire park. The 2018 aerial count estimated the population at 597 which indicates a population with a high fecundity and should continue to be closely managed to prevent further ecological impacts.

The Government of Malawi is implementing a number of projects with a view to enhancing wildlife conservation and management. These include the Malawi - Zambia Transfrontier Conservation Areas (TFCAs), Promoting Investment and Competitiveness in the Tourism Sector (PICTS) Project in Kasungu and Lake Malawi National Parks, and Public Private Partnership in Wildlife Conservation and Management.

In order to further the objectives of conservation and to benefit from interaction with other states, their agencies and NGOs, Malawi's policy is to promote cooperation with regional and international institutions in the conservation and management of wildlife resources, including those that straddle international borders. A Transfrontier Conservation Area (TFCA) between Malawi and Zambia was established in 2004 with a Treaty signed by the Heads of States for Malawi and Zambia in July 2015. The TFCA has a number of protected areas, of different conservation status, covering about 28,000 km^2 which include: (1) Malawi side: Nyika National Park, Kasungu National Park and Vwaza Marsh Wildlife Reserve, and (2) Zambia side: Nyika National Park (Zambia), Lukusuzi National Park; Lundazi, Mitengi and Mikuti Forest Reserves and Musalangu Game Management Area.The Malawi -Zambia Transfrontier Conservation Area aims to promote and facilitate the development of a complementary network of protected areas within the Malawi-Zambia TFCA linked through corridors to safeguard the welfare and continued existence of migratory wildlife species including also issues of climate change.

The broad development objective of the "Promoting Investment and Competitiveness in the Tourism Sector (PICTS) Project" in Kasungu and Lake Malawi National Parks is to create an enabling environment for investment in the tourism sector through enhanced capacity in planning and business management, and improved governance in management of natural resources. The Project aims to strengthen natural resource governance through training of staff, installation of cyber tracker monitoring system, and development of park governance and management framework and also strengthen tourism enterprise development and training of youths and women in business management and entrepreneurship.

In order to enhance the conservation and management of wildlife, the Department of National Parks and Wildlife entered into a Public-Private Partnership with African Parks Network to manage Majete Wildlife Reserve in 2003, and Liwonde National Park and Nkhotakota Wildlife Reserve in 2015, respectively. The partnership has improved the management of the protected areas with animal populations increasing and corresponding tourists numbers increase. For example, in Majete Wildlife Reserve, a total of over 2900 animals from 14 different species were reintroduced including the big five, namely: Elephant, Black Rhino, Buffalo, Lion and Leopard. Similarly, Liwonde and Nkhotakota protected areas have been restocked with various animal species including the cheetah.

4.13 Gender

Gender describes the characteristics associated with being male or female. These attributes, opportunities and relationships are socially constructed and are learned behaviors, influenced not only by our biological sex, but predominantly by the society we live in. Gender is part of the broader socio-cultural context and therefore varies over different cultures and time periods. Gender equality means that women and men have equal value, rights, and opportunities to participate in every aspect of life, at every level of society. Equality does not mean that men and women will become the same, but that women's and men's rights, responsibilities and opportunities will not depend on whether they are born male or female. Gender equality means that the interests, needs and priorities of both men and women are taken into consideration, recognizing the diversity of different groups of women and men.

Gender is an important consideration in development. It is a way of looking at how social norms and power structures impact on the lives and opportunities available to different groups of men and women. Globally, more women than men live in poverty. Women are also less likely than men to receive basic education and to be appointed to a political position nationally and internationally. Understanding that men and women, boys and girls experience poverty differently and face different barriers in accessing services, economic resources and political opportunities helps to target interventions. According to the World Development Report (WDR) of 2012, gender is defined as socially constructed norms and ideologies which determine the behavior and actions of men and women. Understanding these gender relations and the power dynamics behind them is a prerequisite for understanding individuals' access to and distribution of resources, the ability to make decisions and the way women and men, boys and girls are affected by political processes and social development. Compared with men, women control fewer political and economic resources, including land, employment and traditional positions of authority. Acknowledging and incorporating these gender inequalities into programmes and analyses is therefore extremely important, both from a human rights perspective and to maximize impact and socioeconomic development. The WDR 2012 highlights the importance of directly targeting the persistent constraints and obstacles to women's equality (especially in areas of economic empowerment, educational gaps, household/societal voice, and violence against women) in order to enhance productivity and improve longer-term development outcomes. Gender equality is also important for sustainable peace, and there is a growing body of empirical evidence suggesting that a higher level of gender inequality is associated with higher risks of internal conflict

Climate change has a greater impact on those sections of the population that are most reliant on natural resources for their livelihoods and/or who have the least capacity to respond to natural hazards, such as droughts, landslides, floods and hurricanes. Women commonly face higher risks and greater burdens from the impacts of climate change in situations of poverty, and the majority of the world's poor are women. Women's unequal participation in decision-making processes and labor markets compound inequalities and often prevent women from fully contributing to climate-related planning, policy-making and implementation. Parties to the UNFCCC have recognized the importance of involving women and men equally in UNFCCC processes and in the development and implementation of national climate policies that are gender-responsive by establishing a dedicated agenda item under the Convention addressing issues of gender and climate change and by including overarching text in the Paris Agreement.

The Constitution of Malawi upholds equality between men and women, and prohibits sex-`based discrimination. The government (GOM) has reiterated its commitment to promote gender equality by signing regional and international conventions on protecting women and children. The Government has also put in place a National Gender Policy and a national Gender Program for the implementation of the Policy. Women in Malawi constitute 52% of the population; the majority live and work in the rural areas. It is estimated that 70% of full time farmers are women contributing 87% of labor in the agricultural sector. They contribute as producers, processors, and they also market the produce. Despite their numbers and the enormous contribution to the agricultural economy, women continue to face constraints that marginalize them from the mainstream agricultural sector. Gender differentiated access to resources and benefits continue to hinder women's full participation in the agriculture sector. More men than women have access to agricultural resources (land, technology, equipment/tools, capital, information and extension services, markets, credit and labor). This differential access has a negative impact on agricultural productivity. The group most affected are the female headed households. Current data indicate that 30% of smallholder families are female headed (REF). The gender implications of the increased food insecurity is excessive work load burdens on women and the girl-child who are essentially responsible for household subsistence and well-being. Moreover, the problem of lack of control of income derived from agriculture sales, coupled with low productivity on their own smaller plots has increased household vulnerability to food insecurity and child nutrition levels.

Women bear most of the burden in activities that are most impacted by adverse climate, including collection of water, firewood and ensuring daily access to food. In addition, the changing demographics as a result of the impacts of the HIV/AIDS epidemic, are leading to women taking up greater responsibilities as sole heads of households and taking care of the sick and orphans. Several interventions are proposed that target women in highly vulnerable situations, including: (i) empowerment of women through access to microfinance to diversify earning potential, (ii) ensuring easier access to water and energy sources by drilling boreholes and planting trees in woodlots, and (iii) use of electricity provided through the rural electrification programme.

As stated by (REF), gender inequality in Malawi is underpinned by different levels of education, access to resources (such as land) and economic dependence. Gender roles are defined within society and intersect with other social identifiers, such as age, religion and ethnicity, and reflect what is deemed appropriate behavior for men and women. Gender relations stem from the interplay between women's and men's roles in society. Roles and relations are social constructs and thus can, and do, change. Given that patriarchy predominates, women have typically held a less privileged position relative to men, and thus attempts at gender equality typically involve concerted efforts in favor of women's empowerment. Particularly in rural areas gender inequality is reinforced by social norms. Acceptance of male authority over women is taught both implicitly and explicitly through various institutions, including in homes, many schools, churches and community gatherings. Whilst gender inequality is evident in many spheres, it is particularly important to address within agriculture, since this is such a dominant sector in the Malawian economy. Addressing gender inequality in agriculture requires that support interventions, such as climate services, answer the particular (and often different) needs of men and women farmers.

4.13.1 Importance of Gender

Women and girls are raised with gender-specific roles and responsibilities in their families and communities. The unique knowledge held by women and girls should be respected and effectively utilized in responding to and managing climate and disaster risks. Adopting gender-responsive approaches is essential in achieving cost-efficient adaptation measures, disaster risk reduction and sustainable development. In light of the above, it is obvious that climate change, gender equality, and sustainable development are highly inter-related. It is therefore absolutely necessary that the Government of Malawi should take gender considerations into account when implementing climate change related projects.

4.13.2 Vulnerability of Gender

The National Gender Policy of 2015 (GoM, 2015) states that women are the worst affected individuals by environmental mismanagement because of the gender roles they play in resource utilization. For example, deforestation, desertification and decreasing water availability affect women most through compromising their economic productivity and nutritional status. It envisaged that the situation will get worse under climate change scenario. Inequality limits women's ability to adapt to the impacts of climate change. This vulnerability is exacerbated by viewing women as victims, rather than key actors who have critical knowledge of their society, economy, and environment, as well as practical skills, which, when recognized and used, can be effective in risk reduction and adaptation. If women and girls have a limited say in decision-making and their skills are not fully utilized, half the population is unable to contribute adequately to climate change adaptation and overall sustainable development (UN Women, Undated).

Women's increased vulnerability to climate change impacts (including reduced resilience and adaptive capacity) when compared to men include discriminatory, patriarchal laws, norms, customs and institutions that result in women's exclusion from participating in decision-making and community processes; limited awareness of legal rights, including human rights; limited or no access to or control over resources and assets; unequal burden of unpaid domestic and care responsibilities; limited access to necessary sexual and reproductive health care (particularly in natural disaster situations); increased exposure to gender-based harassment and violence; and impoverishment, including when a male spouse migrates or otherwise leaves the household

4.13.3 Potential Adaptation Strategies

Some of the strategies for climate change adaptation regarding Gender are: gender mainstreaming, civic education and public awareness, and climate financing.

Gender mainstreaming may be defined as a strategy for realizing gender equality. It may also be described as a public policy concept of assessing the different implications for people of different genders of any planned policy action, including legislation and programmes, in all areas and levels. Mainstreaming essentially offers a pluralistic approach that values the diversity among people of different genders. It involves the integration of a gender perspective into the preparation, design, implementation, monitoring and evaluation of policies, regulatory measures and spending programmes, with a view to promoting equality between women and men, and combating discrimination. Gender mainstreaming ensures that policy-making and legislative work is of higher quality and has a greater relevance for the society, because it makes policies respond more effectively to the needs of all citizens – women and men, girls and boys. As such, it makes public interventions more effective and ensures that inequalities are not perpetuated. Gender mainstreaming does not only aim to avoid the creation or reinforcement of inequalities, which can have adverse effects on both women and men, but it also implies analyzing the existing situation, with the purpose of identifying inequalities, and developing policies which aim to redress these inequalities and undo the mechanisms that caused them. In light of the above, Gender Mainstreaming is critical in the implementation of climate change adaptation strategies.

Education is critical in helping populations understand and address impacts of climate change, and in encouraging changes in attitudes and behavior needed to help them address causes of climate change, adopt more sustainable lifestyles and develop skills that support different modules of economies, as well as to adapt to the impact of climate change. In article 6 of the United Nations Framework Convention on Climate Change, the 197 parties commit to the development and implementation of educational and public awareness programmes on climate change and its effects, on national and international levels. Equally, the parties to the Paris Agreement commit to enhance climate change education in article 12. Climate change should be embedded in education systems as it is affecting our environment and social fabric, and reshaping the ideas on how we should live our lives.

Capacity-building is critical to the effective integration of gender climate policies, plans and actions. This may entail the implementation of dedicated capacity-building or education and training programmes on climate change, as well as capacity-building on gender as a component of climate projects or programmes. The gender aspect includes the gender balance of participants and experts. Capacity building may include the implementation of training and public information and awareness-raising programmes on climate change that either target women or are led by women who integrate gender perspectives in climate change education and training.

Adaptation of Gender to climate change may involve climate financing to address the needs of women and men under climate change scenario. For example, 80% of climate-related financing by the Swedish International Development Cooperation in 2013–2016 also promoted gender equality. It is the standard policy of the Netherlands to integrate gender in all climate change related development activities. Canada is developing the Feminist International Assistance Policy in the provision of climate finance in collaboration with bilateral and multilateral partners to ensure that gender-responsive indicators and the tracking of sex-disaggregated data are incorporated into all results frameworks. UN Women developed a guidebook on how to apply a co-benefits approach to gender equality and climate action, which includes an introduction to climate finance concepts, sources and instruments and a discussion of their associated gender dimensions. It cannot be emphasized that climate change financing is critical in averting adverse impacts of climate change on the basis of gender.

CHAPTER 5

PROGRAMMES CONTAINING MEASURES TO MITIGATE CLIMATE CHANGE

5.1 Programmes Containing Measures to Mitigate Climate Change

Climate change mitigation is about reducing the impacts of global warming through prevention or reduction of greenhouse (GHG) emissions. This Chapter presents the mitigation options and their analyses for Malawi, up to the year 2040. The mitigation analysis covered the sectors of Energy; Industrial Processes and Other Product Use (IPPU); Agriculture Forestry and other and Use (AFOLU); and Waste. However, the mitigation analysis put more emphasis on energy and forestry, as the key sectors with high mitigation potential. The analysis involved the determination of GHG emission reduction opportunities for all sectors, however, the expected contribution to abatement of the GHG emissions was determined for the forestry and energy sectors using appropriate software. Mitigation measures in the different sectors will also present environmental and socio-economic benefits, in addition to abatement of the GHG emissions.

5.2 Energy Sector

Mitigation analysis has been achieved through calculation of emissions in the categories of the Malawi's energy sector, as informed by the 2006 IPCC Methodology. Then, the emissions that could arise if there is no action to limit them, was compared with the mitigation that would arise under identified mitigation actions. The emission estimation and scenario building were achieved using Long Range Alternative Energy Planning (LEAP) system. LEAP is a robust medium to long term scenario-based software that is used in many countries as part of their commitment to report to the United Nations Framework Convention on Climate Change (UNFCCC).

5.2.1 Malawi's Energy Sector

In Malawi, energy demand and supply are dominated by biomass Figure 5.1, which is sourced unsustainably from forest and used as fuel in form of charcoal and fuel wood (GoM, 2016). The majority of households still use firewood as the main source (77 %), followed by charcoal (18%) and electricity (2%) (NSO, 2019). This translates to 95% of the population using biomass for cooking. The majority of charcoal is used as a cooking fuel in urban areas, where around 15% of the population resides, while firewood dominates in the rural areas. In 2015, biomass contributed 86% of Malawi’s energy supply (GoM, 2016), significantly higher than the 2012 average for the sub-Saharan region (61%; IEA, 2014). The country’s supply of energy from coal, oil and gas (10%) is also below the sub-Saharan region average (37%; IEA, 2014). The household sector dominates energy demand, which is mostly sourced from biomass for the provision of thermal energy services like cooking and heating. In terms of grid-based electricity, the household sector also leads consumption at 41%, followed by Agriculture (25%), manufacturing sector (12%) and construction and mining sector (5%) of the generated electricity (Malunga, 2017). This energy consumption pattern is attributable to generally limited economic activities in the manufacturing and mining sectors, resulting in a relative slow pace of economic development.

During the period from 2001 to 2014, installed capacity for electricity generation in Malawi was 351 MW, including the 64 MW Kapichira hydroelectric power station commissioned in

January 2014. Almost all electricity generation is from run of the river hydroelectric power plants along Shire River, with an additional 4.5 MW Wovwe Power station, located along Wovwe River in Karonga District (GoM, 2016). During this period, the only commissioned thermal power stations were 0.874 MW diesel generators providing power in Likoma and Chizumulu Islands on Lake Malawi. Thus, practically, the available grid-based electricity is not associated with GHG emissions.

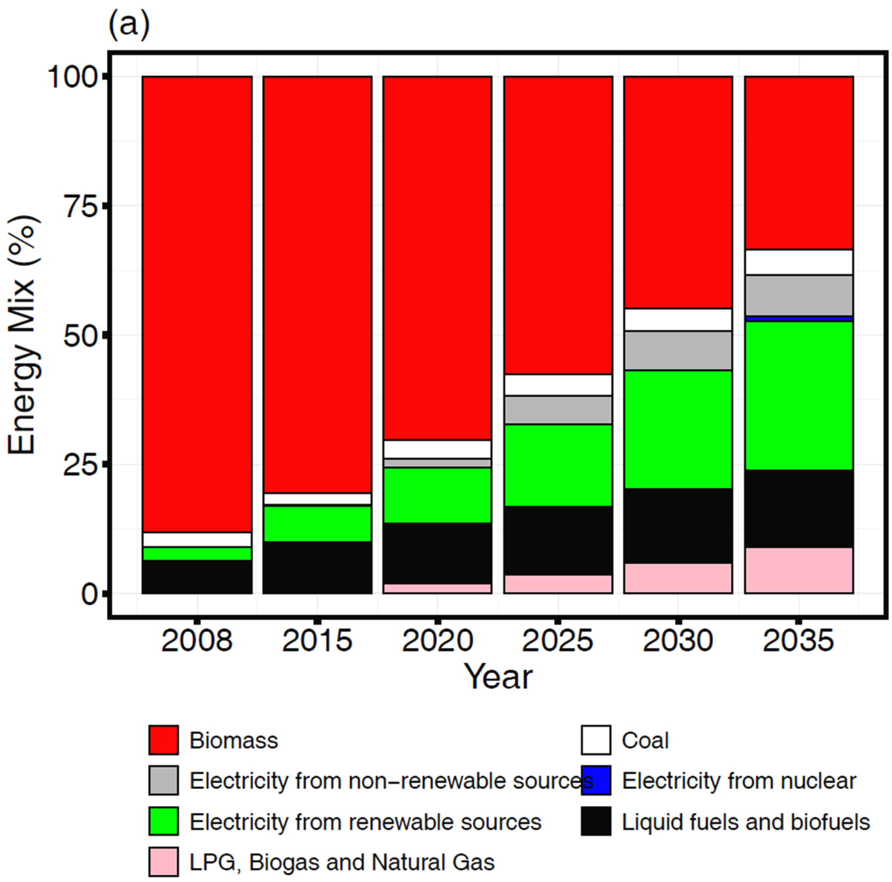


Figure 5. 1 Malawi energy mix

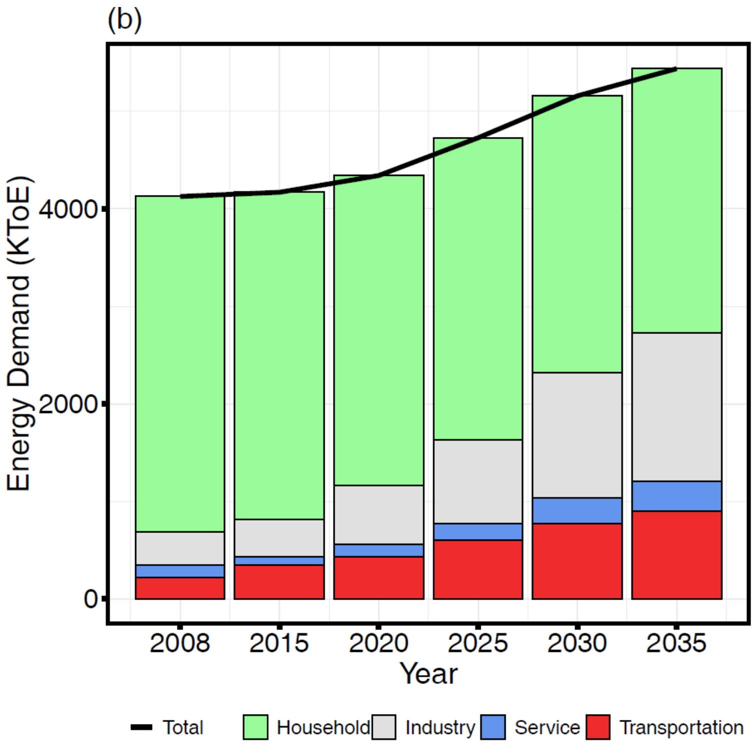


Figure 5. 2 (a) Projected energy supply mix from 2008 to 2035 and (b) Energy demand and its projection for Malawi (Malawi National Energy Policy (GoM, 2018)

However, the hydroelectric power stations are vulnerable to negative impacts of catchment degradation and climate variation. During this period (2001-2014), the country suffered serious power shortages resulting from flooding and siltation. For example, in 2001 Tedzani 1 and 2 was flooded, as a result 40 MW was lost from the grid up to 2008 (MCC, 2011). In 2003, 100 MW was lost from the grid for a period of four months due to flooding of Nkula Hydropower Station (Kaunda and Mtalo, 2013). In 2009, Nkula lost 124 MW due to intake screen damage as a result of aquatic weed infestation (Mzuza et al., 2014), which was exacerbated by supply of nutrients in the silt and floods. Further, low power generation as a result of reduced water levels in Lake Malawi also contributed significantly to blackouts in the country during the period of 2001 to 2017.

The Government of Malawi acknowledges that the current energy situation cannot support socio-economic development goals. The available installed capacity is too limited to attract investors in manufacturing and mining industries. In addition, unsustainable biomass energy supply reduces forest cover, thus, reducing the amount of CO_2 removal (carbon sink). In addition, reduction of forest cover exposes the land to destruction from floods and accelerated soil erosion, thereby lowering capacity to adapt to climate change. As a result, an integrated National Energy Policy was formulated in 2003 (GoM, 2003) and was revised in 2018. The new Energy Policy advocates for diversification of sources of energy, with a long-term goal of "transforming the country's energy economy from one that is overly dependent on biomass to one with a high modern energy component in the energy mix". The new Energy Policy (2018) revised the target for biomass in energy supply mix to 33.5% by 2035 from 88% in 2008 (GoM, 2018). This will be achieved through a staggered increase of modern sources of energy, which includes intensification of renewable power supply Figure 5.2. The reduction of biomass in the energy mix has the added advantage for conservation of forest resources in the country, hence contributing towards climate change mitigation through enhancement of carbon sink.

The formulation of energy policy (in 2003), resulted in some degree of improvements in the energy sector. The country saw energy laws being enacted such as the Energy Regulation Act (2004) which resulted in establishment of Malawi Energy Regulatory Authority (MERA). Private sector participation in energy generation has also been encouraged, with establishment of Power Purchase Agreements Framework (PPAF). Biomass Energy Strategy and Charcoal Strategy have been formulated and are being implemented as strategies for the management biomass energy and charcoal, respectively. During the period of 2001 to 2017, the Government of Malawi and stakeholders have also formulated several plans and implemented several projects in order to achieve the objective of reducing biomass in the national energy mix. These include Electricity Investment Master Plan (2000), Barrier Removal to Renewable Energy in Malawi (2002), Programme for Biomass Energy Conservation (ProBEC) in 2002 and Promotion of Alternative Energy Sources Project in 2006. However, as with any other intervention, there is need to evaluate their effectiveness towards reducing the share of traditional biomass in the energy mix.

During the reporting period (2001 to 2017), a significant amount of installed capacity was not available, critically affecting economic sectors of the country resulting from severe power shortages. The Government has come up with an Integrated Resource Plan, which guides investments in power generation and transmission in the country. The plan anticipates a sharp increase in power demand up to 2040, with estimated base load (electricity demand that is available off-peak) of 719 MW in 2020, 1873 MW in 2030 and 4620 MW in 2040 (GoM, 2017). In line with the Malawi Energy Policy (2003), the Government encourages a vibrant private sector involvement in the power supply sector in order to increase the generation capacity to ensure energy security and keep pace with the requirements for socio-economic development of the country. However, during the reporting period (2001 to 2017), there was no private sector involvement in electricity generation for the sale to the national grid, but there has been a considerable number of Independent Power Producers (IPP) applications in the year 2018 and 2019. The power supply sector is still dominated by Electricity Supply Cooperation of Malawi (ESCOM). However, some industries and businesses generated power for self-consumption using liquid fossil fuel and bagasse. Examples include the Illovo Sugar Factories (in Dwangwa and Nchalo) and the Kayelekera Uranium Mining Company in Karonga District that was commissioned in 2008. Kayelekera Uranium Mines had installed capacity of 10.2 MW, powered by diesel electric-generators. Also, the mobile phone companies and tourism sector had registered significant amounts of stand-alone diesel-electric generators.

During this period (2001 to 2017), the Government, through ESCOM, planned to increase the installed capacity to nearly 450 MW in 2015 and 1.6 GW by the year 2030 (GoM, 2010). The Government had identified economic growth opportunities as electricity demand, with most of the demand anticipated to come from mining and manufacturing sectors drivers Table 5.1; Lapukeni, 2013). This is due to the Government's agenda of income diversification through mining and manufacturing so that these two sectors contribute significantly to the GDP. Two further hydroelectric power stations are planned on Shire River and one on Songwe River. A 200 MW Kholombidzo run-of-river type and a 350 MW Mpatamanga reservoir-type power stations are planned on Shire River and expected by 2021 and 2025, respectively. An additional, 180 MW Songwe reservoir-type power station is expected on Songwe River in 2022. Considering the challenges facing hydropower generation in the country, especially its sensitivity to climate change and state of environment in river catchments, diversification of power generation from other sources such as from coal and solar power stations have been planned. A 300 MW Kammwamba coal power station, with expandable capacity to 1000 MW, is planned to be commissioned in 2021. In addition, a 60 MW Kanzimbe solar power station is expected to be operational in 2021 in Salima District. The plan for power generation for the country is presented in the Integrated Resource Plan for Malawi (GoM, 2017). It is clear that the generation of power from coal would significantly increase GHG emissions.

Table 5. 1 Current electricity demand drivers

Identified growth opportunity	**Estimated power demand (MW)**
Mining	800
Green Belt Irrigation Initiative	130
Service (ICT, Tourism, Banks, Hospital, Offices and Education)	500
Manufacturing	700
Domestic	700
Total	2830

Source: Status of energy demand in Malawi (Lapukeni, 2013)

5.2.1.2 Malawi's Energy Sector GHG Inventory from 2001 to 2017

The 2001-2017 GHG inventory of the Energy Sector includes Energy Industries, Manufacturing Industry and Construction (MIC), fugitive emissions from solid fuels and other sectors (residential) categories. During the reporting period (2001-2017), the transport category dominated GHG emissions in the energy sector, contributing 11020 Gg of CO_2 equivalent, representing 44% of total GHG emissions in the energy sector (24817 Gg of CO_2 equivalent). The other sectors (residential) category was second at 35% (8542 CO_2 equivalent), followed by the MIC (16%), and energy industry (3%) and fugitive emissions from solid fuels (1%) categories Figure 5.3a).

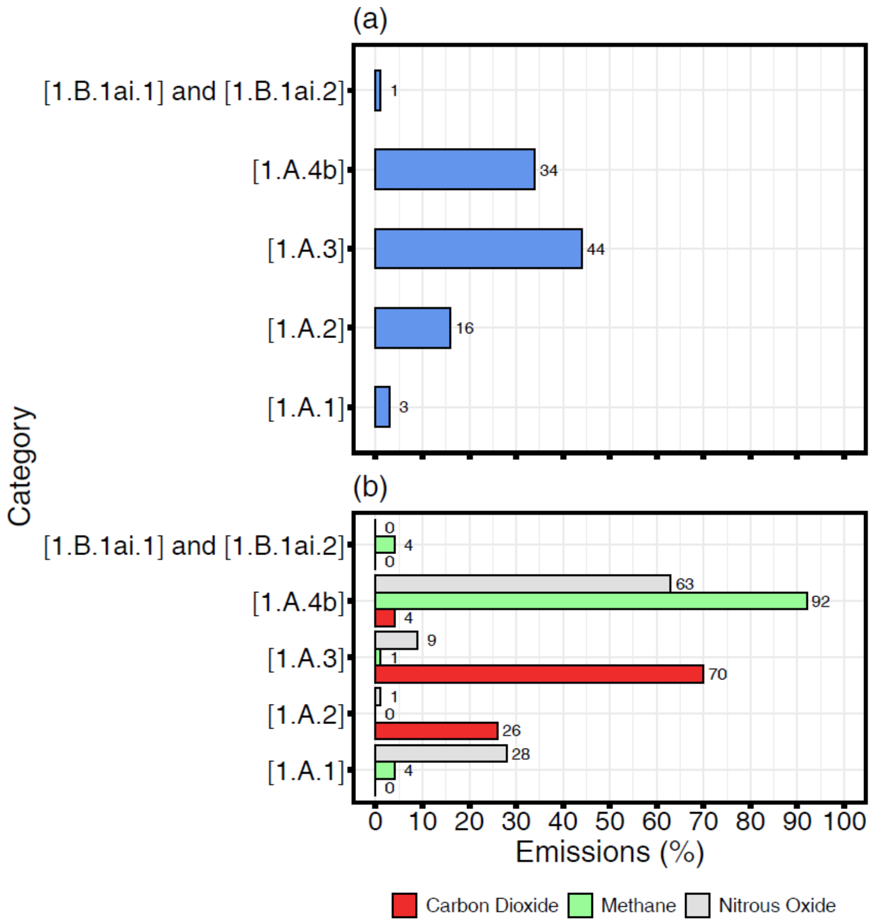


Figure 5. 3 (a) Summary of the GHG emissions in the energy sector (2001-2017), (a) by category of energy sector and (b) by type of gas in each category

As expected, carbon dioxide (CO_2) was the dominant emitted GHG gas (62%) in the reporting period (2011-2017), seconded by methane (CH_4) at 30% and nitrous oxide (N_2O) at 8%. Most of the CO_2 was emitted in the transport category (70%) from combustion of petroleum mainly in road transport. The majority of CH_4 (92%) and N_2O (68%) were emitted in the residential sub-category Figure 5.3b), mainly from use of biomass fuel (charcoal and firewood).

Key category analysis for the 2001-2017 GHG inventory for the energy sector showed that the key categories, in order of importance, are the following:

- Road transportation,
- Other sectors (residential) - biomass,
- MIC- solid fuel (coal)
- Other sectors (residential) - liquid fossil fuels (kerosene),

5.2.3 GHG Mitigation Analysis Methodology

5.2.3.1 Mitigation options

The mitigation analysis adopted mitigation technologies that were identified for Malawi in the country's Technology Needs Assessment (TNA) report for the Energy Sector (GoM, 2020). Firstly, the mitigation technologies were identified through document review and then selected through a participatory process with stakeholders. Documents reviewed included the following: the revised Energy Policy of Malawi (GoM, 2018), the Malawi SEforALL Action Agenda (GoM, 2017), the Intended Nationally Determined Contribution (INDC) for Malawi (GoM, 2015), and Incubator Programme of the Climate Technology Centre and Network (CTCN) in Malawi (GoM, 2018). A total of eleven technologies were identified, as follows: biomass gasification; solar PV; biogas; biofuel as vehicular fuel; energy efficiency and conservation measures in industries and buildings; Liquefied Petroleum Gas (LPG) for cooking; improved charcoal production kilns; biomass briquettes; ethanol cookstoves; efficient firewood cookstoves; and lake Malawi hydrokinetic electric power.

The process of prioritising identified climate technologies was participatory and ensured inclusion and gender mainstreaming. Technology selection was achieved using multi-criteria evaluation tool by an expert working group. The criteria were grouped into costs and benefits associated with the technology. The costs included capital costs, and operating and maintenance of the technology hardware. The benefits included economic, social, and environmental and climate related (potential for greenhouse gas reduction). After evaluation, the top six prioritized technologies are listed as follows:

1. Liquefied Petroleum Gas (LPG) for cooking
2. Biofuel as vehicular fuel
3. Biomass Gasification
4. Lake Malawi hydrokinetic electric power
5. Solar PV
6. Improved charcoal production kilns

These technologies were then mapped to the identified key categories in the energy sector Figure 5.4).

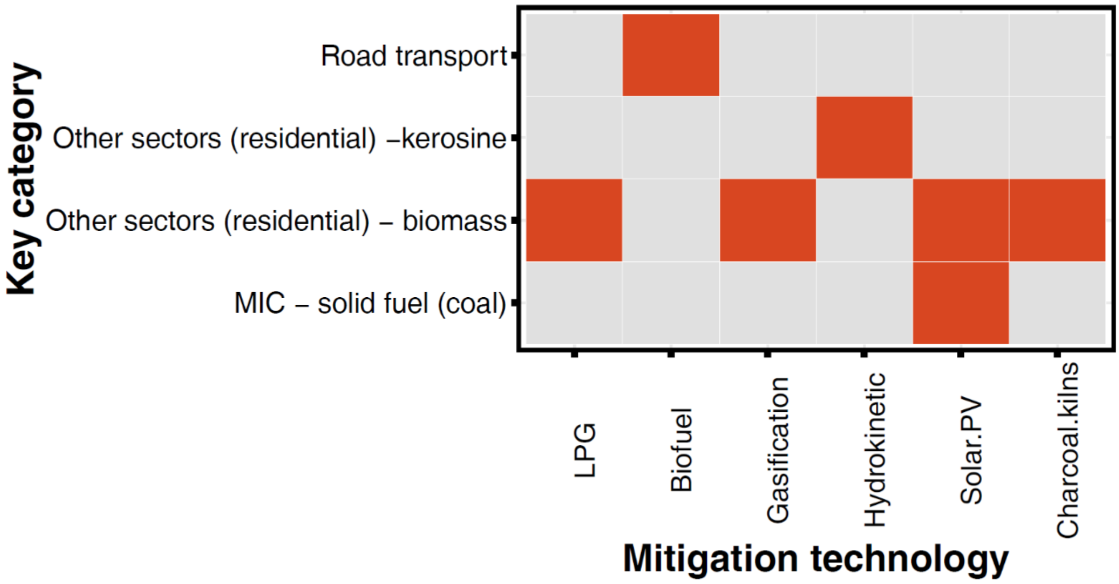


Figure 5. 4 Mapping of mitigation technologies to key categories of the energy sector

5.2.4 Development of Climate Scenarios: Business as Usual and Mitigation

In this communication, scenarios are defined as consistent descriptions of how a future energy emission system might evolve over time in a demographic and socio-economic setting, under set of conditions. To investigate mitigation potential of an identified technology two scenarios were developed: Business as Usual (BAU) and Mitigation (MIT) scenarios. The BAU scenario is when the future energy emissions are estimated to follow the path described by history and without any measure to abate it. The BAU scenario also takes into account the committed projects/interventions that would affect energy emissions in future. The BAU scenario was developed in LEAP by projecting the emissions from 1995-2017 GHG inventory to 2040, using the emission trends displayed during this emission inventory period. The emissions from committed energy projects/interventions in future were calculated and estimated up to 2040.

On the other hand, MIT scenarios were developed according to identified plausible plans to reduce energy emissions in future. The resulting emissions from mitigation actions were estimated, in LEAP, considering respective emission factors and the energy data related to the mitigation actions. The emission factors were those used in the IPCC methodology for conducting national greenhouse gas inventory. In cases where there were no quantifiable data for development of energy mitigation options, these were estimated using expert knowledge of the energy technology and its emissions considering a Malawian demographic and socio-economic setting. For the mitigation analysis in LEAP, the base year was taken as 2000, as it is the first year of the BUR GHG inventory. The mitigation scenario was modelled in LEAP using the selected mitigation interventions and stipulated in the TNA Project (GoM, 2020) as priority mitigation projects for Malawi.

5.2.4.1 Business as Usual Emission (BAU) Scenario

Energy Industries

According to the IPCC, the "energy industry" category comprises emissions from fuels combusted by the fuel extraction or energy producing industries. These are emissions resulting from the main activity of electricity and heat production, by those involved in production of power and heat for sale to the public. Emissions resulting from onsite heat and power generation for private use are considered in the sectors in which they occur. In Malawi, the emissions from energy-producing industries are dominated by emissions from diesel-electric generators operated by Electricity Generation Company (EGENCO) for peak and emergency power supply. According to the key category analysis, the energy industries category is not one of the key categories in the energy sector. However, with the planned diversification of power generation to include coal fired electricity generation, the category may be key in the near future.

During the 2001-2017 period, EGENCO had a total installed capacity of 6.374 MW from diesel generators, distributed as follows: Likoma and Chizumulu Islands, 0.874 MW; Mzuzu, 1.1 MW; and Lilongwe, 4.4 MW (EGENCO, 2017). In 2017, ESCOM leased diesel generators with installed capacity of 78 MW from Aggreko Power Solutions Limited. In 2018, EGENCO installed 10 MW diesel electric generators in Lilongwe, 6 MW in Mzuzu and 20 MW at Mapanga in Blantyre (GoM, 2018). Apart from those on Likoma and Chizumulu Islands, the diesel generators are for peaking purposes in order to ease power shortages as a result of severe reduction of hydroelectric power generation following reduction of flow in Shire River because of lowering of Lake Malawi water level. The Aggreko generators were operated for six hours each day and, as the Aggreko diesel generators are an emergency power supply, their use may be discontinued in the future. It is assumed that the emergency power supply from diesel generators would be abandoned by the year 2025, when the coal fired power plants are expected to have been commissioned. However, the Malawi Government, in its Integrated Resource Planning (IRP) for Malawi, has planned to generate a further 38 MW from a diesel power plant to address the gap in power electricity production (GoM, 2017). It is assumed that this will be commissioned in 2030.

In line with the revised National Energy Policy of Malawi (2018), the Malawi Government is diversifying sources of energy for generation of electricity. Through the IRP, the Government plans to make coal-fired power stations a significant source of electricity in Malawi. The Government has committed to commissioning the 300 MW Kammwamba coal-fired power station in Neno District (GoM, 2017). Construction phase of the project has not started, therefore, with expert knowledge, it is assumed that this power station will be commissioned by 2025. Also the Government has identified the following as feasible coal-fired power plant projects, but there is no commitment to their development: 120 MW Pamodzi thermal power plant in Salima District to be commissioned by 2030 and a further coal plants to be commissioned in 2031, 2033, 2034, 2035, and 2036, with a total installed capacity of 273 MW (GoM, 2017). The amount of coal required to generate one unit of electricity depends on several factors such the efficiency of combustion process, efficiency of thermal power plant and type of coal. Generally, for sub-bituminous coal, an average conversion rate of 1 kg coal producing 8.141 kWh of electricity could be used.

The emissions (CO_2, CH_4, and N_2O) from thermal power projects were estimated according to the IPCC methodology, where the energy consumption (Gg) is multiplied by an appropriate emission factor (kg GHG/TJ) and conversion factor. For diesel peaking power plants, the energy consumption is from power production, time of running the plant and the plant capacity factor. The plants were assumed, with expert knowledge from EGENCO, to operate for 8 hours daily on average, at full load with capacity factor of 70%. The coal power plants were assumed to operate at an average of 80% full load with availability factor of 75%. For the emergency diesel generators, they were assumed to operate at the rate of 6 hours per day, with an availability factor of 30%. The other diesel generators are operated as for the emergency diesel energy power plants. 1 litre of diesel was estimated to produce 11.1 kWh (40 MJ) of electricity when fully combusted, therefore, the fuel consumption of the diesel generators was calculated as follows:

- Amount of diesel energy (kg) = installed power (kW) x capacity factor x availability factor (hours operated in a day) x total hours in a year)/(11.1kWh) x density of diesel (kg/litre)

Transport

The transport category consumes approximately 90% of all petroleum imports into Malawi (GoM, 2010). Therefore, it is a significant source of GHG emissions in the energy sector, with road transport as one of the key categories. For example, in the GHG inventory for the TNC, road transportation was responsible for 96% of the total transport emissions. This is because road transport has the largest share in transporting both cargo and passengers in the country. In the 2000s, road transport accounted for approximately 70% of internal freight traffic, over 90% of international freight traffic and 99% of passenger traffic (Lall, et al., 2009). It is expected that this state will remain up to 2040.

The population of vehicles operating on the Malawian roads is increasing rapidly from 2,226 vehicles in 2002 to 24,286 vehicles in 2014, representing an almost 10-fold increase (Figure 5.5). The increase could arguably be from availability of cheap used cars (sold online) and increased demand for cars being an indicator of increased quality of social life, especially among urban dwellers.

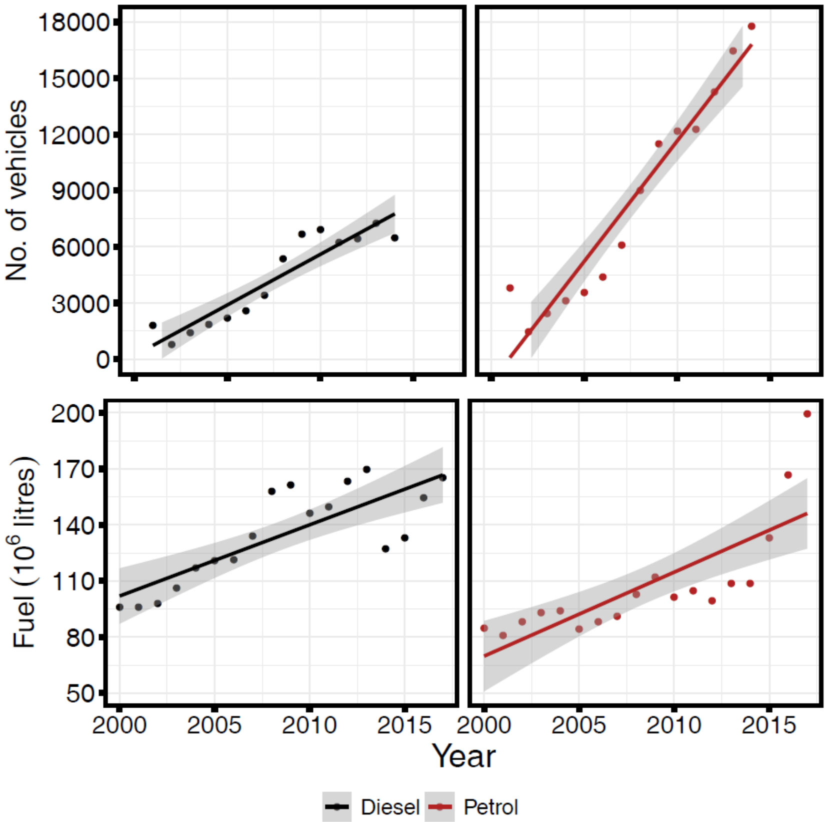


Figure 5. 5 Number of registered vehicles from 2001 to 2014 (GoM, 2017) and consumption of diesel and petrol in the road transport category from 2000 to 2017 (Malawi Energy Regulatory Authority (MERA, 2017)

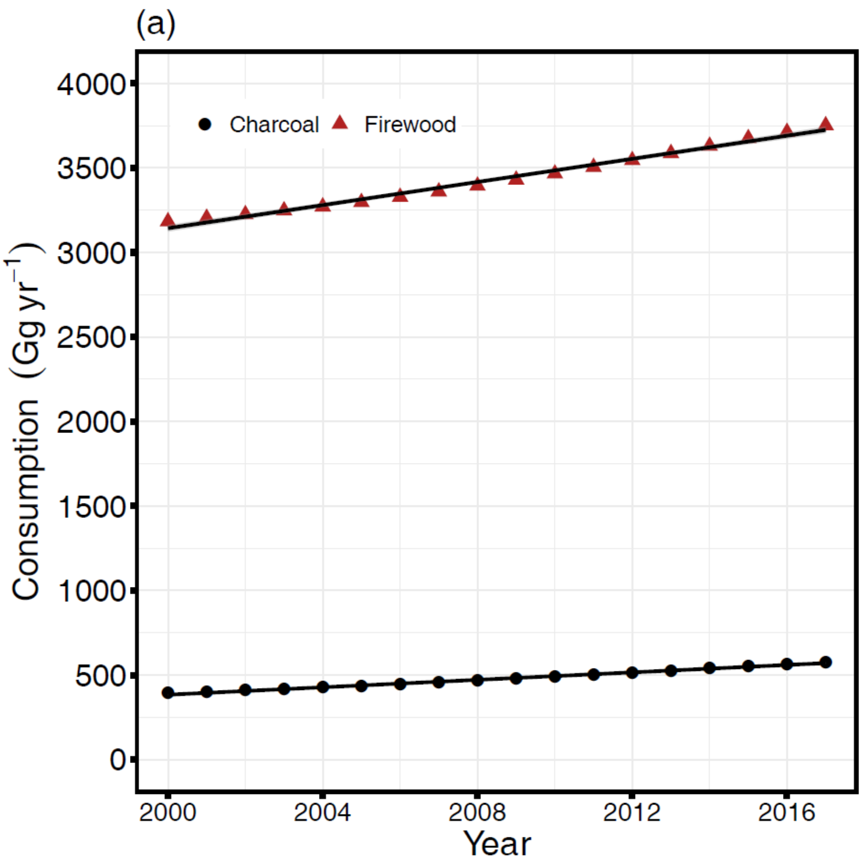
Further, the transport emissions depend not only on the amount of fuel, but also on the nature of roads, state of emission control devices, and the vehicle condition (IPCC, 2006). Poorly maintained roads and vehicles increase fuel consumption per unit distance compared to well maintained and new vehicle. In Malawi, only 26% of the roads are paved, of which 70% are main roads and 19% urban roads (Millenium Challenge Account-Malawi Country Office, 2011). The rapid increase in population of vehicles, mostly in urban areas of Blantyre, Lilongwe, Zomba and Mzuzu, is not commensurate to the expansion of the road network. Therefore, there is vehicle congestion in urban areas, especially during rush hours. Further, most of the vehicles imported into the country are pre-owned, and in most cases, not fitted with emission control systems.

The GHG emissions in the transport category were estimated from its corresponding use of diesel and petrol, which are imported into the country. The activity data used was that from 2000 to 2017 Figure 5.5, which was estimated to 2040, accordingly, using extrapolation. The emissions estimation done by LEAP used the IPCC, Tier 1 methodology.

Other Sectors (Residential)

Malawi's energy supply system is dominated by biomass (GoM, 2003; 2009; Taulo, et al., 2015) in form of fuelwood (firewood, charcoal) and agricultural residues. Firewood dominates per capita biomass consumption in both urban (at 293 kg/year in 2008) and rural (at 601 kg/yr in 2008) populations. Charcoal (at 94.02 kg/yr in 2008) is the second most used form of biomass in urban areas, whereas, agricultural residues (at 21.1 kg/yr in 2008) are the second preferred in rural areas (GoM, 2009). Using this data and the 2008 population data (NSO, 2009), the national consumption (per capita) of biomass was estimated as 592.37 kg/yr.

Most of the firewood provides thermal energy (cooking and heating) for mainly household (residential) category Figure 5.6a, tobacco curing, tea drying, brick and tile burning and rural cottage industry. Most of the charcoal is consumed in urban households, restaurants and hotels, urban cottage industry, as well as in tobacco curing (Nkhonjera, et al., 2013; O'Sullivan and Fitzgerald, 2006; Taulo, et al., 2015). There is some diversification of cooking energy in urban areas where charcoal and firewood contribute almost equal shares of cooking energy Figure 5.6b. Electricity is also a significant form of energy for cooking in urban areas (third, from charcoal and firewood). Paraffin and Gas (LPG) are insignificantly used as a cooking fuel in both urban and rural households. Firewood is the dominant fuel used for cooking in rural areas, dominating with over 93% in all the years Figure 5.6b.



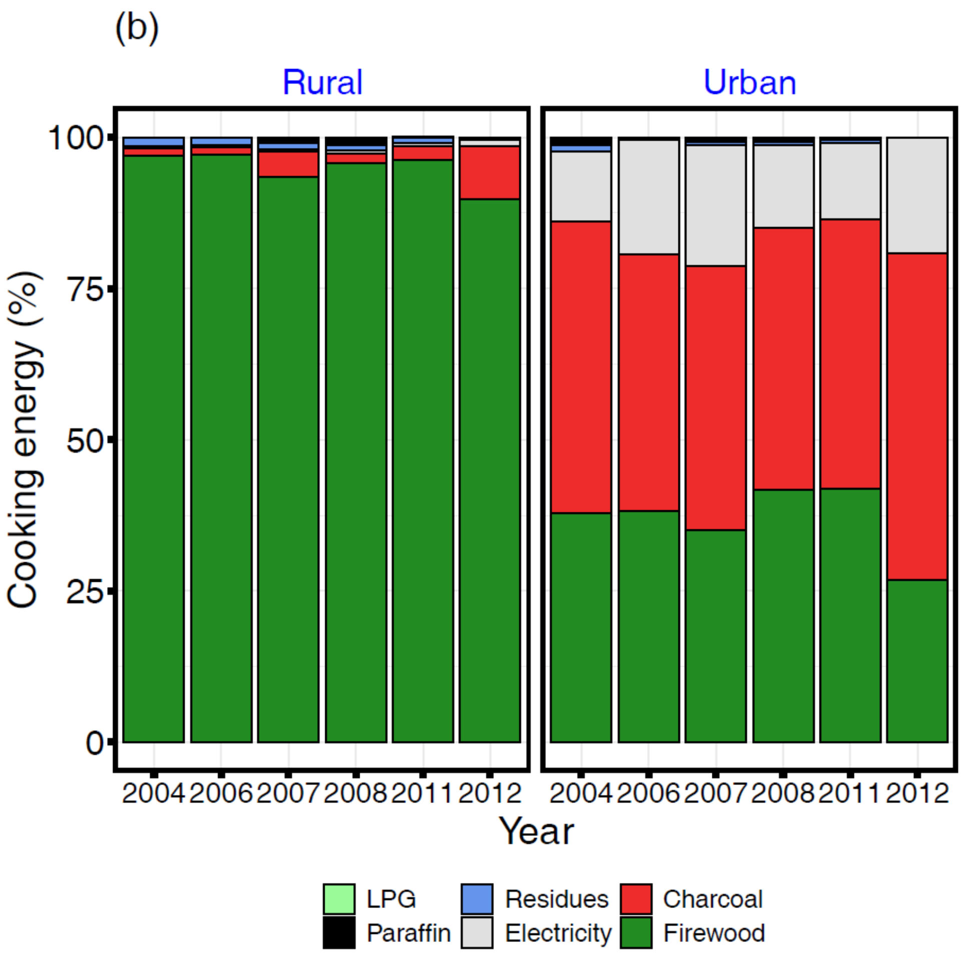


Figure 5. 6 (a) Consumption of wood and charcoal in the residential sector and their trends from 2000 to 2017 (FAO, 2017). (b) Share of cooking energy supplied by different forms of fuels, per population place of residence for different years (MERA, 2014; NSO, 2012, 2009; GoM. 2009)

The dependence on firewood and charcoal as thermal energy, coupled with inefficient conversion technologies, have contributed to deforestation (UNDP, 2007). The loss of trees has reduced the potential of carbon sink, increasing the radiative forcing for Malawi. Also, most of the households use inefficient firewood and charcoal cooking stoves that increase CH_4 and NO_2 emissions and demand for fuelwood. There have been interventions by Government of Malawi and other organizations (e.g. ProBEC and BRREM) to reduce deforestation through introduction and promoting use of efficient cook stoves. The inventions have also focused on making/production of alternative energy sources and technologies (such as briquettes, ethanol, gel fuel and biogas) and promoting their use, in order to meaningfully replace firewood and charcoal (Robinson, 2006; UNDP, 2007; Banks and Gondwe, 2005). However, these interventions have been isolated and their penetration across the country is limited.

The annual data on biomass energy in Malawi is sketchy and is based on localised surveys as pointed out earlier. There is no national energy balance and biomass energy is not recorded in national energy statistics as it is the case with liquid fossil fuels. Instead, fuelwood data was obtained from FAO database (FAO, 2017) and used in the TNC. This data gave a trend of estimated consumption of firewood and charcoal from 2001 to 2017, and the consumption up to 2040 was estimated in LEAP by extrapolation.

5.2.5 Mitigation Scenarios (MIT)

Energy Industries

In general, there is been increased usage of solar PV technologies in the country as a result of favourable policies for promotion of renewable and clean energy technologies. In 1999, the Government carried out a National Sustainable Renewable Energy Programme (NASREP) with support from UNDP (Gobede, 2011). A notable output of the NASREP was a Barrier Removal to Renewable Energy in Malawi (BARREM) project implemented from 2002 to 2007 (Banks & Gondwe, 2007). The Government of Malawi also implemented the Promotion of Alternative Energy Sources Programme in Malawi (PAESP) in 2007 to demonstrate applicability of renewable energy technologies such as solar PV and wind power technologies. Under the PAESP, six solar PV-wind mini-grid technologies were installed, two in each of the three regions (Gobede, 2011). However, the only solar PV system connected to the grid is the 830 KW demonstration solar power plant at Kamuzu International Airport in Lilongwe Table 5.2. The Government of Malawi, with support from development partners, has also demonstrated street lighting technologies using solar PV at Capital Hill, in Lilongwe and in Zomba City. The Centre for Water Sanitation Health and Technology Development (WASHTED) at the Malawi Polytechnic, in collaboration with Strathclyde University, implemented a Malawi Renewable Energy Acceleration Programme (MREAP), with funding from the Scottish Government. MREAP involved the design and installation of solar PV technologies for rural schools and health centres in Chikwawa District.

Most of the solar PV systems in Malawi are used for household lighting and charging mobile phones. They have an average wattage of per system 100 W and are available from various retailers in the country and neighbouring countries (especially the Republic of South Africa). There are also many solar technicians certified by the Malawi Energy Regulatory Authority (MERA), who provide solar PV installation services. Malawi, through its NAMAs of 2015, has projected number of small-scale solar PV systems (for household) to be as follows: 20,000 systems in 2015; 30,000 systems in 2020, 40,000 systems in 2025, and 50,000 systems in 2030. From this trend, it is estimated that in 2035 and 2040, there will be 60000 and 80000 systems respectively.

For large scale solar PV systems, Malawi through the Integrated Source Planning under the renewable energy scenario plans a total 165 MW of solar and 100 MW of biomass capacities to be built over the planning horizon (2017 to 2037). These are large scale mitigation projects that will generate electricity to support industrial development. The 165 MW solar PV installation is spread as in Figure 5.7. Solar PV power systems would off-set emissions from fossil fuel power plants (planned coal power plants). Solar PV power systems have availability factor close to 100% and 95% is assumed in this case. However, they have relatively low capacity factor of 10-25% (SUNMetrix, 2020) and a value of 20% is assumed in this mitigation analysis. For a year, the solar PV would generate energy

(MWh) equal to the product of installed power, 8760 hours availability factor and capacity factor. This is then converted into TJ as shown in Table 5.2.

Table 5. 2 Solar PV Installation Projections from 2015 to 2040

Year	Small-scale solar PV (MW)	Large-scale solar PV (MW)	Total solar PV (MW)	Total solar PV (MWh)	Total Solar PV (TJ)
2015	2	27.5	29.5	49099.8	176.7593
2020	5	55	60	99864	359.5104
2025	9	83	91.5	152292.6	548.2534
2030	14	110	124	206385.6	742.9882
2035	20	137.5	157.5	262143	943.7148
2040	28	165	193	321229.2	1156.425

The solar energy plans detailed in IRP will be realized with private sector participation in the power generation business in the country. Commitment of large-scale solar PV plants that have been committed to/installed by Independent Power Producers (IPPs) include the 60 MW solar PV power plant under construction in Salima District by JCM Power Corporation (Canada), to be commissioned in 2021. The other committed solar PV project is the 46 MW Nkhotakota Solar PV and the 26 MW Golomoti MW plant in Dedza, which would be commissioned in 2022 and 2025, respectively.

Biomass gasification would be produced at a small scale, providing thermal energy for households, but could as well be used to generate electricity for sale. It is expected that out of 100 MW from biomass plants, 30 MW will be for generation of electricity stipulated in IRP would be built and commissioned in the period 2021 to 2040. The rest (70MW) will be for providing thermal energy in the residential sector. The assumed capacity factor of the biomass plant is 70% with availability factor of 50%.

Figure 5. 7 Examples of solar PV installations in Malawi: Kamuzu International Airport (top left), Likuni hospital (top right), solar PV street lighting in Zomba (bottom right) and a min-grid (bottom left).

Transport

One of the mitigation options that the country has identified is increased usage of biofuels in the transport category. Although, the primary aim is to ensure energy security, the current blending of petrol with ethanol (80/20. v/v), is taken as one of the existing climate change mitigation technologies. However, due to limitation in fuel grade ethanol production, a blending ratio of 90/10 (petrol/ethanol) is in use. In 2010, the country's National Commission on Science and Technology (NCST) successfully demonstrated 100% ethanol-powered vehicles Figure 5.8 (NCST, 2010). The ethanol used in petrol blending is produced by fermentation of sugarcane molasses by Ethanol Company Limited (ETHCO) and Presscane Limited. The limitations in molasses to produce adequate quantity fuel grade ethanol hindered efforts to scale up the project. The use of ethanol reduces emissions of greenhouse gases, carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide (SO_2) and particulate matter and ethanol is generally less toxic to handle than petroleum fuels.

Figure 5. 8 Ethanol-driven vehicle demonstrated by the National Commission on Science and Technology

Production of biodiesel, as a replacement for fossil fuel diesel, has also been selected as one of the priority mitigation technologies in the energy sector. Biodiesel production from *Jatropha curcas* has been promoted by Government of Malawi through a company called Bio-Energy Resources Limited (BERL) (Wakeford, 2013). However, as of 2019, the company has not started producing biodiesel.

Biofuel projections in the Sustainable Energy for All (SEforAll) Action Plan for Malawi up to 2030 have been taken as mitigation target in the transport category (GoM, 2017). In the plan, the country commits to producing fuel grade ethanol from a capacity of 19 million litres in 2016 to 40 million litres in 2030. The country also commits to increasing petrol-ethanol blending ratio from 90:10 in 2016 to 70:30 in 2030. Further, biodiesel production has been projected to 55 million litres in 2030 from 150,000 litres in 2016, with a blending ratio increase of 91:9 to 85:15 in 2030. Generally, ethanol has lower heating value than petrol, the energy content being 25.1 MJ/kg on average (petrol is 46.7 MJ/kg on average). For biodiesel it is 37.8 MJ/kg compared to 40 MJ/kg for diesel. The mitigation scenario was quantified by multiplying the capacity of biofuels (in kg) with corresponding heating values. The conversion factor is the density, of which it is 0.79 kg/litre for ethanol and biodiesel is 0.87 kg/litre.

Other Sectors (Residential)

In Malawi, charcoal production technologies are crude and inefficient (10-15%) (Pooter, 2016), implying that more trees have to be cut to produce a unit quantity of charcoal. In addition, the majority of households still use the inefficient three-stone open fire stove for cooking, which again results in the stove consuming more firewood to cook one-unit quantity of food. Alternative fuels for cooking and heating that are clean and affordable are limited. Therefore, the thrust of the technology behind cooking using the biomass stove is on reducing energy losses, which could be achieved using insulation. In addition to insulation and correct design of the stove, the practice/behaviour, fuel management and conditions of cooking determine the amount of energy losses.

Government of Malawi and development partners have carried out programmes and projects, in which technologies have been developed and/or imported and demonstrated, to reduce deforestation on the side of biomass energy supply. These include a clay firewood cooking stove, locally called *Chitetezo mbaula* Figure 5.9, which was promoted by The Government through NASREP and ProBEC in Mulanje, Thyolo and Ntcheu Districts. Currently, the Government and non-governmental organizations are promoting the clay firewood cooking stoves in some parts of the Malawi. In ideal cooking conditions and practice, a *Chitetezo mbaula* stove can save up to 60% of firewood compared to the traditional three-stone open fire (Malinski, 2008). However, this clay firewood cooking stove technology has not diffused to all parts of the country, in the way the Charcoal Ceramic Jiko (technology originated from Kenya, refer to Figure 5.9) has been popularized in Malawi. The Charcoal Ceramic Jiko Stove is similar in design to the clay firewood study except that the Ceramic Jiko has a grate Figure 5.9. The Ceramic Jiko stove is manufactured by local tinsmiths in both rural and urban areas of Malawi; the lining could be made from only clay (to reduce cost), though some local manufacturers mix clay with cement to make the lining strong.

Figure 5. 9 Types of cooking stoves: *Chitetezo mbaula* (left), Ceramic Jiko (middle) and institutional rocket stove (right).

The other firewood cooking stove technology existing in Malawi is the rocket stove. The rocket stove can be adapted for use at the household and in institutions Figure 5.9. In Malawi, the stove was promoted by the Government of Malawi and ProBEC and Ken Steel Engineering, a Malawian company, manufactures the stoves locally for primary schools and other organizations. The rocket stoves are not popular for household uses compared to clay firewood cooking stove due to high cost and deviation from traditional cooking practices.

Biomass-gasification technology is only available at experimental stage. Earlier prototypes were constructed by the Malawi Industrial Research and Technology Development (MIRTDC). Lately, a micro gasifier stove was produced by the Jesuit Centre for Ecology and Development that incorporates a thermal electrical conversion system, thereby producing electricity whilst providing heat for cooking and heating. Biogas production technology, mainly using cow dung as substrate, has been developed and installed in the country for both household and institutional applications. However, most of the installed biogas systems are not functional. Production of biogas from municipal waste and human soil (pit latrines) is also a viable technology in Malawi. Since the feed stock for biomass gasification and biogas systems is widely available, these technologies provide a significant potential for efficient energy generation from biomass and waste.

Liquified Petroleum Gas (LPG) gas stoves are available in urban areas and are sold by Afrox Gas Limited. However, its uptake is hampered by perceptions of explosion risk and high cost. The TNA for Malawi has identified LPG for cooking as the top prioritized mitigation technology in the energy sector. The Sustainable Energy for all Action Agenda for Malawi states that by 2030, there would be 54,000 households cooking using LPG cook stoves from 6,800 in 2016 (GoM, 2017). It is estimated that 1 kg of LPG has a useful energy value of 20.7 MJ/kg. Depending on the type of wood fuel, charcoal production, and cook stove, between 7.3 and 29.7 kg of wood fuel (making an average of 18.5 kg) would be required to provide the same amount of useful cooking energy found in 1 kg of LPG (Energypedia, 2020). Of course, the amount of fuel used depends on conversion and type of technology used. The Latin America Thematic Network (LAMNET) on bioenergy estimates that, in general, Africa requires 1 and 0.287 kg/day/capita firewood and charcoal respectively, for cooking. The average Malawian household size is 4.5, from the 2008 and 2018 housing and population census (NSO, 2019). Therefore, from the number of households planned to have access to LPG, energy for cooking from LPG could be estimated.

In addition, 70% of the planned energy generation from biomass energy systems will be used for thermal services in households, chiefly for cooking (GoM, 2017). This is spread out from 2016 to 2030, but the mitigation analysis assumed this intervention will start in 2021. This will be generated from biomass gasifiers for thermal applications. Cooking (and other house hold thermal application) time per day varies, depending on the type of food, amount and type. In this mitigation analysis, an average of 3 hours per day has been used. This estimates the energy required in a year from biomass gasifiers.

The main target is the increase in the number of energy-efficient cookstoves from 500,000 in 2016 to 5 million by 2030 (GoM, 2017). Regarding energy efficient cookstoves (or improved cook stove) for fuelwood, savings between 25-65% per stove per household are realistic when used correctly, while improved charcoal stoves usually save around 25-35% compared to traditional charcoal stoves (Energypedia, 2020). In this mitigation analysis, an energy savings of 30% is used on fuelwood improved cookstoves.

5.2.6 Mitigation potential of energy sector interventions

The mitigation analysis is assumed to commence in 2021, and it can be seen Figure 5.10 that there is only slight reduction in GHG emissions. If the mitigation actions are actualized, the country will only slightly contribute to abatement of emissions by 130, 171 and 305 Gg of CO_2 in 2040 from mitigation interventions in the energy industry, other categories (residential) and road transport categories, respectively.

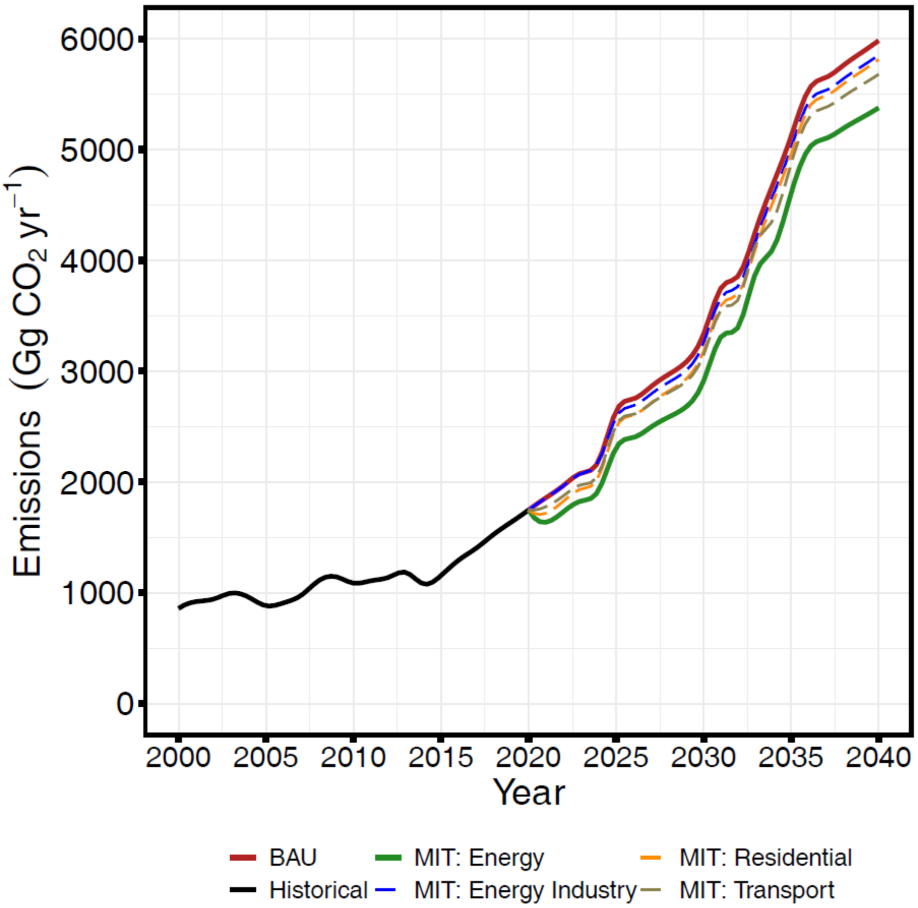


Figure 5. 10 Contribution of mitigation technologies to abatement of GHG emissions in the energy sector. The red line represents BAU emissions for the energy sector, whereas the green line represents the contribution of all mitigation activities in the energy sector.

Overall, total emissions will be increasing sharply due to planned power generation from coal power plants. Therefore, more mitigation measures must be implemented to meaningfully reduce the GHG emissions. This could include significantly increasing the share of renewable energy in the power production mix, increasing production of biofuels above those planned amounts in order to improve on this abatement and introducing technology to capture and store carbon during the operation of the planned coal power plants. In addition, biodiesel should be promoted with the same policy instruments as for ethanol. It is also necessary to popularise use of electric cars as well as cars that operate on dominant biofuel ratios (with petroleum), among others, through incentivising on their purchase and use. There is need to lower the rate of vehicle importation of old vehicles, through measures such limitation on vehicle age to be imported and increasing import duties further.

The CO_2 emissions for biomass are biogenic and thus are not accounted for in the mitigation analysis. However, biomass when combusted for energy is also associated with other non-carbon GHG emissions such as methane and nitrous oxide. In this mitigation exercise, the contributions of these emissions are lumped together in terms of Global Warming Potential (GWP) for the time horizon of 100 years in LEAP software. The results show that the GHG emissions GWP will increase up to 2040. The mitigation measures are shown to significantly reduce GWP by 171 Gg in 2040 from 139 Gg in 2021. It is thus recommended to prioritise the mitigation options presented: biomass gasification for generation of thermal energy for cooking, apart from working on production and popularization of efficient cookstoves.

5.3 Agriculture, Forestry and Other Land Use

5.3.1 Introduction

The Agriculture, Forestry and Other Land Use (AFOLU) sector deals with anthropogenic GHG emissions and removals, defined as all emissions and removals occurring on 'managed land' and that are associated with the use of land, including agriculture and husbandry. Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions (IPCC, 2006). Figure 5.10 provides a synthetic image on how land use and management can influence a variety of ecosystem processes, which in turn can affect greenhouse gas fluxes such as photosynthesis, respiration, decomposition, nitrification/denitrification, enteric fermentation, and combustion. These processes involve transformations of carbon and nitrogen, driven by biological (activity of microorganisms, plants, and animals) and physical processes (combustion, leaching, and run-off).

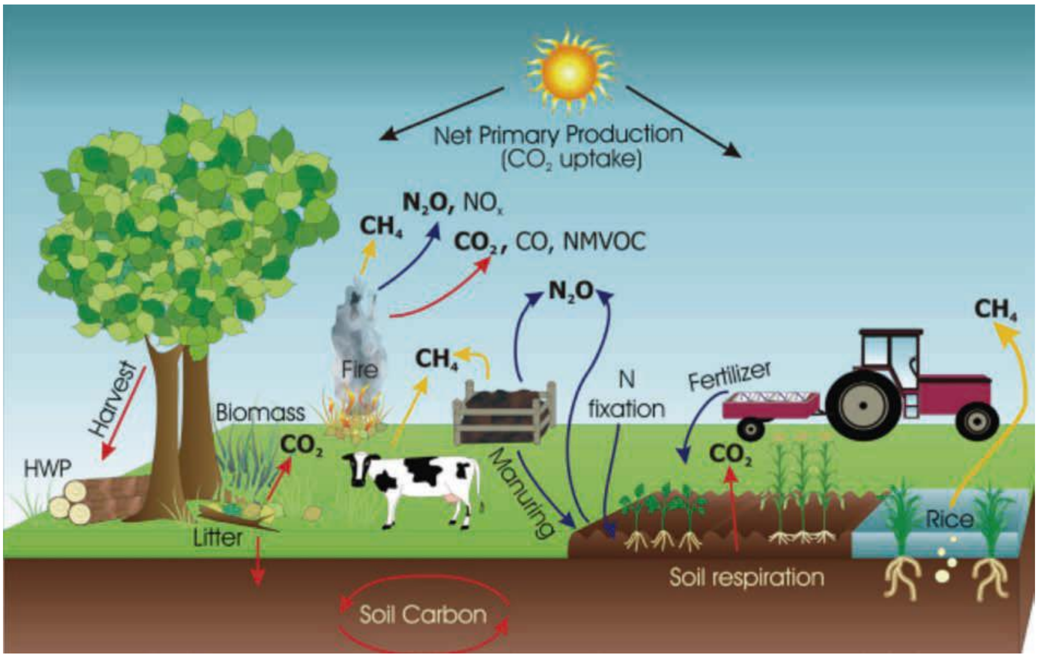


Figure 5. 11 GHG emission sources/removals and processes in managed ecosystems

Source: (IPCC, 2006).

According to the 2006 IPCC Guidelines on conducting national greenhouse inventories, estimates of GHG emissions and removals deriving from AFOLU include the following:

(i). CO_2 emissions and removals resulting from carbon stock changes in biomass, dead organic matter (DOM), soil organic matter (SOM) of organic and mineral soils, and harvested woody products (HWP) for all managed lands;

(ii). CO_2 from cultivated organic soils;

(iii). non-CO_2 emissions from fire on all managed land;

(iv). CH_4 emissions from rice cultivation;

(v). N_2O emissions from all managed soils;

(vi). CO_2 emissions associated with liming and urea application to managed soils;
(vii). CH_4 emissions from livestock enteric fermentation;
(viii). CH_4 and N_2O emissions from manure management systems.

The Malawi's GHG inventory has split emissions from AFOLU into Agriculture and Forestry and Other Land Use (FOLU). The Agriculture emissions comprise non -CO_2 emissions while the FOLU comprise all the CO_2 emissions. The emissions analyzed in Agriculture are from livestock (enteric fermentation and manure management) and rice cultivation. This was necessitated from expert opinion of the inventory compilers. However, due to extensive use of fertilizers and lime in soil management, emissions from managed soils (agricultural soils) need to be considered in the next GHG inventory.

5.3.2 Mitigation Analysis in Agriculture

5.3.2.1 Business as Usual Scenario

The non-CO_2 emissions in the Agriculture sub-sector are increasing, as evidenced by the increasing numbers of livestock (cattle, goat, sheep and rabbits). The significant share of emissions in the sub-sector is from enteric fermentation, methane (CH_4). For example, in 2001, CH_4 emission from enteric fermentation was 33.4Gg while in 2017 was 101.8 Gg, representing an increase of about 200%. The increase is due to the general increase in animal husbandry practices that the Government of Malawi is putting in, as well as the complementary efforts of the NGOs especially in goats and dairy. The CH_4 from manure management was relatively on the lesser side: 1.4 Gg was emitted in 2001 while in 2017, it was 5.8Gg. Manure management and rice cultivation altogether were less compared to those from enteric fermentation, thus CH_4 mitigation actions should focus on enteric fermentation.

The nitrous oxide (N_2O) emission is also from manure management and agricultural soils. During the period of TNC reporting, the indirect N_2O emission totaled 826.5 Gg. The emission was 33Gg in 2001 and in 2017, was 72Gg. The increase in N_2O is mainly due to increase in fertilizer application, especially from the Government of Malawi farm input subsidy programme that was established in 2004 where farmers are provided with subsidized fertilizer to improve on national food security (Chibwana & Fisher, 2011). From expert judgment, CH_4 and N_2O emissions are expected to increase at the rate of 5% annually upto year 2040.

The baseline scenario, in the context of this mitigation analysis, was the trend of emission in the agriculture sector if no mitigation options are adopted. The baseline scenario takes into account the expected effects of climate related policies and strategies that are already in place, and the expected growth of the Sector. The baseline scenario assumes that the emissions will increase at a rate of 0.5% annually starting from the year 2020 up to the tear 2040. 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.

5.3.2.2 Mitigation Scenario

Mitigation Scenario predicts GHG emission trends under interventions to limit their emissions. In the Malawi's NAMAs, the AFOLU sector showed greatest mitigation potential, and thus the contribution from Agriculture Sector in the country's mitigation efforts cannot be downplayed. The mitigation options identified in Malawi's Second National Communication (INC) and in Nationally Appropriate Mitigation Actions for Malawi apply for this assessment. Additionally, these mitigation options are in line with what is recommended by Food and Agricultural Organization (FAO) as GHG reduction options in the Agricultural sector. These mitigations were selected through a screening process by the stakeholders, using the following criteria: cost of implementation, potential to reduce emissions, ease of implementation and compatibility with government programmes and plans. The optimal mitigation options selected are briefly described as follows:

5.3.2.2a Improved rice cultivation practices

For example, employing the System of Rice Intensification (SRI) is known as a climate-smart agricultural practice that increases rice production by changing the management of plants, soil, water, and nutrients. SRI water management relies on intermittent irrigation rather than on the continuous flooding of conventionally managed rice production (Hassan, et al., 2019).

5.3.2.2b Livestock productivity improvements that reduce emission intensities

According to FAO, emission intensities are emissions expressed per kg of milk, meat or egg. The intensities vary among producers in the same area, indicating scope for improvement (FAO, 2017). Further, FAO estimates that improved husbandry practices could reduce emissions by 20 to 30%, across all production systems (FAO, 2017). There are other benefits for increasing livestock production for an agricultural based country like Malawi. Helping farmers to increase the productivity of livestock is a means to improve rural livelihoods and food security. Further, it supports resilience to climate change. Improved animal husbandry practices include the following:

(i). **Feed and nutrition:** Improving feed quality can be achieved by better grassland management, improved pasture species (e.g. mix of grass and legumes), forage mix, feed processing (e.g. chopping, urea treatment) and the strategic use of supplements, preferably those available locally.

(ii). **Animal health and husbandry:** Improving reproductive efficiency and extending the reproductive life of the animal will improve lifetime performance per animal and reduce GHG emission intensities. A higher productivity and efficiency can be reached by reducing the incidence and impact of diseases, parasites and insect burdens. This will also reduce losses and the number of unproductive animals that emit GHG.

(iii). **Animal genetic resources and breeding:** Breeding is key to increasing productivity by improving traits such as live-weight gain and milk yield or fertility. It can also improve livestock’s adaption to changing environments and resistance to stress, shocks and diseases. Well planned breeding programmes and conservation of animal genetic diversity can ensure that farmers have access to the best animals for each environment.

5.3.2.2c Carbon sequestration through improved pasture management;

Solutions to restore the quality of pastures and increase soil carbon are available. These solutions can enhance carbon sink that could have been compromised by unsustainable pasturing practices. Such solutions include adjusting grazing pressure by balancing spatial and temporal presence of livestock (e.g. with new technologies like solar powered electrical fences), fertilization and nutrient management, introduction of species (e.g. legumes) and plant inoculation, improved mobility of animals in pastoral and agropastoral systems, and the integration of trees and pastures. These solutions are applied in the country, but to a lesser extent.

5.3.2.2d Improved manure management practices

It is recommended to employ recommended management practices, such as roofing animal housing, having a water-proof floor or covering manure during storage, causing large nutrient losses during manure storage, increasing greenhouse gas emissions, and reducing the quality of the manure as a fertilizer. However, in Malawi, this practice is not followed most of the times, contributing to increase in CH_4 emissions from manure management. Further, Malawi does not explicitly mention manure management in their policies and does take limited action to promote good practices or enforce legislation on manure management. Furthermore, farmers have limited knowledge on manure management. However, farmers are able to access agricultural extension services from both Government and Non-government organisations, although these extension services rarely include information on improved manure management practices.

5.3.2.2e Improved fertilizer management practices

Chemical fertilizer application is one of the major sources of N_2O emissions in the agriculture soils, especially for Malawi that predominately depends on chemically-fertilized soils for food production and for commercial farming endeavors. Improved fertilizer management practices increase fertilizer efficiency, thus reduce on amount of chemical fertilizer per unit piece of cropped land resulting in emission reduction. However, in Malawi, adoption of such good practices is low and the perceived profit potential of fertilizer use in maize production is unattractive to many smallholders at current maize price to fertilizer cost ratios relative to other uses of available finance.

5.3.2.2f Application of zero tillage or conservation farming

Application of zero tillage or conservation farming is supported by Government and NGOs such as Total Land Care. Conservation farming decreases use of chemical fertilizers and also improves soil storage of carbon. However, there is little incorporation of crop residues in as the crop residue is harvested by uprooting and used for fuel and livestock feed. In other cases, it is burnt to ease land preparation.

5.3.2.2g Application of agro-forestry practices,

Agroforestry includes crop rotations, mixed cropping and intercropping with regumes for soil inoculation.The major challenge for Malawi to practice agroforestry is the tendency for the majority of small scale farmers to grow only one type of the crop (maize) on the same land due to limited land to practice such farming practices (Snapp, et al., 2014). However, there is an opportunity for increasing cultivation of nitrogen fixing crops such as regumes because the Government of Malawi is encouraging growing such crops as a way of diversifying commercial crop away from tobacco. To support this, some of the major tobacco industries started diversifying into legumes and they further help their farmers to access the improved legume seed and the locally produced inoculant. Further, on opportunity to practice agro-forestry on a large scale in Malawi, there is already predominate intercropping cereals with legumes mostly in southern region of Malawi, where up to 10 crops can be found in a field. The pigeonpea is often intercropped with maize.

5.3.2.3 Business as Usual Versus Mitigation Analysis

The experts in the Agriculture sector expect that if all of the above mentioned mitigation options are implemented fully, the sector would reduce emissions by 20%. In this analysis, the base year for mitigation analysis is 2020 and the end year 2040. The emission projections, both for baseline and mitigation scenarios were developed from trend analysis (from historic emissions in the GHG inventory 1994 to 2017) and application of 20% reduction in the mitigation scenario. The mitigation results for CH_4 and NO_2 are presented in Figures 5.11 and 5.12. Methane from enteric fermentation were subjected to mitigation analysis because they are significant compared to CH4 from rice cultivation and manure management altogether. As it can be seen from Figures, there are increasing emission trends for both the baseness as usual and the mitigation scenarios, but the emissions under mitigation scenario are lower. In 2020, there is 115 Gg of CH_4 from emission from enteric fermentation, and if the mitigation options are implemented, 3. 96 Gg CH4 would be avoided. By the end of the mitigation analysis period (2040), 42.19 Gg CH_4 would be avoided. In total, 615.33 Gg CH_4 would be avoided from 2020 to 2040.

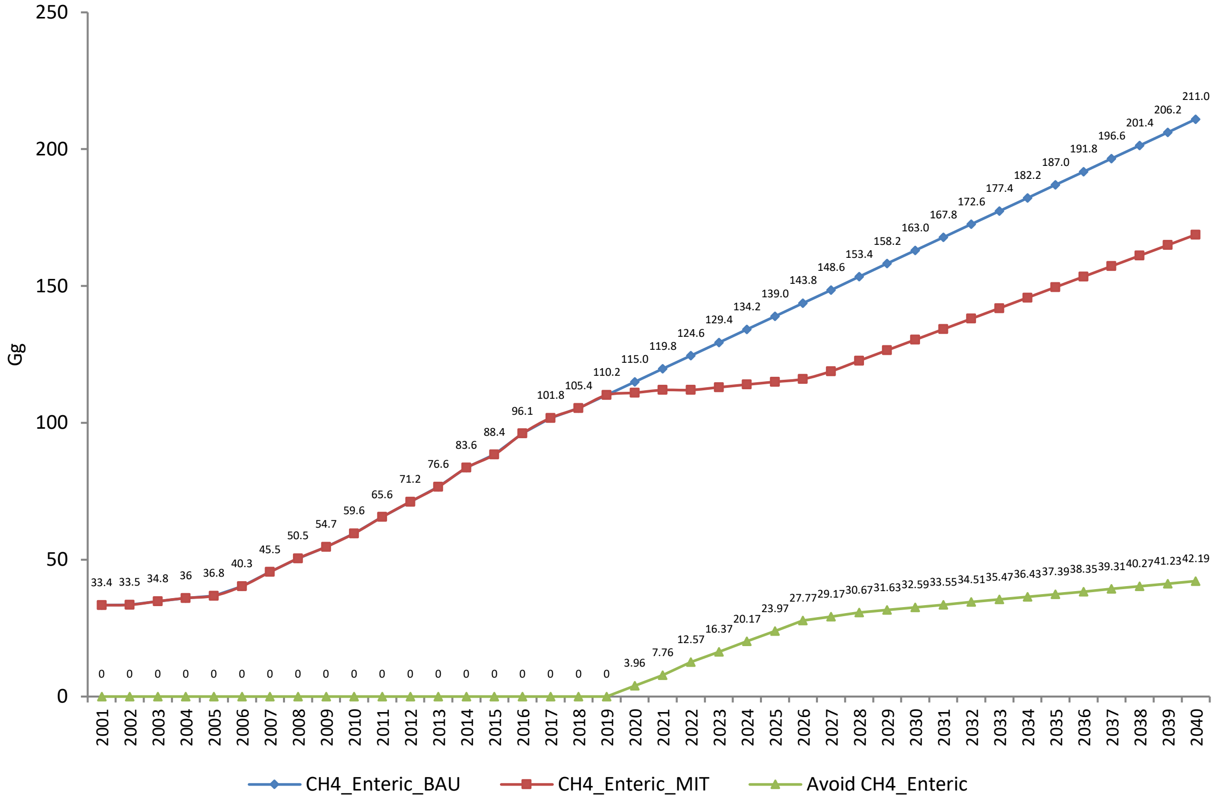


Figure 5. 12 Projected methane (CH_4) from enteric fermentation emissions for both business as usual and mitigation scenarios

The N_2O emissions from manure management have been subjected to mitigation analysis, because these from other sources like from agricultural soils were not available. However, mitigation options to limit N_2O emissions from use of chemical fertilizers (agricultural soils) are valid and would reduce N_2O significantly in Malawi. The results of mitigation analysis on N_2O are presented Figure 5.12. Again, just like in CH4 emissions, the N2O emissions display an increasing increasing trends from 2020 to 2040 in both business as usual and mitigation scenario. The avoided N_2O emissions are also increasing to 44.23 Gg N_2O in 2040, reducing a total 554.5 Gg N_2O within this period.

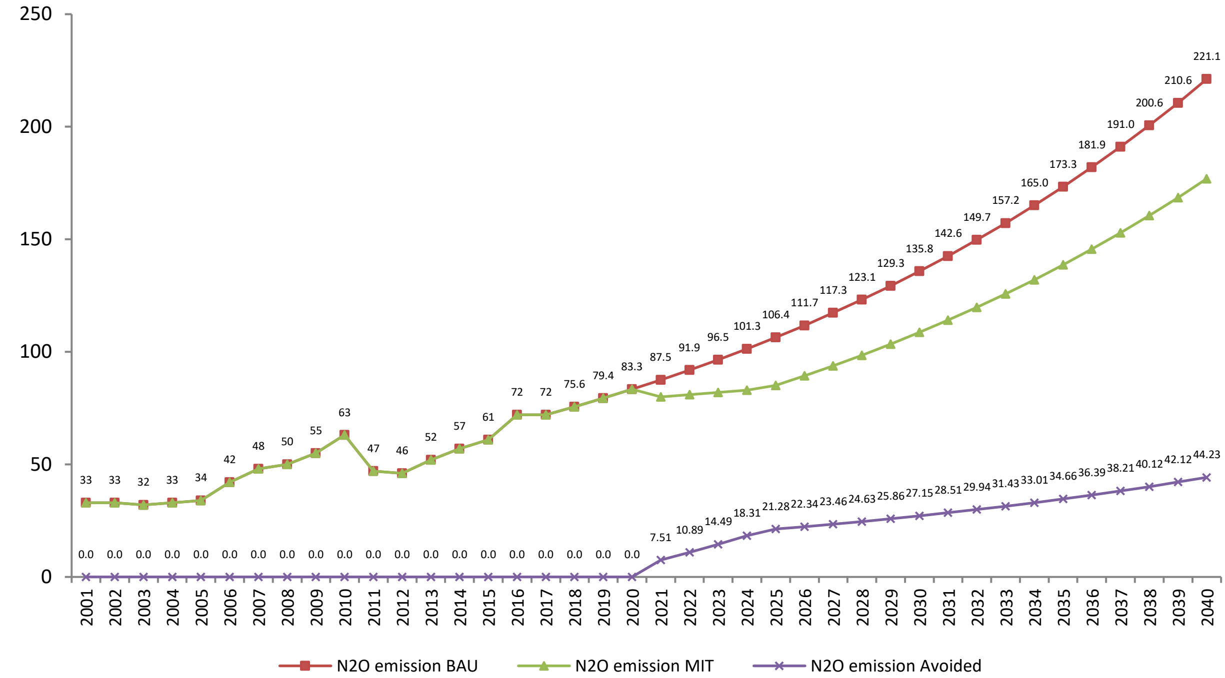


Figure 5. 13 Projected nitrous oxide (N_2O) from enteric fermentation emissions for both business as usual and mitigation scenarios

5.3.2.4 Implementation of the mitigation options

The strategies identified in the second national communication to implement mitigation options in the agriculture sector still apply in the third national communication also. 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).

5.3.2.5 Mitigation Analysis in Forestry and Other Land Use

The Forestry and Other Land Use (FOLU) sector is associated with a large proportion of Malawi's greenhouse gas emissions from forest losses largely due to deforestation and forest degradation. Deforestation results from clearing of forest for agriculture and other land uses as well as from harvesting biomass for timber, pole, and fuelwood. Unsustainable harvesting of forests and forest fires are some of the causes of forest degradation. Precisely, a Forest

Resource Assessment (2011) estimated an annual fuelwood removal of 6 million m^3 from all types of forests in Malawi. In addition, Walker et al. (2015) estimated that the country had lost 3.2 million hectares of forestland, with an annual forest loss of 5.3 thousand hectares. Therefore, Malawi is implementing sector-specific policies to enhance mainstreaming of adaptation and mitigation measures. These include:

(i). National Forest Landscape Restoration,
(ii). Reducing Emissions from Degradation and forest Degradation (REDD+),
(iii). National Charcoal Strategy and
(iv). Tree planting (afforestation and reforestation).

Additionally, there are frameworks that foster development, transfer of technology and capacity building in the context of climate change. For the FOLU sector these technological options include tree survival campaigns, establishment of seed banks for raising drought tolerant tree species, breeding and screening drought tolerant tree species, pest and disease control (e.g. biological control of *Eucalyptus* wasps), sustainable management of forest resources.

5.3.2.6 Mitigation activities in the Forest and Other Land Use

Forest cover is an important source of carbon sink, hence have high mitigation potential. Therefore, mitigation options in the FOLU sector, whether technological and policy interventions that enhance forest cover are needed to reduce GHG emissions in Malawi. The following are the mitigation activities that have been implemented in the country in the reporting period of the Third National Communication:

5.3.2.6a National Forest Landscape Restoration Strategy (NFLRS)

In 2016, Malawi made an ambitious commitment to conserve a total of 3.5 million hectares as part of the African Landscape Restoration Initiative (AFR100), a pan-African, country-led effort to restore 100 million hectares of degraded and deforested landscapes by 2030. The country seeks to conserve and manage forests among others, through the National Forest Landscape Restoration Strategy (NFLRS). In this programme, the country has identified and mapped degraded sites in every district in order to mitigate through integrated landscape management approaches to forest landscape restoration. The NFLRS has developed the following forest-based restoration interventions:

(i). establishment and management of community forests and woodlots,
(ii). forest management (forest reserves and plantations) and
(iii). rehabilitation of stream and riverbanks

5.3.2.6b Reducing Emissions from Degradation and Forest Degradation (REDD+)

Malawi established a national framework to Reduce Emissions from Deforestation and Forest Degradation (REDD+) that will inform future actions on the categorization of greenhouse gases that emanate from forestry and land uses. This forms part of the national greenhouse gas (GHG) accounting and reporting systems as a part of the country's obligations to the three major Rio Conventions (UNFCCC, CBD and UNCCD). The REDD+ initiatives have capacity development as a key component. A review and adoption of policy instruments has always recognized capacity development as central enhancing progress in emerging issues such as climate change and/or REDD+.

5.3.2.6c National Charcoal Strategy

The Government of Malawi recognizes that more than 97% of households rely on illegally and unsustainably sourced biomass (charcoal and firewood) for domestic cooking and heating energy. The dependence on biomass energy has resulted in high levels of deforestation and environmental degradation throughout the country. Therefore, the Government seeks to address this challenge in order to arrest and reverse the rate of deforestation and forest degradation that will ultimately mitigate the emissions that originate from the use of tree biomass as energy.

The 2017 National Charcoal Strategy (NCS) presents a multi-sectoral framework and approach, focused on pillars (for 2017-2027) that define opportunities to incrementally address problems of charcoal production and demand in the near-, medium- and long-term. The pillars (refer to
5.3) serve to mitigate GHG emissions that emanate from the FOLU domain (and also interrelated to the Energy Sector) and they include the following:

(i). promote alternative household cooking fuels,
(ii). promote adoption of fuel-efficient cook-stove technologies,
(iii). promote sustainable wood production,
(iv). regulate sustainable charcoal production and
(v). enhance livelihoods.

Table 5. 3 Pillars and action points in the National charcoal strategy

Pillar	**Main goals**
Promote alternative household cooking fuels	This pillar calls for effective control of illegal charcoal production and reduction of dependence on biomass fuels with affordable, reliable, and readily available alternative energy sources such as (i) electricity, (ii) Liquefied petroleum gas (LPG), (iii)briquettes and pellets and (iv) Biogas.
Promote adoption of fuel-efficient cook-stove technologies	This serves to promote the adoption of improved charcoal and firewood cook-stoves for household cooking and heating with the aim to use comparatively less energy and mitigate on emissions.

Promote sustainable wood production	Recent projections on wood indicate that by 2030 there will not be enough biomass in the country to meet demand for firewood and charcoal (Malawi Government, 2017). This pillar seeks to promote large-scale/commercial cultivation of fast-growing tree species and/or alternative feedstock suitable for charcoal and commercial firewood production, through concessions or other appropriate means.
Regulate sustainable charcoal production	This seeks to establish a regulated charcoal value chain that promotes sustainable and efficient production of charcoal in Malawi based on a business model, as opposed to a charcoal ban that is seemingly being naïve on its effectiveness.
Enhance livelihoods	In recognition of the role that livelihoods and income generation play in charcoal production and marketing the Malawi Government commits to strive to secure livelihoods for legal producers and find alternative livelihoods for others through pillars.

5.3.2.6d Tree planting (afforestation and reforestation)

The Forestry Sector conducts an annual National Forestry Season Campaign that runs between 15th December of one year and 15th April of the following year in order to address the challenge of increased risk of declining tree productivity and mortality as a result of reduced rainfall, increased temperatures, natural disasters and water loss. During this campaign, tree planting (afforestation and reforestation) is implemented countrywide, taking advantage of the rain season. Each year, planting of different tree species is done in all land categories that include; state-owned forest plantations and reserves, customary lands and private-owned lands including estates.

5.3.2.6e Tree survival campaign programme

Inaugurated in August 2016, the Tree Survival Campaign Programme focuses on encouraging the nation to plant, and more importantly manage trees so that they attain the utility age and fulfil their respective intended purposes. This was initiated against the background that most of the replanted or naturally regenerated trees are left unattended and fail establish. Therefore, every year, the Department of Forestry takes an account of trees that have been planted throughout the country. As of 2019, an annual average of 60% tree survival rate has been reported.

5.3.2.6f Establishment of seed banks for raising drought-tolerant tree species

Seed banks is one of the keys to development of the forestry sector as climate conditions change. In response to the call on the need to develop drought resistant species, Forestry Research Institute of Malawi (FRIM) in conjunction with the Mulanje Mountain Conservation Trust (MMCT) has, for example, established tree nurseries and seed research plots of *Widdringtonia whytei* (Mulanje Cedar) in Mulanje and Dedza Mountain Forests and also in the Viphya Plantations. Indigenous to Malawi, the germplasm of *W. whytei* that is being regenerated will be adapted to low and marginal rainfall conditions that are being experienced in the country. Additionally, through other programmes such as Millenium Seed Bank Project, FRIM in collaboration with Kew Garden, UK, has also been engaged in conservation of the country's rare, endangered and endemic tree species' seed for future replanting exercises.

5.3.2.6gBreeding fast growing and drought tolerant tree species

The SNC recommended that a coordinated research approach to tree breeding and/or screening programme is a viable option in identification and development of high yielding, and drought and disease tolerant tree species are concerned. It further indicated the need for developing suitable species for the predicted warmer and drier environments in the future. In response, FRIM has outsourced fast growing hybrid pine seed (*Pinus patula*, *Pinus kesiya*, etc.) which typically is an improved breeding material of 4^{th} and 5^{th} generation. This has been planted in Zomba, Dedza and Viphya Forest Plantations.

5.3.2.6hScreening of disease and pest resistant species and biological control

Disease and pest infestation threaten the forest carbon sink in Malawi. One common group of preferred trees in Malawi that has been adversely affected by pest and disease infestation are *Eucalyptus* species. Research has been conducted to identify the species less susceptible to such pests as *Leptocybe invasa* for adoption in tree planting initiatives. In addition, research on biological control of *L. invasa* is also underway at FRIM using *Selitrichodes neseri* from South Africa. Further, planting of higher resistance tree species such as *Eucalyptus citriodolais* is also recommended. Related research has been recommended on other tree species, and pests and diseases.

5.3.2.6i Sustainable management of forest resources

This 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 interventions include 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.

5.3.3 Mitigation Analysis in Forestry and Other Land Use

EX-Ante Carbon balance Tool (EX-ACT) software was used to estimate GHG reduction potential in the Malawi's FOLU sector. In using the tool, the land use changes were categorized based on key changes between land use classes, mainly CL-FL, GL-FL and FL-FL, the latter being an improvement from a degraded scenario into an improved forest class or a scenario where an intact forest is conserved to remain an intact forest. In the absence of sites properly earmarked for potential project interventions, conversion risk maps from the Malawi (Government of Japan mapping initiative, 2012) were used to identify the forests in need of immediate attention for forest sink expansion or conservation. Data used in estimation of the emissions in the EX-ACT (IPCC GHG estimation) software, such as metrics on change from other lands into forest land, was utilized in estimating amount of land that converts into forest with existing efforts.

Conservatively, five projects were employed in the estimation of potential emission reduction through avoided deforestation and degradation with each project spanning 30 years from 2020 – 2050. The capitalization phase for each project - where benefits from the project intervention continue being accrued after its implementation phase out – was conservatively assumed to be five years based on some previous experiences with forest project that had forest resources degenerating within 6 – 10-year periods once the project had phased out. In terms of degradation, based on expert judgement, the forests were characterized as very low (10% degradation), low (20%) and moderate (40%) degradation. Reforestation and afforestation targets and planted areas in reporting years 2011 – 2017 were used in the estimations as reported by the Forestry Department (DoF, 2017). Two main forest types were utilized in the Ex-ACT software, thus Miombo woodlands and Plantations (Eucalyptus and Pines).

Results indicate that Malawi is likely to reduce its total emissions by 122,993,570 tons of CO_2-eq by 2050 from forest abatement intervention if conservatively a minimum of five projects each in deforestation and forest degradation, as well as afforestation and reforestation efforts are applied. Avoidance of forest degradation with net removals of 85,592,121 tons of CO_2 -eq is likely to reduce more emissions than avoided deforestation (29,217,603 tons of CO_2 -eq) and afforestation and reforestation (8,183,846 tons of CO_2 -eq). These efforts are likely to sequester 88.7 tons of CO_2 - eq per hectare while on an annual basis they are likely to account for a 2.5 tons per hectare. These estimations are likely to be higher if more such projects are implemented beyond these conservative estimates. The level of uncertainty for the estimates ranged between 30.3 and 33.3%.

5.4 Waste Management Sector

In the Waste Management Sector (WMS), GHG emissions that have been 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 GHG emissions for the period 2000 to 2015 are shown in Figure 5.14. In general, the generated solid waste constitutes: (i) organic matter (70 - 90%), (ii) plastic and rubber (4-10%), (iii) paper (4-7%), (iv) metal (1.0 %), (v) textile (0.5%), and (vi) glass (0.5%) (Chinyama and Mandhlopa, 1999).

The carbon footprint from wastes has been increasing significantly from 2009. This growth follows national population explosion and changing lifestyles. The N_2O emissions from solid waste disposal sites arising from anaerobic digestion of organic matter are considered insignificant (IPCC, 2006). Composting emits N_2O in the range of 0.5 to 5% of the initial nitrogen content in the material (Vesterinen, 1996). However, there is paucity of data on these emissions because compositing data is not systematically collected and catalogued. Therefore, there is need for systematic recording, based on volume and weight for compost making activities. The N_2O accounted for in the WMS is from open burning and domestic wastewater treatment. Wastewater treatment and discharge is practiced mainly in urban areas.

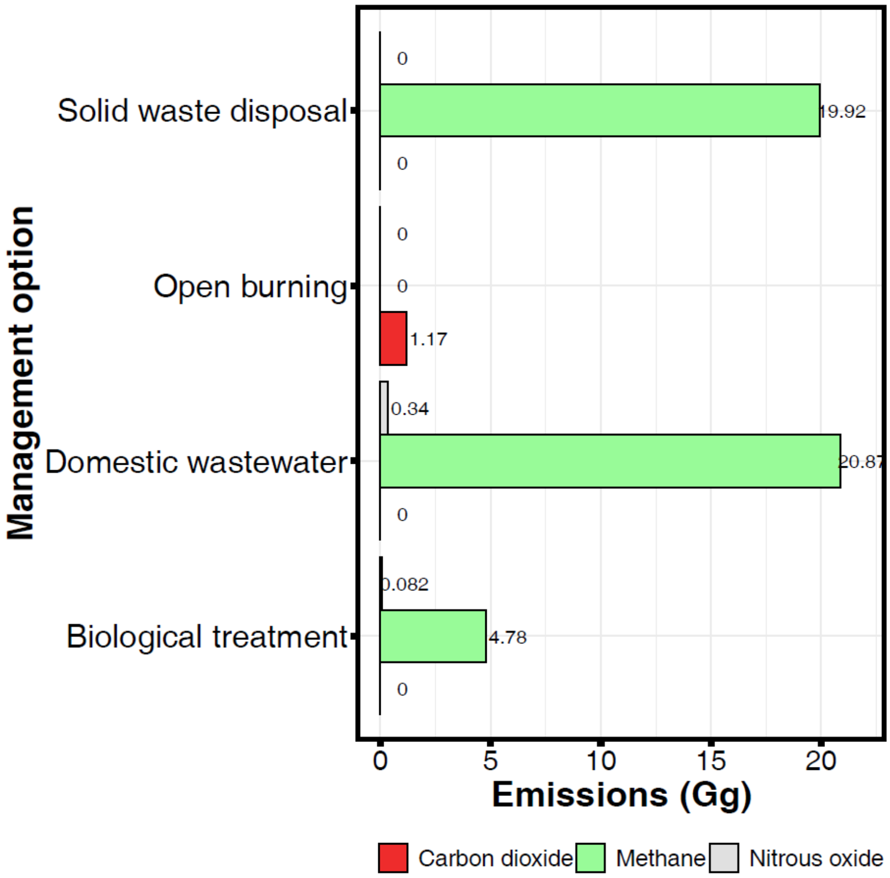


Figure 5. 14 GHG Emissions in waste sector by management option

5.4.1 Mitigation options

Waste management in Malawi is practiced with limited capacity in urban Councils (Cities and towns) and almost insignificant in the rural areas. For example, in Lilongwe (the Capital City of Malawi), the Council only manages to collect 10-20 % of the total solid waste generated within the city per day. Therefore, Integrated Solid Waste Management (ISWM) principles have not been internalised as it requires high organization, high cost of infrastructure and robust supply of human resource base. Therefore, screening for mitigation of GHG in the waste sector in Malawi covers mainly two options: waste reduction and composting.

Waste Reduction

Reduction at source, or waste prevention, refers to practices that reduce the amount of materials entering the waste stream, or at source of generation including changes in the design, manufacture, purchase or use of materials. 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%. 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.

When materials are reduced at source, GHG emissions associated with producing the material and/or manufacturing the product and managing the post-consumer waste are avoided. Consequently, reducing at source provides GHG emission benefits by: (1) avoiding the "upstream" GHGs emitted in the raw material acquisition, manufacture or production and transport of the source-reduced material; (2) increasing the amount of carbon stored in forests (when wood and paper products are reduced at source); and (3) avoiding the downstream GHG emissions from waste management.

Reducing waste at household level has many economic, social and environmental benefits. In Malawi, it is only in the four cities that waste collection is undertaken. Solid waste collection ranges between 20 to 30 % of household wastes. In the city of Lilongwe, private waste collection operators collect more wastes than the city council. The challenge however is the indiscriminate dumping by these licensed private waste collection operators. Other urban local authorities have a dysfunctional waste collection system. Waste disposal bunkers were constructed at selected sites and the Government provided tractors and trailers to the local authorities around 2006. Each urban local authority received one tractor and one trailer for waste management.

Composting

The composting option involves the conversion of solid waste into humus by microorganisms, largely through aerobic decomposition of organic fraction, producing 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 carbon content in the material (Beck-Friis, 2001; Detzel et al., 2003). Composting can also produce N_2O from 0.5% to 5% of the initial N content of the material (Vesterinen, 1996).

Composting has the greatest GHG mitigation potential in Malawi. Active composting takes two months to mature while passive composting takes three to six months, at a per capita waste generation rate of 0.5 kg, and the national passive composting rate is 71%. In all households whether rural or urban, they practice passive composting. The rubbish pits are emptied once a year. Organic wastes are in the pit for twelve months of the year, but the organic wastes that decompose into compost is that for the period of ten months of the year. As the material used for composting is of biogenic origin, any CO_2 emissions are assumed to be reused for photosynthesis by plants while any NO_2 emitted is assumed to be oxidized into CO_2 by bacteria on the upper aerobic part of the compost, which is equally used for photosynthesis by plants.

5.5 Industrial Processes and Product Use (IPPU)

According to IPCC, GHG emissions from Industrial Processes and Product Use (IPPU) are those from that arise from industrial processes, which involve transformation of materials where emissions are part of the by-products. The emissions from combustion of fuels for energy supply in the industrial processes are not taken into account. The industrial processes include those concerned with mineral processing, chemical industry, metal production, and electronic industry. Depending on the materials that undergo transformation, the gaseous by-product could be greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated greenhouse gases (e.g., HFC-23). In the Malawi's Third National Communication GHG inventory, emissions from mineral processing (cement and lime production), ethanol and paint production industries have been evaluated. Malawi is also engaged in glass production, which employs a variety of raw materials such as limestone, dolomite and soda ash as stabilizers, emit process-related CO_2 emissions during glass melting process. Emissions from glass and aluminium production were not considered due to lack of activity data despite the fact that the activities are happening in the country. However, the *PGI Glass and Aluminium* and *Aluminium Industries* in Blantyre are involved in glass production and aluminum production, respectively, which the next GHG Inventory could consider.

The other source of IPPU emissions is from the use of GHGs in products (e.g solvents, refrigerants in refrigeration and air conditioning industry), and from non-energy uses of fossil fuel carbon such as in paraffin wax and in lubricants. Despite emissions from lubricants not being included in the IPPU emissions for Malawi, they would contribute a significant share of emissions in the sector. The lubricants include cutting oils, white oils, insulating oils, spindle oils, automotive lubricants and lubricating greases. In the period of this Third National Communication, according to UNdata (UNdata, 2020), import of lubricants in Malawi ranged between 5 and 6 thousand metric tons (Figure 5.1.5), mostly by oil companies such Total Malawi, Puma Energy Malawi.

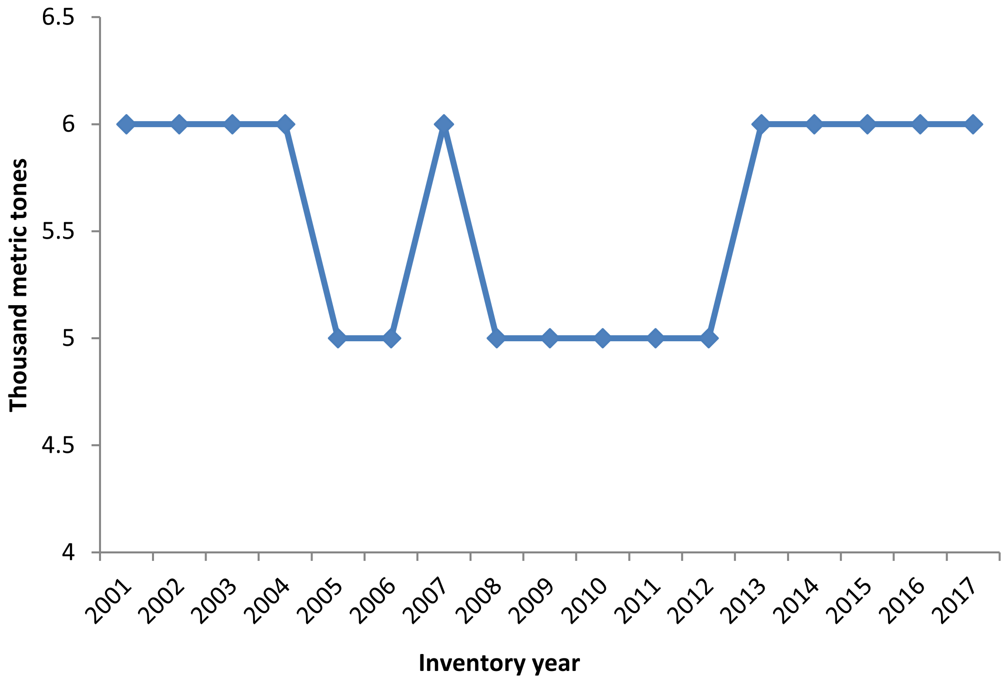


Figure 5. 15 Import of lubricants in Malawi from 2001 to 2017

5.5.1 Mitigation Analysis in Industrial Processes and Product Use

5.1.2 Baseline scenario

Cement production is an energy- and raw material-intensive process that results in the generation of CO_2 both from the energy consumed in making the clinker precursor to cement and from the chemical process (caclination) to make the clinker. As already stated, emissions from fuels (especially coal) consumed for energy purposes during the production of cement are accounted for in the Energy Sector. During the clinker production process, the key reaction occurs when calcium carbonate ($CaCO_3$), in the form of limestone or similar rocks, is heated in a cement kiln at a required temperature to form lime (i.e., calcium oxide or CaO) and CO_2 in a process known as calcination or calcining (refer to equation 5.1). The quantity of CO_2 emitted during clinker production is directly proportional to the lime content of the clinker. The CO_2 is vented to the atmosphere as part of the kiln lime exhaust. For the case of Malawi, the signficant share of IPPU emissions came from cement production (64%) followed by lime production (34%).

$$CaCO3 + heat \rightarrow CaO + CO2 \quad (5.1)$$

Malawi has three cement producing plants, namely: LaFarge Cement Company in Blantyre, Shayona Cement Limited plant in Kasungu and Cement Products in Mangochi. Although the production of cement has risen, the country continues to import the product to meet the ever increasing demand in the contruction sector. During the period of formulating this Third National Communication, the country consumed between 700,000 and 800,000 MT of cement a year. Shayona Corporation Limited (SCL) has recently increased its production capacity to 1,500 MT per day at their Kasungu facility. Cement Products Limited (CPL) has also commissioned its 1,200 MT per day of cement at the Njereza Plant in Mangochi. The shortfalls in cement demand are being filled by imports from neighbouring countries and as far afield as Pakistan, China, India and Eastern Europe. Lafarge/Holcim presently imports close to 190,000 MT of clinker per year for its Blantyre grinding unit. A new Bwanje Cement plant has been proposed that will have an expected annual production capacity of 1,500 MT of clinker per day.

The country experienced a major decrese in cement production from Changalume from 2004 to 2008 (SOER, 2010) and an influx of imported cement from Zambia, Zimbabwe and Tanzania (SNC, 2011) in the years between 2005 to 2009 to cover the deficit. This resulted in decrease in carbon dioxide emissions resulting from reduced calcination activity. However, between 2009 and 2014, there was an increase in cement production and, consequently, CO_2 emissions owing to increase in clinker importation and opening of new Shayona factory in Kasungu district. Emissions from cement between 1994 and 2014 amounted to 889.76 gigga tonnes of CO_2 released into the atmosphere.

Lime production in Malawi has grown from from 3544 tonnes in 1994 to 110,000 tonnes in 2014, and is expected to growth exponentially (refer to **Figure 5.14**). The CO_2 emission emissions from lie production will correspondingly increase. The increase in lime production has increased due to the following factors:

- projected increase in demand for agricultural lime during the period especially in the tobacco estates and pouttry farming;
- the One Village One Product (OVOP) program had positive impact in increasing production capacities of smallholder lime producers (EP&D, 2011);
- demand from poultry and paint industries remained robust during the period;
- Shayona Cement Company had become operational and increased its lime output hence carbon dioxide emissions. The coming into operation of Shayona Cement Company that led to higher emissions of CO_2 especially after commissioning the clinker production in 2013. The other developments that led to increased lime production as stated above did not necessarily lead to higher emissions as they do not involve calcination..

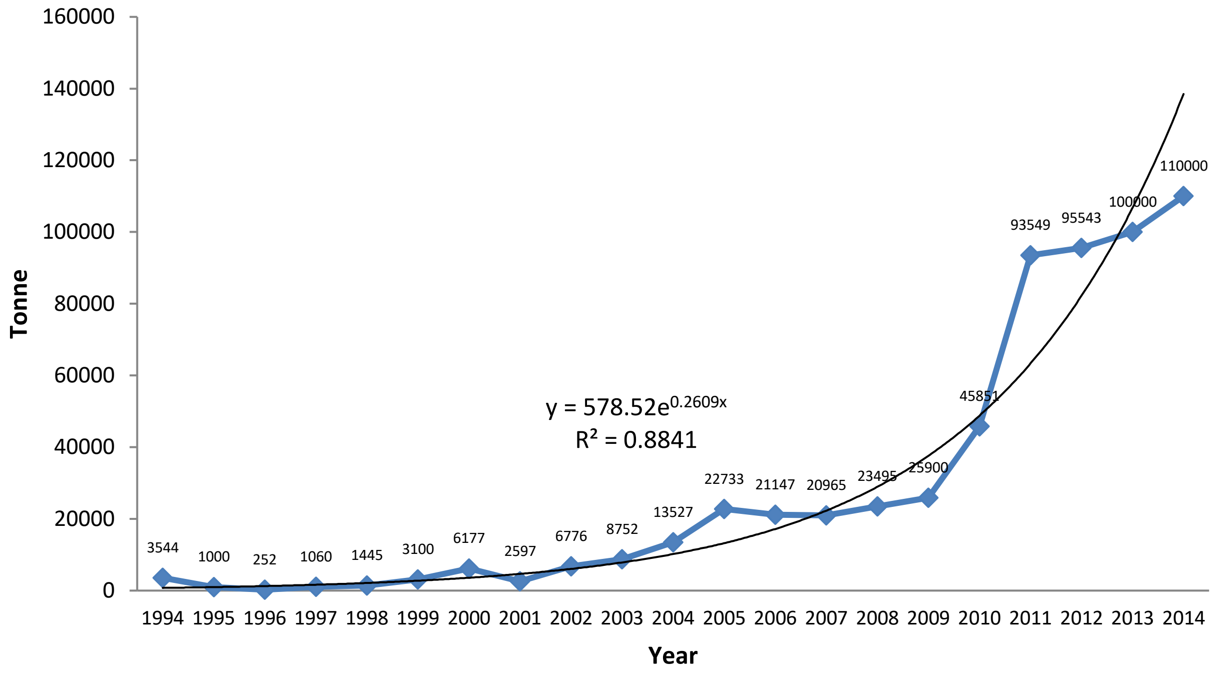


Figure 5. 16 **Production of lime from 1994 to 2014**

The demand for lime in construction and agriculture sectors cannot be met by local production; as such a considerable amount of lime is imported into the country. It is also expected that as coal fired thermal electric power plants projects are installed (e.g the 300MW Kammwamba power project), there will be extra demand for lime for flue gas desulfurization, as part of air pollution control, thereby releasing further CO_2. The companies that produce like, apart from Shayona, include Terrastone. There are several small scale enterprises that produce lime, especially in Zalewa area close to Blantyre City. There has been projects to modernize lime production by local small-scale miners, which would result in emission reduction as well as engagement in economically productive mining ventures among the ordinary quarrying communities. An example of this is the Lime Production Kiln at Chenkumbi in Balaka District. This kiln has a production rate of 4 tonnes of lime per day, with mixed feed, vertical shaft and forced air. This project was the collaboration between the Intermediate Technology and the INDEFUND (a Malawian lending bank promoting small industries). This lime plant only continued production for short time afterwords. The need to transport limestone to the kiln from the Chenkumbi Hills added considerably to the production costs. Also, the quality of lime was poor, and the lime was not favorable by the sugar production companies in Malawi, being the main customer.

5.5.1 Mitigation Scenario

5.5.1.1 Description of Mitigation options

Mitigation options in the IPPU sector are those that were identified in the Malawi's Nationally Appropriate Mitigation Actions (NAMAs) of 2015 (GoM, 2015). The selection of mitigation options was guided by multi-criteria analysis, where the criteria used were cost -effectiveness, socio-economic and environmental benefits, feasibility of implementation and sustainability.

Just like in other sectors, key stakeholders were invited to rank and select the identified mitigations. The prioritised options are as follows: promotion of earth stabilised blocks, use of cement blends (rice or coal ash) (GoM, 2015), and use of machinery that produces low carbon cement.

5.5.1.1a Promotion of Earth Stabilised Blocks

Earth stabilised blocks are building materials that could replace cement stabilised blocks. These are made of soil/earth, compressed in a machine to the required pressure. In most of the cases, a binding material is used, such as a small amount of cement. It requires less energy to produce a block, compared to cement blocks. Cement Stabilized Soil Blocks (SSBs) were introduced into Malawi by DFID in 1998 primarily because of the deforestation caused by burning clay bricks. The Government of Malawi has banned use of burnt bricks in construction, which increase demand for CSSBs especially in commercial and institutional construction projects. This has correspondingly increased demand for cement, hence associated CO_2 emissions.

Malawi uses Earth Stabilised Blocks (ESBs) especially in building of institutional building like rural schools. This is mainly championed by non-governmental organisations that promote environmental sustainability. However, the popularisation of ESBs is not widespread. Increasing the share of ESB in the construction sector would reduce demand for cement; hence mitigate CO_2 emissions related to cement production. Promotion of ESBs is in line with National Construction Industry Council of Malawi position of using environmentally sustainable construction materials (NCIC, 2018).

5.5.1.1b Use of cement blended with pulverised rice husks

The demand for cement in construction industry could be reduced by mixing/blending cement with pulverized rice husks (rice husk ash) in the production of concrete. Use of rice husk ash (RHA) with cement, as a building material, has been proven through scientific; results show that it is a viable construction material, depending on the blending ratio. According to review research by Fapohunda and others, up to 10% cement replacement with RHA results in concrete with strength suitable for construction (Fapohunda, et al., 2017). The supply of rick husks for use in construction industry would be readily available for Malawi, because rice is one of the crops grown on commercial scale, and is well established. Its popularization as one of the construction material would also bring an extra economic value to rice farming. However, the challenge is that use of RHA is not tried in the country on actual construction projects, and therefore, the technology would not be accepted easily.

5.5.1.1c Use of machinery that produce low carbon cement

Reduction in CO_2 could also be achieved by using equipment that produces low carbon cement. For example, Lafarge reports of investing in clinker (Aether)which produces cement of less CO_2 compared with cement from other ordinary machines (clinkers) (Lafarge Malawi, 2020). The new clinker *Aether* uses less limestone compared to ordinary clinkers and is operated a lower temperatures. These conditions results into a 25 to 30% cut in CO_2 emissions during the cement production process using Aether clinkers (Aether Cement, 2020). The low carbon cement still offers similar performances to Portland Cement in a wide range of concrete applications (Aether Cement, 2020).

5.5.2 Baseline scenario and Mitigation scenario analysis

Only emissions from cement and lime production are analysed for baseline and mitigation scenarios analysis, because they are the key categories in the IPPU Sector. The baseline scenario is developed assuming that there is no intervention to limit emissions, thus future emissions are predicted from emission historic trends. For mitigation scenario, it is assumed that by the year 2040, reduction of 40% is possible through mitigation options described for the cement and lime production activities. This is projection is supported by Malawi's Second National Communication, and it is assumed that the reduction is gradual from year 2020. Figures 5.16 and 5.17 shows graphs CO_2 emissions trends for baseline and mitigation scenarios for cement and lime production, respectively.

From the mitigation analysis presented in Figures 5.18 and 5.19, it is seen the emissions for both business as usual and mitigation scenarios show increasing trends. For CO_2 emissions in cement production, without mitigation options, in 2020 the emission was 17.4 Gg CO_2 while in 2040, it would be 444.25 Gg. For mitigation scenario, the CO_2 by the 2040 would be 266.5 Gg CO_2, reducing a total of 1798.3 Gg CO_2. This is a meaningful reduction in GHG emissions, worthy investing in the stated mitigation options. For, CO_2 emissions in lime production, it is the same trend as for the cement production for both scenarios. The business as usual scenario had emission rising from 110.56 Gg CO_2 from 2020 to 293.34 Gg CO_2 by 2040. The mitigation analysis showed a total CO_2 reduction of 1150.4 Gg CO_2 over the 20 year period.

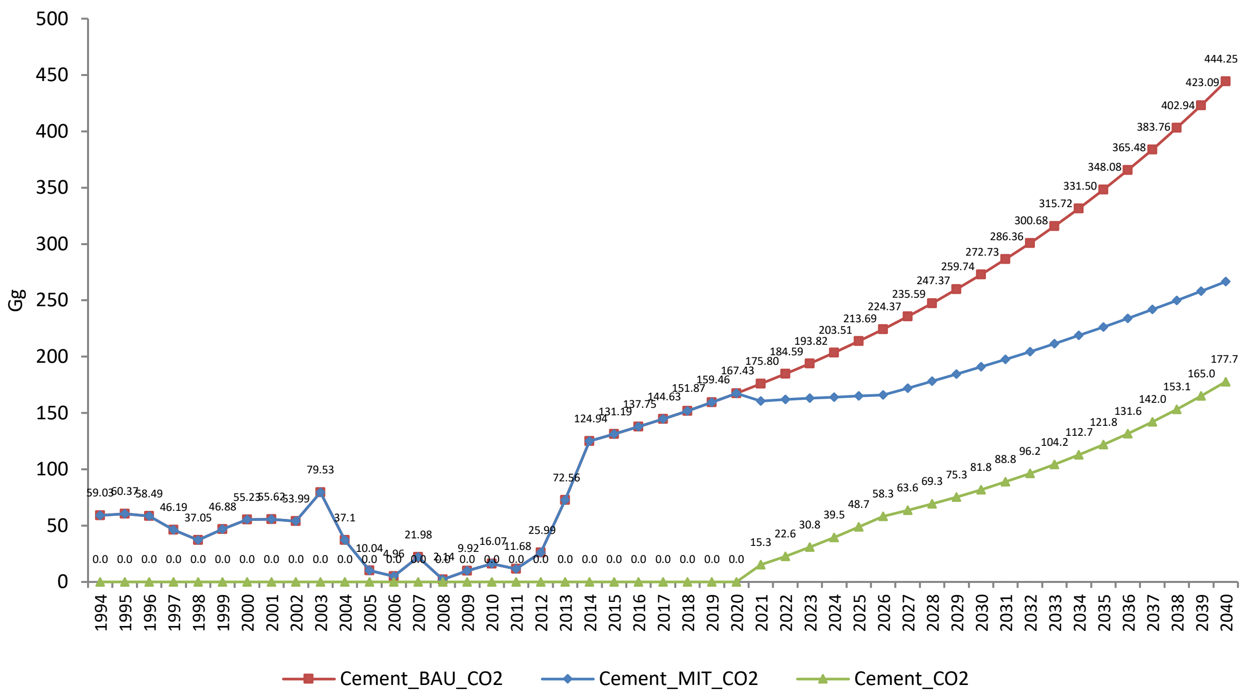


Figure 5. 17 Emissions trends for baseline and mitigation scenarios for CO_2 emissions arising from cement production

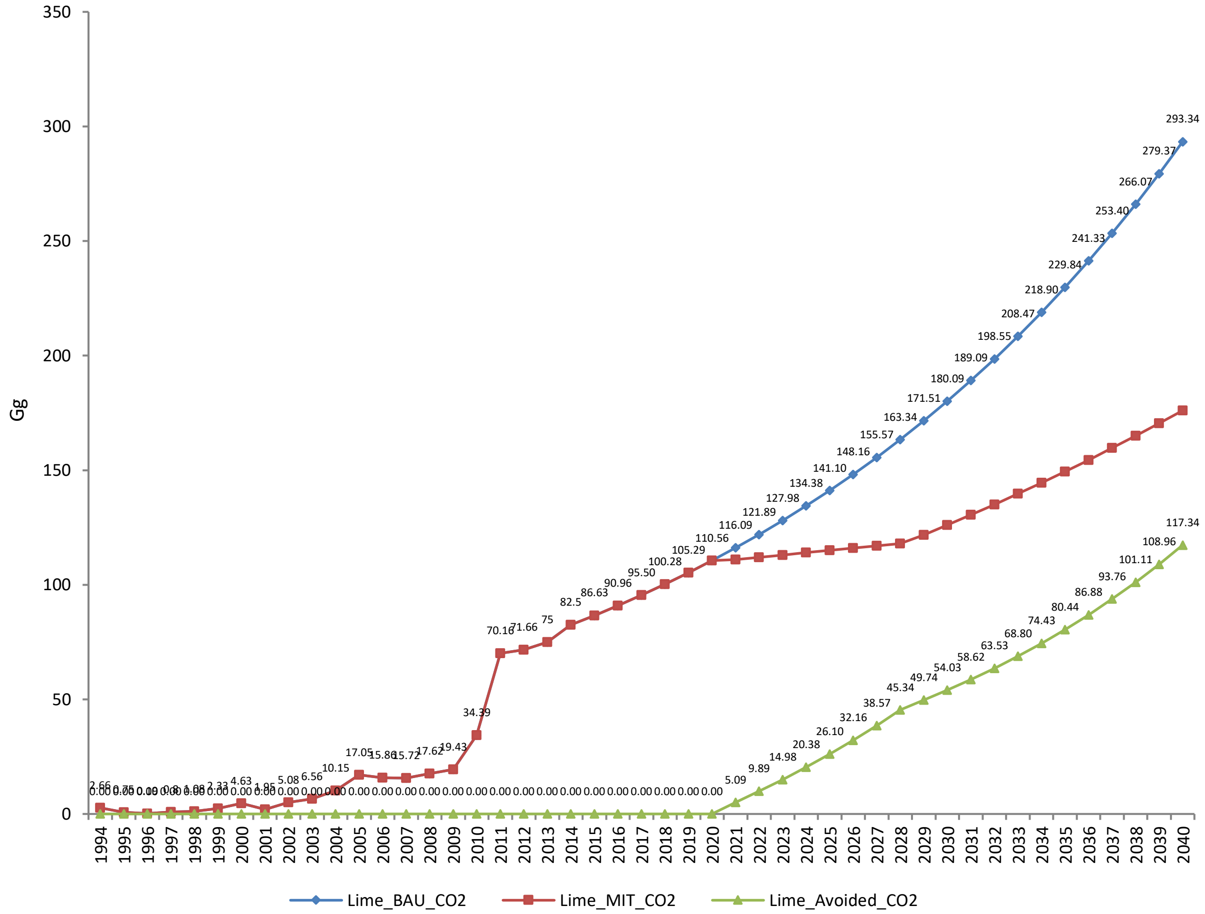


Figure 5. 18 Emissions trends for baseline and mitigation scenarios for CO_2 emissions arising from lime production

CHAPTER 6

OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENT OF THE OBJECTIVE OF THE CONVENTION

6.1 Other Information Considered Relevant to the Objective of the Convention

Malawi has implemented a number of climate change related responses to changing socio-economic circumstances, including development and propagation of national policies, strategies and programmes. 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, etc.

6.2 Steps taken to integrate climate change into relevant social, economic and environmental policies, actions and strategies

The guidelines for the preparation of national communications from Parties not included in Annex I to the Convention encourages Parties, as appropriate, to provide information on any steps they have taken to integrate climate change considerations into relevant social, economic and environmental policies and actions in accordance with Article 4, paragraph 1 (f), of the Convention.

Climate change poses a serious threat to the achievement of Malawi's sustainable development. The emergency and increased intensity of climate hazards such as floods and droughts exacerbated by high rates of population growth, land degradation and overdependence on rainfed agriculture amidst low financial, technical and institutional capacity to adapt, threatens the country's economic and social development efforts. Hence mainstreaming of climate change into relevant social, economic and environmental policies, actions and strategies is pertinent to build and increase resilience and boost greenhouse gas mitigation efforts. Mainstreaming of climate change into national policies and development strategies emphasizes the role of climate change, as an important pillar for sustainable socio-economic growth and development, poverty alleviation, food security, and environmental protection.

The following are the key national development strategies, policies and plans which have been integrated with climate change in order to manage climate change and minimize its impacts on Malawi's sustainable development:

6.2.1 National Vision and National Development Strategies

6.2.1.1 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. Currently Malawi is developing the successor of the Vision 2020 (2063) which will be aligned to 2030 Agenda for Sustainable Development and African Union (AU) Agenda 2063.

6.2.1.2 Malawi Growth and Development Strategy (2017- 2022)

The Malawi Growth and Development Strategy (MGDS) III with its theme 'Building a Productive, Competitive and Resilient Nation' was developed in 2016 when the country was experience shocks including floods and drought. This national development strategy for the period 2017 to 2022 among its commitments, highlights Malawi's obligation to implement the Sustainable Development Goals (SDGs) and AU Agenda 2063. MGDS III integrates climate change into development planning through its Key Priority Area (KPA) on agriculture, water development and climate change management. Climate change management has been attributed as an integral component of the economy in particular for the achievement food security and poverty alleviation programmes. The MGDS III also recognizes 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.

6.2.1.3 National Strategy for Sustainable Development (NSSD)

National Strategy for Sustainable Development (NSSD) adopted by the Malawi Government in 2004, responds 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, awareness and dissemination of climate change issues and the preparation of different country studies on climate change including this Third National Communication (TNC) are some of the activities which have been implemented in accordance with the NSSD.

6.2.1.4 National Resilience Strategy (2018 – 2030)

The National Resilience Strategy (NRS) developed in 2018, is a 12-year strategy planned for implementation in two five-year phases. The NRS medium-term goal is to start the transition from recurrent humanitarian appeals to protective and productive investments targeting chronically and/or predictably food insecure and poor households, while also strengthening markets, infrastructure, and economic growth supported through strong institutional coordination and multi-sectoral planning and implementation. This will be achieved through the following 4 pillars:

- Resilient agriculture: The outcome for this is increase real farm-based household incomes through crop and livestock diversification, irrigation farming, market development, improving strategic grain reserves, drought risk reduction, and increasing access to farm inputs;
- Catchment protection and management: Forest and landscape restoration, Payment for ecosystem services, sustainable energy, forest-based enterprises;
- Risk reduction, flood control, early warning and response; and
- Human capacity, Livelihoods and social protection: shock responsive social support, livelihoods and nutrition.

6.2.1.5 Intended Nationally Determined Contributions (2015)

In 2015, Malawi submitted its Intended Nationally Determined Contributions (INDC) to UNFCCC. The INDC contains pledges on adaptation and mitigation actions to be implemented

from 2015 to 2040, some with domestic support, others need external financial and technical support. These are aimed at reducing carbon emissions and building climate resilience to contribute towards sustainable development, food security and poverty eradication.
The INDC include mitigation measures such as renewable energy, energy efficiency, climate resilient agronomic practices, afforestation and reforestation as well as adaptation measures such as drought tolerant crops varieties, water harvesting, irrigated agriculture and aquaculture.

6.2.2 Climate change policies, plans and frameworks

Malawi Government has developed an enabling framework to guide climate change activities, foster development, transfer of technology and capacity building. The following are national policies and plans which integrates climate change:

6.2.2.1 National Climate Change Management Policy (2016)

The Malawi Cabinet approved the National Climate Change Management Policy (NCCMP) in 2016. The policy aims to guide and coordinate formulation, implementation, monitoring and financing of climate change programmes in the country. The Policy further promote climate change adaptation, mitigation and capacity building for sustainable livelihoods through green economy measures for Malawi. The Policy has identified six (6) priority areas and these include:

- Climate change adaptation;
- Climate change mitigation;
- Capacity building, education, training and awareness;
- Research, technology development and transfer and systematic observation;
- Climate financing; and
- Cross-cutting issues (includes gender considerations, population dynamics and HIV and AIDS).

Considering that climate change significantly impacts key sectors of the economy and is multi-sectoral as well as crosscutting in nature, a number of institutions and sectors are key in management of climate change in Malawi. The Policy outlines the institutional arrangements which are key in the governance, coordination and leadership across the sectors and stakeholder groups.

6.3 Institutional Coordination Framework for Climate Change

The institutional arrangement provides for several committees. These committees include:

- the Cabinet Committee enables all arms of government to coordinate their actions;
- the Parliamentary Committee serves to assist in lobbying for passing of environment related policies and legislations in the national assembly;
- National Technical Committee on Climate Change (NTCCC) and the Natural Resources Sector Working Group (NRSWG) will provide oversight over the institutional coordination framework.

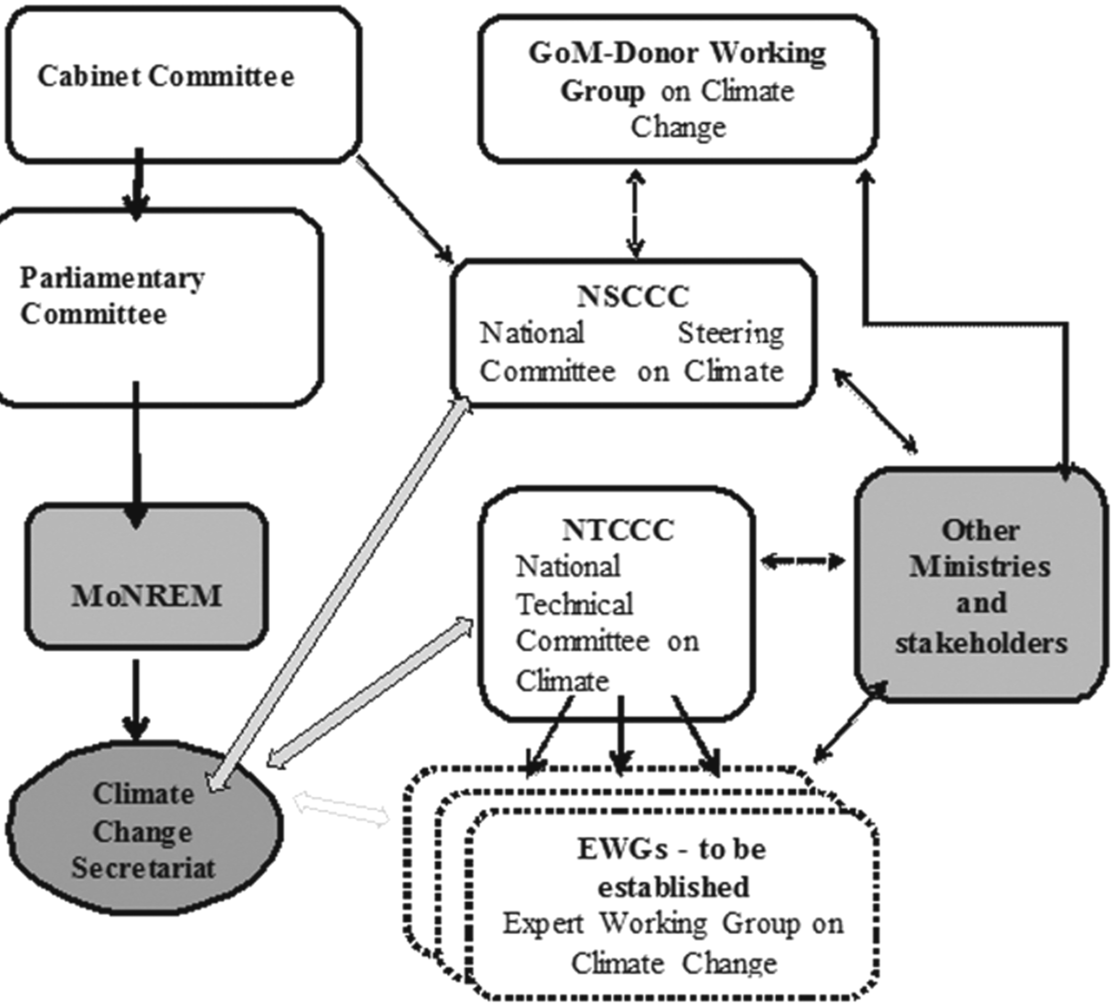


Figure 6. 1 Institutional Coordination Framework for Climate Change in Malawi

The Policy through its priority area 3.5 on climate change finance, calls for the establishment of a Climate Change Fund, which is a financing mechanism which is meant to aid the country's efforts in climate change management.

6.3.1 National Climate Change Fund

Domestic and international public and private climate finance is crucial for Malawi to deliver on its commitments on climate change management. In line with the NCCMP policy priority area 3.5 and Environmental Management Act, the National Climate Change Fund was established. Among other provisions, the climate change fund regulations ring-fence the funds; open the fund for capitalization by donor, private and public funding sources.

The Fund is expected to enhance financing for implementation and coordination of climate change management activities through increased national budgetary allocation, improved access to international climate financing and private sector investment. The fund will focus on financing programmes and projects under the key thematic areas of climate change management which include; adaptation, mitigation, capacity building, and technology development and transfer. The fund will be accessed by both public and private sector entities seeking to implement climate change related programmes or projects. The projects will be vetted so as to ensure consistency with National priorities.

The fund will be financed by both domestic and international sources for disbursement to implementing institutions. Among other sources, the fund will draw resources from domestic sources including; levies and penalties relating to climate change under written law, contribution from, advances made by the Ministry of Finance in order to meet a deficiency in the Fund.

6.3.2 National Disaster Risk Management Policy (2015)

Climate change shocks such as floods and droughts have been the major disasters in Malawi affecting the socioeconomic development of the country. The National Disaster Risk Management Policy was adopted and approved in 2015 to sustainably reduce disaster losses in lives and in the social, economic and environmental assets of communities and of the nation. The Policy provides an enabling framework for the establishment of a comprehensive disaster risk management system for Malawi. Furthermore, the Policy outlines the following six priority areas:

- The mainstreaming of disaster risk reduction into sustainable development policies and planning processes at all levels of government. This includes consideration for climate change impacts that may increase exposure and vulnerability to hazards in the present and future development policies and plans;
- The establishment of a comprehensive system to identify; assess and monitor disaster risks.
- Develop and strengthen a people-centred early warning system;
- Promoting a culture of safety and resilience through knowledge, education and innovation at all levels;
- Reduce the underlying risk factors which includes, among other mechanisms, development of mechanisms to ensure that all existing and future environmental protection, natural resource management and climate change policies and plans at all levels include disaster risk reduction to build the resilience of vulnerable groups, people with disabilities and communities;
- Strengthen the preparedness capacity for effective response and recovery at all levels.

6.3.3 Environment Management Act (2017)

The Parliament in 2017 approved the Environment Management Act (EMA). The Act provides for the protection and management of the environment; conservation and sustainable utilization of natural resources. The Act further provides for control and management of factors affecting climate change through development of guidelines and prescription measures.

6.3.4 The National Disaster Preparedness and Relief Act (1991) and the National Disaster Risk management Bill (2019)

The legal framework for disaster risk management in Malawi was set up in 1991 through the National Disaster Preparedness and Relief act. The 1991 act took a more responsive approach to DRM and did not provide for measures to reduce Disaster risk and impacts. The new DRM

Bill, awaiting Malawi parliament approval, includes issues of risk reduction as well as financing. Emerging issues such as building resilience to disasters and climate shocks have been provided for in the new Bill.

6.3.5 National Climate Change Investment Plan (2013 - 2018)

The National Climate Change Investment Plan (NCCIP) developed in 2014, identifies four key priority areas for action that would promote climate change management in Malawi. The priority actions include adaptation; mitigation; technology development and transfer; and capacity building, research, and education. These priority areas are also aligned to the NCCMP key policy areas. Implementation of programmes in these key priority areas focuses on the short, medium- and long-term periods.

Under each priority area, Programmes have been designed to target women, youth, and disadvantaged groups. Implementation is done by various key stakeholders including Government, development partners, private sector, civil society organizations, academia and local communities. The NCCIP also provides an estimated budget for implementing these actions.

6.3.6 National Adaptation Plan (NAP)

Malawi is in the process of developing the National Adaptation Plan (NAP) which will advance adaptation efforts in the medium and long-term periods. NAPs provide medium to long-term adaptation plans to ensure resilience to climate change. Prior to receiving the $2.8 million NAP readiness grant from the Green Climate Fund (GCF) for the advancement of the NAP development process, the Government of Malawi developed a NAP road map and finalized the NAP Stock-taking report. Malawi hopes that the NAP will provide a framework for integration of climate change adaptation in sectoral policies, plans and programmes to: increase adaptive capacity; build climate resilience; provide for livelihoods; restore degraded ecosystems, and contribute to poverty eradication and economic growth and sustainable development.

6.3.7 Nationally Appropriate Mitigation actions (NAMAs)

Malawi through its commitment to mitigate greenhouse gas emissions and enhance its carbon sinks, developed Nationally Appropriate Mitigation actions (NAMAs). The NAMA is in line with the Bali Conference of the Parties (CoP) and Cop 16 in Cancun, that urged Parties to voluntarily take “nationally appropriate mitigation actions” (NAMAs) and implement them in a way that they could be measured, reported and verified (MRV), using local or international standards respectively.

The NAMA prioritizes the following key sectors namely: Energy; Transport; Industrial Products and other Products Use (IPPU); Agriculture, Forestry, and Land Use (AFOLU), and Waste. Furthermore, the NAMA identified and led to the formulation of six project concepts which capture most of the prioritized sectoral activities.

6.4 Other Sectoral Policies and Legal Frameworks

In addition to climate change policies, plan and strategies, Government of Malawi recognizing the multisectoral dimension of climate change impacts on sustainable development, developed sector specific policies, strategies 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.

6.4.1 Transfer of Technologies

Pursuant to decision 4/CP.7, its annex, and the implementation of Article 4, paragraph 5, of the Convention, Malawi as a non-Annex I Party is encouraged, to provide information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies.

In 2003, Malawi developed the Technology Transfer and Needs Assessment (TTNA) Report with technical guidance from the Climate Technology Initiative (CTI) of the United States of America (USA). The report aimed to prioritizes climate technologies using the following three criteria: (i) development benefits, (ii) implementation potential, and (iii) contribution to climate change response measures and goals.

Building and learning on the TTNA process and report, Malawi through the Environmental Affairs is implementing the Technology Needs Assessment (TNA) project. The project is funded by Global Environment Facility and supported by United Nations Environmental Programme (UNEP) and Denmark Technical University. The project aims at identifying, prioritizing and developing an enabling framework for climate technologies.

The TNA is also aligned with National Climate Change Management Policy under priority area 3.4: Research, Technology Development and Transfer, and Systematic Observation. Under this priority area, the Policy highlights the role and contribution of technology and its transfer in the management of climate change. The TNA therefore provides a link between National Climate Change Management Policy and other policies and strategies to achieve Malawi's overarching development plan presented in the Malawi Growth and Development Strategy III. Due to the crossing cutting nature of climate change and its related impacts on national developmental sectors, the TNA also provides a framework for implementation of national sectoral priorities, strategies and plans which are related to climate change.

Four sectors with the greatest contribution to resilient building and mitigation efforts for Malawi were selected. These include agriculture and water sectors for adaptation, and energy and forestry sectors for mitigation theme respectively. The process of developing Technology Needs Assessment Report for Malawi in the adaptation and mitigation sectors involved stakeholder participation, ensuring gender inclusion at very stage.

A Multi-Criteria Analysis (MCA) methodology was used to priorities climate change technologies. The MCA process involved stakeholder expert working group establishing the evaluation criteria, weighting of the criteria and scoring the technologies against the criteria set. The criteria were grouped into costs and benefits of the climate technology for both adaptation and mitigation. The costs included the sub criteria of capital costs, and operating and maintenance of the technology hardware. The benefits included economic, social, and environmental and climate related (potential for greenhouse gas reduction and resilience building) benefits.

A minimum of ten climate technologies for each of the prioritized adaptation and mitigation sectors were identified and taken through the prioritization process using a participatory MCA. Through the MCA process, the ten climate technologies for each sector were ranked by stakeholders from the highest to the least priority technologies. In each sector, the top three climate technologies were selected to become the priority climate change technologies in Malawi. These technologies prioritized by Malawi's stakeholders are presented in the tables below, per sector.

Table 6. 1 Results of MCA process for Agriculture and Water Sectors, Adaptation Technologies

Sector	Priority (rank)	Adaptation Technology
Agriculture	1	*Landscape restoration for improved land productivity*
	2	*Integrated crop-livestock-aquaculture-forest production systems*
	3	*Community-based agricultural extension*
Water	1	*Rainwater harvesting*
	2	*Integrated river basin management*
	3	*Integrated flood management*

.

Malawi recently completed the first step of the TNA process. Please note that the TNA Reports provide a shop list of technologies and their attributes described in the related Technology Fact Sheets (TFS) appended to the TNA reports. Currently, the country is in the second step of TNA process, of identifying barriers for the prioritized climate technologies in tables 6.1 and 6.2. Once the technology barriers have been identified and analyzed, and enabling framework developed, Technology Action Plans (TAPs) will be developed to guide the implementation and transfer of such technologies.

6.4.2 Education, Training and public Awareness

Malawi has responded to Articles 4.1 (i) of the UNFCCC and Article 83 of the Paris Agreement by developing strategies and plans to foster education and public awareness on climate change, its impacts, mitigation and how the people can adapt to the changing climate. The National Environmental Action Plan (NEAP) of 2002 articulates the need for the provision of environmental education and public information as necessary actions to address environmental issues including climate change and air pollution. Although, illiteracy and poverty continue to be a stumbling block to education and training initiatives in Malawi, the Ministry of Forestry and Natural Resources through its Environmental Affairs Department has been implementing inclusive initiatives that target both the literate and the illiterate to ensure that nobody is left behind in the fight against anthropogenically accelerated climate change and its negative effects. Besides these nationally organised initiatives, some professionals in both public and private sectors have acquired knowledge on climate change through participating in international trainings, workshops, conferences, meetings and study tours organized by development partners.

This section provides information on the steps that Malawi has taken to implement Article 6 of the UNFCCC, part of the Buenos Aires Plan of Action of 1998 and Article 84 of the Paris Agreement. 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.

Activities Undertaken to Implement Article 6 of the Convention

The continued occurrence of human activities that are known to accelerate climate change has been blamed on inadequate information and knowledge among the populace in Malawi. Therefore, education, training and public awareness on climate change remains critical for desirable behavioral change. Due to the cross-cutting nature of the issues related to climate change, provision of information and general awareness raising on climate change is being done by various institutions either directly or indirectly through climate change mainstreaming initiatives as briefly described in the sections that follow.

Government has created a dedicated Ministry of Natural Resources, Energy and Mining with Departments that oversee implementation of various mandates in the environment, natural resources and climate change management. The Ministry has five Departments viz Environmental Affairs, Climate Change and Meteorological Services, Geological Surveys, Forestry, and National Parks and Wildlife. The Environmental Affairs Department has the mandate to promote, coordinate, monitor and oversee compliance to environment and natural resources policies, programmes and legislation in order to ensure sustainable development and poverty reduction. In this regard, the Ministry works in close collaboration with all relevant Ministries, Departments and Agencies (MDAs) and Non-State Actors (NSAs) in ensuring that climate change issues are properly addressed through mainstreaming and outreach services.

As a coordinating institution, the Environmental Affairs Department (EAD) has a dedicated Information, Education and Outreach Division whose aim is “to ensure that all Malawians are aware of environment, natural resources and climate change issues and are prepared to take appropriate action to ensure sustainable use of the environment" for sustainable social and economic development. The Division is responsible for coordinating environment, natural resources and climate change education and public awareness programmes. These are guided by the National Environment and Climate Change Management Communication Strategy (NECCMCS), a tool developed by the EAD to guide communication and public awareness for behavioural change.

A few instances of activities being undertaken by EAD include organising Symposia, coordinating commemoration of environmental days, management of environmental information system and coordination of district education and public awareness programmes. Additionally, the Division develops and disseminates public notices, press releases, jingles, drama and press conferences on climate change issues, both on radio and television stations in the country. The Division also has active social media platforms namely Facebook, Twitter and YouTube. Through these platforms, the Department is making strides in encouraging participation of everyone in decision-making in environment and climate change management. Despite the commendable effort made in all these, low budgetary allocations to the environment, natural resources and climate change sector still remains a challenge for EAD to upscale on its intended output regarding education and public awareness raising.

EAD took a step in organising the journalists who have special interest in reporting on environment, natural resources and climate change issues in the country into an Association of Environmental Journalists (AEJ). The Association was established with the aim of strengthening the capacity of journalists in reporting on issues of environment, natural resources and climate change management as well as promoting the public awareness on the same. The Association holds yearly event to reflect on progress of implementation of their activities which are normally characterized by media capacity building sessions, Annual General Meeting and the Green Media Award ceremonies.

The Department also facilitates development of environment and climate change management training materials for use by various national stakeholders. Collaborating with other institutions, using difference channels of communication and delivering trainings on environment and climate change ensures that access to information on environmental issues and climate change issues is enhanced and level of awareness on environment and climate change issues among Malawians is increased. Suffice to say that the EAD in collaboration with Ministry of Education developed and implemented, and is revising a National Strategy for Climate Change Learning. The Strategy aims at strengthening human resources, climate change learning, and skills development to advance the national climate change development agenda in the Malawi. The Strategy identifies key priority areas and learning needs in key areas relevant for Nationally Determined Contributions (NDCs) and National Adaptation Plan (NAP) implementation.

To ensure adequate inclusion of environment and climate change content in formal education, Government through the Ministry of Education, Science and Technology works with relevant institutions to mainstream environment and climate change into the primary through to tertiary education curricula. All universities in Malawi have one or more subject on environment and climate change. Other universities such as the University of Malawi, the Malawi University of Science and Technology, the Lilongwe University of Agriculture and Natural Resources, the University of Livingstonia, the University of Mzuzu and the Catholic University have degree programmes on environment and climate change at undergraduate and graduate levels.

In syllabuses for primary and secondary schools, climate change has for so long only been included as a component of other subjects, such as geography. Recently, introduction of Social and Environmental Science as a subject has increased prominence of environment, natural resources and climate change issues in the formal primary education system. However, considering climate change as an independent discipline in both primary and secondary school curriculum would bring a bigger impact in imparting knowledge to the learners. Thus, there is still need to mainstream climate change into both primary and secondary school. Similarly, efforts should be put in place to strengthen tertiary education syllabuses. However, the formal education system is constrained in terms of basic equipment, materials, infrastructure and facilities, among others.

For efficient and effective climate change public awareness initiatives, Mandated by the Local Government Act of 1998, Malawi is implementing the decentralisation policy, under which plans, functions, oral recurrent transaction and development budgets, human resuorces and assets are devolved to District, Town and City Councils in undertaking local development activities in all socio-economic sectors. The environment, natural resources and climate change sector is among the sectors that are being devolved. In this vein, some of the environmental activities have been devolved to the local councils. The Environmental District Office is established in all the twenty eight (28) district councils in the country. This office spearheads all programmes related to environment, natural resources and climate change, education and public awareness inclusive. The office further prepares District State of Environmental Outlook Reports and District Environmental Action Plans (DEAPs), from which climate change interventions emanate.

CHAPTER 7

CONSTRAINTS, GAPS AND RELATED FINANCIAL, TECHNICAL AND CAPACITY BUILDING NEEDS

7.1 Constraints, Gaps and Related Financial, Technical and Capacity Building Needs

This section under constraints and gaps, and related financial, technical and capacity building needs provides a brief overview of the identified constraints and challenges relating to capacity, technical, financial and research needs on climate change issues, in the following areas: Disaster Risk Reduction, Information sharing and networking, Biodiversity, Monitoring, Reporting and verification of climate change mitigation actions.

7.2 Information sharing and networking

Despite the importance of information sharing and networking in fostering positive environmental behavior among people, technical and resource challenges hamper government's efforts. These challenges include;

1. There is low uptake of modern information and communication technologies due to poverty.
2. There is limited mobile network coverage in remote areas.
3. Multiple competing priorities in institutions. The financial resources in institutions mandated to implement information and networking initiatives are not adequate.
4. There is inadequate human capacity to implement modern sophisticated but effective information and networking initiatives. For example, Environmental Affairs Department does not have a trained Information, Communication and Technology (ICT) expert.
5. There is inadequate and old (outdated) ICT equipment and infrastructure. In the fast-paced ICT world, equipment needs to be upgraded regularly. However, the cost is high.
6. Limited participation at regional and international information sharing and networking fora. Participation at conferences and training workshops requires generous financial and time investment. Due to inadequate availability of these resources, Malawi's participation to regional and international information sharing and networking fora is mostly funded by development partners. This means that the number of people and the number of times such people can participate from Malawi is dictated by the development partners' budgets.
7. Absence of legally binding information sharing agreement between data/information producers or holders and users. Although efforts are being made under NEIN, the network is not yet formalized and sharing of data and information is purely voluntary.

7.3 *Biodiversity*

Given the poor state of capacity and knowledge on relationship between GMO's and biodiversity in Malawi, baseline information and capacity needed to make a case for biodiversity and biosafety at national development planning. There is a need for financial support to close gaps in capacity and training for biosafety regulatory framework enforcement. There is evidence that integrating biodiversity and ecosystem management objectives into production sectors such as agriculture, forestry, fisheries, mining and tourism support sustainable development objectives. However, there is a need for better understanding about how to mainstream biodiversity goals into these sectors to get stronger commitment from government and realise effective enforcement of legislation.

The major challenge affecting the commission is finance. S&T Act established a science and technology fund which is supposed to be operational in support research activities. However, it has not been easy to convince government and development partners to appropriate money into the fund.

The other challenge is the lack of a centralized coordination unit for the climate change research programs. Climate change issue as cross-cutting as it is requires a central coordination unit to make sure that there is no duplication of efforts.

7.4 Challenges encountered in during the compilation on the National Inventory Report (NIR)

Most Councils fail implement proper waste management practices due to numerous challenges, such as;

- Inadequate waste collection vehicles, inadequate fuel allocation for waste collection vehicles and high frequency rate of vehicle downtime;
- Indiscriminate disposal of waste at all levels of the society (burning, dumping in open space);
- Limited waste collection services to households (waste is collected mainly from low and medium density areas), institutions and other commercial entities
- Weak enforcement of the laws and by-laws governing solid waste management in the cities;
- Inadequate communal bins in residential areas, irregular collection schedules and non-collection of waste resulting in waste over spilling onto the surrounding areas causing nuisance and posing health risks;
  (Munthali et al., 2016)
- Future climatic conditions and their impact such as emissions in petroleum fuels and others have not been considered.
- Data on projected deforested area and projected wood fuel demand was not available in this study.

The department has a number of challenges in implementation of climate change adaptation interventions. These include the following:

- ➢ Low technology uptake by farmers due to inadequate knowledge of the benefits of such technologies
- ➢ Long term realization of climate change adaptation benefits from most of the sector's interventions such as agroforestry
- ➢ Financial constraints that limit greater investments in implementing adaptation interventions.
- ➢ Weak collaboration and coordination with other sectors working in the sustainable land management areas such as forestry, irrigation and environmental affairs

The major limitation of the study was the use of insufficient biomass data for Lake Shore Forest Areas. The data used was only from Nkhata-bay. However, the uncertainty (14.8%) was within the acceptable range (not more than 15%). In the next National Communication, biomass data from Karonga, Nkhotakota, Salima and Mangochi would be of great importance to be added.

The study had several limitations namely:

- Information gathered based on desk research, that is, general literature review and the researcher's professional experience on application of research findings to the Malawi scenario;
- Overall, there is limited study conducted on climate change in the field of tourism including a vulnerability and adaptation assessment study
- Limited time to conduct a survey to scientifically validate issues and recommendations made in the paper;
- Lack of specific literature on impact of climate change on Malawi tourism

A number of limitations negatively affected the quality of the waste sector GHG inventory compilation process. These include;

- Since waste was not segregated from source of generation, it is hard to collect samples in waste categories at the disposal site, which had also an effect in analyzing waste by category hence the laboratory analysis was done on crude sample.
- The data collected from various councils was done in one type of season (dry), it was not repeated during other seasons, which could have a bearing on other factors such as Dry matter, fraction of Carbon in dry matter etc.
- The samples collected at the time of study could not include the other forms of waste which are seasonal in nature, i.e. Garden waste is usually abundant during and soon after rain season and may have a significant effect on factors like Carbon content. This was evident, for example, in Salima where Malawi Mangoes is one of the major waste generators, and during the first data collection the site was full of banana peels, which was not the case during the second collection.
- The unavailability of ready data forced the respondents to give estimates based on calculation of expected situations; this meant that the data may somehow reflect the anticipated situation and not necessarily the real practical time situation on ground.
- It is because of this situation that the calculation was done mainly based on the default values (for the sake of validity of the data) as a requirement in tier one.

While there is need to improve the monitoring system through sustained capacity building and improvement of its core elements such as data archiving, specific to the inventory, in the next inventory cycle.

There were limitations encountered in the course of conducting the study (IPPU), the most notable of which were:

- Reluctance to release data from companies. Some companies treated data as confidential and were unwilling to provide such data to the study team;

- Completeness of data availability for the reporting periods. While data was required for the period from the year 1992 to 2014, it was difficult to get data for some years for certain sector such as ceramics and ethanol.

7.5 Challenges in Climate Change Adaptation

The main limitation of this study was the inability to use latest water balance models in conducting climate change vulnerability assessment of water resources in Malawi. A request was made in July 2013 to Dr. David Yates who developed the WatBal Model and Dr. Joel Smith, Lead Author of the Third, Fourth, and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change about what type of water balance models Malawi could use in the vulnerability assessment of water resources to climate change. They both recommended the Water Evaluation And Planning (WEAP) Model. But because of time constraints, the Malawi team did train to use the WEAP model, although they were given the software by the developers. As such, it is the Team's hope that the WEAP Model will be used in the compilation of the Fourth National Communication (FNC). Hence data on climate change scenarios and findings from previous studies were used in the compilation of this report.

The study on vulnerability and adaptation assessment for the health sector in Malawi had several limitations. The study largely relied on desk reviews for data collection. This resulted in missed information due to the non-availability of the required data and inadequate consultations with key stakeholders. Furthermore, the study design failed to generate new information on adaptation of the health sector to impacts of climate change. There was also high non-response rate (28%) to the mailed questionnaire from the District Health Officers. Hence, adaptation issues were not fully covered. And as a result, the Health NAPA on which this report is based looked at the same diseases that were discussed in Malawi's NAPA of 2006

Usually, for appropriate climate projection one requires data collected for a minimum period of 30 years. However, in this study projections of future disease occurrences were made based on eight years of disease data collected from the health facilities due to non-availability of long series health data, and these were inadequate for conducting statistical analyses. As such, it is likely that the study may not have drawn accurate statistical inferences from the vulnerability analysis.

Table 7. 1 Technical and Finacial support for preparing National Communications

Technical Support	**Financial Support**
East and Southern Africa workshop on climate change reports project management and regional Measurement, Reporting and Verification Network development, 28th to 30th May, 2018, Dar-es Salam, Tanzani	GEF Contribution: US$ 500,000 Government in Kind contribution: US$ 100,000 Total Budget: US$ 600,000
Southern Africa Regional MRV first peer review and training workshop, 3rd to 6th September. 2019, Ezulwini, Swaziland	

Global Stocktake workshop on Quality Assurance of GHG Inventory Systems and Full Lands Integration Tool (FLINT), 14TH TO 17TH October, 2019	
In-Country training on Quality Assurance and Quality Contro (QA/QC) by UNFCCC, 12th to 16th August, 2019, Lilongwe, Malawi	
Malawi IPCC Methodology virtual training dry run, 12th August, 2020	
Malawi's review of NCs and BURs/GHG Inventory reports by GSP as a quality assurance exercise, November, 2020	

Table 7. 2 Technical and Finacial support for climate activities in Malawi

Technical Support	Financial Support
train scientists in conducting research, systems analysis, and computer simulation modelling	Development of local emission factors for livestock supported by USAID
Capacity building for local academic institutions in developing country-specific emission factors	
Development of historical data for hazard analysis leading to recurrence of disasters. There is need for a multi-hazard approach to disaster risk and climate change management	
comprehensive national wide risk assessments that would help to better address the root causes of disasters	

7.6 Opportunities for Implementation of Adaptation Measures

Malawi NDC

In 2015, Malawi submitted its Intended Nationally Determined Contributions (INDC) to UNFCCC. The INDC contains pledges on adaptation and mitigation actions to be implemented from 2015 to 2040, some with domestic support, others need external financial and technical support. These are aimed at reducing carbon emissions and building climate resilience to contribute towards sustainable development, food security and poverty eradication.

The INDC include mitigation measures such as renewable energy, energy efficiency, climate resilient agronomic practices, afforestation and reforestation as well as adaptation measures such as drought tolerant crops varieties, water harvesting, irrigated agriculture and aquaculture.

Malawi National Adaptation Plan (NAP)

Malawi is in the process of developing the National Adaptation Plan (NAP) which will advance adaptation efforts in the medium and long-term periods. NAPs provide medium to long-term adaptation plans to ensure resilience to climate change. Prior to receiving the $2.8 million NAP readiness grant from the Green Climate Fund (GCF) for the advancement of the NAP development process, the Government of Malawi developed a NAP road map and finalized the NAP Stock-taking report. Malawi hopes that the NAP will provide a framework for integration of climate change adaptation in sectoral policies, plans and programmes to: increase adaptive capacity; build climate resilience; provide for livelihoods; restore degraded ecosystems, and contribute to poverty eradication and economic growth and sustainable development.

7.7 National Technology Needs

Malawi recently completed the first step of the TNA process. The TNA Reports provide a shop list of technologies and their attributes described in the related Technology Fact Sheets (TFS) appended to the TNA reports. Currently, the country is in the second step of TNA process, of identifying barriers for the prioritized climate technologies in table 8.0. Once the technology barriers have been identified and analyzed, and enabling framework developed, Technology Action Plans (TAPs) will be developed to guide the implementation and transfer of such technologies.

Table 7. 3: Results of MCA process for Agriculture and Water Sectors, Adaptation Technologies

Sector	**Priority (rank)**	**Adaptation Technology**
Agriculture	1	*Landscape restoration for improved land productivity*
	2	*Integrated crop-livestock-aquaculture-forest production systems*
	3	*Community-based agricultural extension*
Water	1	*Rainwater harvesting*
	2	*Integrated river basin management*
	3	*Integrated flood management*

CHAPTER 8

PROPOSED CLIMATE CHANGE PROJECTS

8.1 Proposed Climate Change Projects for Funding

8.1.1 Project Title: Establishment of an Energy Data Management System and an Energy Balance for Malawi

8.1.2 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, construction and in the home would be retarded and 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.

8.1.3 Project justification: Since 1994, Malawi has not been able to prepare energy balances for the country. The lack of such data have 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. 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. .

8.1.4 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.

8.1.5 Project description: A number of energy studies and surveys have been conducted in urban areas to estimate energy requirements and use 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.

8.1.6 Lead institutions. The lead institutions will be: (i) Department of Energy Affairs (DoEA), (ii) Environmental Affairs Department (EAD), and (iii) National Statistical Office (NSO).

8.1.7 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.

8.1.8 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 energy balances. .

8.1.9 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.

8.1.10 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 local National Experts will have to understudy the consultant over the one-year period, and undergo an on-the-job training. However, these local experts will also undergo specialized training, especially in energy database management.

8.1.11 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 local experts: US $ 350,000.00. It proposed to conduct the project over a three-year period.

8.2 Project Title: Developing Appropriate Agricultural Technologies for Mitigating and Adapting to Climate Change in Different Agro-ecological Zones of Malawi

8.2.1 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.

8.2.3 Project objectives. The overall objective is to develop appropriate, environmentally-friendly and production-increasing 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.

8.2.4 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.

8.2.5 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).

8.2.6 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, (xi) reduced environmental degradation and air pollution.

8.2.7 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.

8.2.8 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.

8.3 Project Title: Determination of Emission Factors and Minimum Data Sets for Model Calibration, Validation, Testing and Experimentation

8.3.1 Project linkage to national priorities. The findings from various studies in Malawi, including the Third National Communication (TNC) 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.

8.3.2 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. .

8.3.3 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. .*

8.3.4 Stakeholders*. The lead institutions will be the proposed Climate Change Unit (CCU) in the Environmental Affairs Department (EAD) or the National Climate Change Commission (NCCC) in the Office of the President and Cabinet (OPC). 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. .*

8.3.5 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.

8.3.6 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.

8.3.7 Project budget and timeframe*. The proposed budget for the project US$ 5,000,000, over a period of between 2 and 3 years.*

BIBLIOGRAPHY

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., et al. (2007). Africa Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Eastman, J., Ayamba, A., & Ramachandran, M. (1996). The spatial manifestation of ENSO warm phase events in southern Africa. Harare.

Epstein, P. R. (2002). Climate Change and Infectious Disease: Stormy Weather Ahead? Epidemiology. Epidemiology, Vol 13 No.4.

GoM. (2002). The Initial National Communication of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Lilongwe: Ministry of Ntural Resources, Energy and Environment.

GoM. (2006). Malawi's National Adaptation Programme of Action. Lilongwe: Ministry of Mines, Natural Resources and Environment.

GoM. (2010). Malawi State of Environment and Outlook Report: Environment for Suitable Economic Growth. Lilongwe: Ministry of Natural Resources, Energy and Environment.

GoM. (2011). The Second National Communication of the Republic of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Lilongwe: Ministry of Natural Resources, Energy and Environment.

GoM. (2013). National Disaster Risk Management Policy. Lilongwe: Department of Disaster Preparedness and Management.

GoM, 2017, The Malawi Growth and Development Strategy (MGDS III) (2017-2022), Malawi.

GoM, 2018. Annual Economic Report. Ministry of Finance, Economic Planning and Development, Lilongwe, Malawi.

Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre), 2007, Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia, Nairobi – Kenya

IPCC, 2001, Third Assessment Report, IPCC

IPCC. (2007). Climate change 2007: Synthesis Report, Contribution to Fourth Assessment Report. IPCC.

IPCC, 2013, Fifth Assessment Report, IPCC

Irish Aid (2018). Malawi Country Climate Risk Assessment Report. Resilience and Economic Inclusion Team, Policy Unit. Lilongwe, Malawi.

McSweeney, C., New, M., & Lizcano, G. (2008). UNDP Climate Change Country Profiles: Malawi. Oxford: University of Oxford.

Moss RH, Meehl GA, Lemos MC, Smith JB, Arnold JR, Arnott JC, Behar D, Brasseur GP, Broomell SB, Busalacchi AJ, Dessai S, Ebi KL, Edmonds JA, Furlow J, Goddard L, Hartmann HC, Hurrell JW, Katzenberger JW, Liverman DM, Mote PW, Moser SC, Kumar A, Pulwarty RS, Seyller EA, Turner BL, Washington WM, Wilbanks TJ (2013) Hell and high water: practice-relevant adaptation science. Science 342:696–698.

Oxfam International. (2009). Winds of Change: climate change, poverty and environment in Malawi. Malawi: Joint Oxfam Programme in Malawi.

Smith, J. (2001). A Summary of Climate Impact Assessments from US Country Studies Program, Climate Change. Netherlands: Springer.

Tadross, M., P, S., Lotsch, A., Hachigonta, S., Mdoka, M., Unganai, L., et al. (2009). Growing-season rainfall and scenarios of future change in southeast Africa: implications for cultivating maize. Climate Research. Climate Research, Vol 40:147-161.

UNDP. (2010). United Nations Country Assessment Report for Malawi. Lilongwe: UNDP.

World Bank. 2007. World Development Report 2008: Agriculture for Development, Washington DC: The World Bank.

Arndt, C., Schlosser, A., Strzepek, K. and Thurlow, J. 2014. Climate Change and Economic Growth Prospects for Malawi: An Uncertainty Approach. Journal of African Economies, Volume 23.

Chinseu E.L., Stringer L.C., & Dougill A.J. 2019. An Empirically Derived Conceptual Framework to Assess Dis-Adoption of Conservation Agriculture: Multiple Drivers and Institutional Deficiencies. *Journal of Sustainable Development Vol. 12, No. 5.* https://doi.org/10.5539/jsd.v12n5p48.

Civil Society Network on Climate Change (CISONECC), 2014. Documentation Of Climate Change Adaptation Practice: The Case Of Livestock. Blantyre, Malawi.

Government of Malawi, 2019. Annual Economic Report. Ministry of Finance, Economic Planning and Development, Lilongwe, Malawi.

Government of Malawi, 2018. Annual Economic Report. Ministry of Finance, Economic Planning and Development, Lilongwe, Malawi.

Government of Malawi (2018a). Climate trends projections for Malawi: Future climate extremes. Department of Climate Change and Metrology Services, Blantyre, Malawi.

Government of Malawi (2017). Agriculture Production Estimates Survey report. Ministry of Agriculture, Irrigation and Water Development, Lilongwe, Malawi.

Government of Malawi (2017b). National Livestock Development Policy, 2017-2022. Department of Animal Health and Livestock Development, Ministry of Agriculture, Irrigation and Water Development. Lilongwe.

Government of Malawi (2016). National Agriculture Policy. Ministry of Agriculture, Irrigation and Water Development, Lilongwe, Malawi.

Government of Malawi (2015a). Malawi 2015 Floods PDNA report. Department of Disaster Management Affairs, Lilongwe. Malawi

Government of Malawi (2015b). Malawi Floods Emergency Recovery Project. *Environmental and Social Management Framework.* Ministry of Finance, Economic Planning and Development, Lilongwe, Malawi.

Government of Malawi (2014). Malawi Agricultural Statistics. National Statistics Office, Zomba, Malawi.

Government of Malawi, 2013. Annual Economic Report. Ministry of Finance, Economic Planning and Development, Lilongwe, Malawi.

Government of Malawi, 2012. Annual Economic Survey (AES), National Statistical Survey (NSO). 2011-2012. Lilongwe, Malawi.

Irish Aid (2018). Malawi Country Climate Risk Assessment Report. Resilience and Economic Inclusion Team, Policy Unit. Lilongwe, Malawi.
Irish Aid (2016). Malawi Climate Action Report: Resilience and Economic Inclusion Team. Irish Aid. Lilongwe, Malawi.

Karl, P., Thurlow, J. and Seventer, D. 2010. Droughts and floods in Malawi: Assessing the economywide effects. IFPRI discussion paper 00962.

McKinsey Global Institute. 2015. The Power of Parity: How Advancing Women's Equality Can Add $12 Trillion to Global Growth. McKinsey & Company.

Moser S.C. & Ekstrom J.E. 2010. A framework to diagnose barriers to climate change adaptation. *PNAS vol. 107 no.51*. www.pnas.org/cgi/doi/10.1073/pnas.1007887107.

NSO 2019. Malawi in Figures 2019 edition. National Statistics Office. NSO: Zomba

Olson, J., Alagarswamy, G., Gronseth, J. and Moore, N. 2010. Impacts of Climate Change on Rice and Maize, and Opportunities to Increase Productivity and Resilience in Malawi. Global Center for Food Systems Innovation (GCFSI). Malawi Report No. 009.

Pauw, K., Thurlow, J., Bachu, M. and Van Seventer, D. E. 2011. The Economic Costs of Extreme
Weather Events: A Hydro-Meteorological CGE Analysis for Malawi, *Environment and Development Economics.* vol. 16

Thornton P.K., Rosenstock T., Förch W., Lamanna C., Bell P., Henderson B., and Herrero M. (2018). A Qualitative Evaluation of CSA Options in Mixed Crop-Livestock Systems in Developing Countries. In L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw, & G. Branca (Eds.), Climate Smart Agriculture, Natural Resource Management and Policy 52 (pp. 385-423). Rome: FAO.

UN Women, UNDP, UNEP, and World Bank Group. 2015. The Cost of the Gender Gap in Agricultural Productivity in Malawi, Tanzania, and Uganda. Washington, DC: World Bank Group.

World Bank. 2003. *Malawi - Country assistance strategy (English)*. Washington, DC: World Bank

Atkins, 2011, Water Resources Investment Strategy, Malawi

Chavula G.M.S., 1989, An assessment of groundwater potential for small scale crop irrigation in the Lower Shire Valley, M.Sc. thesis, University of Newcastle (UK).

Chavula, G., & Chirwa, A. (1996). Impacts of climate change on water resources of Malawi. 1996 RPC Conference. Sun and Sand-Mangochi: University of Malawi.

Chilton P.J., Foster S.S.D (1995.) Hydrogeological characterization and water supply potential of basement aquifers in tropical Africa, Hydrogeology Journal, 3, 36-49.

Eastman, J., Ayamba, A., & Ramachandran, M. (1996). The spatial manifestation of ENSO warm phase events in southern Africa. Harare.

GoM. (2002). The Initial National Communication of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Lilongwe: Ministry of Ntural Resources, Energy and Environment.

GoM, 2015, Decentralized Early Warning System in Malawi, Malawi

Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre), 2007, Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia, Nairobi – Kenya

IPCC, 2013, Fifth Assessment Report, IPCC

Kamdonyo D.R., 1992, Drought: nature, causes, frequencies and its monitoring, paper presented at the drought management workshop held in Blantyre, organized by EVARD, Malawi

Kanyika G. Y., (2000), Water balance model for Lake Malawi, M.Sc. Thesis, University of Dar es Salaam, Tanzania.

Kululanga G. K. and Chavula G. M. S., (1993), National environmental action plan – a report on water resources, Report submitted to Ministry of Research and Environmental Affairs, Malawi

Menz A. (edt.), (1995), The Fishery Potential and Productivity of the pelagic zone of the Lake Malawi/Niassa, Natural Resources Institute, UK

Nicholson S.E., Klotter D., Chavula G., (2013), A detailed rainfall climatology for Malawi, Southern Africa, International Journal of Climatology (2013);

Nicholson SE, Yin X., 2002, Mesoscale patterns of rainfall, cloudiness and evaporation over the Great Lakes of Africa. In The East AfricanGreat Lakes: Limnology, Palaeolimnology and Biodiversity, Odada EO, Olago DO (eds). Kluwer Academic Publishers: Dordrecht, Holland. 93–119. Nicholson SE, Dezfuli

S. E. Nicholson, D. Klotter and G. Chavula, 2013, A detailed rainfall climatology for Malawi, Southern Africa, International Journal of Climatology, *int. j. climatol.* (2013)

Shela O. N., (2000), Naturalization of Lake Malawi levels and Shire River flows: challenges of water resources research and sustainable utilization on the Lake Malawi – Shire River system. Paper presented at the Water Net Symposium on Sustainable Use of Water Resources held in Maputo 1-2 November, 2000.

TOGA, 1992, Chart on the evolution of El Nino, USA.

UNEP, 2012, Climate Early Warning Systems Feasibility Report: Early Warning Systems and Hazard Prediction, Oxford University, UK.

Water Department / UNDP, (1986), National Water Resources Master Plan: Report and Appendices, Malawi.

Yates D., 1994, WatBal- An Integrated Water Balance Model for Climate Impact Assessment of River Basin Runoff, IASA

GoM. (1998). State of the Environment Report. Lilongwe: Environmental Affairs Department.

GoM. (2002). The Initial National Communication of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Lilongwe: Ministry of Ntural Resources, Energy and Environment.

GoM. (2006). Malawi's National Adaptation Programme of Action . Lilongwe: Ministry of Mines, Natural Resources and Environment.

GoM. (2010). Malawi State of Environment and Outlook Report: Environment for Suitable Economic Growth. Lilongwe: Ministry of Natural Resources, Energy and Environment.

GoM. (2011). The Second National Communication of the Republic of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Lilongwe: Ministry of Natural Resources, Energy and Environment.

GoM. (2011 a). Malawi Health Sector Strategic Plan: moving towards equity and quality. Lilongwe: Ministry of Health.

GoM. (2011 b). Malawi Growth and development Strategy II (2011-2016). Lilongwe: DEP&D.

GoM. (2013). National Disaster Risk Management Policy. Lilongwe: Department of Disaster Preparedness and Management.

GoM, 2017, The Malawi Growth and Development Strategy (MGDS) III (2017-2022), Malawi

Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre), 2007, Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia, Nairobi – Kenya

IPCC, 2001, Third Assessment Report, IPCC

IPCC. (2007). Climate change 2007: Synthesis Report, Contribution to Fourth Assessment Report. IPCC.

IPCC. (2013), Fifth Assessment Report, IPCC.

Johnson R.A., Wichern D.W., (1998) Applied Multivariate Statistical Analysis. 4th Edition, Prentice-Hall, New York.

Manangan Arie Ponce, Christopher K. Uejio, Shubhayu Saha, Paul J. Schramm, Gino D. Marinucci, Claudia Langford Brown, Jeremy J. Hess, George Luber, (Undated), Assessing Health Vulnerability to Climate Change A Guide for Health Departments, CDC

McSweeney, C., New, M., & Lizcano, G. (2008). UNDP Climate Change Country Profiles: Malawi. Oxford: University of Oxford.

Oxfam International. (2009). Winds of Change: climate change , poverty and environment in Malawi. Malawi: Joint Oxfam Programme in Malawi.

Patz J., M. Hatch, (2014), Public health and global climate disruption Public Health Rev., 35 (2014)

UNDP. (2010). United Nations Country Assessment Report for Malawi. Lilongwe: UNDP.

WMO. (2003). Health and environmental change. Geneva: WMO.

WHO. (2013). 2.23. WHO, 2013, Protecting health from climate change: vulnerability and adaptation assessment, Switzerland? Geneva: WHO.

Badjeck M-C, et al. 2009. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy. doi:10.1016/j.marpol.2009.08.007

Buckley, L. 2017. Trilateral cooperation in agriculture. Achievements and lessons from AgriTT. International Institute for Environment and Development (IIED).

Chavula, G.M.S. (2016). Malawi: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Ficke A.D, Myrick CA, Hansen LJ. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries, 17(4):581-613.

Kidd, C.H.R. (1983). A water resources evaluation of Lake Malawi and the Shire river. Geneva: World Meteological Organization.

IPCC. 2007. Climate change 2007: Synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Pachauri RK, Reisinger A (eds). Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Mangala C.S. De Silva, Cornelis A.M. van Gestel. 2009. Comparative sensitivity of Eisenia andrei and Perionyx excavatus in earthworm avoidance tests using two soil types in the tropics, Chemosphere, Volume 77, Issue 11, pp 1609-1613, ISSN 0045-6535, https://doi.org/10.1016/j.chemosphere.2009.09.034.

Sayer, C.A., Palmer-Newton, A.F. and Darwall, W.R.T. (2019). Conservation priorities for freshwater biodiversity in the Lake Malawi/Nyasa/Niassa Catchment. Cambridge, UK and Gland, Switzerland: IUCN. xii +214pp.

Patterson, G, and O. Kachinjika. 1995. Limnology and phytoplankton ecology. Pages 1-67 In Menz, A. (ed.), The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa. Chatham, UK: Natural Resources Institute.

Weyl, O.L.F., Ribbink, A.J. and Tweddle, D. (2010). 'Lake Malawi: fishes, fisheries, biodiversity, health and habitat', Aquatic Ecosystem Health & Management, 13(3), pp. 241–254. https://doi.org/10.1080/14634988.2010.504695

BECKEN, S. Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.622.7087&rep=rep1&type=pdf Date of access: 27 Sept 2019

BUNGHEZ C.L. 2016 The importance of tourism to a destination economy. *Journal of Eastern Europe Research in Business and Economics*.

CLARKE, D.J. 2012. Cost-benefit analysis of the African risk capacity facility: Malawi country case study. http://www.africanriskcapacity.org/wp-context/uploads/2017/09/malawi-country-case-study.pdf Date of access: 30 Sept 2019

MALAWI GOVERNMENT. 2019. Department of Climate Change and Meteorological Services reports. http://www.metmalawi.com/news.php Date of access: 29 Sept 2019

MALAWI GOVERNMENT. 2019. Economic report 2019. Department of Economic Planning and Development

MALAWI GOVERNMENT. 2019. National Tourism Policy. Department of Tourism.

MALAWI GOVERNMENT. 2018. Annual Tourism Statistics Reports 2008,2009,2010,2011,2012, 2013, 2014, 2015, 2016, 2017. National Statistics Office

MALAWI GOVERNMENT. 2002. Initial National Communication of Malawi on Climate Change. Department of Environmental Affairs

MARSH, I.; MASKEY, S.; MUSSA,F.E.P. & PRAMBAUER, P. 2014. A review of the African continent: a geospatial and long-term perspective. *Hydrology Earth System Science. Vol. 18:3635-3649*

MKANDA, F.X. 1996. Potential impacts of future climate change on nyala tragelaphus angus in Lengwe National Park Malawi. *Climate Research Vol. 6:156-164*

NJOROGE, J.M. 2015. Climate change and tourism adaptation: literature review. *Tourism & Hospitality Management. Vol. 21:195-108*

NHLANE, C. 2017. Malawi tourism and the burden of climate change. *The Nation. 27 September 2017. p27 – 28*. Nations Publications

NICHOLLS, M. 2014. Climate change: implication for tourism – key findings from the intergovernmental panel on climate change fifth assessment report. University of Cambridge.

UNITED NATIONS EDUCATION AND SCIENTIFIC ORGANISATION (UNESCO). 2019. World heritage and tourism in a changing climate. https://www.whc.unesco.org Date of access: 27 Sept 2019

UNITED KINGDOM GOVERNMENT. 2019. Malawi travel advice. http://www.gov.uk/foreign-travel-advise/malawi Date of access: 30 Sept 2019

UNITED NATIONS WORLD TOURISM ORGANISATION (UNWTO). 2019. UNWTO tourism highlights: 2018 edition. https://www.e-unwto.doi/pdf/10.1811.9789284419876 Date of access: 30 Sept 2019

USAID. 2019. http//www.usaid.gov.crisis/malawi Date of access: 29 Sept 2019

USAID 2012 Climate change adaptation in Malawi http.//www.climatelinks.org/sites/default/files/asset/document/Malawi_adaptation_fact_sheet_jan2012.pdf Date of access: 29 Sept 2019

SIFOLO, P.P.S. & HENAMA, U.S. 2017. Implications of climate change for tourism in Africa. *Geo Journal of Tourism & Geosites. Vol.20 2 Nov 2017p 191-198.*

WEAVER, D. 2011. Can sustainable tourism survive climate change. *Journal of Sustainable Tourism. Vol 19:1: 2011*

SIMPSON, M.C., GOSSLING, S., SCOTT, D., HALL, C.M. and GLADIN, E. 2008. Climate hange adaptation and mitigation in the tourism sector: frameworks, tools and practices.UNEP, University of Oxford, UNWTO, WMO: Paris, France.References

Beck-Friis, B. G., 2001. Emissions of ammonia, nitrous oxide and methane during composting of organic household waste. Ph.D. Diss. Swedish University of Agricultural Sciences. Uppsala. pp 331

Banks, D., Gondwe, K., 2005. Barrier Removal to Renewable Energy in Malawi - Midterm Review Report. https://erc.undp.org/evaluation/documents/download/275 [Accessed 8 March 2008].

Banks, D., Gondwe, K., 2007. Barrier Removal to Renewable Energy in Malawi: Mid-term Review Report, Lilongwe: UNDP Malawi Country Office.

Chilima C.Z., Jenya H, Moyo D.R., Meke G.S. (2017). Comparison of the Susceptibility of Six Eucalyptus Tree Species to Leptocybe invasa-Fisher & La Salle (Hymenoptera: Eulophidae) Attack in a Forest Nursery in Zomba District. Journal of Ecology & Natural Resource, Vol.1, Issue1.

Chinyama, M. P. M., and A. Mandhlopa, 1999. Assessment of municipal solid wastemanagement in the city of Mzuzu. Malawi Journal of Science and Technology 5: 40-49

Department of Forestry (DoF) (2018). Annual Progress Report-2017/18Tree Survival Campaign: Department of Forestry.

Department of Forestry (DoF) (2017) Annual Progress Report-2017/18Tree Survival Campaign: Department of Forestry.

Detzel, A., B., H. Vogt, F. Fehrenbach, F. Knappe, and U. Gromke, 2003. Anpassung der deutschen Methodik zur rechnerischen Emissionsermitthung und internationale Richtlinien: Teilbericht Abfall/ Abwaser. IFEU Insitut- Oko-Institut,77 pp

Lober, D., 1996. Municipal solid waste policy and public participation in household source reduction. Waste Management and Research 14: 129-145

Embassy of Japan in Malawi, 2013. Grant Aid Program for Environment and Climate Change Solar Electricity Generation System Handover Ceremony at Kamuzu International Airport. https://www.mw.emb-japan.go.jp/Handover%20ceremony%20of%20Solar%20Electricity%20Generation%20System%20at%20Kamuzu%20International%20Airport.html [Accessed 6 November 2019]

FAO, 2017. Forestry Production and Trade. http://www.fao.org/faostat/en/#data/FO Accessed 12 December 2017].

GEF, 2020. Climate Change Mitigation. https://www.thegef.org/topics/climate-change-mitigation [Accessed 12 3 2020].

Gobede, L., 2011. Solar Development in Malawi. A presentation made at SADC – Europe Solar Energy Research Symposium in Lilongwe from 20th – 22nd September, 2011. https://caast-netplus.org/object/document/217/attach/0_SolarEnergyDevelopmentinMalawi-S1-LeornardGobede.pdf [Accessed 7 November 2019].

GoM, 2003. Malawi Energy Policy, Lilongwe: Ministry of Energy and Mining.

GoM, 2003. National Energy Policy for Malawi, Lilongwe: Ministry of Energy and Mines.

GoM, 2009. Malawi Biomass Energy Strategy. http://www.euei-pdf.org/sites/default/files/field_publication_file/EUEI_PDF_BEST_Malawi_Final_report_Jan_2009_EN.pdf [Accessed 18 December 2017].

GoM, 2010. Malawi State of Environment and Outlook Report: Environment for sustainable economic development, 2010, Lilongwe: Environmental Affairs Department.

GoM, 2012. Integrated Household Survey 2010-2-11: Household socio-economic characteristics report, Zomba: National Statstical Office.

GoM, 2015. Intended Nationally Determined Contribution, Lilongwe: Environmental Affairs Department.

GoM, 2015. Nationally Appropriate Mitigation Actions for Malawi, Lilongwe: Environmental Affairs Department.

GoM, 2017. Characteristics of registered vehicles by Road Traffic Directorate, Lilongwe: s.n.

GOM, 2017. Independent Power Producer (IPP) Framework for Malawi. https://energy.gov.mw/index.php/resource-centre/documents/policies strategies?download=18:final-ipp-framework-26th-may-2017 [Accessed 2 November 2019].

GoM, 2017. Integrated Resource Plan (IRP) for Malawi, Lilongwe: Ministry of Natural Resources, Energy and Mining Government of Malawi.
GoM, 2017. Malawi SEforALL Action Agenda, Lilongwe: Ministry of Natural Resources, Energy and Mining.
GoM, 2017. Malawi SEforALL Action Agenda for Malawi , Lilongwe: Ministry of Natural Resources, Energy and Environment.
GoM, 2018. Incubator Programme of The Climate Technology Centre and Network (CTCN) in Malawi: Report on Climate Technology Sectors, Stakeholders and Technologies, Lilongwe: Environmental Affairs Department.
GoM, 2018. National Energy Policy, Lilongwe: Ministry of Natural Resources, Energy and Mining.
GoM, 2018. Revised Energy Policy (2018), Lilongwe: Ministry of Natural Resources, Energy and Environment.
GoM, 2020. Malawi Technology Needs Assessment Report – Mitigation (Energy sector), Lilongwe: Ministry of Natural Resources, Energy and Mining.
GoM, 2010. Malawi Electricity Master Plan: Demand Projection, Lilongwe: Department of Energy Affairs.
GoM., 2016. Draft National Energy Policy for Malawi, Lilongwe: Department of Energy Affairs.
GoM., 2010. Malawi State f Environment and Outlook Report: Environment for sustainable economic development, 2010, Lilongwe: Environmental Affairs Department.
GoM., 2016. National Climate Change Management Policy: Ministry of Natural Resources Energy and Mining-Environmental Affairs Department.
GoM., 2017. The National Charcoal Strategy 2017–2027. The Ministry of Natural Resources, Energy and Mining, Lilongwe, Malawi.
GoM., 2012. Forest Resource Mapping Project under the Japanese Grant for the Forest Preservation Programme to the Republic of Malawi
GoM., 2011. The Second National Communication (SNC) of the Republic of Malawi under the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC): Environmental Affairs Department-Republic of Malawi.
Gondwe, K. et al., 2017. Crop residues as a potential renewable energy source for Malawi's cement industry. Journal of Energy in Southern Africa, 28(4), pp. 19-31.
Hansen M. C., Potapov P. V., Moore R., Hancher M.,Turubanova S. A., Tyukavina A., Thau D., Stehman S. V., Goetz S. J.; Loveland T. R., Kommareddy A., Egorov A., Chini L., Justice C. O., Townshend J. R. G. (2013) High Resolution Global Maps of 21st-Century Forest Cover Change. Science. Vol 342 no 6160 pp 850-853.
IEA, 2014. World Energy Outlook Special Report: Africa Energy Outlook 2014. https://www.iea.org/reports/africa-energy-outlook-2014 [Accessed 16 March 2020].
IPCC, (. P. o. C. C., 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories , Energy Sector. 2nd ed. Kanajawa: Institute for Global Environmental Strategies (IGES).
Kaunda, C., 2016. Promotion of Public Transport in Malawi: UNEP Report. http://wedocs.unep.org/bitstream/item/21643/Promotion%20of%20Efficient%20Public%20Transport%20in%20Malawi%2C%20Chimwemwe%20kaunda.pdf?sequence=9 [Accessed 22 November 2017].

Kaunda, C. and Mtalo, F., 2013. Impacts of environmental degradation and climate change on electricty generation in Malawi. Interntional Journal of Energy and Environment, 4(3), pp. 481-496.

Kenya Climate Innovation Centre, 2018. The role of technology in Climate Change. https://kenyacic.org/blog/role-technology-climate-change [Accessed 1 November 2019].

Lall, S., Wang, H. & Munthali, T., 2009. Expalining High Transportation Costs within Malawi: Bad Roads of Lack of Tracking competition?, s.l.: World Bank.

LAMNET, n.d. Average amount of Biofuels needed by one person per day in developing countries. http://new.etaflorence.it/wpcontent/uploads/2017/02/LAMNET_gas_generators_01.pdf [Accessed 8 April 2020].

Lapukeni, P., 2013. Status of Energy Sector in Malawi. https://eneken.ieej.or.jp/data/5006.pdf [Accessed 20 January 2017].

Malinski, B., 2008. Impact Assessment of Chitetezo Mbaula (Firewood Clay stove), on behalf of Programme for Basic Energy and Conservation (ProBEC). https://energypedia.info/images/1/13/Impact_assessment_clay_stoves_malawi_2008.pdf [Accessed 6 November 2019].

Malunga, T., 2017. Country report for Malawi on Energy Issues: Presnted at Energy Policy Training, JICA, Japan. http://eneken.ieej.or.jp/data/7475.pdf [Accessed 6 December 2017].

Mauambeta, D., Chitedze, D., Mumba, R. & Gama, S., 2010. Status of forests and tree management in Malawi: a position paper prepared for the Coordination Union for Rehabilitation of Environment (CURE). https://cepa.rmportal.net/Library/biodiversity/Status%20of%20Forests%20and%20Tree%20Management%20in%20Malawi.pdf [Accessed 3 December 2017].

MCC, 2011. Concept Paper for the energy sector: Public private partnerships on electricity generation for rural areas, Lilongwe: Milleniun Challenge Account_Malawi Country Office.

MCC, 2011. Project Concept for the transport sector: Promoting economic growth and poverty reduction through addressing transport infrastructure constraints in Malawi, Lilongwe: Millenium Challenge Account-Malawi Country Office.

MERA, 2014. Malawi Energy Survey Report. http://www.meramalawi.mw/index.php/resource-center/reports/send/12-reports/41-malawi-energy-survey-report-2012 [Accessed 8 March 2018].

MERA, 2017. Fuel Importation into Malawi, Lilongwe.

Mzuza, M. et al., 2014. Impact of Aquatic Weeds in the Shire River on Generation of Electricity in Malawi: A Case of Nkula Falls Hydro Electric Power Station in Mwanza District, Southern Malawi. American Open Aquaculture & Fisheries, 1(1), pp. 1-11.

NCST, 2010. Ethanol Driven Vehicle Project. A National Commission on Science and Technology Project. https://www.ncst.mw/?page_id=245 [Accessed 2 November 2019].

Nkhonjera, L., Sameer, S. & Kosamu, I., 2013. Towards sustainable energy utilisation: An analysis of various cooking fuel options in Malawi. Journal of Mechanical Engineering Research, 5(3), pp. 68-75.

NSO, 2009. National Census of Malawi: main Report. http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2008/Main%20Report/Census%20Main%20Report.pdf [Accessed 28 February 2018].

NSO, 2012. Integrated household survey 2010-2011 for Malawi, Zomba: National Statistical Office of Malawi.

NSO, 2019. 2018 Malawi Population and Housing Census, Zomba: National Statistical Office of Malawi.

O'Sullivan, K., Fitzgerald, K., 2006. Household Energy Use in Malawi (World Bank Open Knowledge Repository). http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/08/13/000112742_20120813141655/Rendered/PDF/705580ESW0P0800ld0Energy0Use0Malawi.pdf [Accessed 5 March 2018].

Pooter, G., 2016. Making charcoal in Malawi sustainable. http://mbaula.org/wp-content/uploads/2017/11/Day-2-2-Making-Charcoal-Production-in-Malawi-Sustainable.pdf [Accessed 18 December 2017].

Robinson, J., 2006. Bio-Ethanol as a Household Cooking Fuel: A Mini Pilot Study of the SuperBlu Stove in Peri-Urban Malawi, Leicestershire: Loughborough University (Thesis).

Stern, D., 2004. Economic Growth and Energy. Encyclopedia of Energy, Volume 2, pp. 35-51.

SUNMetrix, 2020. What is capacity factor and how do solar and wind energy compare? https://sunmetrix.com/what-is-capacity-factor-and-how-does-solar-energy-compare/ [Accessed 7 April 2020].

Taulo, J., Gondwe, K., Sebitosi, A., 2015. Energy supply in Malawi: Options and issues. Journal of energy in Southern Africa, 26(2), pp. 19-32.

Taulo, J., Gondwe, K., Sebitosi, A., 2015. Energy supply in Malawi: Options and issues. Journal of Energy in Southern Africa, 26(2), pp. 19-32.

Tembo, K., Mafuta, M. & Dauenhauer, P., n.d. MREAP Solar PV strategic energy project in Southern Malawi: Development, design and impacts. http://www.washted.mw/index.php/component/k2/item/download/9_a8930681c7be0015b88eb48078a286a4 [Accessed 2 November 2019].

UNDP and GEF, 2000. Barrier Removal to Renewable Energy in Malawi Project Document, s.l.: UNDP.

UNDP, 2005. Barrier Removal to Renewable Energy in Malawi, Lilongwe: UNDP.

UNDP, 2007. Feasibility study for the use of ethanol as a household cooking fuel in Malawi http://projectgaia.com/files/Malawi%20Ethanol%20HH%20Cooking%20Feasibility%20Study%20UNDP-GSB_ERG%2011-07.pdf [Accessed 8 March 2018].

UNEnvironment, 2017. Malawi Disseminates Its Fuel Economy Baseline Study Findings. http://staging.unep.org/Transport/new/PCFV/pdf/11gpm/11gpm_SecondHandVehicles.pdf [Accessed 30 January 2018].

Vesterinen, R., 1996. Impact of waste management alternatives on greenhouse gas emissions: Greenhouse gas emissions for composting. Jyväskylä: VTT Energy. Research Report ENE 38/ T0018/96. (in Finnish), 30

Wakeford, J., 2013. Innovative jatropha biofuel production in Malawi. http://m.engineeringnews.co.za/article/innovative-jatropha-biofuel-production-in-malawi-2013-07-05/rep_id:4433 [Accessed 5 November 2019].

Walker S.M., Brown K.R. and Makungwa, S. (2015). Inputs from the PERFORM project to the draft INDC report developed by Climate Analytics. Focus: Deforestation, Afforestation, and Degradation. USAID, Malawi.

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, The Second National Communication of Malawi 340 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 The Second National Communication of Malawi 342 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, sustainable 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.