UNITED REPUBLIC OF TANZANIA

SECOND NATIONAL COMMUNICATION TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

VICE PRESIDENT'S OFFICE

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FOREWORD

The first report of the Intergovernmental Panel on Climate Change (IPCC) published in 1990 confirmed that climate change was not a subject of controversy; as such, subsequent IPCC reports have affirmed that the atmospheric warming observed over the last 50 years is attributable to human activities that emit greenhouse gases (GHG). Unfortunately, global efforts to combat GHG emissions are still inefficient and disaggregated. Therefore, adaptation as we engage in Climate Change mitigation is necessary *as a measure of addressing the increased adverse impacts of climate change, need concerted national and global efforts now and in the future*[1]".

The United Republic of Tanzania ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1996 and became obligated to submit national communications as per Article 4 paragraph 1(a) and (b) of the Convention. The Initial National Communication (INC) was submitted to the UNFCCC in 2003. Tanzania now has the honour and privilege to present the Second National Communication (SNC) to the Conference of the Parties to the UNFCCC.

Since submission of the INC, the Government has undertaken many initiatives in the context of climate change that include enactment of the Environment Management Act in 2004 that enhances stakeholders participation in the implementation of the UNFCCC; and formulation of the National Clean Development Mechanism (CDM) Investor's Guide in 2004 that has been guiding the CDM initiatives in the country. Moreover, the National Adaptation Programme of Action (NAPA) was prepared in 2007 and the Quick Scan on the Impacts of Climate Change was conducted in 2009. Furthermore, Tanzania developed her National Climate Change Strategy (NCCS) in 2012, the National REDD+ Strategy and Action Plan in 2013, and the Zanzibar Climate Change Strategy in 2014. These documents provide guidance on how to address climate change in Tanzania mainland and Zanzibar. Above all, several climate change projects and programmes have been implemented. All of these initiatives have contributed to better understanding of the present and future impacts of climate change and possible mitigation opportunities in various sectors.

[1] H.E. Jakaya M. Kikwete, President of the United Republic of Tanzania and the Coordinator of Committee of Heads of State and Governments on Climate Change – CAHOSCC, A speech by him at the Africa Union-AU Summit, Malabo, Equatorial Guinea, 25 June 2014)

This SNC provides an update of quantitative assessment of greenhouse gas emissions from some major sectors and activities, and develops plausible climate change scenarios on the potential impacts of the projected climate change on some key sectors. However, due to technical reasons, the updates of GHG emissions inventory in various sectors covers from 2000 to 2005. The subsequent communication, (i.e. Third National Communication), is expected to take care of the missing data.

Generally, Tanzania has mitigation potentials in many sectors (e.g., energy, forestry, agriculture, transport and waste management) which are also identified and prioritized in the NCCS. These potential sectors present an opportunity for continued contribution of Tanzania in the global efforts to mitigate GHG while attaining its sustainable development agenda. However, inadequate funding constrains the exploitation of such opportunities. It is expected that, Development Partners will join and support Tanzania to tap the existing prospects in order to enhance the contribution to the global GHG mission while enhancing the adaptation capacities at national and local levels.

This report demonstrates the willingness of the Government of Tanzania to cooperate with the international community to combat climate change.

Eng. Dr. Binilith Satano Mahenge (MP)

MINISTER OF STATE

VICE PRESIDENT'S OFFICE (ENVIRONMENT)

ACKNOWLEDGEMENT

The preparation and finalization of this Second National Communication (SNC) for submission to the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) by the United Republic of Tanzania engaged the assistance, participation and cooperation of various key stakeholders and experts from both the public and private sector. I would like to acknowledge and appreciate their efforts and valuable contributions. Indeed, it would be impossible to list all whose support and comments proved valuable in preparing this national communication.

I would like to take this opportunity to thank all the Sector Ministries, Government departments, Local Government Authorities, Research and Academic Institutions, Private sector, Non-governmental Organizations, Civil Society and other institutions for participating in the preparation of this report. Their proactive commitment to contribute in one way or another in the collection of baseline information, participatory stakeholder consultations (formal and informal) and building a national consensus for this communication, captures the aspirations of the country to address the impacts of climate change.

This report is the outcome of a long process of collaboration, capacity building and consultation led by the Division of Environment under the Vice President's Office. In this regard, I would like to thank all the individuals and organisations that have contributed to this document and also all of our partners who have been supporting the Government of Tanzania in meeting its national development targets and global goals in combating climate change.

Special appreciation is extended to the following team of experts who worked within tight schedules to finalise this communication:- K. F. K. Manyika (Principal Forest Officer); Eng. L. Kyaruzi (Senior Mining Engineer); G. R. Kafumu(Principal Forest Officer); J. M. Limbe (Environmental Engineer) ; J. Enock (; Dr. L. Changá (Director of Research and applied Meteorology); Prof. R. Y. M. Kangalawe (Associate Professor - IRA); T. W. Massoy (Senior Livestock Officer I); E. Nashanda (Principal Forest Officer I); Eng. E. Nkini (Principal Environmental Engineer; S. H. Vuai (

Director of Policy, Planning and Research - First Vice President's Office - Zanzibar); and Y. A. Muya (Transport Safety and Environmental Officer) . The team worked diligently under R. S. Muyungi, the Assistant Director of Environment responsible for Environmental Assessment and the National Focal Point for UNFCCC.

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Finally, I wish to thank the GEF and UNEP for providing financial support for the preparation of this Report.

Sazi B. Salula

PERMANENT SECRETARY

VICE PRESIDENT'S OFFICE

ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zones
AF	Adaptation Fund
AFOLU	Agriculture Forest and Land Use
AfDB	Africa Development Bank
AGF	African Green Fund
AWG-KP	Ad Hoc Working Group on Further Commitments of developed
CBD	Convention on Biological Diversity
CCIAM	Climate Change, Impacts, Adaptation and Mitigation in Tanzania
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CIF	Climate Investments Funds
CO_2	Carbon Dioxide
COP	Conference of the Parties
COSTECH	Tanzania Commission for Science and Technology
CS	Cabinet Secretariat
CSOs	Civil Society Organizations
DART	Dar es Salaam Rapid Transit Agency
DAWASA	Dar es salaam Water and Sewage Authority
DAWASCO	Dar es Salaam Water and Supplies Company
DM	Dry Matter
DNA	Designated National Authority
DoE	Division of Environment
DPs	Development Partners
EAC	East African Community
ECF	East Coast Fever
EEZ	Exclusive Economic Zone
EMA	Environmental Management Act
ESMs	Earth System Models
ESRF	Economic and Social Research Foundation
ET	Emission Trading
EWG	Environmental Working Group
FAO	Food and Agricultural Organization of United Nations
FYDP	Year Development Plan
GCF	Green Climate Fund
GCM	Global Circulation Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHGs	Greenhouse Gases
GIZ	Gesellschaft für Internationale Zusammenarbeit (German Federal Enterprise for International Cooperation)
HFCs	Hydro-fluorocarbons
HFO	Heavy Fuel Oil
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IMS	Institute of Marine Sciences
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KP	Kyoto Protocol

LDCF	Least Developed Countries Fund
LDCs	Least Developed Countries
LEG	Least Developed Countries Expert Group
LGAs	Local Government Authorities
LULUCF	Land use, Land-use change and Forestry
MAFC	Ministry of Agriculture, Food Security and Cooperatives
MCDGC	Ministry of Community Development, Gender and Children
MCST	Ministry of Communication, Science and Technology
MDAs	Ministries, Departments and Agencies
MDB	Multilateral Development Banks
MDGs	Millennium Development Goals
MEM	Ministry of Energy and Minerals
MFAIC	Ministry of Foreign Affairs and International Cooperation
MIT	Ministry of Industry and Trade
MKUKUTA II	Mkakati wa Pili wa Kukuza Uchumi na Kuondoa Umaskini Tanzania
MLFD	Ministry of Livestock and Fisheries Development
MLHHSD	Ministry of Lands, Housing and Human Settlements Development
MNRT	Ministry of Natural Resources and Tourism
MoEVT	Ministry of Education and Vocational Training
MoF	Ministry of Finance
MoHSW	Ministry of Health and Social Welfare
MoT	Ministry of Transport
MoW	Ministry of Water
MTEF	Medium Term Expenditure Framework
MMSCFD	Million standard cubic feet per day
N_2O	Nitrous Oxide
NAFORMA	National Forest Resources Monitoring and Assessment
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action
NAPs	National Adaptation Plans
NCCFP	National Climate Change Focal Point
NCCS	National Climate Change Strategy
NCCSC	National Climate Change Steering Committee
NCCTC	National Climate Change Technical Committee
NCF	National Climate Change Fund
NDC	National Development Cooperation
NEMC	National Environment Management Council
NF_3	Nitrogen trifluoride
NFP	National Forest Programme
NFRA	National Food Reserve Agency
NHC	National Housing Corporation
NIMR	National Institute for Medical Research
NSGRP II	Second National Strategy for Growth and Reduction of Poverty
NWSDS	National Water Sector Development Strategy
PAF	Performance Assessment Framework
PES	Payment for Ecosystem Services
PMO	Prime Minister’s Office
PMO-RALG	Prime Minister’s Office-Regional Administration and Local Government
PO	President’s Office
POPs	Persistent Organic Pollutants

PPP	Public Private Partnership
PS	Private Sector
R&D	Research and Development
RAHCO`	Reli Assets Holding Company
RCPs	Representative Concentration Pathways
REA	Rural Energy Agency
REDD	Reduced Emissions from Deforestation and forest Degradation
REPOA	Research on Poverty Alleviation
SCCF	Special Climate Change Fund
SF	Special Fund
SF_6	Sulphur hexafluoride
SNC	Second National Communication
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
SUMATRA	Surface and Marine Transport Regulatory Authority
TAA	Tanzania Airports Authority
TANAPA	Tanzania National Parks
TANESCO	Tanzania Electricity Supply Company
TANROADS	Tanzania Roads Agency
TAZARA	Tanzania Zambia Railway Authority
TBS	Tanzania Bureau of Standards
TEMESA	Tanzania Electrical, Mechanical and Electronics Services Agency
TFDA	Tanzania Food and Drugs Agency
TIC	Tanzania Investment Centre
TIRDO	Tanzania Industrial Research and Development Organisation
TMA	Tanzania Meteorological Agency
TNA	Technology Needs Assessment
TPA	Tanzania Ports Authority
TPDF	Tanzania People's Defence Force
TRL	Tanzania Railways Limited
UDSM	University of Dar es Salaam
UNFCCC	United Nations Framework Convention on Climate Change
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
URT	United Republic of Tanzania
UWSA	Urban Water Supply and Sanitation Authorities
VETA	Vocational Education and Training Authority
VPO	Vice President's Office
WHO	World Health Organization
WMO	World Meteorological Organization
MW	Mega Watt
W/m^2	Watt per square meter

EXECUTIVE SUMMARY

The United Republic of Tanzania ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1996. Articles 4 paragraph 1 (a) and (b) and 12 of the Convention commits all parties to the UNFCCC to prepare and submit an inventory of GHGs, mitigation options of GHG emissions, an assessment of its vulnerability to adverse effects of climate change and adaptation measures to the Conference of Parties through the UNFCCC Secretariat. Therefore, the United Republic of Tanzania has prepared the Second National Communication (SNC) in this context. The report presents the National Greenhouse Gases Emissions Inventory for the years 2000 to 2005, and updates the vulnerability and adaptation as well as GHG mitigation studies. The 1996 IPCC Guidelines were used for GHG emissions inventory and the reporting is according to Decision 17/CP.8.

The SNC is composed of the following chapters:-

- National Circumstances
- National GHG Inventory
- Vulnerability and Adaptation to Climate Change impacts
- Mitigation Options Analysis
- Policies and Measures to ensure the fulfilment of the UNFCCC Objectives
- Other Information relevant to the implementation of the Convention
- Constraints, Gaps and related Financial, Technological and Capacity Needs

This Second National Communication was prepared with financial and technical support from the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). The process of preparing this report included consultations with various stakeholders including Academia, Government Institutions, Private Sector and Non-governmental organizations. A national team of experts was formed for the purpose of preparing the report. The team of experts included representative from government Ministries, Departments and Agencies (MDAs), Research Institutions and Academia. This approach aimed at imparting knowledge, capacity building and enhancing national ownership of the national communication process. This multidisciplinary team worked closely with the National Climate Change

Focal point under the Division of Environment, Vice President's Office (VPO. The team of experts held a number of consultations and working sessions with various stakeholders from the Private Sector, Public Sector, Development Partners as well as the academia to validate this report.

The National Greenhouse Gas Inventory from year 2000 to 2005 was undertaken during the preparation of this report. The GHG inventory results used 2000 as base year. The report indicates that the total national greenhouse gas emissions were 76,766.5 Gg of carbon dioxide equivalent (CO_2 equivalent). Out of this, Agriculture, Forestry and Other Land Use (AFOLU) accounted for 93.2% of the total emissions followed by the Energy sector at 3.8%, waste management (1.5%) and industrial processes and product use (0.5%). On a per gas basis, the largest emissions were associated with carbon dioxide (CO_2) which accounted for 87.1% of the total emissions followed by methane (CH_4) (8%), NO_x (4.6%) and nitrous oxide (N_2O) (0.3%).

Furthermore, statistical significant increasing temperature trends have been observed in both mean annual maximum temperature and in mean annual minimum temperature across the country. Trend in mean annual minimum temperature is much faster and more significant than trend in mean annual maximum temperature in most parts of the country. A slight declining rainfall trend is observed in mean annual rainfall in most part of the country; however, in most of the cases the trend is not statistically significant.

Temperature projection at both medium time scale (2050) and longer time scale (2100) indicates that the entire country is projected to experience an increase in temperature, with more warming being projected over the South-western Highlands and Western part of the country, where a warming of up to 3.4^0C is projected. Other parts of the country will experience a warming of between 1^0C to 3.3^0C from 2050 to 2100.

Rainfall projections indicates that the country is projected to experience an increase in mean annual rainfall of up to 18 to 28% by 2100, particularly over the Lake Victoria Basin and North-Eastern Highland. An increase of about 10-12% in 2050 and 18.2-28.3% in 2100 is projected over Lake Victoria Zone. The north eastern highlands areas are projected to experience an increase of up 13.4% in 2050, and 16.3% in 2100. The South-western highlands and west zones of the country are projected to experience an increase in annual rainfall by up to 9.9% in 2050 and by up to 17.7% in 2100. The north coast zone is projected to have an increase of about 1.8% in 2050 and 5.8% in 2100 while the central zone is projected to have an increase of up to 9.9% in 2050 and up to 18.4% in 2100. The southern coast zone is projected to have a decrease of up to 7% in 2050 and an increase of annual rainfall of about 9.5% in 2100. The rainfall in the northern coastal strip and the Unguja and Pemba Islands is projected to have an increase of less than 3% in 2050 and less than 2% in 2100.

It is projected that, the country will face a water stress situation, considering that being below 1,700 cubic metres per capita per year signifying water scarcity. Consequently, Subtropical thorn woodland currently in existence will be completely replaced. Subtropical dry forest and subtropical moist forest will decline by 61.4 % and 64.35 % respectively.

Recommended adaptation options include use of improved manure and fertilizers; improved cultivars; and integrated weed/pest and disease control and biotechnology. Proposed options include intensive livestock stocking; improved food production technologies; animal breeding and related technologies; animal waste treatment. Adaptation options include establishment of protected areas; restoration of degraded habitats; erosion control, and line structures.

Moreover, mitigation options include forest protection and conservation; and establishment and management of forest plantations including the sustainable harvesting of the forestry products, timber or inputs for bio-energy production. Adaptation measures include better forest management practices; afforestation; application of alternative materials; forest seed banks and the development of new plant varieties; and encouraging private and community forestry. Mitigation measures include vehicle technology improvement; fuel technology improvement; fuel substitution; and transport infrastructure and system changes; fuel switching; energy efficiency and conservation; co-generation; and cleaner technologies; re-use and recycling; composting; energy recovery; and engineered/sanitary landfills.

Implementation strategy and coordination of climate change issues in Tanzania are guided by an institutional arrangement as provided by the EMA (2004) and the National Climate Change Strategy (2012). In this context, the overall coordination rests in the Division of Environment under the Vice President's Office while implementation of specific strategic interventions and activities is done by the respective Ministries, Department and Agencies (MDAs); and local government Authorities (LGAs) as well as NGOs and Civil Society organisations according to their roles and responsibilities under EMA and mandates.

Furthermore, there are constraints, gaps and related financial and technological. These challenges constrain Tanzania's ability to set aside adequate resources for implementing climate change projects in many sectors. Given this challenge, it is recommended that technical capacity and skill to develop sound project proposals is developed strengthened and maintained at various levels. This includes capacity in data collection and packaging (according to the UNFCCC standards), research in climate change including downscaling of models and undertaking climate change adaptation and mitigation measures.

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1. INTRODUCTION

The United Republic of Tanzania ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1996. The ultimate objective of the UNFCCC is "to achieve, in accordance with the relevant provision of the Convention, stabilization of greenhouse gas 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 substantial manner". Articles 4 paragraph 1 (a) and (b) and 12 of the Convention commits all parties to the UNFCCC to prepare and submit an inventory of GHGs, mitigation options of GHG emissions, an assessment of its vulnerability to adverse effects of climate change and adaptation measures to the Conference of Parties through the UNFCCC Secretariat. Therefore, as a Party to the Convention, the United Republic of Tanzania is obliged to periodically report on its levels of greenhouse gas. The Initial National Communications was reported in 2003.

Since the Initial National Communication in 2003, a number of initiatives have been undertaken in Tanzania. Such initiatives include: the Environment Management Act which was enacted in 2004, Tanzania prepared and is already implementing the National Clean Development Mechanism - CDM Investor's Guide has been formulated since 2004. The National Adaptation Programme of Action (NAPA) was prepared in 2007, the Quick Scan on the Impacts of Climate Change was conducted in 2009. Tanzania has also put in place a National Climate Change Strategy (2012), the National REDD+ Strategy and Action Plan (2013); and the Zanzibar Climate Change Strategy (2014). These documents provide policy and legal guidance on how to address climate change in Tanzania. Above all, several climate change projects and programmes have been implemented. All of these initiatives have contributed to better understanding of the present and future impacts of climate change and possible mitigation opportunities in various sectors in Tanzania. Therefore, this Second National Communication (SNC) presents the National Greenhouse Gases Emissions Inventory for the years 2000 to 2005, and updates the vulnerability and adaptation as well as GHG mitigation studies. The 1996 IPCC Guidelines were used for GHG emissions inventory and the reporting is according to Decision 17/CP.8. The

SNC is composed of the following chapters in accordance with the UNFCCC guidelines for the preparation of Non-Annex 1 national communication:-

- National Circumstances
- National GHG Inventory
- Vulnerability and Adaptation to Climate Change
- Mitigation Options Analysis
- Policies and Measures to ensure the fulfilment of the UNFCCC Objectives
- Other Information relevant to the implementation of the Convention
- Gaps, Constraints, and Related Financial, Technical and Capacity Needs

The preparation of the Second National Communication preparation was coordinated and supervised by the Division of Environment under the Vice President's Office which is the National Climate Change Focal Point. Inputs from stakeholders both public and private sectors were key in the preparation of the Second National Communication. Participation in trainings and workshops which were organized nationally and internationally facilitated experience sharing with other institutions and nations. A national team of experts was used to finalize the preparation of SNC. This approach has helped Tanzania to build a strong team for future work on national communications under UNFCCC.

This National Communication was prepared with financial and technical support from the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). The funds received allowed the improvement of the climate change scenarios, emissions inventory, and supported the development of studies on climate change mitigation and adaptation in Tanzania. On this occasion, the process of planning the National Communication content included consultations with various stakeholders including academia, government institutions, private sector and non-governmental organizations, in order to capture their opinions and views on elements of the previous communication to be improved in this communication.

2. NATIONAL CIRCUMSTANCES

2.1 Physiography

The United Republic of Tanzania is located on the East Coast of Africa between latitudes 1° South and 12 ° South and between longitudes 29 ° East and 41 ° East. It extends from Lake Tanganyika in the west, to the Indian Ocean in the east, Lake Victoria in the north, Lake Nyasa and River Ruvuma in the South. Tanzania shares borders with Kenya and Uganda to the North, Rwanda, Burundi, Democratic Republic of Congo and Zambia to the West, Malawi, Mozambique to the south and Indian Ocean to the East.

Tanzania is constituted by Tanzania Mainland and Zanzibar with a total area of 945,087 km^2 comprised of land area of 883,749 km^2 (881,289 km^2 mainland and 2,460 km^2 Zanzibar), and 59,050 km^2 of inland water bodies and part of the Indian Ocean. Tanzania mainland encompasses island of Mafia (518 km^2) while Zanzibar comprises islands of Unguja (1,666 km^2) and Pemba (795 km^2) as major islands. There are numerous smaller islands both in the mainland and Zanzibar.

2.2 Main Physical Features

The country has a wide variety of physical features extending from a narrow coastal belt of the western Indian Ocean with sandy beaches to an extensive plateau with altitude ranging from 1000 to 2000 meters above sea level. The plateau is fringed by narrow belts of highlands, including Mount Kilimanjaro (5,895m) the highest mountain in Africa, Mount Hanang (3,420m), Mount Meru (4,566m), and other mountain ranges such as Livingstone, Kipengere, Udzungwa, Uluguru, Nguu, Usambara and Pare. Tanzania has several fresh water bodies, including Lake Victoria, the largest in Africa; Lake Tanganyika, the longest and deepest in Africa; and Lake Nyasa. The country also has many large rivers, draining into nine drainage basins. The major rivers include Rufiji, Ruvu, Wami, Kagera, Mara, Ruaha, Pangani, Ruvuma and Malagarasi. The nine water basins are Wami-Ruvu, Pangani, Lake Victoria, Lake Nyasa, Lake Tanganyika, Lake Rukwa, Rufiji, Ruvuma and the Internal Drainage Basin.

There are also other spectacular physical features including the diverse vegetation types such as extensive savannah and bushy vegetation that are fringed by narrow belts of forested highlands, the Itigi thickets, the Masai steppes, the miombo woodlands covering a greater part of the land area, and the mangrove systems along the coast. These ecosystems are famous habitats for diverse types of wildlife. The Mainland Tanzania is intersected by the Rift valley, with both the western and eastern wings cutting across the country. The western arm in which Lake Nyasa, Tanganyika and Rukwa fall in, runs along the western part of the country, while the eastern arm crosses in the central part with Lake Eyasi, Manyara and Natron.

The country is divided into four main climatic/topographical zones.

a) **The Lowland Coastal Zone**: This is an area with an elevation that ranges between 0 and 1000 meters above sea level. This zone is generally wet with rainfall ranging from 1000mm to 1800mm per annum.

b) **The Highlands Zone**: This comprises of the North Eastern Highlands and the Southern Highlands. As catchment areas, these are generally areas of high rainfall of up to 2000mm per annum.

c) **The Plateau Zone**: Areas forming up this zone are found around Lake Victoria and much of the West. These are mainly dry areas with an average rainfall of around 600mm.

d) **The Semi Arid Zone**: This comprises the central regions of the country and on average it receives less than 600mm per year.

2.3 Climatic Condition

The climate is diverse as a result of proximity of the ocean and inland lakes, wide altitudinal range, and latitude which govern temperature. It is characterized by two main rain seasons namely the long rains *(Masika)* and the short rains *(Vuli)* which are associated with the southward and northwards movement of the Inter-Tropical Convergence Zone (ITCZ). The long rains begin in the mid of March and end at the end of May, while the short rains begin in the middle of October and continues to early December. The northern part of the country including areas around Lake Victoria Basin, North-Eastern Highlands and the Northern Coast experience a bimodal rainfall regime. Central, South and Western areas have a prolonged unimodal rainfall regime starting from November, continuing to the end of April. In general, annual rainfall varies from 550 mm in the central part of the country up to 3690 mm in some parts of south-western highlands (Chang'a *et al*, 2010). Spatial distribution of mean annual rainfall is presented in Figure 2-1. Most of the country receives less than 1,000mm, except the highlands and parts of the extreme south and west where 1,400 to 2,000mm can be expected. The average annual rainfall in the central regions is around 600mm.

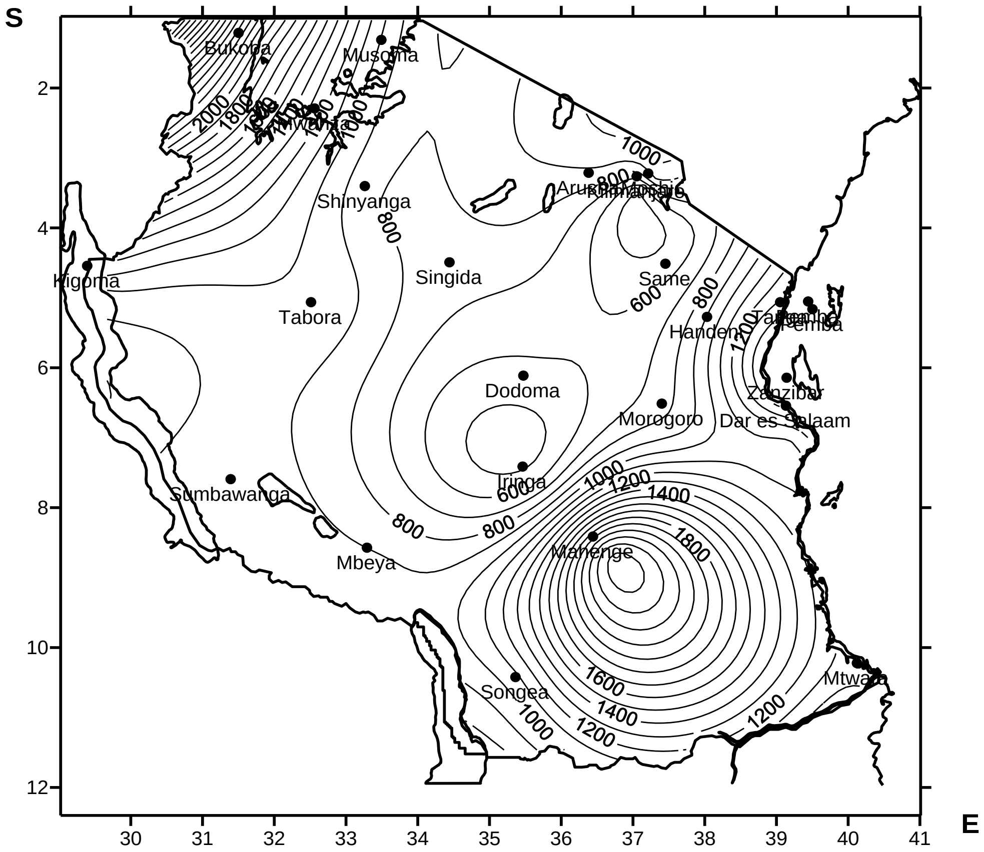

Figure 2-1: Spatial distribution of mean annual rainfall (1970 – 2000)

Source: URT (2012)

The temperature varies according to the geographical location, relief and altitude. Along the coast and in the off shore islands the average temperature ranges between 27°C and 29°C, while in the central, northern and western parts temperatures range between 20°C and 30°C. Temperatures are higher between the months of December and March and coolest during the months of June and July. In the Southern highlands and mountainous areas of the north and northeast, temperature occasionally drops below 15°C at night (URT, 2008), and in the cold months in June and July sub-zero temperatures can also be experienced. Spatial patterns of mean annual maximum (Tmax) and minimum temperature (Tmin) are presented in Figure 2 -2. Distribution of Tmin is identical to that of Tmax, lower values of Tmin are centred on south-western and north-eastern highlands. Mbeya, Igeri[2], Arusha, Moshi and Kilimanjaro are the coolest areas characterized by mean annual Tmin values which are less than 15°C. Coastal areas including Dar es Salaam, Tanga, Mtwara, Zanzibar and Pemba are characterized by relatively higher values (> 20°C) of mean annual Tmin (Figure 2-2).

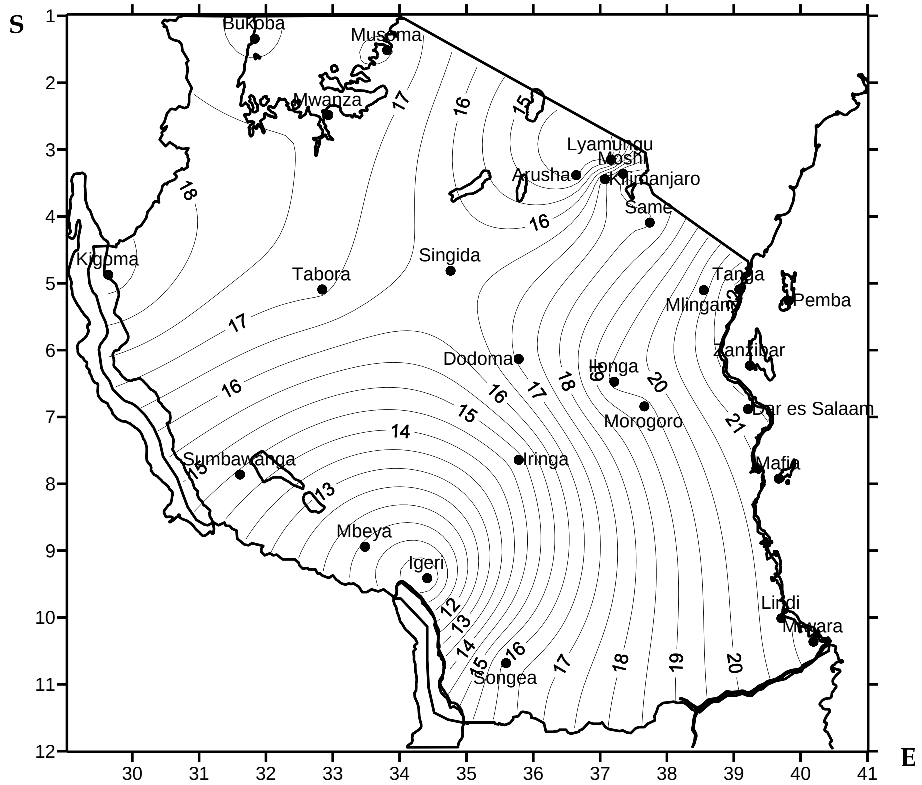

Figure 2-2: Mean annual minimum temperature (°C)
Source: URT (2012)

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[2] Igeri is one of the weather stations located in Njombe Region

2.4 Demographic Profile

The population of Tanzania has grown from 12,313,469 persons in the 1967 to 44,928,923 persons in 2012 as shown in Figure 2-3. The population growth rate has declined from 3.3 percent in 1967 to 2.7 percent in 2012. Tanzania Mainland shows a decline from 3.2 percent in 1967 to 2.7 percent in 2012. Tanzania Zanzibar shows a different pattern of growth. The growth rate increased from 2.7 percent in 1967 to 3.1 in 2002 and then declined to 2.8 percent in 2012.

According to the 2012 census the average annual intercensal growth rate from 2002 to 2012 is 2.7 and population density is 51. The number of households is 9,362,758 with an average household's size of 4.8 and Sex ratio of 95.

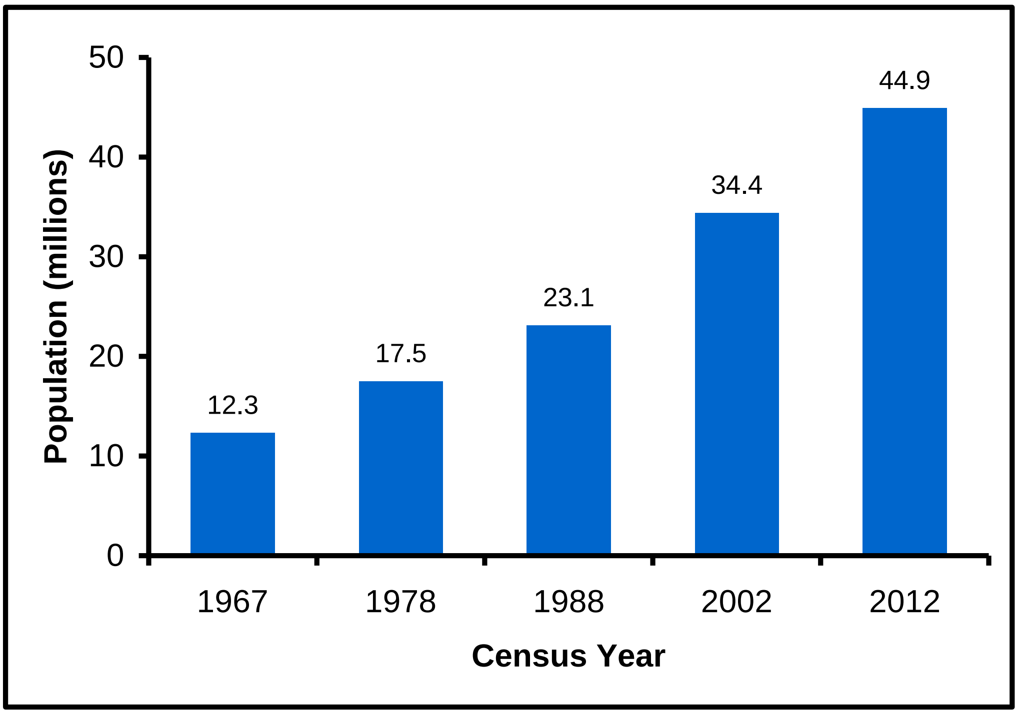


Figure 2-3: Population trends in Tanzania, 1967-2012
(*Source: NBS, 2013*)

2.5 The Economy

Over the last decade (2004 – 2013), the economy of Tanzania grew by 7.4% in 2004 compared to 7.0% in 2013. Growth was strongest in the services and manufacturing sector (with annual growth rates of 8.0% and 8.6% respectively), but was weaker in the agricultural sector (4.2% growth since 2004). The rate of economic growth however has been fluctuating over the same timeframe, growing by an annual average of 7.0%. The GDP in real terms grew by 6.9% in 2012, compared to 6.4% in 2011. In 2013, the real GDP increased to 7.0% compared to 6.97% in 2012. The growth was a result of improved transport and communication infrastructures; improved industrial production following government's efforts to ensure reliable power supply, as well as the use of alternative power sources for industrial production. In addition, the growth was on account of improved agriculture sector, following favourable conditions as well as government's effort to timely supply subsidies on improved seeds and fertilizers. Annex 1 gives a comparison of shares of GDP percentage by kind of economic activity.

2.6 Poverty Situation in Tanzania

The 2012 Household Budget Survey reveals that the pace of reducing poverty is low with poverty remaining highest in rural areas where 33.3 percent of the population fall below the basic needs poverty line. In urban areas, only Dar es Salaam has the lowest level of poverty (4.2% in 2012) compared to other urban areas (21.7%). When looking at other dimensions of poverty like ownership of assets and access to social services, the HBS findings show that there is a substantial improvement in some areas such as increases in the proportion of households with telephone, usage of mosquito nets, use of permanent housing materials and use of metal roofs. As regards access to social services such as education, drinking water and health services have increased considerably.

2.7 Sector Profile

2.7.1 Energy

The energy sector in Tanzania covers non-commercial primary energy sources and commercial energy sources (petroleum, natural gas, hydroelectricity, coal and geothermal energy). Biomass forms an important energy source in the domestic sector while other renewable energy development opportunities are being explored in the fields of solar power, geothermal and wind. Biomass accounts for 90% of final energy consumption in Tanzania and will continue to dominate the national energy balance in the near future. Forests are the main source of biomass-based fuels.

Moreover, commercial energy, such as liquefied petroleum products counts for 8%, electricity 1.5% and other sources such as coal, wind and solar energy counts for 0.5% for domestic energy requirements (URT, 2010b). Besides domestic sector, other consumer of woodfuel includes agro-based industries such as tobacco production, brick making, tea drying and fish smoking. Biomass is currently used for co-generation of heat and electricity in the sugar industries, and bio-gas is generated from waste biomass by individuals and private institutions. The potential for biomass exploitation and co-generation is substantially higher. Figure 2-4 indicates the extent of the use of firewood across Mainland Tanzania. Charcoal making follows access road and road system master plan. Trees are the main source of biomass-based fuels. Tanzania charcoal consumption per annum is 1m tonne; Dar-es-Salaam alone consumes 500,000 tonnes per annum (World Bank, 2010).

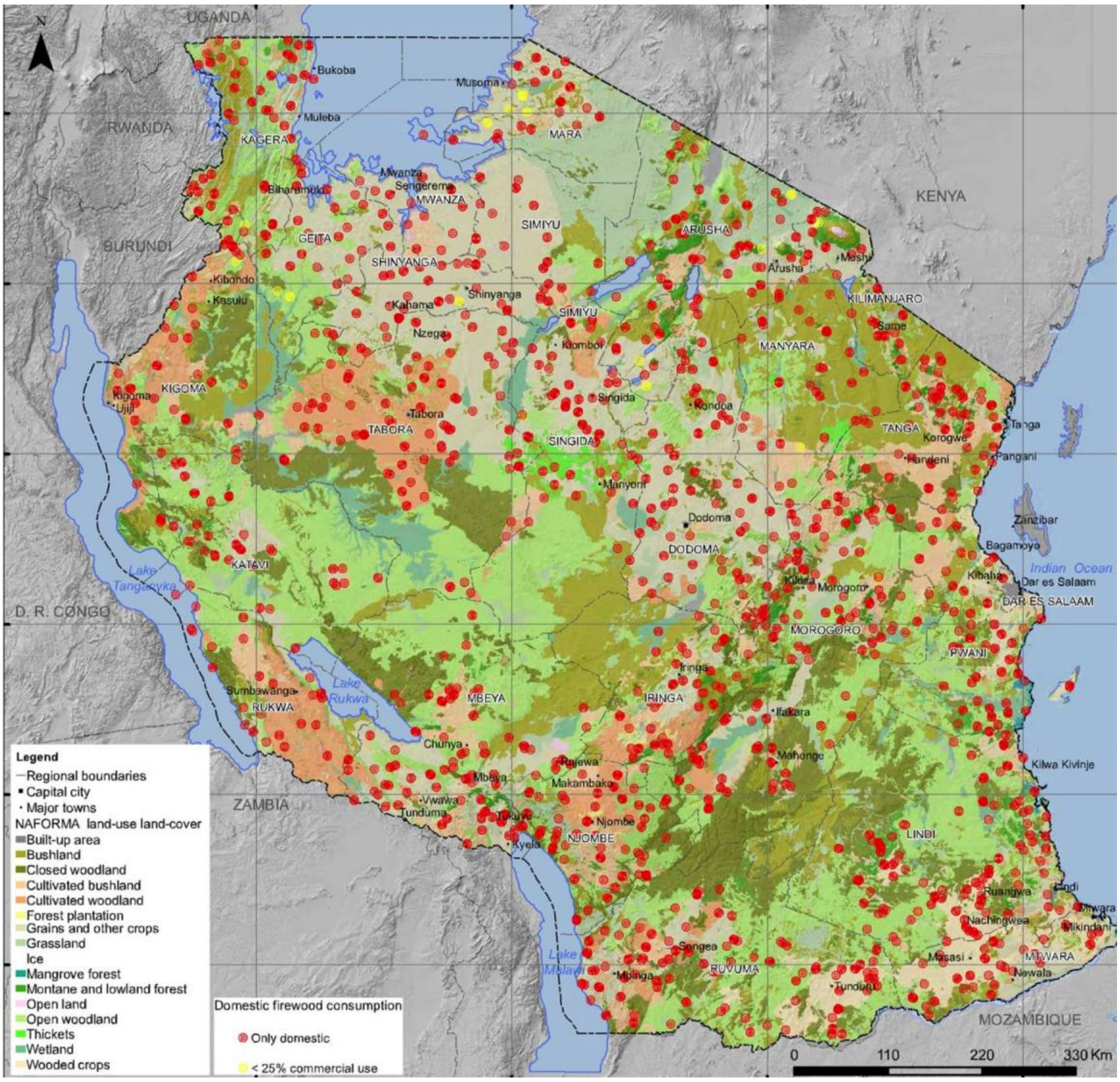


Figure 2-4: Domestic firewood consumption

The total forested area of Tanzania is 48 million ha (MNRT/NAFORMA, 2013) much more than previously reported 33.5 million ha, mainly savannah and intermediate woodland. Plantations occupy about 0.15 million hectares. The observed more forest land area does not imply more vegetation. However, recorded deforestation and forest degradation stand at 1.1% (400,000 ha/annum) more or less equal to previous reported rate.

Electricity generation

The Government is currently promoting less dependence on the hydropower generation due the prolonged droughts which faced the country between 2003 and 2006 and between 2010 and 2012 that led to drastic dropping of water levels in hydropower reservoirs resulting to load shedding. At present the total national grid installed capacity is 1,583MW with a combination of natural gas 527MW, hydro 561.8MW and Liquid petroleum products (HFO/GO/Diesel) 333.4MW. The natural gas contributes 34%, Hydro 36% to the total grid installed capacity. The natural gas power plants includes: Songas 189MW with three units, Ubungo Gas Plant 102MW with twelve units, Tegeta Gas Power Plant 45MW with five units, Symbion Ubungo Gas Power Plant 105MW with three units.

The power demand in Tanzania is projected to grow to about 10-15% per annum due to the improvement of the social economic activities. The total national electricity access is 36% and electricity connectivity is 24%. The Government plan is to increase electricity access to 75% by 2025.

Natural gas exists at Songo Songo Island and Mnazi Bay. A field with 29.02 billion cubic metres of proven, probable and possible recoverable high quality natural gas has been discovered at SongoSongo. The Mnazi Bay gas field was discovered in 1982 and commercial production started in 2006. The processing plant does process 10 mmscfd while the demand is 1.5 - 2.0 mmscfd. 18MW gas generators installed in Mtwara but actual consumption is about 15MW.

Currently natural gas power generation is 527MW and future plans are in place to increase power generation from natural gas to reach additional 940MW. Tanzania's gas reserves have the potential to sustain countries' electricity supplies as depicted in Figure 2-5.

Hydroelectric energy is still the single most important indigenous source of commercial energy in the country. The country has a potential of 4700MW of installed capacity and about 3200MW of firm capacity. Only 10 percent of the potential installed capacity has been developed. Figure 2-5 shows trends in the electricity generating capacity for the period 2000-2006. However, the trend with hydropower generation has a tendency of declining at times because of drought.

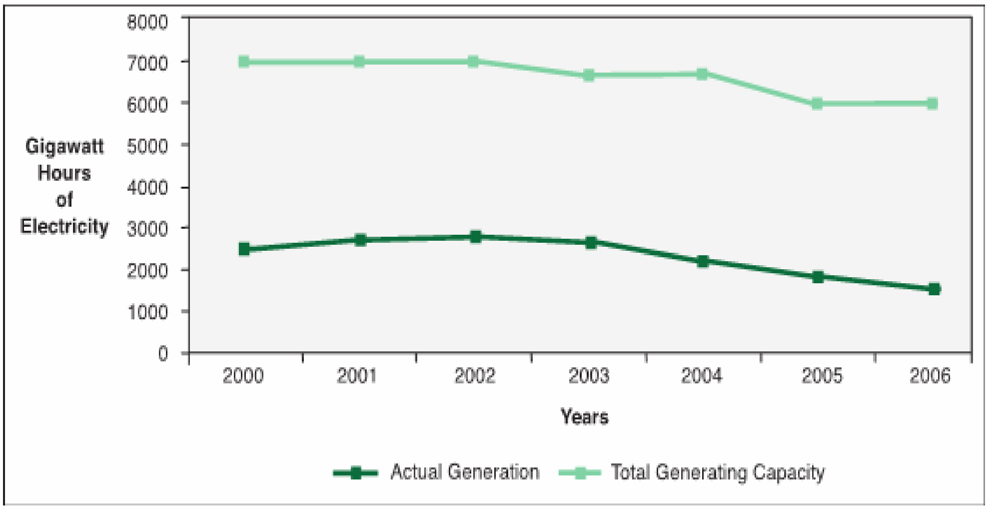


Figure 2-5: Trends in electricity generating capacity 2000-2006
Source: Ministry of Energy and Minerals (2007)

Tanzania has not yet discovered oil hence is 100% importer of white products of which almost 70% is consumed by transport sector. Figure 2-6 shows imports of fuels in Tanzania from 2009 to 2014.

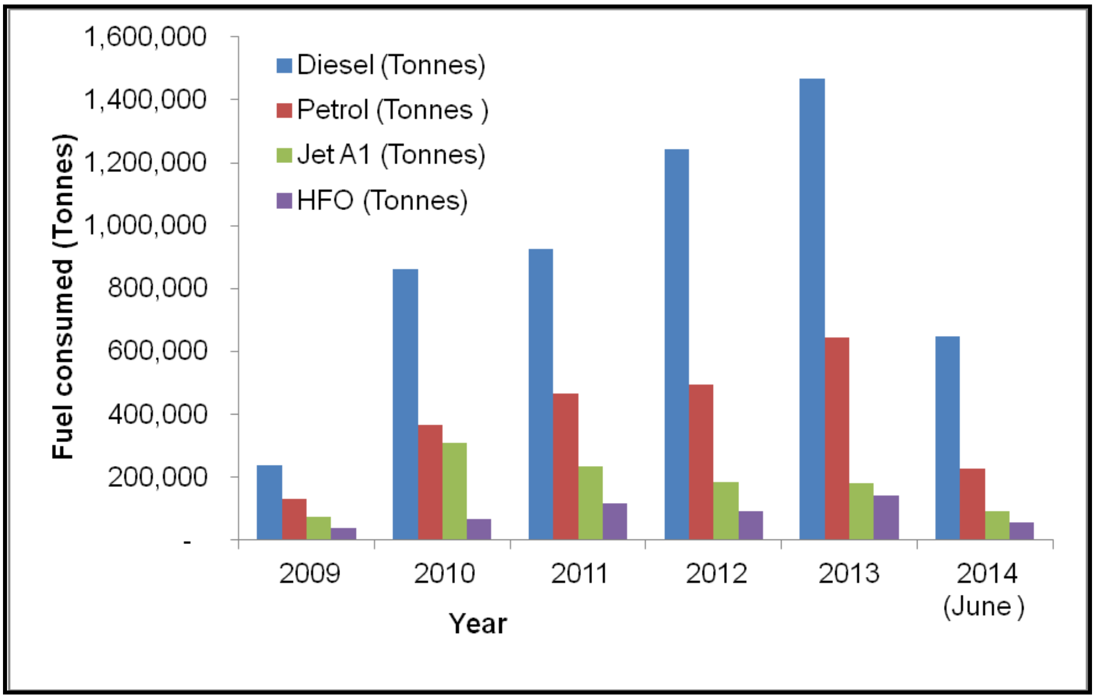


Figure 2-6: Fuel imports for domestic consumption (Source: URT, 2014b)

Domestic use of electric power is almost exclusively concentrated in urban areas. Only 7 per cent of the rural population are connected with electricity. The per capita consumption is around 100kW.

Furthermore, solar, wind and geothermal energy are virtually untapped energy resources. The mean solar energy density is of the order of 4.5 kW per square metre per day, an indication of a good potential for use as an energy source. Wind resource assessment indicated that potential is quite good for power generation in few selected areas and private firms have started development of this resource. Uranium deposits are known to exist in Tanzania but exploitation of which has not yet started. Government is finalizing the bio energy policy which will form part of Tanzania's energy mix. Table 2-1 indicates potential energy sources in the country and the status of their exploitation.

Table 2-1: Potential energy sources and status of exploitation

Resource	Proven Total Potential	Developed
Hydro Power	4,700MW (firm Capacity (3,200)	12% (562 MW)
Natural gas	• Songosongo-30 million m^3 • Mnazi Bay - 15 million m^3	361 MW
Coal	13200 Million Tons (300 Million Tons at Kiwira Field).	0.04% /annum
Biomass wood	1.8 Billion, m^3	2.2% /annum
Biomass residues	• Crop residues = 15 million tons/annum • Animal droppings = 25 million tons / annum • Volatile solids of sisal waste = 0.2 million tons/annum. • Forest residues = 1.1 million tons/annum	• About 1,000 biogas digester units of 50 m3 • 22.75 MW electricity from steam and sisal plants. • 3.5MW from forest residues.
Wind	Speed 0.9 – 9.9 m/s	129 windmills (8.5kWp) Feasibility studies on going
Solar	Approximately 215 W/m^2/day	More than 2MW electricity.
Geothermal	About 650MW	Studies are being undertaken.
Nuclear	Uranium potential exists but not yet assessed	Not exploited (limited studies)
Tidal wave	There are indications of potential	Studies are being undertaken

Source: URT (2010b)

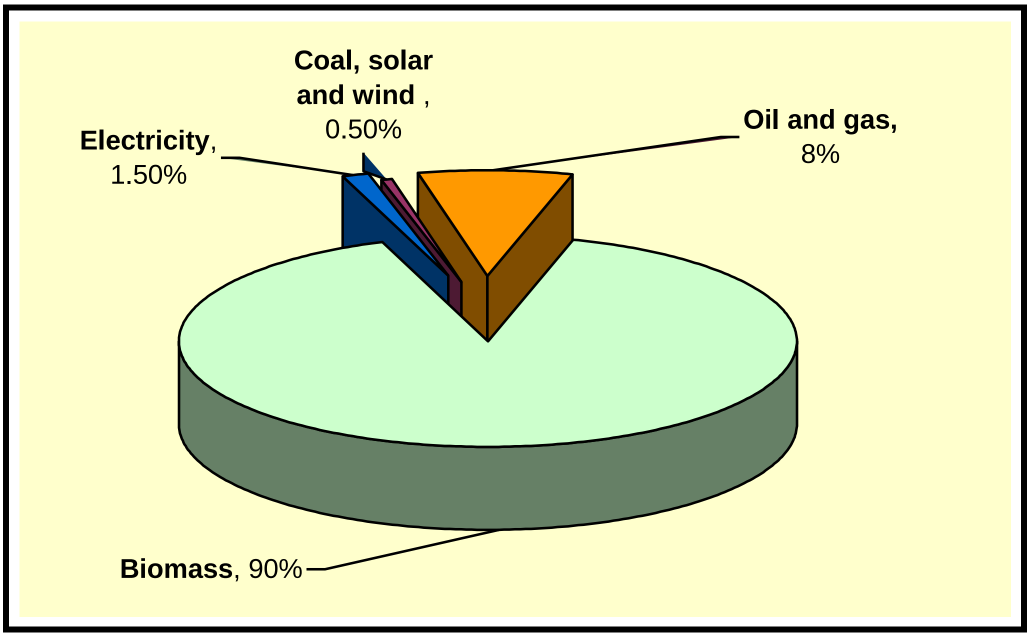


Figure 2-7: Energy consumption by sources in Tanzania
Source: URT (2010b)

The energy sector covers non-commercial primary energy sources and commercial energy (petroleum, natural gas, hydroelectricity, coal and geothermal energy). Tanzania's energy demand and end-use structure reflects the low level of development. Biomass accounts for 90% of final energy consumption in Tanzania and will continue to dominate the national energy balance *haipo* For example, fuel wood and agricultural residues used to meet domestic energy needs account for 80% of the domestic energy requirements.

2.7.2 Water

Water resources in the country include rivers, lakes, wetlands, springs, reservoirs and groundwater aquifers. Some of these are shared with neighbouring countries. The total area of freshwater cover is 54,337 km^2 which is about 6.1% of the total country's surface area. The country has a territorial sea of 64,000 km2 (6.4 million ha), an Exclusive Economic Zone (EEZ) covering an area of about 223,000 km^2 (22.3 million ha) and a coastline of about 800 km stretching from Mtwara Region in the South to Tanga Region in the North.

Water is essential for human health, social and economic well-being of rural and urban livelihoods. The performances of all key sectors of the economy (agriculture, energy, and industry) as well as emerging sectors (mining, tourism, fisheries) depend on reliable water supply. Water is central to social and economic growth of Tanzania, particularly for sustainable and secure future for its people (to meet the goals of the National Strategy for Growth and Reduction of Poverty), reliable water supply is a prerequisite. The National Strategy for Growth and Reduction of Poverty (MKUKUTA) commits Tanzania to achieving the Millennium Development Goals (MDGs) for access to safe water, sanitation and a sustainable environment. The targets defined in the MKUKUTA, the National Water Policy and the National Water Sector Development Strategy (NWSDS) call for increasing the proportion of the rural population with access to clean and safe water from 53% in 2003 to 65% in 2010. They also call for increased access to clean and safe water for the urban population to rise from 73% in 2003 to 90% by December 2013.

Domestic supply (both urban and rural) is a largest user of groundwater and consumes 755,000 m3 per day (60% of total use) against demand of 0.8 to 3.4 Million Cubic Metres (MCM)/day (IWMI, 2010). Irrigation for sugarcane, flowers, vegetables and fruits such as grapes consumes 130,000 m3 of water/day (10%) while mining and industrial use consume about 30,000 m3 per day (2%) Livestock and others, such as aquaculture use, about 350,000 m3 per day (28%). Total groundwater use is about 1.265 MCM/day which is about 12% of available groundwater resources (11 MCM/day).

Tanzania is endowed with abundant freshwater sources such as rivers, springs, lakes, wetlands, and aquifers. On average, it has about 2,300 m^3 of renewable freshwater per capita per year. The three largest African freshwater lakes, (Lake Tanganyika, Lake Victoria, Lake Nyasa which hold about 390 times the total mean annual runoff from all of its rivers, provide a huge natural storage capacity. Current stocks of freshwater are sufficient for meeting all of the country's current and future water resources development and supply needs.

The ability of Tanzania to manage water resources became a national issue in the mid-1990s as a result of new opportunities in agriculture, and the greater demand for water for irrigation and hydropower. This coupled with the long dry season and several years of less-than-average rainfall, contributed to water scarcity and conflicts, while the lack of information on water quantity and quality, and an inadequate framework for tackling cross-sectoral water issues severely constrained sustainable water resource management.

Water is not available uniformly or reliably in many parts of the country because of many factors including climate variability and geography. Furthermore, due to inadequate investments and management of water resources, localized water shortages and water-use conflicts are growing in many cities and rural areas.

Although the Water sector share to Gross Domestic Product (GDP) is only 0.2 percent which is very insignificant compared to what other sectors contribute e.g. agriculture which in 1999 accounted for 48.9 percent of the national GDP. The sector plays a more important role to social economic development in Tanzania (MoWI, 2002).

With respect to water access of the total data for household services, Tanzania Demographic Health Survey 2004/05 data show that rural households spend, on average, 27.1 minutes to collect water for domestic uses while the average collection time in urban areas is 5.9 minutes. Overall, about 66 per cent of households are not served by a water supply utility.

The management of water resources was decentralized to basin level in 1981 instead of administrative boundaries in order to manage water more efficiently. As such, Tanzania is divided into nine (9) water management basins namely Lake Victoria basin, Lake Tanganyika basin, Lake Nyasa basin, Lake Rukwa basin, Ruvuma and coastal Basin, Rufiji Basin, Pangani Basin, Wami/ Ruvu Basin and Internal Drainage Basin. These basins have variably been impacted by climate change, causing a decrease of water flow. In this work, three water basins, namely the Pangani water basin, Rufiji water basin and Wami / Ruvu water basin were considered.

2.7.3 Health

Health is one of the key sectors that are affected by the impacts of climate change. This manifests itself through increase of average temperature leading to among others, widespread of malaria in highland areas, outbreak of dengue fever and cholera. It is very likely that climate change will alter the ecology of some diseases in Africa and consequently the spatial and temporal transmission of such diseases (cf. Tonnang *et al*, 2010). Potential risks to health include deaths from thermal extremes and weather disasters, vector-borne diseases, a higher incidence of food-related and waterborne infections, photochemical air pollutants and conflict over depleted natural resources. This is likely going to compromise the human health by a range of factors.

Over recent decades climatic changes have already affected some health outcomes. According to WHO Report (2009), climate change will have the greatest effect on health in societies with scarce resources, little technology and frail infrastructure. It is estimated that Climate change was responsible for approximately 6% of malaria in some developing countries and 2.4% of world wide diarrhoea. Recent estimate show climate change was already responsible for 3% of diarrhoea, 3% of malaria and 3.8% of dengue fever deaths worldwide in 2004 (WHO, 2009). Malaria is a disease of public health importance to date in 90 countries of the world where 40% of the human population live. It is estimated that one in twenty people in the world are current infected with malaria, with approximately 350 million new cases occurring annually (WHO, 1998). It kills up to 3 million people per year worldwide. Africa alone accounted for 80% of the global malaria mortality in 2002. It is estimated that Africa accounts for 9 out of every 10 child deaths due to malaria (WHO, 2009). In Tanzania malaria is a threat to 94% of the total population. It is a major cause of under-five and pregnant women morbidity and mortality.

Climatic changes have also influenced the occurrence epidemics of cholera widely known as diarrhoeal diseases. In 1997, a total of 118,349 cholera cases and 5,853 deaths were reported in Africa. Most outbreaks followed heavy rainfall and flooding. Cholera remains a global threat and one of the key indications of social development. Almost every developing country, Tanzania inclusive, is now facing a cholera outbreak. Worldwide, is estimated that Africa accounted for half of the world’s child deaths due to diarrhoeal disease and pneumonia by 2009 (WHO, 2009).

Generally, many of the major killers such as diarrhoeal diseases, malnutrition, malaria and dengue are highly climate-sensitive and are expected to worsen as the climate changes. WHO (2013) reports that global warming that occurred since the 1970s has caused over 140,000 excess deaths annually by the year 2004. The direct damage costs to health (i.e. excluding costs in health-determining sectors such as agriculture and water and sanitation), is estimated to be between US$ 2-4 billion/year by 2030. It is noted further that areas with weak health infrastructure, particularly those in developing countries, will be the least able to cope without assistance to prepare and respond (WHO, 2013). As such the overall health effects of a changing climate are likely to be overwhelmingly negative. This is particularly because climate change affects social and environmental determinants of health such as clean air, safe drinking water, sufficient food and secure shelter.

2.7.4 Agriculture and Food Security

Agriculture is the mainstay of the Tanzanian economy contributing about 24.7% of GDP in the year 2013, 24% of export earnings and employs about 74% of the total labour force (URT, 2014a). Over the past decade, the agricultural sector grew at an average rate of 4.4%. The rate of growth in agriculture is higher than the average annual population growth rate of 2.9%, implying growth in incomes. However, the above average agricultural growth rate is insufficient to lead to significant wealth creation and reduction of poverty given the very low level of agricultural development. Attaining poverty reduction would require an annual agricultural growth rate of about 10% (URT, 2009a).

The agricultural sector comprises of crop and livestock sub sectors. Policy wise, the agricultural sector relates to crop production taking into account the synergies with other closely related policies like that of livestock, marketing and irrigation. On average, crop production contributes about 19.0% of GDP and grows at 4.1% (URT, 2008a) while livestock production contributed about 5.9% of the GDP and grow at 4.3%. Food crop production is growing at a rate of about 2.8%, accounting for about 65% of agricultural GDP while cash crops account for about 10%. Maize is the most important crop accounting for over 20% of total GDP. Food and cash crops account for about 70% of rural incomes.

Climate change has numerous impacts on food production and security. Shifting weather patterns and extreme weather will increase the incidence of droughts and floods, heat waves and other extreme events affecting all four key dimensions of food security: availability, access, stability and utilization (Turnbull *et al.*, 2013). Unpredictable weather patterns affecting yields of certain crops or the regular start of farming season of staple foods. This is an imperative impact mostly on rain-fed agriculture which is commonly practiced by the local communities. Reducing the farmers' vulnerability and strengthening their resilience to weather shocks is an essential part of any agricultural development plan of action (Meybeck and Gitz, 2013).

2.7.5 Livestock sector

Tanzania ranks third in terms of numbers of livestock in Africa, and the sector has a good contribution to the national economy. The livestock sector contributed about 4.4% of the GDP in 2013. Tanzania is estimated to have about 22.8 million cattle, 15.6 million goats, 7 million sheep, 2.01 million pigs and 35.5 million local chickens (URT, 2014a). Approximately 95% of ruminant livestock in Tanzania are kept under traditional production systems depending mostly on pastures and crop residues as the main feed resources. In this system, limited inputs such as feed additives, supplementary feeds are offered. This system produces about 93% of the milk and 99% of the meat consumed in the country.

Rangelands resources comprise approximately 60% of the total land whereas livestock resources rank third in Africa. Livestock production systems dominated by the indigenous Tanzania Short Horn Zebu (TSZ) of which 80% are under a traditional agro-pastoral system, 14% pastoral and the remaining 6 % commercial ranches and dairy farms. An attempt has been made to transform the livestock Industry in Tanzania in order to increase animal productivity through use of artificial insemination and selection of superior indigenous strains.

On the other hand, overall meat and milk production in Tanzania indicate that consumption significantly increased from 1,604,126 metric tonnes in 2008/2009 to 1,990,183 metric tonnes in 2013/2014 whereas milk per capita consumption reached 45.0 litres in 2013/2014. The trade in livestock animals was improved in year

2012/2013 with a trade 126 tonnes of beef, 667.8 goat meats and 88.4 mutton which declined to 2.8 tonnes of beef, 1,048.85 tonnes of goat meat and 58.97 mutton in year 2013/2014.

Cattle population increased from 18,398,327 in 2002 to 22.8 million in 2012 census period and all classes of livestock increased in Arusha (1,959,760), Dodoma (1,281,015), Manyara (1,796,393), Mara (1,827,369), Mwanza (2,136,253), Singida (1,716, 847), Shinyanga (3,945,428) and Tabora (2,304,950). The high DSM produced in Bukoba region (17.5 – 23.8 tonnes) and DSM region (12.9 – 14.1 tonnes) is a general reflection of the amount of precipitation received in these regions over the three decadal years. The increased mean maximum temperatures (28.4^{0}C to 28.8^{o}C) as decadal year period increased and this is in agreement with general observation of global warming.

Although carcass weights for tradition herds have increased from 107.1 kg/year (2002) to 137 kg/year 2013 the contribution of the sector to the economy has remained low (4.6% of GDP) (URT, 2013).

The potential productivity of the livestock in Tanzania has been constrained by poor nutrition resulting from poor quality pastures, diseases, tsetse flies, low genetic potential of most of traditional stock, low investment, lack of processing facilities for livestock products and by products, lack of enough water sources for livestock, poor infrastructure and frequent droughts which is a result of climate change.

The creation of Ministry that is specifically responsible for livestock industry development has demonstrated the Government's resolve to give the livestock industry the priority it deserves in contributing to poverty alleviation and the national economy at large. There are however, still a number of structural, regulatory and institutional gaps that need to be addressed. Laws and regulations are many and some are outdated and need to be rationalized and harmonized or updated. These include the Compulsory Dipping Act, Tsetse Fly Control Act, etc. While a number of new legislations have been enacted in the last few years (the Dairy Industry Act no 8, 2004; the Veterinary Act, No 16, 2003; the Meat Industry Act, No. 6 of 2006, The Grazing-land and Animal Feed Resources Act, 2010; and The Livestock

Identification, Registration and Traceability Act, 2010) some of the regulatory institutions (e.g. the Dairy Board, Meat Board) are not yet fully operational.

The role of Central Government and its various institutions and employees, Local government authorities and the private sectors in the implementation of the livestock sector needs to be more clearly defined. Services that are public goods need to be clearly discerned from private sector service delivery and adequately supported by the government. Public-Private sector Partnerships need to be rolled out in key strategic interventions such as control of transboundary diseases, zoonoses, animal genetic resources improvement and conservation.

Changes in the mean temperature and rainfall, and the increased variability of rainfall, have resulted to prolonged length of dry seasons and increased severity of periodic droughts that reduces water and pastures availability for the livestock. It has been noted that warming shortens the growing seasons and, together with reduced rainfall, reduces water availability, and can also increase livestock diseases. On the other hand, this reduced the availability of crop residues, which are important sources of feed for livestock especially during the dry seasons. Limited availability of pastures and water has often resulted into resource use conflicts between crop cultivators and livestock keepers, particularly in the catchment areas and crater basins (URT, 2012).

2.7.6 Manufacturing

The manufacturing sector has registered some growth in the recent past due to the impact of government policies of privatization and creating environment for foreign investment which encouraged investors to establish new manufacturing industries particularly in agro-processing, steel and steel products, construction material and equipment as well as beverages. Furthermore, the Small and Medium Enterprises (SME) development policy enabled enhanced local and foreign investment in the industrial sector. Manufacturing industrial activities in Tanzania are relatively small and at an infancy stage, contributing to about 8.6% of the GDP in the last decade. Most industrial development in Tanzania is either light manufacturing industries or agro-processing plants and mills located mainly in urban centres. Small-scale industries concentrate in agro product processing for value addition and are scattered throughout the cities and municipalities; and some are located in residential areas.

Growth in manufacturing sector increased from 7.8 percent in 2011 to 8.2 percent in 2012 due to the increased industrial production particularly in agro-processing, beverages, steel and iron products and cement production. A total of 542 industries were registered between 2005 and 2012.

Dar es Salaam is Tanzania's main administrative, industrial and commercial City. It accommodates about 40% of the total manufacturing firms in the country and contributes about 45% of Tanzania's gross manufacturing output (UN-HABITAT, 2009). The city is endowed with a major harbour and is an epicentre for manufacturing. In Dar es Salaam, most large-scale industries are located in the designated industrial areas of Nyerere Road, Ubungo and Mikocheni.

2.7.7 Natural resources and Tourism

Natural resources sector comprises of forestry and beekeeping, wildlife, mineral, wetlands and fisheries sub-sectors.

a) Forestry

Tanzania has a total area of about 94.5 million hectares out of which 88.6 million hectares are covered by landmass and the rest is water bodies. The country has a total of 48.1 million hectares of forests of which 93% is woodlands and only 7% is categorised as forests (mangroves, coastal forests, humid montane and plantations (NAFORMA, 2013). About 28 million ha (33%) of lands in Tanzania are under legal protection (protected forests and wildlife resources). Production forests where harvesting can be practiced are 20 million ha (22%) and accounts for 35% of the total volume. The forests contribution to the national GDP is estimated to be between 2.3% and 10% of the country's total GDP. This contribution is underestimated because of unrecorded consumption of wood fuels, bee products, catchment and environmental values and other forest products. The forest sector act as a carbon sink, absorbing all emissions produced at national level and more, making Tanzania a net sink of GHGs.

b) Wildlife

The wildlife sector has an important contribution to the national development, mainly from activities of tourism such as photographic sceneries, wild animal hunting and licensing of trophy business. The sector is rapidly growing, for instance, in 2009, receipts from wildlife sector increased to TShs 23,575.7 million from TShs 18,387.4 million in 2008, equivalent to an increase of 22% (URT, 2010). This sector like other sectors of the economy is constrained by the impacts of climate change. Many species around the country are affected by the combined impacts of climate factors, anthropogenic factors such as the encroachment, land fragmentation and destruction of natural habitats. Such changes in natural habitats may alter wildlife distribution patterns, and compounded by climate change, such situation may increase conflict for resources. This may be the case particularly amongst migratory species, which use a network of sites, and may constrain their ability to adapt to changes. Conversely, anthropogenic factors are likely to exacerbate the impacts of climate change on wildlife. For example, increased water abstraction for rice irrigation upstream Katuma River system has already contributed significantly to water shortage for wild animals in Katavi National Park (Elisa *et al*, 2011). A similar experience is also reported for the Great Ruaha River ecosystem.

c) Minerals

Tanzania is endowed with large deposits of gold, diamond, tanzanite, ruby, tin, copper, nickel, iron, phosphate, gypsum, coal, natural gas, uranium and oil. Mining involves large and small scale, both of which are potential. In 2007, the sector grew at about 15% annually, but dropped to 2.5% in 2008 and to a further 1.2% in 2009 due to decline in export of diamonds and gold production. The contribution of mining and quarrying sub activities to Gross Domestic Product (GDP) dincreased marginally from 3.4% in 2008 to 3.3% in 2009 (URT, 2010). Nevertheless it is expected the mining sector to decrease to 3.2% by 2015.

Mining in Tanzania is also affected by the impacts of the Climate Change e.g Extreme rainfall in January 2008 led to floods displaced hundreds of people and flooded mining pits in Mererani resulting in over 70 deaths. In all these cases the costs of addressing the flood situation were enormous.

d) Fisheries

Marine fisheries contribute about 15% of the total fish production in the country with the rest coming from freshwater. The annual marine fish catches increased from 36,684 tonnes in 1993 to 44,838.2 tonnes in 2009, while the corresponding quantities for freshwaters were 294,782 and 299,729 tonnes in 1993 and 2009 respectively. The contribution of fisheries both fresh water and marine to the GDP varied from 1.7% in 1998 to 1.4% in 2009 (URT, 2010a).

The impact of climate change in fisheries is mainly associated with destruction/degradation of fish nursery grounds, breeding and feeding areas. One of the most striking signs that climate change has an impact to marine fisheries is the destruction of coral reefs which is a critical habitat for fishes in the coastal environments. Destruction of coral reefs due to coral bleaching caused by rise of sea surface temperature is among the factors impacting marine fisheries. Sea level rise which is associated with global warming may cause sea water to rise above optimal levels of some corals.

e) Wetlands

Wetlands in Tanzania cover 10% of the total land area, of which 5.5% is presently for the four Ramsar sites. Among them include Malagarasi-Moyovosi (32,500 km^2), Lake Natron Basin (2250 km^2), Kilombero valley floodplain (7,950 km^2) and Rufiji-Mafia-Kilwa (5,969.7 km^2). Millions of people depend on wetlands for fishing and related livelihood activities (URT, 2012). They are also important ecosystems, which in their natural state play an important role in the water cycle through numerous functions. By way of ground water recharge, wetlands and filter underground aquifers for potable water. The same would then move out of the aquifer to become surface water through Ground water discharge. Wetlands also store large volumes of rain water which subsequently run slowly into rivers. This diminishes the destructive effects of flooding downstream. As for coastal areas, wetland vegetation such as mangroves stabilizes shorelines by reducing the energy of waves, currents, or other erosive forces.

f) Tourism

Tanzania's tourism sector is among the sectors with great economic potential. The tourism sector experienced improvements in infrastructure, although in 2009 the number of tourists who visited the country decreased to 714,367 compared to 770,376 in 2008. The country has many tourist attractions that include 14 national parks and 31 game reserves with large herds of wildlife, such attractions, include Ngorongoro Conservation Area, as well as Serengeti and Ruaha National Parks - Tanzania's largest national parks. Other tourist attractions include mountains, islands, beaches, historical sites, cultures and traditions, some of which are world heritage sites such as Mountain Kilimanjaro, the highest mountain in Africa while Kilwa Kisiwani, Songo Mnara and Zanzibar are among the most beautiful islands in the world. The sector contributes about 17.5% in GDP (URT, 2011). Notably tourism performance shows that the number of international visitors has increased from 501,669 in 2000 to 770,376 in 2008. Likewise, receipts accruing from international visitors have increased significantly from USD 376.1 million to USD 1,269.68 million within the same timeframe.

Tourism has close connections to the environment and is considered to be a highly climate sensitive sector. Climate variability determines the length and quality of tourism seasons thus plays a major role in the destination choice and tourist spending. Climate affects a wide range of the environmental resources that are key attractions for tourism, such as snow conditions over Mount Kilimanjaro, wildlife productivity and biodiversity, water levels and quality. Apart from the impacts of sea level rise, which have destroyed some of the cultural, historical, archaeological and heritage sites along coastal areas in the country, heat stress and drought have also caused massive wildlife deaths in the northern tourist zone. Destruction of infrastructure such as roads and bridges is devastating. Road maintenance becomes particularly difficult and expensive during prolonged heavy rains in many parts of the country.

2.7.8 Transport Infrastructure

The transport infrastructure systems in Tanzania are key factors in efforts to promote growth and reduce poverty and consist of road, railway, air, water and pipelines modes.

a) Ports

The major sea ports are Dar es Salaam, Tanga, Zanzibar and Mtwara while smaller sea ports are Kilwa, Lindi, Mafia, Pangani; Bagamoyo, Mkokotoni, Wesha, Mkoani and Mikindani. The lake ports are formally operated by the Marine Services Company Limited (MSCL) under TPA mandate and are situate on Lake Victoria, including Mwanza North and South Ports, Nansio, Kemondo Bay, Bukoba and Musoma; Lake Tanganyika, including Kigoma and Kasanga; and Lake Nyasa including Itungi Port, Manda Liuli and Mbamba Bay. Tanzania Ports Authority (TPA) administers a diverse system of Tanzania’s mainland sea and inland water ways.

b) Railway Network

Tanzania Railway systems have a total track length of 3,676km out of which 2,701km are owned by Rail Asset Holding Company (RAHCO) and operated by Tanzania Railways Limited (TRL). The remaining 975km are operated by the Tanzania - Zambia Railway Authority (TAZARA) co-owned by the governments of Tanzania and Zambia. TAZARA network covers a total track length of 1860km out of which 975km are on the Tanzania side and the remaining 885km on the Zambia side. The two railway systems link 14 out of the 22 regions on the mainland.

i) RAHCO

The RAHCO network consists basically of two main lines. The Central line running from Dar es Salaam to Tabora (840 km) and from Tabora to Kigoma (411 km) and a major branch from Tabora to Mwanza (378 km); and the Tanga line which starts from

Tanga to Moshi and Arusha with total length of 438km. The two lines are connected by a link line between the Ruvu Junction Station on the Central line and Mnyuzi Junction on the Tanga line (188 km). Also, the system has four branch lines, that is, Kilosa-Kidatu (107 km), Kaliua-Mpanda (214 km), Manyoni-Singida (115 km), and Kahe-Border (16 km). The RAHCO railway has a design capacity of carrying 5 million tons of freight per annum.

ii) TAZARA

TAZARA operates a railway line between the port of Dar es Salaam and New Kapiri Mposhi in Zambia over a distance of 1860km of which 975km are on the Tanzanian territory. TAZARA has a gauge of 1,067mm, which conforms to other Central and Southern African railway networks. The railway has a design capacity of carrying 5.0 million tons of freight per annum, that is, 2.5 million tons in each direction and 3.0 million passengers per annum.

c) Air Transport

Tanzania has a total of 368 aerodromes which are owned, managed and operated by different entities. Tanzania Airports Authority (TAA) owns, manages, operates and develops 58 airports. There are four international Airports namely, Mwalimu Julius Kambarage Nyerere Airport, Kilimanjaro Airport, Mwanza International Airport and Zanzibar Airport. Out of four International Airports, two of them are managed by TAA (namely Julius Nyerere and Mwanza International Airports). Zanzibar International Airport is managed by The Revolutionary Government of Zanzibar.

d) Road Network

In Tanzania, road transport is the dominant mode and accounts for over 80% of passenger traffic and over 95% of freight traffic. The trunk and regional roads in Tanzania are estimated to be 34,263.1 km, out of which trunk roads are 12,205.4 km, regional roads 21,979 km and designated roads 78.6 km. This classification is based on the Road Act, 2007 and subsequent re-classification of roads in 2009, 2010 and 2012. 42.8% of the Trunk Road network are paved and 3.9% of Regional Road network are paved The district, urban, and feeder road network is 52,241 km of which only 1.5% is paved and 5,796km are unclassified rural and community roads. The road network density in Tanzania is 96.5m per square km (or 5.0 m per square km for paved roads). Tanzania has one of the lowest road densities in Africa, for example, Kenya has 261.9m and Uganda 330.8m according to statistics in 2007. This means a large part of Tanzania is inaccessible. The inaccessibility, especially in the rural areas, makes travel cumbersome and expensive.

e) Pipeline Transport

Tanzania has three long-distance pipelines: the TAZAMA Pipeline is the first with a distance of 1,710km transporting crude oil from Dar es Salaam to Ndola refinery terminal in Zambia; the second pipeline with a distance of 232 km, including a submarine part transports gas from Songo-Songo Island to Dar es Salaam; and the third pipeline with a distance of 28km transports gas from Mnazi Bay Field to the power generation facility in the Mtwara region. There is a short distance pipeline network in Dar es Salaam that connects each depot of oil marketing companies to the Kurasini Oil Jetty of the Dar es Salaam Port.

TAZAMA Pipeline: The TAZAMA Pipeline with a distance of 1,710 km of 8 inch (200 mm) and 769 km of 12 inch (300mm) loops transports crude oil from the single point mooring at the outer anchorage of Dar es Salaam port in Tanzania through TIPER refinery that is not operational in Dar es Salaam to the Indeni Refinery Facility at Ndola in Zambia. The pipeline was designed for a throughput of 1.1 million metric tonnes per annum. Currently the optimum operating capacity is 700,000 metric tons per annum. The diameter of pipeline varies between 8 and 12 inches (and 300 mm).

2.7.9 Waste management

2.7.9.1 Solid waste management

It is estimated that more than 10,000 tonnes of municipal solid waste is generated per day countrywide (URT, 2014a). In urban areas and the major cities such as Dar es Salaam, Mwanza and Arusha, the amount of organic waste accounts for almost 70% of the total waste generated from households, food vending places and industries. On average, about 50% of solid wastes generated in urban areas are collected daily and disposed at dump sites. Due to inadequate capacity, some of solid wastes are disposed by burning or burying and others may end up in drains or, open spaces, along and across streets, manholes, water bodies or onto beaches and river banks. In the rural areas solid wastes are in most cases managed onsite by digging a dumping hole around the homestead, institutions or public places which when filled up, the wastes are buried or burnt.

2.7.9.2 Wastewater management

On-site sanitation: About 90% of households in urban and rural areas use pit latrines and septic tanks to dispose human excreta. For urban areas, when the pit latrines and septic tanks are filled up, they are emptied by trucks to waste water treatment ponds and few cases haphazardly disposed off. In the rural areas where emptying trucks are not available, when a latrine or septic tank is filled up it is abandoned and a new one is constructed. In Mainland Tanzania, about 14% of the total households do not have access to a latrine (Tanzania Demographic Health Survey, 2010). For schools, the national average for Pupil Latrine Ratio (PLR) is 53 pupils per latrine, which when disaggregated by sex is 1:51 for girls and 1:54 for boys. This is far below the national standard of 20 girls and 25 boys per drop hole by 2015 (URT, 2010). The statistics clearly show the daunting challenge to provide hygienic and safe sanitation for all Tanzanians.

Sewerage System: Sewerage systems cover a very small part of the municipalities and about 10-15 % of the urban population have access to sewerage systems. However, in some cases the systems are not properly maintained leading to leaking and draining of wastes into the streets. In most municipalities, the collected sewerage is treated in waste stabilization ponds before being discharged into receiving water bodies. However, most of the ponds are not working properly, which means that raw sewerage may be discharged into surface and ground water resources.

2.7.10 Coastal and marine environment

The coastal plain of Tanzania is relatively narrow, less than 20 km at the Kenya border, and broadening gradually to 150 km in the vicinity of Dar es Salaam. These plains are traversed by permanent and seasonal rivers, and by numerous creeks. Rivers including Pangani, Wami, Ruvu, Rufiji, Matandu, Mbemkuru, Lukuledi and Ruvuma flow to the Indian Ocean, influencing the coastal environment through creation of productive brackish water environments in estuaries, maintenance of deltas, tidal flats and shorelines, as well as nourishment of mangroves and seagrass beds. The coastline stretches over 1,424 kilometres, which encompasses fourteen coastal districts. It also includes the three large islands of Mafia, Pemba and Unguja.

The coast is one of the country's most valuable natural resource. It is this area that is characterized by a wide diversity of habitats including sandy beaches, rocky outcrops, coral reefs, estuaries, bays, sea-grass beds and extensive coastal forests (mangrove stands). In these habitats, there are a wide range of important and valued species. This make the country being one of the most important countries in Africa for biodiversity, ranking high in the number of species of different living organisms and also important for endemic species and the remnant patches of coastal forests being important for endemic species.

Coastal resources contribute significantly to the national income and provide social and economic benefit to the population. The five coastal regions contribute about one third of the country's Gross Domestic Product (GDP), with Dar es Salaam leading overall with 20 percent of the national GDP. The diversity of coastal and marine habitats supports a wide variety of natural resources. A high population and vigorous economic activities including tourism, industries, subsistence agriculture, mining and fisheries characterize the coastline. This makes the coastal and marine resources important for the well being of the people and the national economy. In Tanzania, more than 1000 kilometres of coastline are highly sensitive, including natural resources and the livelihood of coastal people (Waweru, 2002). Sensitivity is influenced by a variety of factors, including the geological characteristics of the shoreline (e.g., rock type, relief, coastal landforms) and ocean processes (e.g., tidal range, wave height).

The coastal areas of Tanzania are increasingly attracting a wide range of human activities such as major settlement centers and tourism infrastructures. Most of coastal tourist hotels are concentrated in Dar es Salaam and Coast Regions as well as in Zanzibar. Some of these tourism centers have stimulated the development of support infrastructures such as the improvement of ports of Zanzibar and Dar es Salaam. The major ports (Dar es Salaam, Tanga, Mtwara and Zanzibar) handle not only Tanzania's cargo, but also transit goods to land-locked countries of Burundi, Democratic Republic of Congo, Malawi, Rwanda, Uganda and Zambia. Initiative for Mtwara development corridor will also create markets for investors wishing to establish export businesses and therefore increase in resource utilization. The port of Dar es Salaam handles about thrice as much trade as the rest of the Tanzanian ports. Moreover, the coastline of Tanzania consists of mangrove areas, salt marshes, fringing coral reefs, intertidal floods, estuaries, lagoons and bays, within which there are potential sites for mariculture.

These habitats buffer strong wave action and thus help to control shoreline erosion. They are also important assets in bringing foreign currency through tourism, and have significance in educational and scientific value. However, these areas are subjected to increasing population and economic pressures manifested by a variety of coastal activities such as fishing, coastal aquaculture, salt-making, urbanization, industrialization, waste disposal, and indiscriminate cutting of mangroves and coastal forests for fuel wood and timber including the diverse effects caused by global warming. In Tanzania seagrass beds are found in all bays and on the west side of Pemba, Unguja and Mafia Islands. Tanga in northern Tanzania has rich fringing and patch reefs, mangroves, seagrass meadows and estuaries. Mariculture activities especially seaweed farming has been practicesed in almost all coastal areas (Table 2-2). However, the instability of the coastline is threatening the sustainability of all the development.

Table 2-2: Chronology of mariculture experiments and attempts in Tanzania

Year	Experiment	Place
1982	Finfish Siganus	Unguja-Zanzibar
1983	Seaweed farming	Tanga, Zanzibar
1985	Seaweed farming	Unguja –Zanzibar
1989	Seaweed farming	Unguja –Zanzibar
1991	Shellfish Anadara	Mji Mwema – Dar es Salaam
1992	Seaweed farming	Pemba – Zanzibar
1994	Finfish polyculture	Pete – Zanzibar

1995	Seaweed farming	Mtwara, Lindi, Tanga
1996	Oysters	Muheza - Tanga
1998	Finfish, Shellfish and Seaweed	Unguja –Zanzibar

Source: (UNEP/DGIC/URT/UDSM (eds.) 2002)

3. GREENHOUSE GAS INVENTORY

3.1 Overview of the GHG emissions

Tanzania's second national GHG inventories contain six modules including energy, agriculture, waste, LULUCF, industrial processes and solvents. Thus estimates of the key sources, sensitivity analysis and uncertainty level have been provided in this regards. The GHG inventory reported on estimates of aggregated GHG emissions and removals expressed in CO_2 equivalent.

The main activities undertaken by the inventory thematic team were as follows:

i) Review the GHG Inventory Manual of Procedures;
ii) Analyse the acceptability of the available methodologies estimates;
iii) Made decision on Tier levels based on the decision trees as guided by IPCC GPG;
iv) Decision and selection of a methodology for estimates of new gases;
v) Decision on GHGs source categories to which surveys for filling data gaps was carried out;
vi) Review available activity data already archived;
vii) Acquired all required data from all possible sources of data;
viii) Collection and analysis on necessary activity data from the available sources;
ix) Finalized data analysis and archiving in the LULUCF sector;
x) Review of the draft GHG inventory report by national experts; and
xi) Validation and finalization of the Draft GHG inventory report.

The time series covered under the inventory study included years 1995 to 2005. Sub sectors that were covered under the energy sector include: energy industries (electricity production); manufacturing industries and construction; transport; residential; and coal mining, and handling. In Tanzania there are limited applications and/or information for other sectors that include: chemical industry; non-energy products from fuels and solvent use like lubricants, paraffin wax and solvents; electronics industry; product uses as substitutes for ozone depleting substances; and other product manufacture and use like electrical equipment and propellant for pressure and aerosol products. Therefore, cement production was the main sub sector covered for the industrial processes and product use. Sub sectors covered for the agriculture, forestry and other land use included livestock, land, and aggregate sources and non-CO_2 emissions sources on land. Sub sectors covered for waste were: solid waste disposal; biological treatment of solid waste,; incineration and open burning of waste; and wastewater treatment and discharge.

The IPCC 2006 guidelines provided the main methodology utilized in implementing the inventory study. Basically, the IPCC Tier 1 approach was widely adopted for estimating the greenhouse inventory since there are limited site specific emission factors for Tanzania that can be utilized to establish emissions for the sectors like energy, industrial processes and waste. Activity data for this inventory was mainly collected from the national statistical body, the National Bureau of Statistics, and other international statistical bodies like FAO, and the International Energy Agency (IEA), complimented the statistical data. In other cases, individual firms bearing the activity data were consulted.

Time series greenhouse gas inventory for Tanzania indicated an increasing trend for the sectors of energy, industrial processes and product use, and waste. The increasing emission trend is particularly due to increasing population and economic activities. Table 3-1: summarizes the greenhouse gas inventory for Tanzania for reference year 2000.

Table 3-1: Greenhouse gas inventory for reference year 2000

SUB SECTOR	EMISSIONS SUMMARY, Gg			
	Carbon Dioxide, CO_2	Methane, CH_4	Nitrogen Oxides, NO_x	Nitrous Oxide, N_2O
1: Energy				
1A1: Energy Industries (Electricity production)	281.37	0.011527	-	0.002305
1A2: Manufacturing Industries and Construction	482.16	0.018636	-	0.003719
1A3: Transport	1,817.51	0.245014	-	0.119040
1A4: Others (Residential)	368.45	0.015000	-	0.003000
1B: Fugitive Emissions (Coal Mining and Handling)	-	1.085065	-	-
1C: Carbon dioxide Transport and Storage	-	-	-	-
Sub Total	**2,949.49**	**1.375242**	-	**0.128064**
2: Industrial Processes and Product Use				
2A: Mineral Industry (Cement Production)	411.50	-	-	-
3: Agriculture, Forestry and Other Land Use				
3A: Livestock				
3A1: Enteric fermentation	-	616.000000	-	-
3A2: Manure management	-	22.000000	-	1.000000
Sub Total:	**-**	**638.000000**	-	**1.000000**
3B: Land				
3B2: Agricultural soils	-	-	-	61.000000
3C: Aggregate sources and non-CO_2 emissions sources on land				
3C1: Biomass burning	63,529.83	17.016918	-	2.268922
3C1b: Field burning of agricultural residues	-	89.000000	3,502.00	122.000000
3C1c: Prescribed burning of savannahs	-	4,166.000000	40.00	1.000000
3C7: Rice cultivation	-	54.000000	-	-
Sub Total:	**63,529.83**	**4,326.016918**	**3,542.00**	**125.268922**
4: Waste				
4A: Solid waste disposal	-	1,165.800000	-	-
4B: Biological treatment of solid waste	-	-	-	-
4C: Incineration and open burning of waste	-	-	-	-
4D: Wastewater treatment and discharge	-	10.480000	-	5.210000
Sub Total:	**-**	**1,176.280000**	-	**5.210000**
GRAND TOTAL:	66,890.82	6,141.672160	3,542.00	192.606986

3.1.1 Emissions of Carbon Dioxide, CO_2

The AFOLU sector is the major emitter of CO_2 emissions sharing 94.98% of all emissions. This corresponds to 63,529.83Gg of CO_2 emissions. The next is the energy sector that emitted 2,949.49 Gg of CO_2. The industrial processes and product use emitted 411.50 Gg. Figure 3-1 shows the carbon dioxide emissions for the reference year 2000.

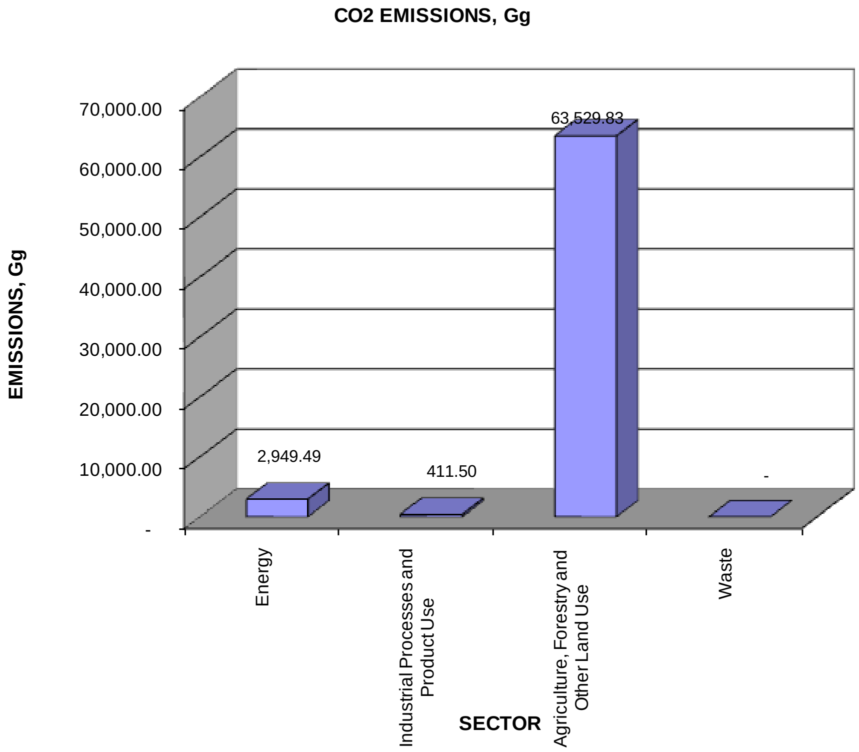


Figure 3-1: Carbon dioxide emissions for the reference year 2000

3.1.2 Emissions of Methane, CH4

In year 2000 the agriculture, forestry, and other land use sectors emitted 80.83% (4,964.02 Gg) of total CH_4 emissions, whereas the waste sector emitted 19.15% (1,176.28 Gg). The energy sector emitted 0.02% (1.38 Gg) of the total CH_4 emissions. The share of CH_4 emissions per sector is detailed in Figure 3-2.

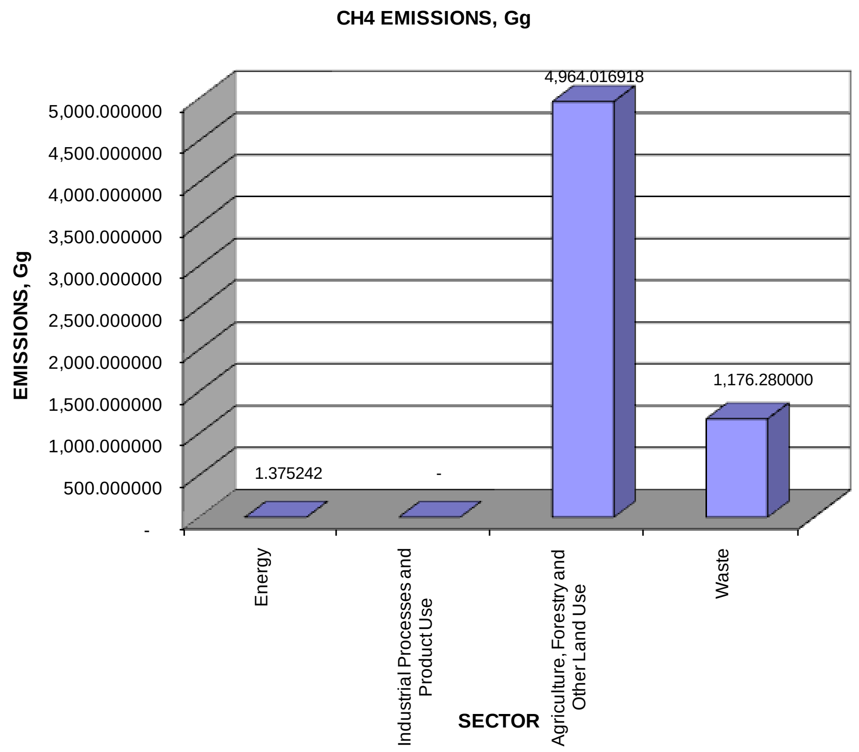


Figure 3-2: Methane emissions for the reference year 2000

3.1.3 Emissions of Nitrous Oxide, N_2O

The agriculture, forestry and other land use sectors are the main emitter of nitrous oxides. In year 2000, the sectors emitted 187.27 Gg of N_2O emissions that represent 97.23% of total emissions in the reference year. The waste sector was second in by emitting 5.21 Gg of N_2O, which shares 2.70% of total emissions. Finally, the energy shared the remaining 0.07% of the total emissions, which is equivalent to 0.13 Gg. Figure 3-3 presents the emissions of Nitrous Oxides per sector.

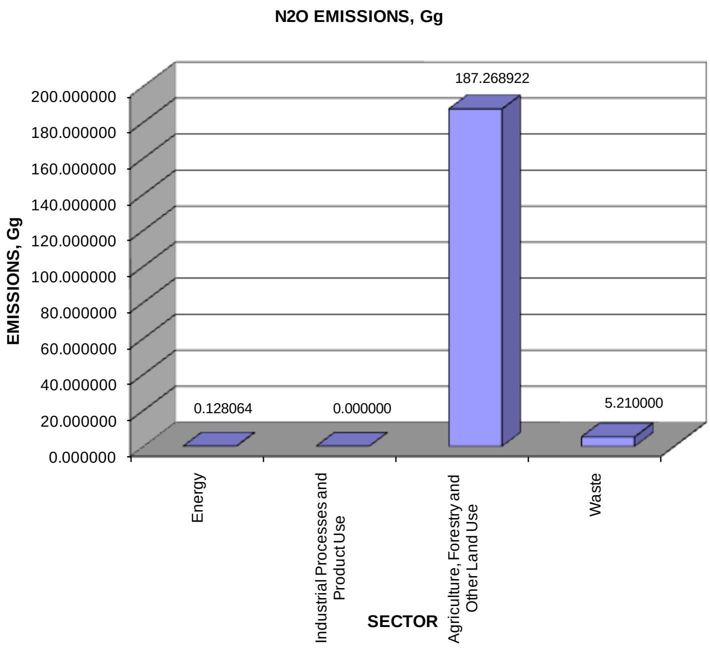


Figure 3-3: Nitrous oxide emissions for the reference year 2000

3.2 Emissions Reporting by Sector

3.2.1 AFOLU sector

According to the GPG LULUCF (2003) the change in biomass is only estimated for perennial woody crops. For annual crops, increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year – thus there is no net accumulation of biomass carbon stocks. The estimated loss of biomass from harvested perennial woody crops was 42,240 Gg CO_2 e in year 2000.

Most of the area for agriculture in Tanzania is used for annual crops which imply that the carbon is not stored over a very long time in above ground biomass. Although the soil carbon is also affected by management practices (for example: ploughing and fertilization), the current agricultural practices are not fully mechanized. The category is disaggregated into 5.B.1 Cropland remaining Cropland and 5.B.2 Land converted to Cropland. Category 5.B.2, disaggregated into conversions from Forest Land, Grassland and Settlements is not estimated due to unavailability of data. N_2O emissions from disturbance associated with land use conversion to Cropland are not reported as shown these are considered to be small.

Emissions under the forest land remaining forest land category are based on deforestation rate and were estimated excluding the mangrove forests category. This is because the area under mangrove forest has shown an increasing trend in the years 1995 – 2002.

For cropland and wetland categories emissions figure does not vary over years since the activity data in these categories did no vary significant over the years 1995 – 2000. Although effort has been made to describe potential emission sources and sinks for all land use categories as recommended in GPG LULUCF (2003) Emissions from grassland and settlements sectors were not estimated (NE) due to unavailability of activity data as required in GPG LULUCF (2003). In addition, emissions due to transformation to or from AFOLU categories were not estimated. Table 3-2 shows emissions from the AFOLU Sector for forest land, cropland and wetland categories.

Table 3-2: Emissions and removals in the land use change and forestry sector (Gg CO_2)

		1995	1997	2000	2002
5A	**Forest-Land**	134,893	137,012	138,035	140,441
5A1	Forest-Land remaining Forest-Land	134,893	137,012	138,035	140,441
5A2	Land converted to Forest-Land	NE	NE	NE	NE
5B	**Cropland**	42,240	42,240	42,240	42,240
5B1	Cropland remaining Cropland	42,240	42,240	42,240	42,240
5B2	Land converted to Cropland	NE	NE	NE	NE
5C	**Grassland**	NE	NE	NE	NE
5C1	Grassland remaining Grassland	NE	NE	NE	NE
5C2	Land converted to Grassland	NE	NE	NE	NE
5D	**Wetland**	330	330	330	330
5D1	Wetland remaining Wetland	330	330	330	330
5D2	Land converted to Wetland	NE	NE	NE	NE
5E	Settlements	NE	NE	NE	NE
5E1	Settlements remaining Settlements	NE	NE	NE	NE
5E2	Land converted to Settlements	NE	NE	NE	NE
Non CO_2 emissions					
5A1	Vegetation fires Gg CH_4/year	2	2	2	2
5A1	Vegetation fires Gg N_2O/year	0.05	0.05	0.05	0.05
5D1	Wetlands Gg CH_4/year	1	1	1	1

Source: Inventory data, 2006

3.2.2 Energy Industries

Energy industries for Tanzania are mainly based on thermal power plants that utilize fossil fuels for electricity generation. Grid connected power plants are owned by the Government utility company, the Tanzania Electric Supply Company Limited (TANESCO). The utility owns interconnected system of generation, transmission and distribution. Transmission line comprise of 4,866.85 km of high voltage. Combined heat and power generation is only carried out in sugar plants that utilizes waste bagasse to generate electricity and process heat. Due to closure of the Tanzania and Italian Petroleum Refining Company (TIPER), which was the sole refining company, there are no further activities in this category.

TANESCO has a network of grid connected thermal power plants located in Dar es Salaam, Mwanza, Mbeya, Tabora, Musoma, Dodoma, Shinyanga, Sumbawanga, and Bukoba. On the other hand, isolated thermal power plants are still being used in some areas which consume substantial amount of diesel to generate power (Table 3-3). Study has not yet being conducted to determine the amount of emissions from these generators. This information will be presented in the next report.

Table 3-3: Isolated Power Stations using gas/diesel

S/N	Station	No. of Units	Unit Capacity (KW)	Capacity (KW)
1	Mpanda	2	660	2600
		2	640	
2	Namtumbo	1	400	400
3	Ngara	2	476	952
4	Songea	2	1800	8095
		1	1915	
		1	660	
		3	640	
5	Sumbawanga	5	1250	6250
6	Tunduru	2	640	1980
		2	350	
7	Somanga	3	2500	7500
8	Mtwara	7	2000	21800
		4	1950	

Source: TANESCO (2005)

Emissions in the electricity generation sub sector are summarized in Table 3-4. The general trend in the emissions is a decreasing due to the intermittent operations of the grid connected thermal power plants. Since they are operating in back up mode, the grid connected plants are usually shut down when there is a satisfactory performance in existing hydro power plants

Table 3-4: Emissions summary from electricity production

Year	Methane (CH_4) (Gg)	Carbon dioxide (CO_2) (Gg)	Nitrous Oxide (N_2O) (Gg)
1995	0.012538	305.19	0.002508
1996	0.011525	280.92	0.002305
1997	0.010645	259.80	0.002129
1998	0.009658	236.16	0.001932
1999	0.008814	215.98	0.001763
2000	0.011527	281.37	0.002305
2001	0.004736	118.60	0.000947
2002	0.002285	58.28	0.000457
2003	0.003615	90.60	0.000723
2004	0.007295	180.09	0.001459
2005	0.003122	79.65	0.000624
Total	**0.08576**	**2106.64**	**0.017152**

Source: TANESCO (2005)

3.2.3 Manufacturing Industries and Construction

Tanzania's industrial sector is still at infancy stage with limited and isolated number of operating units. Traditional industries in Tanzania include steel rolling mills, food processing, cement, textiles, breweries, soap and detergents, cigarettes, and beverages. Currently, there is also a growing number of mining industries. Due to the limitations in availability of specific industry's activity data, industries that are included in this inventory include iron and steel (steel rolling mills), soap and detergents, tobacco, textiles, and cement.

Cement production is one of the major emitter of GHGs in the industrial sector in Tanzania. Tanzania produces Portland cement from three factories namely: Tanga Cement Limited, Mbeya Cement Limited, and Tanzania Portland Cement Company Limited, which are respectively located in the regions of Tanga, Mbeya and Dar es Salaam. These factories produce about 878,000 metric tonnes of clinker annually. Due to the abundance of raw materials, the factories are rarely importing the clinker. During the production of clinker in these industries, limestone, which is mainly calcium carbonate ($CaCO_3$), is calcined to produce lime (CaO) and CO_2, which is the main greenhouse gas from the cement industry. The CaO then reacts with silica (SiO_2), alumina ($Al2O_3$), and iron oxide (Fe_2O_3) in the raw materials to make the clinker minerals (chiefly calcium silicates). As per the IPCC guidelines Tier 1 methodology, the Portland cement production data was utilized to estimate clinker production. There are no imports and export of clinker and therefore the estimated emissions from cement production were entirely locally accounted.

The general trend in emission levels in the manufacturing industries and construction sub sector shown in Table 3-5 portrays increasing levels. This is due to the overall increasing production levels in the respective production plants.

Table 3-5: Emissions in the manufacturing industries and construction sub sector

Year	**Methane (CH_4)** (Gg)	**Carbon dioxide (CO_2)** (Gg)	**Nitrous Oxide (N_2O)** (Gg)
1995	0.017354	450.16	0.003559
1996	0.016677	435.30	0.003313
1997	0.014310	369.58	0.002856
1998	0.016183	419.32	0.003228
1999	0.019967	514.43	0.003984
2000	0.018636	482.16	0.003719
2001	0.020890	539.88	0.004169
2002	0.023467	578.75	0.004681
2003	0.024003	618.95	0.004795
2004	0.027173	702.27	0.005428
2005	0.026955	696.58	0.005418

The GHG emissions share per sub sector in the industrial sector is as shown in Figure 3-4.

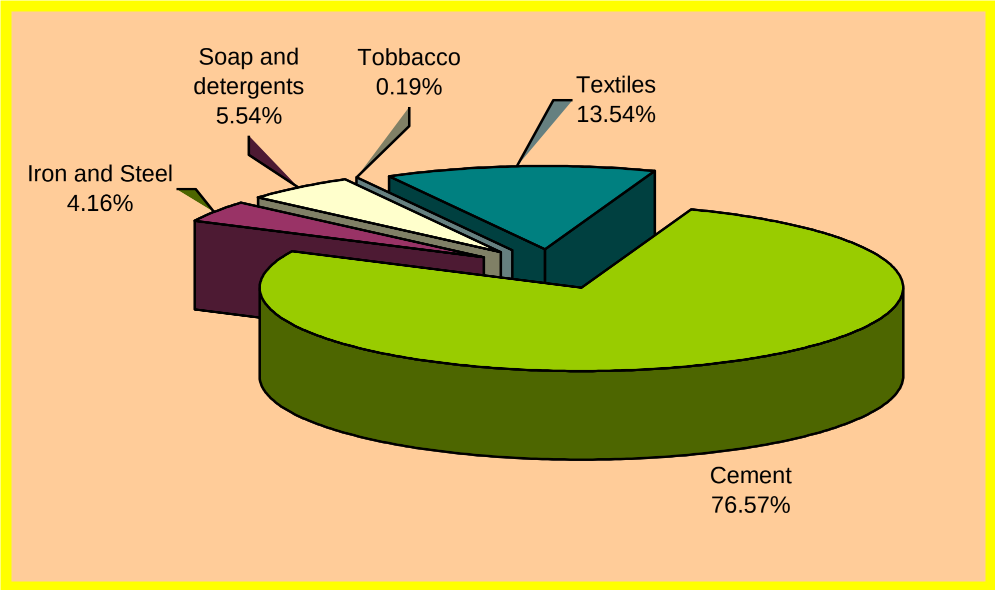


Figure 3-4: CO_2 emissions share per sector for the manufacturing industries and construction sector

3.2.4 Transport Sector

The main mobile combustion sources for Tanzania include international and domestic aviation; road transport, railways, and water-borne navigation. There is also a pipeline that transports fuel from the coast of Dar es Salaam city to the hinterland Zambia. There are well-established international aviation routes via two international airports in Dar es Salaam and Kilimanjaro. Further, due to widespread nature of the country and also based on the rich tourist attraction, domestic aviation is also well established in Tanzania. There are two railways networks; the first is a 1,860 km, 1067 mm gauge network, which is owned by the Tanzania Zambia Railways Authority (TAZARA) that joins Kapiri Mposhi town in Northern Lusaka, Zambia to Dar es Salaam port in Tanzania. The second is the 2,720 km, 1000 mm gauge central railway network that is owned by Tanzania Railways Limited – TRL, which on privatization acquired the parastatal Tanzania Railways Corporation (TRC). Water-borne navigation constitutes of international bunkers plying through sea ports located in Dar es Salaam, Tanga, and Mtwara. While there is also domestic water-borne navigation along the sea, there are also local water-borne navigation along the inland lakes, which are mainly Lakes Victoria, Tanganyika, and Nyasa.

Characteristics of motor vehicles in Tanzania have been described by Wilson (1987) and shows that the percentage of cars are 46.81% (with salon cars being 2.39% and station wagon 20.42%); buses 7.84% (micro buses 5.75%, mini buses 2.5%, and large buses 0.75%); goods trucks 29.17% (light goods trucks 19.25%, medium goods trucks 1.75%, and heavy goods trucks 7.25%); motor cycles 10.80%; tractors/earth movers 2.71%; and trailers 2.57%. It has further been established that the proportion of diesel propelled vehicles was 55.32% whilst that for petrol was 44.68%.

Table 3-6 shows emissions summary for the sub sectors of civil aviation, road transport, railways, and water-borne navigation.

Table 3-6: CH_4 Emissions summary for the transportation sector, Gg

Year		Civil aviation	International aviation	Off-road	Rail transport	Road transport	Waterborne	Totals
1995	CH_4	0.000894	0.000437	0.001158	0.003337	0.201509	0.000208	**0.207543**
	CO_2	127.45	62.46	20.68	59.58	1,268.87	2.20	**1,541.25**
	N_2O	0.003576	0.001747	0.007981	0.022997	0.064729	0.000059	**0.101091**
1996	CH_4	0.000889	0.000413	0.001321	0.003337	0.213672	0.000208	**0.219839**
	CO_2	126.68	59.03	23.58	59.58	1,414.98	2.20	**1,686.05**
	N_2O	0.003554	0.001651	0.009101	0.022997	0.072351	0.000059	**0.109714**
1997	CH_4	0.000876	0.000383	0.001304	0.003747	0.215724	0.000229	**0.222263**
	CO_2	125.08	54.83	23.29	66.91	1,416.65	2.42	**1,689.19**
	N_2O	0.003503	0.001534	0.008990	0.025826	0.072409	0.000065	**0.112327**
1998	CH_4	0.000987	0.000241	0.001199	0.003441	0.207911	0.000238	**0.214018**
	CO_2	140.74	34.53	21.41	61.43	1,313.18	2.52	**1,573.81**
	N_2O	0.003950	0.000966	0.008264	0.023711	0.066999	0.000068	**0.103958**
1999	CH_4	0.000971	0.000043	0.001199	0.003585	0.168239	0.000250	**0.174287**
	CO_2	138.37	6.15	21.41	64.01	1,128.15	2.64	**1,360.74**
	N_2O	0.003884	0.000172	0.008264	0.024707	0.057717	0.000071	**0.094815**
2000	CH_4	0.000916	0.000332	0.001420	0.003660	0.238435	0.000250	**0.245014**
	CO_2	130.86	47.52	25.36	65.35	1,545.77	2.64	**1,817.51**
	N_2O	0.003664	0.001329	0.009789	0.025223	0.078962	0.000071	**0.119040**
2001	CH_4	0.000944	0.000507	0.001488	0.003842	0.273805	0.000244	**0.280830**
	CO_2	134.70	72.55	26.57	68.60	1,669.81	2.58	**1,974.82**
	N_2O	0.003775	0.002029	0.010257	0.026478	0.085051	0.000070	**0.127660**
2002	CH_4	0.000942	0.000598	0.001488	0.003835	0.322297	0.000244	**0.329403**
	CO_2	134.40	85.45	26.57	68.47	2,074.56	2.58	**2,392.04**
	N_2O	0.003766	0.002390	0.010257	0.026428	0.105939	0.000070	**0.148850**
2003	CH_4	0.000964	0.000485	0.001877	0.004360	0.292288	0.000262	**0.300236**
	CO_2	137.61	69.37	33.52	77.85	1,847.56	2.77	**2,168.68**
	N_2O	0.003855	0.001940	0.012937	0.030048	0.094267	0.000075	**0.143123**
2004	CH_4	0.000973	0.000507	0.001749	0.004205	0.304489	0.000262	**0.312185**
	CO_2	138.89	72.52	31.23	75.09	1,931.14	2.77	**2,251.63**
	N_2O	0.003890	0.002029	0.012052	0.028980	0.098547	0.000075	**0.145573**
2005	CH_4	0.000968	0.000529	0.001820	0.003806	0.321255	0.000355	**0.328734**
	CO_2	138.27	75.68	32.50	67.96	2,027.34	3.76	**2,345.51**
	N_2O	0.003873	0.002117	0.012544	0.026230	0.103432	0.000101	**0.148297**

Source: Inventory (2005)

3.2.5 Residential and Commercial sectors

The residential and commercial sectors are the main areas for greenhouse gases inventory established for this sector. Though the majority of energy utilized in the residential sector is mainly comprised of wood based fuels, the IPCC guidelines prescribe that emissions reporting for the residential sector does not include the wood-based fuels, which are included in the AFOLU. Residential and commercial emissions reported for Tanzania will therefore emanate from combustion of kerosene and liquid petroleum gas (LPG). The residential and commercial sectors include all homes and commercial businesses (excluding agricultural and industrial activities). Greenhouse gas emissions from this sector come from fossil fuel combustion for heating and cooking needs, management of waste and wastewater, and leaks from refrigerants in homes and businesses

The kerosene and LPG activity data for this sector were collected from Tanzania Petroleum Development Corporation (TPDC). The energy consumption balance from TPDC and from the Ministry of Energy and Minerals and based on experience of petroleum fuels resellers show that almost 100% of imported kerosene is used in the residential sector. Further, it is reported that about 45% of imported LPG is consumed in the residential sector where as the remaining 55% is for the industry and commercial applications. The activity data for residential and commercial sector is therefore shown in Table 3-7.

Table 3-7: Fuel consumption in the commercial and residential sector

	Consumption Per Year, Gg										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PARAFFIN	154.38	202.80	177.62	122.63	76.07	87.21	115.60	122.97	80	70	58
LPG	3.15	4.02	1.26	1.57	1.67	1.47	1.64	2.21	1.08	0.99	0.90

Source: TPDC (2005)

Emissions inventory for the commercial and residential sector are summarized in Table 3-8.

Table 3-8: Emissions summary for the commercial and residential sector

Year	Methane (CH_4) Gg	Carbon Dioxide (CO_2) Gg	Nitrous Oxide (N_2O) Gg
1995	0.020435	495.58	0.004072
1996	0.026838	650.66	0.005349
1997	0.026708	642.42	0.005336
1998	0.016188	390.88	0.003230
1999	0.010075	390.88	0.002007
2000	0.015000	368.45	0.003000
2001	0.015267	368.94	0.003046
2002	0.016263	393.84	0.003242
2003	0.016209	390.48	0.003237
2004	0.009245	223.40	0.001844
2005	0.007664	185.34	0.001528

3.2.6 Fugitive Emissions from Fuels

In the period covering this inventory, the main fugitive emissions were a result of coal mining and post mining activities. The emissions covered under the IPCC guidelines are methane.

Tanzania has an operational bituminous coal deposit, which is located in Mbeya and Ruvuma regions. The coal mine known as Kiwira Coal and Power Limited became operational in year 2005 after acquiring the government owned Kiwira Coal Mines. The company operates two underground bituminous coal mines with an estimated potential of 304 million metric tonnes. The average depth of the two mines is 105 meters. Currently, there are no abandoned mines and both mines are not gassy. Coal production at Kiwira Coal deposit is detailed in Table 3-9. The coal production data was collected from the plant and it was updated using data from the International Energy Agency. Methane emissions were calculated from the production data by using the IPCC Tier 1 approach. Fugitive CH_4 emissions resulting from coal mining and handling are shown in Table 3-9.

Table 3-9: Methane emissions from Kiwira coal production

Year	Coal Production in M. Tons	Methane (CH_4) emission (Gg)
1995	44,000.01	0.604340
1996	57,000.02	0.782895
1997	28,000.01	0.384580
1998	45,000.01	0.618075
1999	75,000.02	1.030125
2000	79,000.03	1.085065
2001	78,000.03	1.071330
2002	79,000.03	1.085065
2003	55,000.02	0.755425
2004	19,000.01	0.260965
2005	59,806.00	0.821435

Source: Inventory (2006)

3.2.7 Agriculture sector

Emissions of GHGs from this sector include all anthropogenic emissions from agricultural activities, except for emissions from fuel combustion and sewage. These emissions are considered under Energy 1A and Waste 6B sub-categories, respectively. Emissions from enteric fermentation, manure management, and agricultural soils emissions from the field burning of agricultural residues are included. In addition, emissions from savannah burning are estimated in this sector.

Rice cultivation is a source of CH_4 in Tanzania. This category contributes to about 2% of the total CH_4 emissions in the agricultural sector. Although annual emissions have been fluctuating unevenly between the years 1995 and 2002, ranging from an annual increase of 33 percent in 1998 to an annual decrease of 38 and 60 percent in year 1999 and 2001 respectively, there was an overall increase of 20 percent between 1995 and 2000, due to an overall increase in the area under rice cultivation. The factors that affect the rice acreage in any year vary, although the rain or drought condition is the primary controlling variable.

Livestock emission estimates represent emissions from all domesticated animals i.e. cattle, goats, sheep and swine/pigs. Cattle, due to their large population, large size, and particular digestive characteristics, account for the majority of CH_4 emissions from livestock. A less detailed approach (i.e. IPCC Tier 1) methodology was therefore applied to estimate emissions for all cattle, sheep, swine, and goats, without exception. The annual livestock population data for the livestock types were obtained for all years as indicated in Table 3-10.

Table 3-10: Livestock population data

	Dairy Cattle	**Non-dairy Cattle**	**Sheep**	**Goats**	**Swine**	**Poultry**
1995	212,334	15,340,896	3,493,022	9,202,404	435,000	28,370,849
1996	339,734	15,494,305	3,552,000	10,362,000	422,000	28,587,372
1997	280,281	15,647,714	3,551,000	10,694,000	435,000	28,803,895
1998	314,254	15,801,123	3,550,000	11,034,000	449,000	29,047,484
1999	349,932	15,943,827	3,488,534	11,643,093	465,000	29,283,372
2000	363,504	16,100,373	3,548,000	11,888,955	480,000	29,507,195
2001	385,807	16,308,620	3,547,000	12,101,990	496,000	29,731,019
2002	409,528	16,586,741	3,546,000	12,324,220	513,000	29,954,842

Source: Ministry of Agriculture/National Bureau of Statistics (2006)

Emissions of anthropogenic CH_4 and N_2O from manure stored or treated in systems that promote anaerobic conditions (e.g., as a liquid/slurry in lagoons, ponds, tanks, or pits), the decomposition of materials in the manure tends to produce CH_4. In cases where manure is handled as a solid (e.g. in stacks or dry lots) or deposited on pasture, range, or paddock lands, it tends to decompose aerobically and produce little or no CH_4. Other factors related to how the manure is handled which can result in production of CH_4 include ambient temperature, moisture, and manure storage or residence time.

Tables 3-11 and 3-12 present emission estimates for the Agriculture sector. Between 1995 and 2002, CH_4 emissions from agricultural activities increased by over 50% percent while N_2O emissions increased by 35 percent. Most of the increase in these emissions is attributed to the field burning of agricultural residues accounting for over 80 percent of the total CH_4 emissions.

Table 3-11: Emissions of greenhouse gas from Agriculture (Gg)

	Enteric fermentation	Manure management		Agricultural soils	Prescribed burning of savannahs		Field burning of agricultural residues		Rice cultivation
	CH_4	CH_4	N_2O	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4
1995	573	20	1	59	89	1	3,474	104	54
1996	589	20	1	60	89	1	3,374	100	55
1997	593	21	1	60	89	1	3,589	106	58
1998	601	21	1	60	89	1	3,738	107	86
1999	610	21	1	60	89	1	4,022	118	63
2000	617	21	1	61	89	1	4,166	122	54
2001	625	22	1	61	89	1	3,954	121	43
2002	636	22	1	62	89	1	5,617	159	85

Table 3-12: Emissions of greenhouse gas from Agriculture (Gg CO_2 eq)

	Enteric fermentation in Domestic Livestock	Manure management		Agricultural soils	Prescribed burning of savannahs		Field burning of agricultural residues		Rice cultivation
	CH_4	CH_4	N_2O	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4
1995	12,036	417	247	18,257	1,869	341	72,961	32,167	1,137
1996	12,367	428	247	18,448	1,869	341	70,854	31,055	1,164
1997	12,460	432	250	18,492	1,869	341	75,370	32,759	1,218
1998	12,625	438	254	18,606	1,869	341	78,504	33,245	1,814
1999	12,802	445	258	18,705	1,869	341	84,471	36,522	1,314
2000	12,954	451	262	18,815	1,869	341	87,495	37,829	1,137
2001	13,133	457	267	18,951	1,869	341	83,036	37,551	897
2002	13,362	466	273	19,127	1,869	341	117,959	49,402	1,782

In addition to CH4 and N2O, field burning of agricultural residues was also a source of indirect greenhouse gases carbon monoxide (CO) and nitrogen oxides (NOx). Table 3-13 presents emissions of indirect greenhouse gases carbon monoxide (CO) and nitrogen oxides (NOx) from agriculture sector, from prescribed burning of savannahs and field burning of agricultural residues source categories.

3.2.8 Waste management

Methane emissions from solid waste disposal were calculated using the IPCC First Order Decay (FOD) model. The FOD model is capable of implementing Tier 1 emission estimation approach. The model was adopted due the absence of detailed date characteristic for Tanzania. Since waste disposal on land is not a key category for Tanzania, the FOD model is expected to deliver an acceptable estimate.

Solid waste activity data was calculated based on the per capita waste generation of 0.68kg/person/day which is typical for Tanzania. Further, industrial waste generation was calculated from the historical GDP and population data for Tanzania. The primary GDP data was obtained from the UN Statistics[3,4]. Since no comprehensive data on waste characteristics was available, all the emission factors and parameters on waste fractions and composition was adopted from the default values relevant for Tanzania. Table 3-13 summarizes methane emissions from municipal solid waste disposal.

Table 3-13: Methane emissions from municipal solid waste disposal

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CH4 EMISSIONS, Gg	928.1	936.4	974	1037	1109	1166	1246	1308	1377	1437	1513

Methane and nitrous oxide emissions from domestic wastewater were calculated using the default emission factors provided in the IPCC guidelines. The total amount of organically degradable material in the wastewater (TOW) based on the Tanzania population for each year under consideration and the default BOD value. The degree of utilization of treatment or discharge of the wastewater i.e. septic tank, latrine, or other method was adopted from the regional values that were developed by IPCC guidelines from Kenya.

Similarly, industrial wastewater activity data (TOW) based on the industrial production data for Tanzania as provided by the National Bureau of Statistics. However, the wastewater generation per tonne of product and the concentration of degradable organic compounds in the wastewater was adopted from the IPCC guidelines.

The inventory of emissions of nitrous oxide and methane resulting from wastewater treatment and disposal is summarized in Table 3-14. Methane emissions from domestic wastewater accounts 98% of total methane emissions from both domestic and industrial combined.

[3] http://unstats.un.org/unsd/snaama/selectionbasicFast.asp
[4] http://esa.un.org/unpp/

Table 3-14: N_2O and CH_4 emissions from wastewater treatment and disposal, Gg

Year	Nitrous Oxide (N_2O) – Domestic	Methane		
		Industry Wastewater	Domestic Wastewater	Total
1995	4.60	0.09	9.08	9.16
1996	4.61	0.11	9.10	9.21
1997	4.70	0.13	9.27	9.40
1998	4.79	0.14	9.44	9.59
1999	4.87	0.16	9.61	9.77
2000	5.21	0.20	10.28	10.48
2001	5.04	0.20	9.95	10.16
2002	5.32	0.23	10.49	10.72
2003	5.22	0.25	10.29	10.54
2004	5.30	0.27	10.46	10.73
2005	5.92	0.29	11.68	11.97

4. CLIMATE CHANGE SCENARIOS

4.1 Introduction

Useful information about possible future climate and their impacts can be obtained using various scenario construction methods. These include climate model based approaches, temporal and spatial analogues and incremental scenarios for sensitivity studies. The most commonly used method for developing climate scenarios for quantitative impact assessments is to use results from GCM experiments. GCMs are the most advanced tools currently available for simulating the response of the global climate system to changing atmospheric compositions (Hulme *et al.,* 2000). Projections of changes in the climate system are made using hierarchy of climate models ranging from simple climate models, to models of intermediate complexity, to comprehensive climate models, and Earth System Models (ESMs). These models simulate changes based on a set of scenarios of anthropogenic forcing (IPCC, 2013). A new set of scenarios, the Representative Concentration Pathways (RCPs), was used for the new climate model simulation carried out under the Framework of the Coupled Model Inter-comparison Project Phase 5 (CMIP5) of the World Climate Research Programme Regional downscaling methods provide climate information at the smaller scales needed for many climate impact studies. There is high confidence that downscaling adds value both in Region with highly variable topography and for various small-scale phenomena.

Moreover, incremental scenarios describe techniques where particular climatic (or related) elements are changed incrementally by plausible though arbitrary amounts (e.g. +1, +2, +3, +4°C change in temperature). In addition, incremental scenarios provide information on an ordered range of climate changes and can readily be applied in a consistent and replicable way in different studies and regions, allowing for direct inter-comparison of results. Analogue scenarios are constructed by identifying recorded climate regimes, which may resemble the future climate in a given region. Both spatial and temporal analogues have been used in constructing climate scenarios. Temporal analogues make use of climatic information from the past as an analogue for possible future climate. In any case of the cases, the first step towards development of climate change scenarios is to determine the baseline climate from historical data and assess the trends. In this Report, the analysis of the baseline climate is presented in Section 4.2, the trend analysis in Section 4.3, and the projected climate change is presented in Section 4.4.

In the assessments of the baseline climatology, observed trends and the projected climate change seven climatological zones were considered (Figure 4-1). These climatological zones are: Lake Victoria Basin (which includes the regions of Mara, Kagera, Mwanza and Shinyanga); North Eastern Highlands Zone (including the Kilimanjaro, Arusha and Manyara regions); North Coast Zone (which includes Dar es Salaam, Tanga, Zanzibar, Pemba and part of Morogoro region); Southern Coast Zone (which includes Mtwara and Lindi regions); South Western Highland Zone (which includes Mbeya, Iringa, Ruvuma, part of Rukwa, part of Morogoro); Central Zone (which includes Dodoma, Singida, part of Tabora regions); and Western Zone (which includes Kigoma, part of Rukwa and part of Tabora regions).

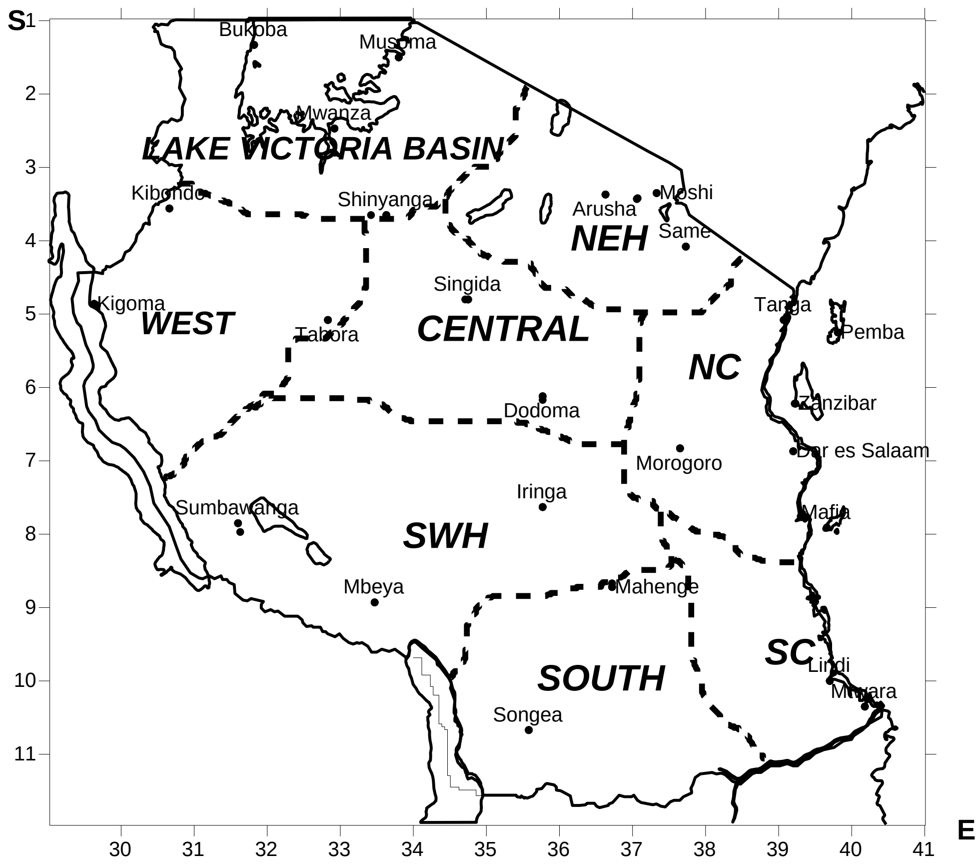


Figure 4-1: Climatological zones and the meteorological stations used in the analysis

4.2 Baseline climatological statistics

The Lake Victoria Basin Zone

Lake Victoria Basin is characterized by bimodal rainfall regime with peaks in November and April. Mean annual rainfall is 1128 mm. Mean monthly maximum temperature is observed in September and is 29^{0}C and mean monthly minimum temperature is observed in July and is 15.4^{0}C.

The North Eastern Highlands (NEH)

Rainfall regime is bimodal with peaks in December and April. Mean annual rainfall is 786 mm. Mean monthly maximum temperature is observed in February and is 33.1^{0}C. Mean monthly minimum temperature is observed in May and is 8.3^{0}C.

The Northern Coastal zone (NC)

Rainfall regime is bimodal with peaks in November and April. Mean annual rainfall is 1268 mm. Mean monthly maximum temperature is observed in February and is 32.4^{0}C. Mean monthly minimum temperature is observed in July and is 18.2^{0}C.

The Southern Coastal Zone (SC)

Rainfall regime is unimodal starting from November to May. Mean annual rainfall is 1180 mm. Mean monthly maximum temperature is observed in November and is 32.4^{0}C. Mean monthly minimum temperature is observed in July and is 18.2^{0}C.

The Central Zone

Rainfall regime is unimodal, starting from late November to late April. Mean annual rainfall is 630 mm. Mean monthly maximum temperature is observed in November and is 31.1^{0}C. Mean monthly minimum temperature is observed in July and is 13.7^{0}C.

The South Western Highlands (SWH)

Rainfall regime is unimodal starting from November to the end of April. Mean annual rainfall is 776 mm. Mean monthly maximum temperature is observed in October and is 26.6^{0}C. Mean monthly minimum temperature is observed in July and is 5.3^{0}C.

The Western Zone

Rainfall regime is unimodal starting from October to April. Mean annual rainfall is 1105mm. Mean monthly maximum temperature is observed in September and is 30.3^{0}C. Mean monthly minimum temperature is observed in July and is 16.5^{0}C.

Table 4-1: Current mean rainfall and temperature for the seven climatological zones in Tanzania

S/N	Climatological Zone	Mean Annual Rainfall (mm)	Mean Monthly Max. temperature (°C)	Mean Monthly Min. temperature (°C)
1.	Lake Victoria Basin (Mara, Kagera, Mwanza and Shinyanga)	1128	29.0	15.4
2.	North Eastern Highlands (Kilimanjaro, Arusha and Manyara)	786	33.1	8.3
3.	Northern Coast (Dar es salaam, Zanzibar, Tanga, Pemba and part of Morogoro)	1268	32.4	18.2
4.	Southern Coast (Mtwara and Lindi)	1180	32.4	18.2
6.	Central (Dodoma Singida and part of Tabora)	630	31.1	13.7
5.	South Western Highlands (Mbeya, Iringa, Ruvuma, part of Rukwa, and part of Morogoro)	776	26.6	5.3
7.	Western (Kigoma, part of Rukwa and part of Tabora)	1105	30.3	16.5

4.3 Observed Climate trends

In this section, a trend analysis of the current climate (1961 – 2013) is conducted for Synoptic meteorological stations in order to depict and describe the observed trends in both rainfall and temperature. The results from the analysis of temperature and rainfall trends are presented in sub-sections 4.3.1 and 4.3.2 respectively.

4.3.1 Observed temperature trends

Trend analysis results for the period 1961 – 2013 shows a statistically significant increasing trend in mean annual maximum and minimum temperature throughout the country. The trend in mean annual minimum temperature is much faster as compared to the trend in mean annual maximum temperature. Results for Zanzibar, Arusha and Musoma are presented for illustration in Figures 4-2 to 4-7.

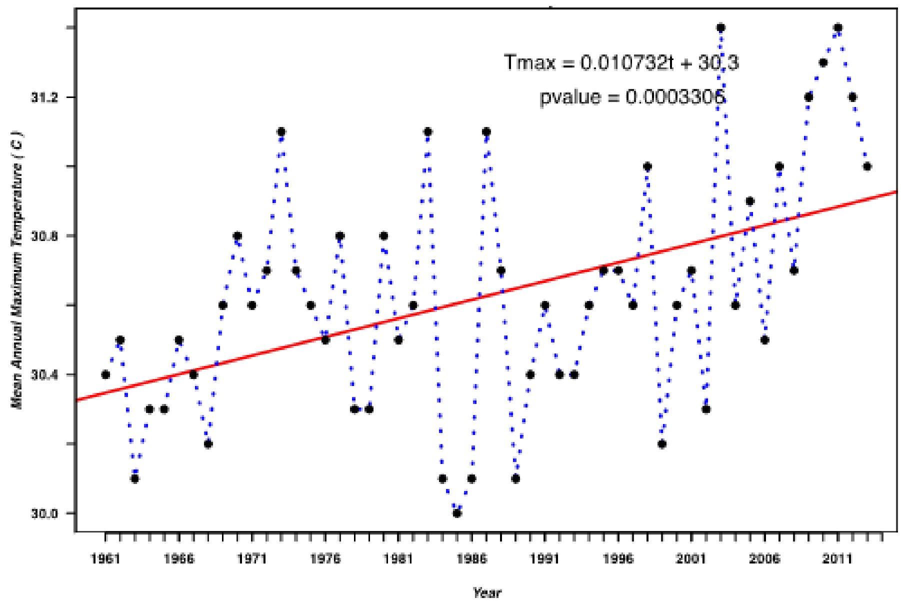


Figure 4-2: Trend in mean annual maximum temperature in Zanzibar

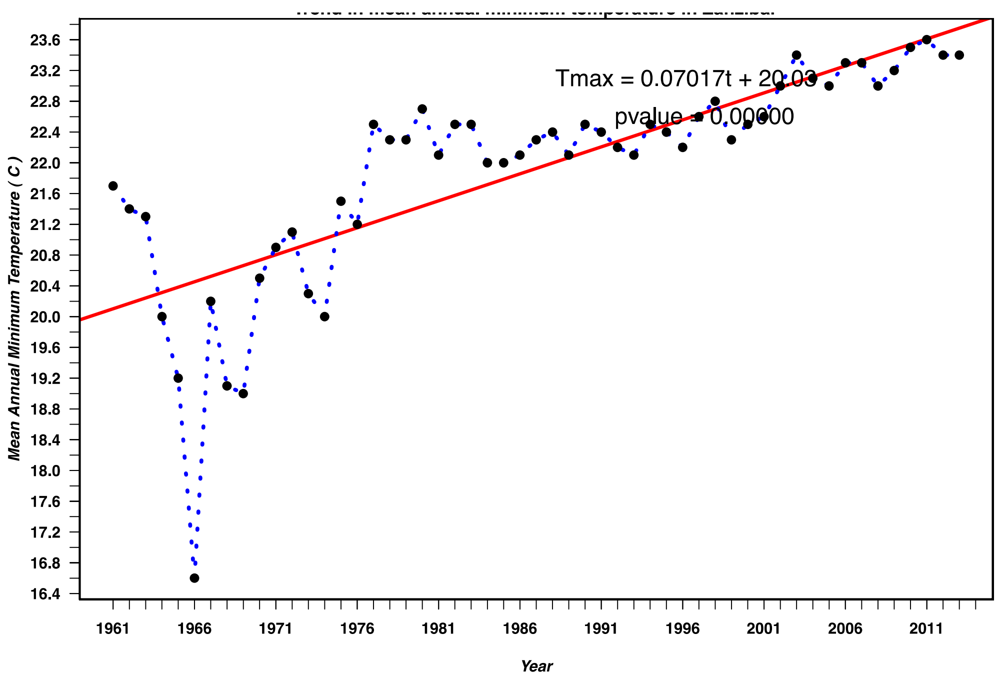


Figure 4-3: Trend in mean annual minimum temperature in Zanzibar

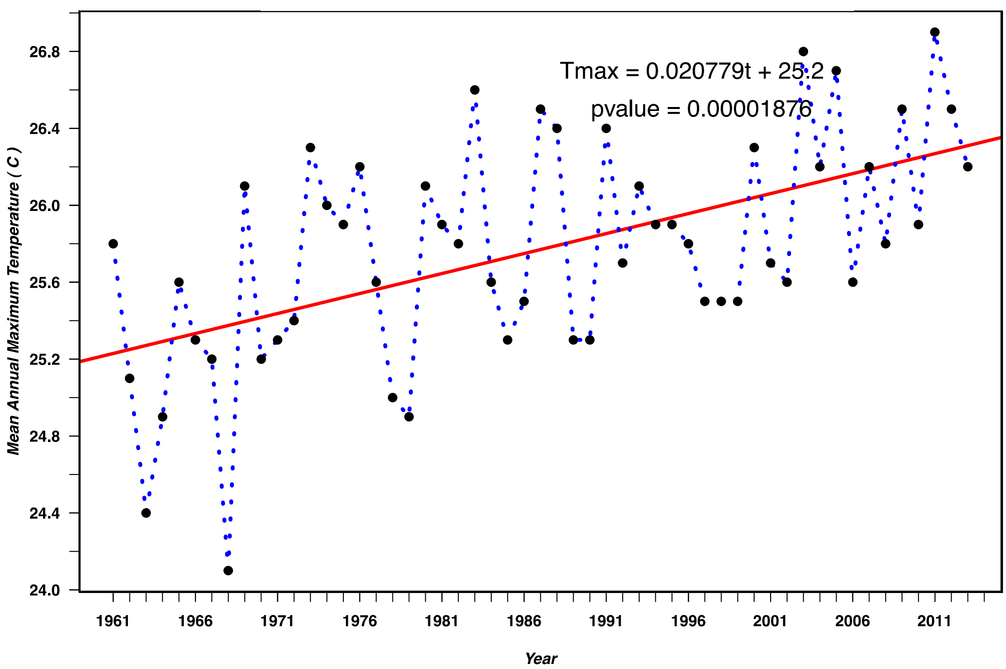


Figure 4-4: Trend in mean annual maximum temperature in Arusha

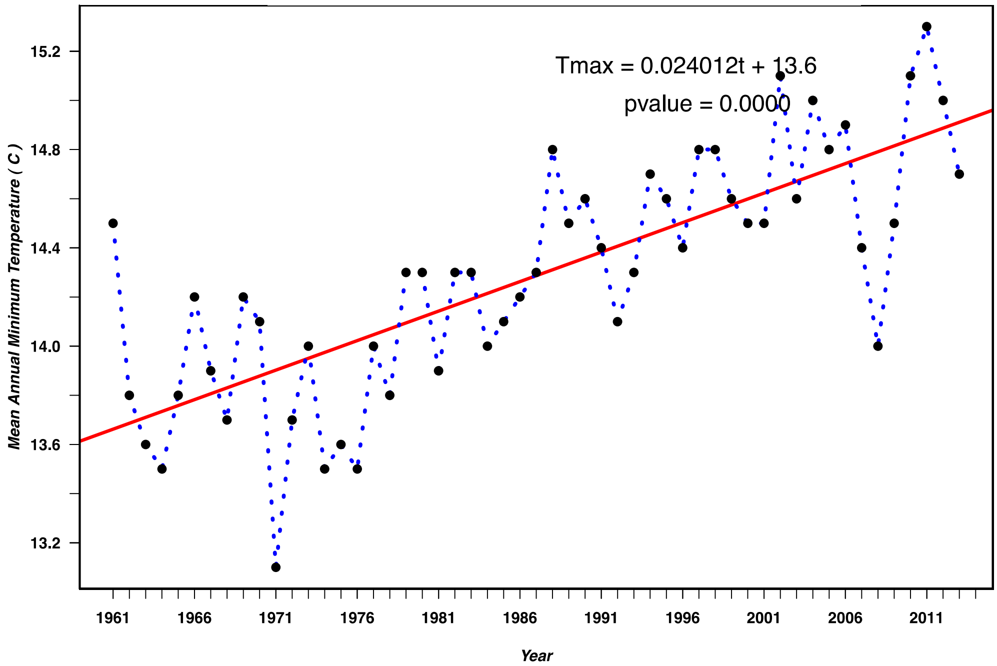


Figure 4-5: Trend in mean annual minimum temperature in Arusha

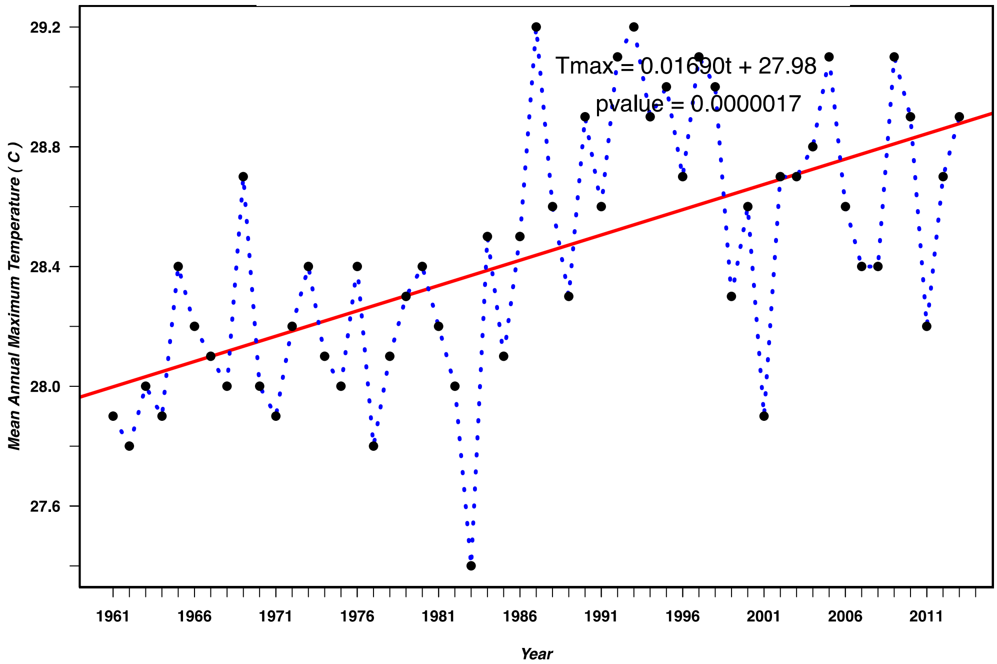


Figure 4-6: Trend in mean annual maximum temperature in Musoma

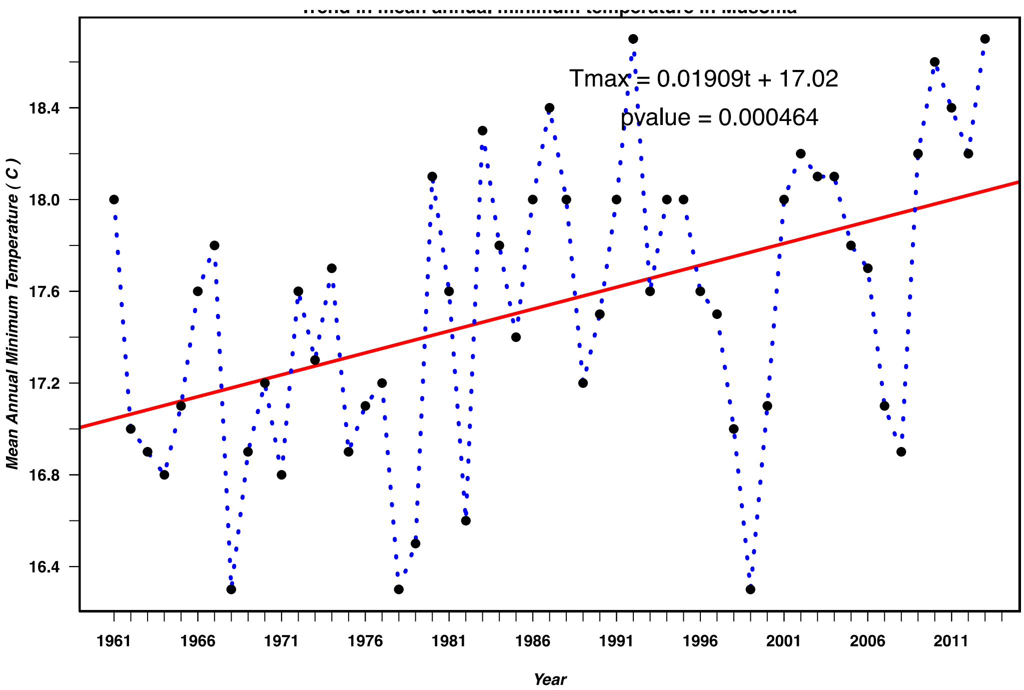


Figure 4-7: Trend in mean annual minimum temperature in Musoma

4.3.2 Observed Rainfall Trends

Results from trend analysis on mean annual rainfall time-series indicates a slightly declining trend in most of the stations. However, the observed trends are not statistically significant. The trend analysis results for Zanzibar, Arusha and Musoma are presented in Figures 4-8 to 4-10 for illustrations. Mean rainfall and temperatures in the seven climatological zones are shown in Table 4-1.

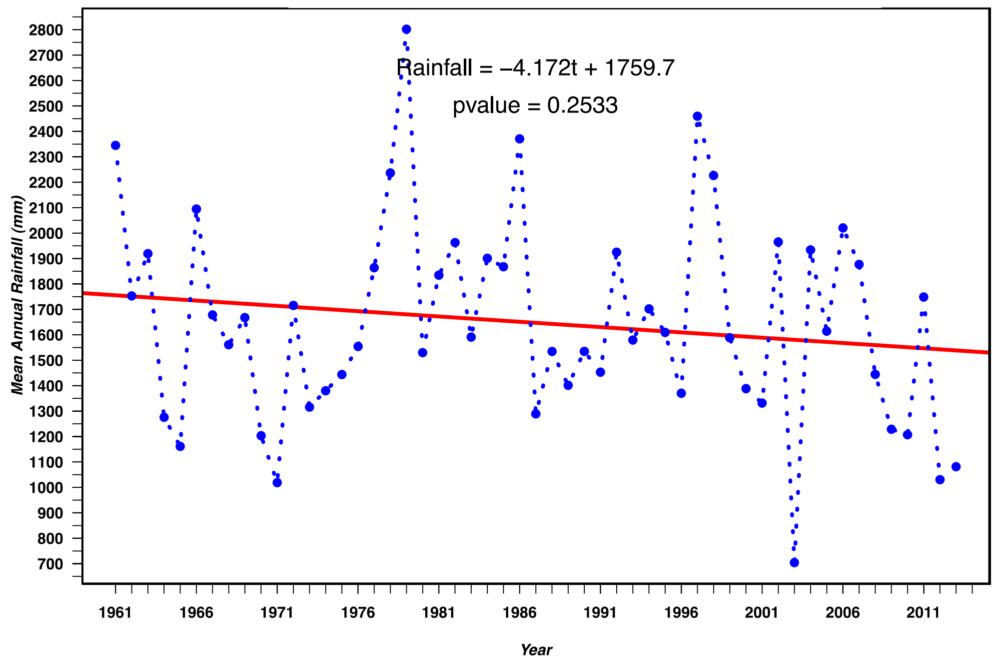


Figure 4-8: Trend in mean annual rainfall in Zanzibar

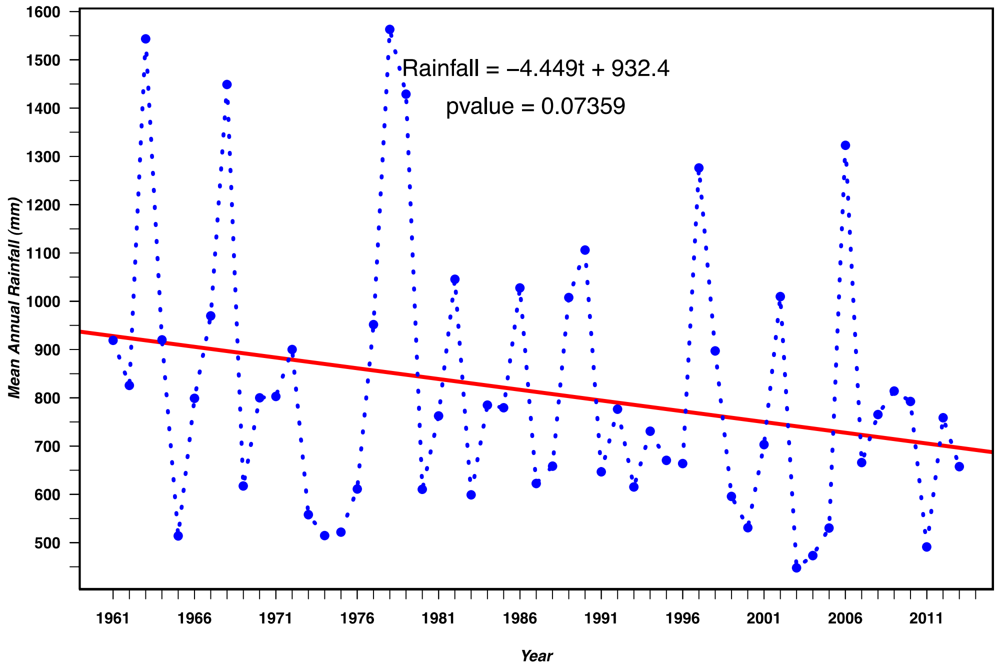


Figure 4-9: Trend in mean annual rainfall in Arusha

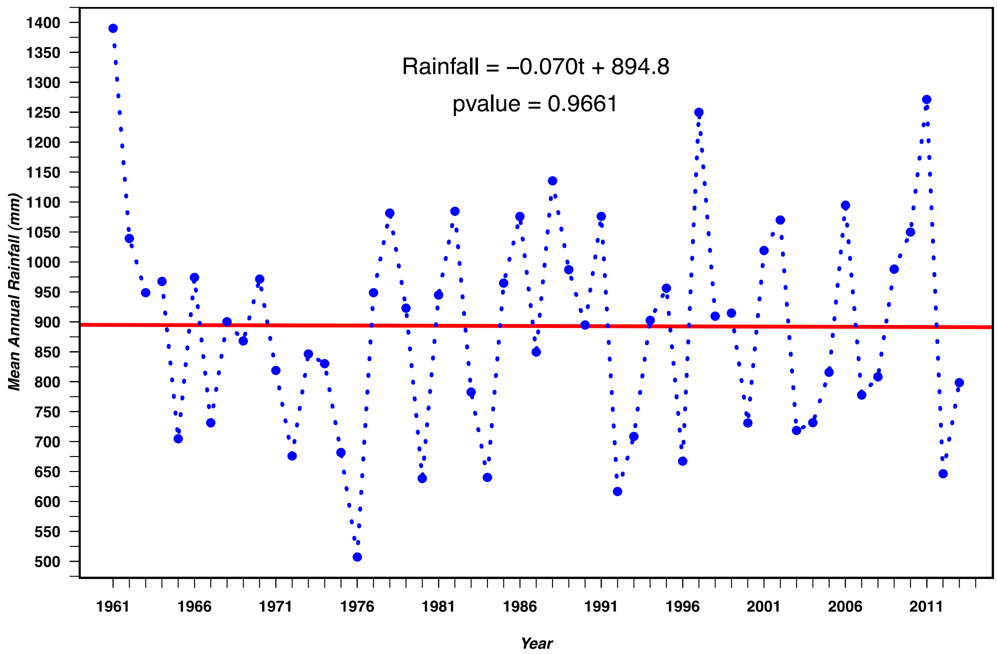


Figure 4-10: Trend in mean annual rainfall in Musoma

4.4 Climate Change projections based on GCMs

Climate change scenarios for Tanzania were developed by using high-resolution Global Circulation Models. MAGICC/SCENGEN models were used to downscale the climate change projections for the country using an ensemble approach. The selection of the models to be used in climate change projection was based on the ability of the respective models in simulating the current climate. Models that better simulated the current climate were selected for projection of the future climate of the country.

4.4.1 Projected change in temperature

The projected change in mean seasonal and mean annual temperature for the year 2050 and 2100 is presented in Figures 4-11 to Figure 4-18, and Table 4-2. Generally the entire country is projected to experience an increase in temperature, though the temperature increase varies from zone to zone (Table 4-2). More warming is projected over the Western side of the country, whereby a warming of up to 3.4^{0}C is projected by 2100.

A warming of less than 1.76ºC for 2050 and 3.28ºC for 2100 is projected over parts of the northern coast regions and north-eastern highlands, and a warming in excess of 1.77ºC for 2050 and 3.3ºC for 2100 is projected over the Lake Victoria zone, and central Tanzania zone while a warming in excess of 1.39ºC for 2050 and 3.18ºC for 2100 is projected for the southern coast including Mtwara and Lindi regions. Table 4-2 shows the annual and seasonal projections.

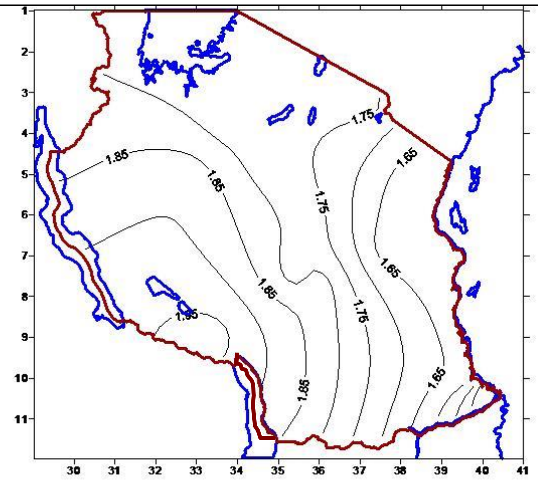


Figure 4-11: Projected change in mean annual temperature by 2050

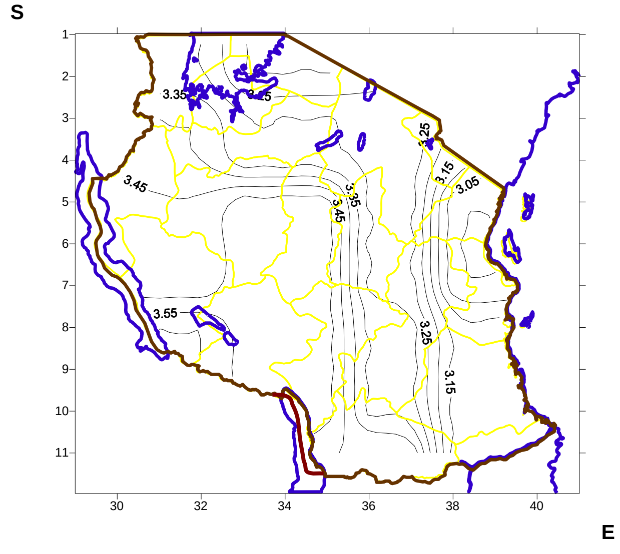


Figure 4-12: Projected change in mean annual temperature by 2100

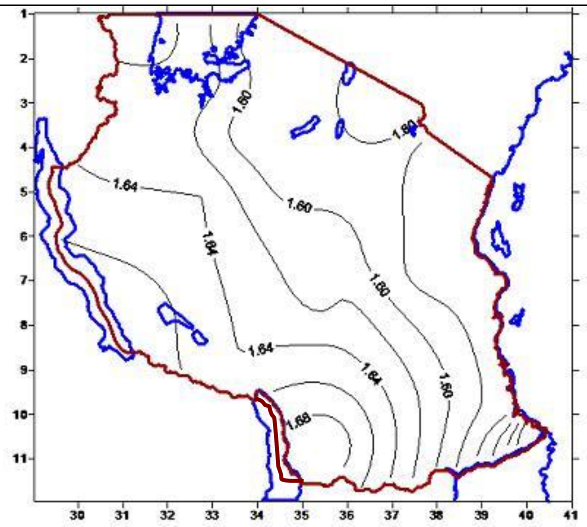


Figure 4-13: Projected change in mean temperature during the warmest season (Dec-Feb) by 2050

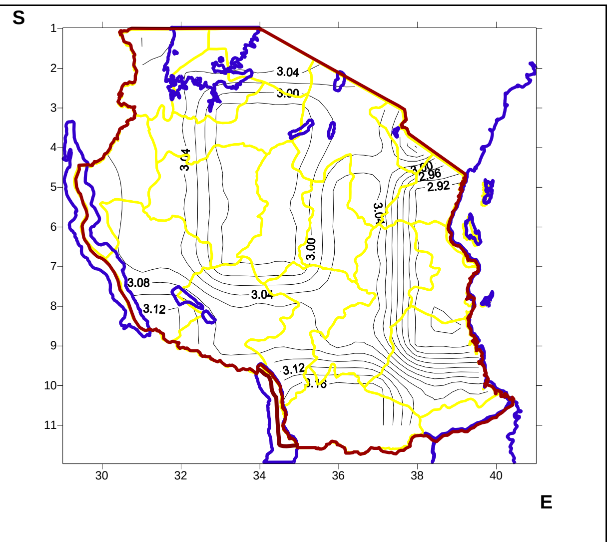


Figure 4-14: Projected change in mean temperature during the warmest months (Dec-Feb.) by 2100.

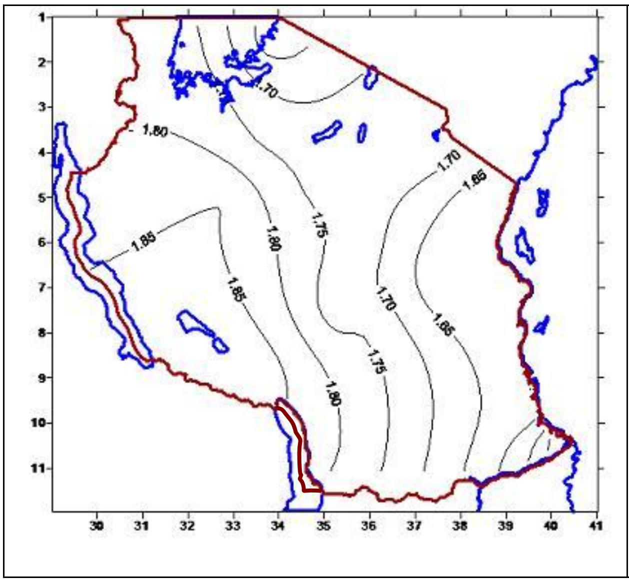


Figure 4-15: Projected change in mean March-May (MAM) temperature by 2050

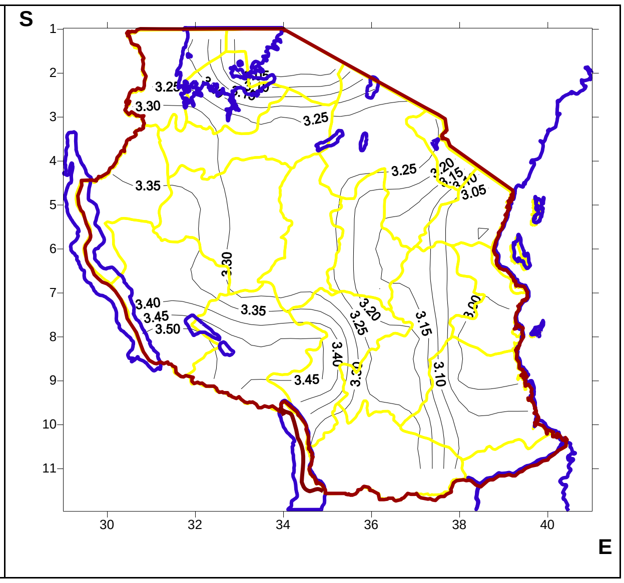


Figure 4-16: Projected change in mean March-May (MAM) temperature by 2100

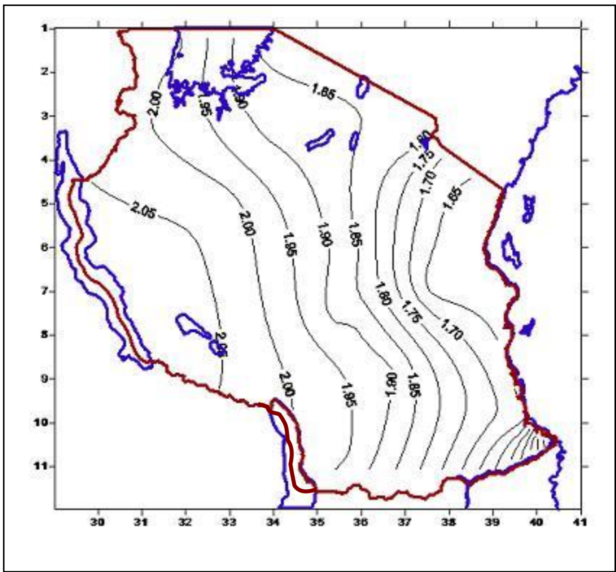


Figure 4-17: Projected change in mean June – August (JJA) temperature by 2050

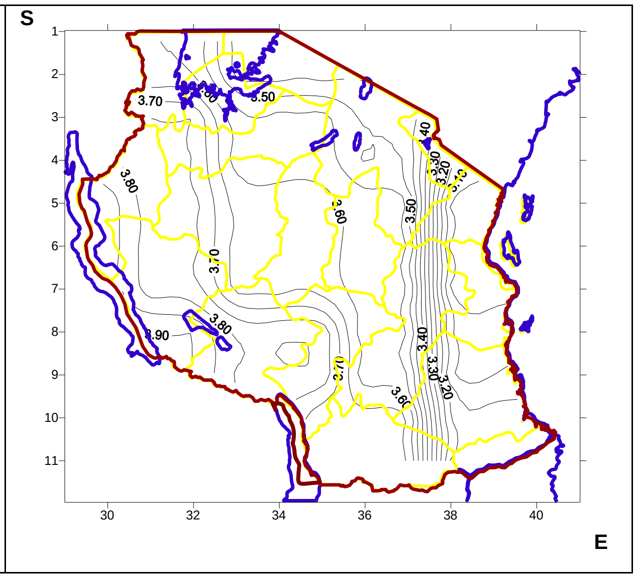


Figure 4-18: Projected change in mean June – August (JJA) temperature by 2100

Table 4-2: Projected change in temperature in 2050 and 2100

Climatological Zone		Projected change in temperature (ºC) by 2050	Projected change in temperature (ºC) by 2100
Lake Victoria Basin (Mara, Kagera, Mwanza and Shinyanga)	Annual mean change	1.77	3.3-3.4
	DJF season	1.6	3.0
	MAM season	1.62-1.74	3-3.2
	JJA season	1.8-2	3.4-3.6
North Eastern Highlands (Kilimanjaro, Arusha and Manyara)	Annual mean change	1.69-1.76	3.28
	DJF season	1.61	3.01
	MAM season	1.75	3.28
	JJA season	1.84	3.49
North Coast (Dar es salaam, Zanzibar, Tanga, Pemba and part of Morogoro)	Annual mean change	1.61	3.01
	DJF season	1.57	2.91
	MAM season	1.61	3.01
	JJA season	1.62	3.03
Southern Coast (Mtwara and Lindi)	Annual mean change	1.39-1.62	3.13
	DJF season	1.45-1.56	3.8
	MAM season	1.45-1.60	3.08
	JJA season	1.32-1.66	3.19
Central (Dodoma Singida and part of Tabora)	Annual mean change	1.77-1.78	3.31-3.53
	DJF season	1.59-1.61	2.97-2.98
	MAM season	1.73-1.74	3.26-3.28
	JJA season	1.87-1.91	3.57-3.63
South Western Highlands (Mbeya, Iringa, Ruvuma, part of Rukwa, and part of Morogoro)	Annual mean change	1.85-1.93	3.53
	DJF season	1.63-1.67	2.98-3.07
	MAM season	1.75-1.89	3.28-3.45
	JJA season	1.9-2.09	3.63-3.79
Western (Kigoma, Part of Rukwa and part of Tabora)	Annual mean change	1.82-1.84	3.40
	DJF season	1.62-1.65	3.05
	MAM season	1.80	3.33
	JJA season	2.01-2.06	3.75

4.4.2 Projected change in rainfall

The projected percentage change in mean annual and mean seasonal rainfall for the year 2050 and 2100 are presented in Figures 4-19 to 4-26 and Table 4-3.

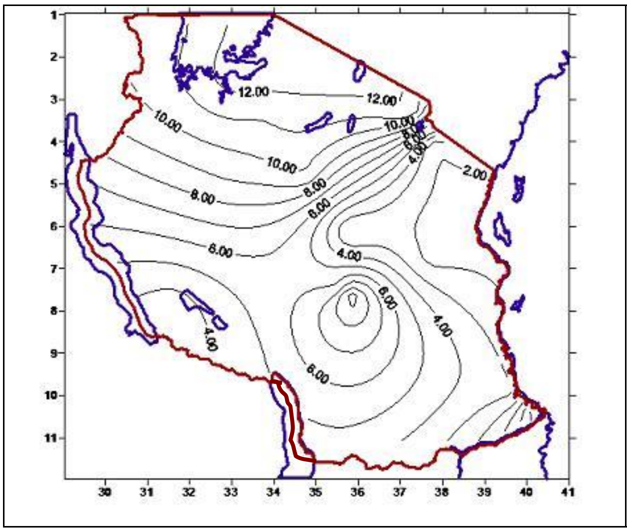


Figure 4-19: Projected percentage change in mean annual rainfall by 2050

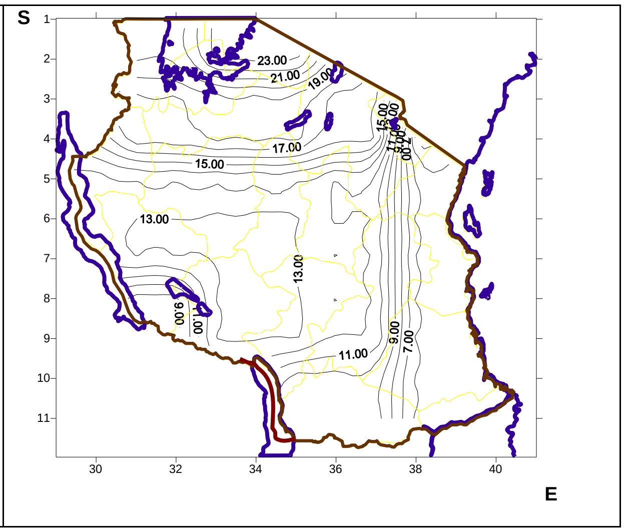


Figure 4-20: Projected percentage change in mean annual rainfall by 2100

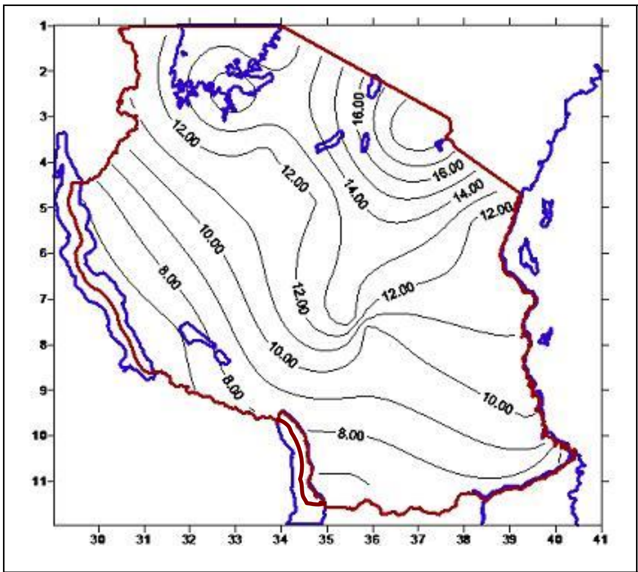


Figure 4-21: Projected percentage change in mean December-February (DJF) rainfall by 2050.

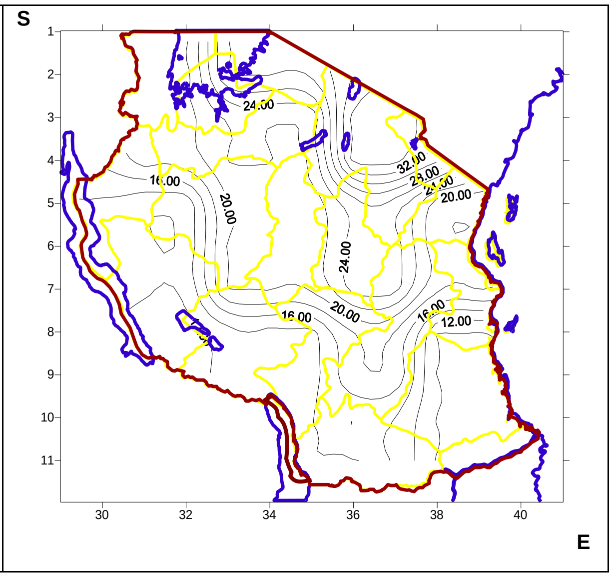
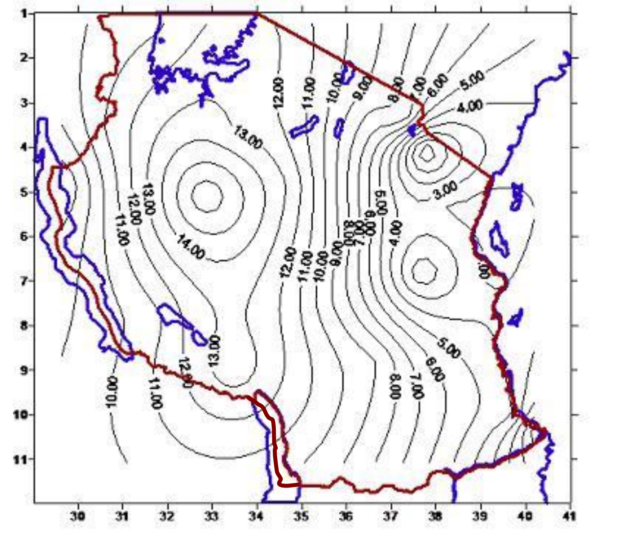


Figure 4-22: Projected percentage change in mean December-February (DJF) rainfall by 2100.



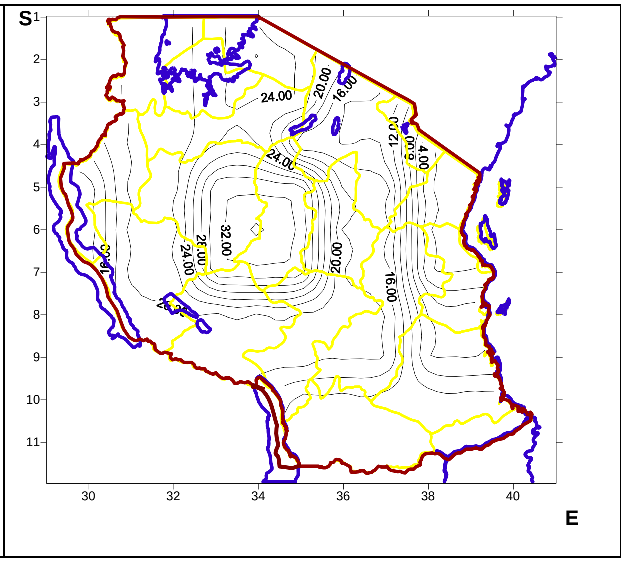
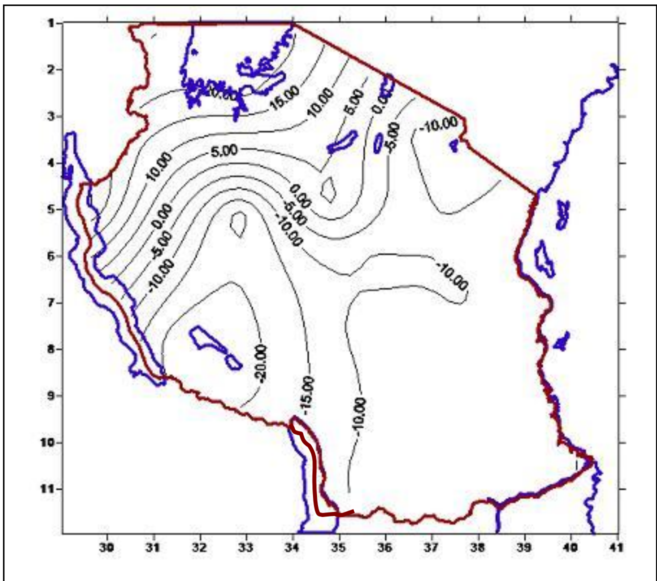


Figure 4-23: Projected percentage change in mean March-May (MAM) rainfall by 2050.

Figure 4-24: Projected percentage change in mean March-May (MAM) rainfall by 2100



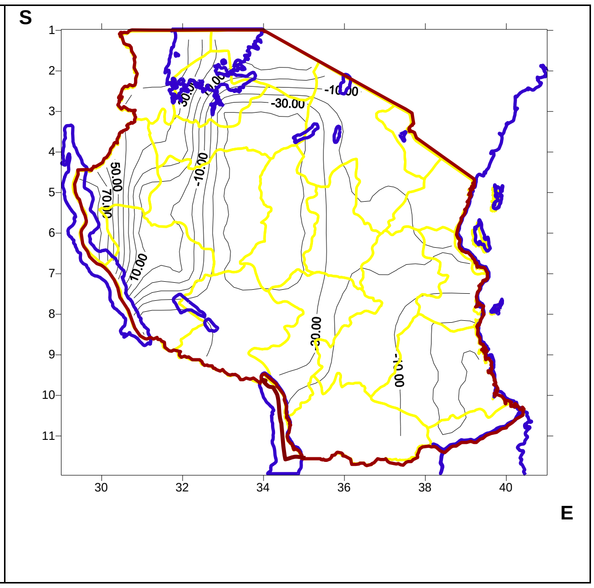


Figure 4-25: Projected percentage change in mean June-August rainfall by 2050 (medium emission scenario).

Figure 4-26: Projected percentage change in mean June-August rainfall by 2100 (medium emission scenario).

Rainfall projections indicate that some parts of the country may experience an increase in mean annual rainfall of up to 18 to 28% by 2100, particularly over the Lake Victoria Basin and North-Eastern Highland. An increase of about 10-12% in 2050 and 18.2-28.3% in 2100 is projected over Lake Victoria Zone. The North Eastern Highlands areas are projected to experience an increase of up 13.4% in 2050, and 16.3% in 2100. The South Western Highlands and Western Zones of the country are projected to experience an increase in annual rainfall by up to 9.9% in 2050 and by up to 17.7% in 2100. The North Coast Zone is projected to have an increase of about 1.8% in 2050 and 5.8% in 2100 while the Central Zone is projected to have an increase of up to 9.9% in 2050 and up to 18.4% in 2100. The Southern Coast Zone is projected to have a decrease of up to 7% in 2050 and an increase of annual rainfall of about 9.5% in 2100.

In December–February (DJF) season, percentage increase of above 12% in 2050 and 19% in 2100 is projected over Lake Victoria Zone and some parts of Central region and an enhanced increase over the North Eastern Highlands, while the rest of the country has an increase of between 6.7% - 12% in 2050 and 19% - 34% in 2100. In March-May (MAM) season, Lake Zone areas, Western Zone, South Western Highlands and the Central region are projected to have a percentage increase of rainfall of between 7% - 13% in 2050 and 2% - 31% in 2100, an enhanced increase is visible over some parts of the Western and Central regions. The remaining part of the country is projected to have percentage increase of between 4% and 7% in 2050 and 2% - 13% in 2100. The Northern Coastal strip and the Zanzibar and Pemba Island are projected to have an increase of less than 3% in 2050 and less than 2% in 2100.

In June-August (JJA) season, percentage decrease of rainfall by up to 24% and 45% is projected by 2050 and by 2100 respectively, particularly over the coastal areas, parts of north eastern highlands, north coast zone, central zone, south western highlands and southern coast zone.

Table 4-3: Projected rainfall change in percentage

Climatological Zone		Percentage change in rainfall by 2050	Percentage change in rainfall by 2100
Lake Victoria Basin (Mara, Kagera, Mwanza and Shinyanga)	Annual change	10.7-12.5	18.2-23.3
	DJF season	11.9-15.2	19.1-28.3
	MAM season	10.9-12.8	20.4-23.9
	JJA season	6.5-23.9	-40.8-44.6
North Eastern Highlands (Kilimanjaro, Arusha and Manyara)	Annual change	-13.4—11.1	16.3
	DJF season	16.4-18.7	34.9
	MAM season	-1.2-7.4	13.8
	JJA season	-13.4—11.1	-16.4
North Coast (Dar es salaam, Zanzibar, Tanga, Pemba and part of Morogoro)	Annual mean change	1.8	5.8
	DJF season	11.7	18.5
	MAM season	4.2	2.1
	JJA season	-7.2	-19.4
Southern Coast (Mtwara and Lindi)	Annual change	-7.0-3.1	5.8-9.5
	DJF season	6.7-9.9	9.8-14.0
	MAM season	-0.5-4.2	13.1-13.2
	JJA season	-10.3—7.2	-16—0.4
Central (Dodoma Singida and part of Tabora)	Annual change	1.8-9.9	13.1-18.4
	DJF season	11.9-13.3	20.4-22.2
	MAM season	9.3-12.8	23.6-31.5
	JJA season	-11.1-6.5	-40.8
South Western Highlands (Mbeya, Iringa, Ruvuma, part of Rukwa, and part of Morogoro)	Annual change	4.7-9.9	5.8-13.1
	DJF season	6.6-9.6	10.6-24.9
	MAM season	8.9-10.4	2.1-19.4
	JJA season	-24.1—7.7	-45—19.4
Western (Kigoma, part of Rukwa and part of Tabora)	Annual change	7.1-9.5	17.7
	DJF season	6.9-10.3	19.1
	MAM season	6.9-11.2	20.4
	JJA season	15.8-25.6	29.6

5. VULNERABILITY AND ADAPTATION

The vulnerability assessment was done basing on the projected climate change and its impact to the various sectors. The sectors covered during the assessment of vulnerability and adaptation to climate change impacts were Health; Agriculture; Water; Forestry; Tourism; Wildlife; and Marine and Coastal resources.

The main activities undertaken are as follows:

- Analysis of the sector vulnerabilities and impacts within the context of the climate change scenarios;
- Review of the policy process and development context for the selected sectors;
- Compilation of sectoral data and information for Water, Health, Agriculture, Rangelands and Livestock, Forestry and Tourism, Coastal resources;
- Development of reliable indicators for the application of baseline scenarios;
- Identification of the vulnerability and adaptation options for the sectors;
- Organizing national consultative workshop for collecting comments and additional inputs from the relevant stakeholders on sectoral draft of the V&A reports; and
- Review of the Draft sectoral V&A reports by national experts. A national technical and consultative workshop for discussing draft V&A sectoral reports was held in November 2007, more than 50 technical experts attended the workshop.

5.1 Water Sector

5.1.1 Status of water resources in Tanzania

Based on projected population, the number of people is expected to increase rapidly from 44.9 million in the years 2012 to about 65.2 million by the year 2025. The annual average of available water per capita was 2,000 cubic metres in 2012, which will be reduced by 30% to about 1,400 cubic metres per capita per year in 2025. This indicates that the country will face a water stress situation, considering that below 1,700 cubic metres per capita per year signifies water scarcity.

Water access TDHS 2004/05 data show that rural households spend, on average, 30 minutes to collect water for domestic uses while the average collection time in urban areas is 5.9 minutes. Overall, about 66 per cent of households are not served by a water supply utility. However, The Poverty and Human Development Report (PHDR) 2011 indicates that the proportion of the rural population with access to improved sources of water within 30 minutes (approximately 400m) increased from 28% in 2007 to about 47% in 2013.

Table 5-1: Number of people with access to water supply service in rural areas between 2003 and 2013

No.	Authorities	Total population receiving water supply	Percentage of population receiving water supply
1	Arusha	756,188	50
2	Dar es Salaam	2,645,494	50
3	Dodoma	404,283	37
4	Iringa	557,732	65
5	Njombe	458,407	68
6	Kagera	953,674	53
7	Kigoma	578,490	75
8	Kilimanjaro	951,152	82
9	Lindi	254,520	38
10	Manyara	395,553	60
11	Mara	267,324	35
12	Mbeya	1,163,187	62
13	Morogoro	664,817	35
14	Mtwara	221,347	32
15	Geita	244,238	41
16	Mwanza	885,582	50
17	Pwani	658,803	66
18	Katavi	105,921	31
19	Rukwa	325,910	41
20	Ruvuma	477,031	45
21	Simiyu	400,791	45

Source: URT (2013)

The percentage of population supplied with clean water in urban areas increased from 78 in 2005 to 86 percent in 2013 having the total number of people supplied with clean water increased to 2.8 million (Table 5-1 and 5-2).

Table 5-2: Urban water supply during the year 2013

No.	Authorities	Total population receiving water supply	Percentage of population receiving water supply
1	Tabora	420,510	26.94
2	Iringa	780,552	55.93
3	Singida	369,188	37.17
4	Morogoro	635,923	51.73
5	Lindi	260,762	37.66
6	Coast	527,029	58.42
7	Dodoma	1,070,339	78.53
8	Kilimanjaro	762,596	58.96
9	Mbeya	952,018	56.04
10	Mtwara	669,818	65.68
11	Tanga	807,786	61.35
12	Mara	509,851	44.35
13	Shinyanga	1,323,403	49.30
14	Kagera	1,139,074	59.28
15	Ruvuma	534,419	56.67
16	Arusha	788,203	56.28
17	Manyara	467,837	45.76
18	Rukwa	621,694	59.03
19	Mwanza	1,178,373	47.01
20	Kigoma	734,478	63.37
	TOTAL	14,553,853	53.47

Source: UWSSAs Annual reports (2013)

5.1.1.1 Pangani Water Basin

Pangani Water Basin is situated in the North-eastern part of the country and drains into the Indian Ocean. Pangani basin occupies an area of 43,650 km^2, with about 5% of the area in Kenya, and the remainder distributed across the Arusha, Manyara, Kilimanjaro and Tanga regions of Tanzania. The Pangani river system drains the southern and eastern sides of Mt Kilimanjaro (5,985 m) as well as Mt. Meru (4,566 m), then passes through the arid Masai Steppe in the west, draining the Pare and Usambara Mountains before reaching the coastal town of Pangani, marking its estuary with the Indian Ocean. The basin hosts an estimated 3.7 million people. 80% of people rely directly or indirectly on irrigated agriculture for their livelihoods

The climate in the catchment varies considerably. Pangani River Basin comprises several sub-catchments of widely different characteristics. The upper parts in the slopes of Mt. Kilimanjaro and Mt. Meru receive 1200-2000mm rainfall per year, and the rest of the catchment areas receive only about 500mm per year.

The Pangani water basin is faced with water demand stress from different sectors, such as irrigation, hydroelectric power, domestic, industry, tourism, etc. Such stress has created a drastic impact to the downstream users especially the national hydropower plants of Nyumba ya Mungu constructed early, 1969 with installed capacity of 8 MW, Hale (21MW, 1964), Old Pangani (17.5 MW, 1934) and New Pangani falls constructed in 1995 with installed capacity of 68 MW. All plants operate under their designed electrical production capacity. Similarly, the climate variability has had a significant effect on the basin and the situation is expected to worsen. The prolonged drought, floods, coupled with human water demanding activities will further worsen the already precarious situation. The glacial ice caps of Mt Kilimanjaro, towering over the basin, are expected to disappear completely by 2020 and increased temperatures are expected to result in a 6-9% annual reduction in surface flows (URT, 2003). Climate change and abstractions over the past decades have reduced in-stream flows from several hundred to less than 40 cubic metres.

The source of water for the Pangani River and also source of water recharging groundwater is the snowmelt from Mt Kilimanjaro. In the recent years the ice cap of Mount Kilimanjaro has been declining. The reduction, and eventual loss, of the snow-cap due to climate change which changes the timing of runoff and recharge to water resources of Pangani basin. The predicted increase in December-February precipitation may lead to an increase in river flows during that period. Effects of climate change are already apparent in Tanzania, with the glaciers on Mt. Kilimanjaro receding rapidly. The volume of the ice cap at the Kibo Summit of Kilimanjaro has been reduced by 82 percent since 1912, when the ice cap was thoroughly surveyed.

5.1.1.2 Rufiji Water Basin

Climate change scenario for Rufiji Water Basin shows spatially averaged values of rainfall and temperature increments for January to December. There would be an increase in runoff at Mtera and Kidatu during the period November to March which corresponds well with an increase in rainfall during the same period. The overall increase would be about 5% and 11% at Mtera and Kidatu respectivelly.

Table 5-3: Climate change projections for Rufiji Basin

	Climate		**Mtera Runoff (mm/ day)**		**Kidatu Runoff (mm/ day)**	
	Rainfall (mm)	**Temperature (^{0}C)**	**Observed**	**Simulated**	**Observed**	**Simulated**
January	1.03	2.4	0.142	0.329	0.169	0.376
February	1.1	3.2	0.275	0.357	0.287	0.359
March	1.3	3.4	0.342	0.424	0.294	0.407
April	0.8	3.9	0.297	0.191	0.309	0.226
May	0.7	4.6	0.230	0.043	0.217	0.059
June	1.0	4.6	0.10	0.009	0.123	0.026
July	1.0	3.8	0.043	0.007	0.069	0.0245
August	1.0	3.3	0.020	0.007	0.045	0.0245
September	1.0	3.4	0.011	0.007	0.029	0.0245
October	1.0	4.1	0.006	0.007	0.020	0.0245
November	1.2	4.4	0.005	0.029	0.016	0.051
December	1.4	3.0	0.073	0.196	0.060	0.214
			1.552	**1.605**	**1.639**	**1.815**

(Source: Mwandosya *et al,* 1998)

5.1.1.3 Wami-Ruvu Water Basin

Wami - Ruvu Basin covers the catchment areas of Wami and Ruvu river systems and the coastal rivers of Dar es Salaam that drain to the Indian Ocean. The Basin serves all regional centres of Dar es Salaam, Morogoro, Kibaha and Dodoma. The Socio – economic importance of the Basin includes water supply for the City Of Dar es Salaam, regional centres and the villages, irrigation, livestock, National Parks and Coastal Zone Ecosystem. The Basin is faced with various water resources related challenges including water scarcity, water pollution due to increased industrial activities, saline water intrusion, uncontrolled and unregulated abstractions.

Climate change is negatively affecting the hydrological cycle and the water resources in the basin. The Ruvu River is projected to decrease the annual runoff by 6-10 percent by the year 2010 (URT, 2003). Reduced runoff of Ruvu River would adversely affect socio-economic activities in the country. Under the climate change scenario, there is a decrease in runoff for the whole period January to December.

Table 5-4: Climate change projections for Wami-Ruvu Basin

	Temperature (^{0}C)	Rainfall ratio	Runoff values	
			Observed (mm/ day)	Simulated (mm/ day)
January	2.1	1.14	0.26	0.491
February	4.2	0.71	0.21	0.328
March	2.8	1.37	0.30	0.428
April	2.7	0.72	0.75	0.727
May	4.3	0.49	0.10	0.401
June	4.3	0.45	0.35	0.120
July	3.4	0.62	0.18	0.086
August	2.7	1.38	0.12	0.100
September	3.0	0.5	0.10	0.112
October	3.3	0.44	0.10	0.102
November	1.8	1.23	0.12	0.180
December	2.9	1.31	0.19	0.347
Annual			**3.77**	**3.420**

(Source: Mwandosya *et al,* 1998)

5.1.2 Adaptation of Water Sector

The predicted changes of surface water resources due to anticipated perturbed future climates in the three basins (Rufiji, Pangani and Wami/Ruvu) would affect water resources because of reduced river discharges/levels. Predicted lengthening of zero flow duration due to a decrease of rainfall would aggravate the problem of water scarcity as it corresponds to an increase of the period in which water is unavailable for allocation. Water supply infrastructures including distribution network will be under risks of being damaged by sweeping (flash) floods following rainfall increase predicted in some basins. Moreover, floods may impair the quality of water and consequently raise its treatment costs or reducing its availability due to its low quality.

Possible adaptation measures that can be applied to cope with reduced water supply and demand management may involve construction of a reservoir at Ruvu River. Rain water harvesting for domestic use and development of groundwater wells are alternatives which can supplement water supplies from rivers. Table 5-5 shows the suggested possible adaptation measures in the water sector.

Table 5-5: Possible adaptation measures in the water sector

Water Use	Proposed adaptation Measures
Domestic use	• Efficient use of water • Reuse and recycle used water • Leaks repair • Rainwater harvesting
Agricultural use	• Efficient use of water by using modern irrigation technology • Use of lined canal • Reuse of wastewater effluents • Protect water sources
Industrial use	• Recycling of water • Efficient use of water Reuse of water

Demand management involves reductions in water demand by investing in new water-saving technologies and changed use practices. A variety of adaptation measures can be taken to reduce water use as shown in the Table 5-4 above on a list of suggested adaptation measures.

a) Adaptation at Basin Level

For water resources, three priorities for adaptation to impacts of climate change are essential (Bergkamp *et al*., 2003). These include:-

i) Reduction of vulnerability of societies to climatic changes including shifts, trends and increasing variability of hydro meteorological variables [*Understanding and managing risks and uncertainties*]
ii) Protection and restoration of ecosystems that provide critical land and water resources and services [*Addressing measures to prevent land and water degradation and restore already degraded ecosystems*]
iii) Closing gaps between water supply and demand [*Ensure adequate and sustainable water supplies to all sectors*]

b) Adaptation for Water Supply

Adaptation against droughts

Impacts of perturbed future climates in the basins on water supply would require adequate measures to adapt to anticipated drier conditions. Among the adaptation measures include:-

i) Construction of a cascade of storage reservoirs to store water that is received during the rainy season for stream flow augmentation and water supplies during the dry season. This will ensure adequate availability of water for socio-economic usage

ii) Planned exploitation (investigation, quantification, planned abstraction locations) of deep groundwater resources for areas where prolonged dry river durations are anticipated. A few well-fields are recommended for long term planning against household's boreholes for short to medium term planning

iii) Artificial groundwater recharge to improve shallow groundwater reliability

iv) Exploration of appropriate and affordable water recycling technologies

Adaptation against floods

Impacts of perturbed future climates in the basins on water supply would require adequate measures to adapt to anticipated wetter conditions that might be related to increasing flooding and inundations. Among the adaptation measures include

i) Construction of cascade of reservoir to retain flood water for the protection of downstream communities, lands and properties. Their design should ensure periodic sediment renewal to downstream floodplains to support agriculture. Engineering revision of designs of components of water supply system (reservoirs, rising mains and distribution pipelines, etc) to provide adequate protection against sweeping (flash) floods damages and declining lake levels.

ii) Engineering revisions and technological innovations for water treatment facilities to account for occurrence of muddy flood waters following frequent floods in the future that may require extra treatment to currently practiced.

c) Adaptation for Water Resources

The predicted impacts of perturbed future climates in the basins on surface water resources would need to be adapted through application of appropriate measures to reduce them. Several such measures are necessary and can be used for lakes and rivers includes;

Lakes

Catchment protection and restoration measures such as measures for conservation of native vegetation (e.g. forest reserve declarations) particularly at water sources and other areas within the catchments of the lakes to reduce impacts of siltation of lakes from large volumes of soils eroded from uplands by heavy rainfall. This will reduce likelihood of spreading of the silted shallow lakes to large areas causing inundation problems to farms and settlements. For areas which will receive reduced rainfall amounts, spreading of shallow lakes might lead to high evaporation rates from shallow water and consequently drying of the lakes.

Rivers

The predicted mixed impacts of future dry and wet climates in areas within the basin related to increasing stream flows in some rivers and reduction in others would need adequate measures to adapt to. Among the measures include:-

i) River catchment protection measures to safeguard river sources and river reaches against destruction of sources, river banks and floodplains as well as against siltation that might reduce river cross sections leading to flooding problems from medium stream flows;

ii) Construction of storage reservoirs in the upper catchments of rivers to store adequate amounts of water during the rainy season that will be released during the dry season to maintain river flows; and

iii) Resettlement of communities and farms from river banks and floodplains to safeguard communities against flooding and rivers against destruction from human activities.

d) Adaptation at National Level

Policies for Adaptation

The policies directly governing water resources management in Tanzania are the National Water Policy (2002), National Environmental Policy (1997) and National Irrigation Policy (2010). There exist several provisions in these policies that can contribute to implementation of several adaptations measures, which might reduce the negative impacts of climate variability and change on Tanzanian water resources. Provisions in these 3 main policies relevant for adaptation to impacts of climate variability and change on water resources are described below.

National Water Policy, 2002

The Policy contains relevant provisions to address issues to adaptation to impacts of climate change and variability on the water sector include:-

i) Water resources allocation and use for various purposes
ii) Water conservation and quality management for in-country and transboundary resources
iii) Water resources assessment, planning and development
iv) Data and information
v) Research and technological development
vi) Human capacity development and institutional framework for management of water resources
vii) Stakeholders' participation in the management, use and conservation of water resources and water supply infrastructure.

Therefore, these provisions of NAWAPO provide direction for an integrated water resources management in the context of climate variability and change. However, implementation of such provisions of the policy requires relevant and adequate legislations and regulations detailing how each measure is appropriately implemented and ways of mitigating negative consequences of implementation. Dynamic water allocations, for example, should be practiced in the context of climate change to provide periodic (e.g. 5-year) water rights that take into account seasonality of water availability (step abstraction rights in different months) and category of a year (wet, normal, dry)

National Irrigation Policy, 2010

The Policy provides a direct towards achieving irrigation development in Tanzania at both small and large scales. The policy specific provisions in the policy that can facilitate adaptation to impacts of climate variability and change on the water sector include:-

i) Investment for irrigation development;
ii) Management of irrigation schemes;
iii) Irrigation research and development and promotion of appropriate technologies; and
iv) Cross-sectoral cooperation.

These policy provisions are essential in relation to management of water abstractions and utilization and improving efficiency of irrigation schemes to reduce annual rate of expansion of agricultural areas, water loss through evaporation and infiltration and therefore conserve the catchments. These are essential future requirements in controlling the ever increasing water demand for various uses including irrigation. However, implementation in the context of climate variability and change requires appropriate and adequate legislations and regulations.

National Environmental Policy, 1997

Several provisions of the Policy are of relevance for adapting to impacts of climate variability and change in the water sector in an integrated manner. They include

i) Enhancement of the role of women in natural resources (including water) management;
ii) Provision of clean and safe water supplies, protection of water sources and prevention of environmental pollution;
iii) Control of indiscriminate urban development particularly in vulnerable sites (coastal beaches, flood-prone, hills, etc);
iv) Development of environmentally sound waste management systems; and
v) Rational exploitation of forest resources that is accompanied by reforestation and afforestation programmes.

These provisions are important in adaptation of water resources to impacts of climate variability and change while considering principles of IWRM (e.g. on the role of women in water resources management). The provision for protection of water sources, for example, is among recommended adaptation measures for catchment conservation, protection and restoration of ecosystem. Implementation of these policy provisions, however, is dependent on appropriate legislation and regulations that are currently adequate. Some of these legislation and regulations are in place, requiring some improvements/amendments or shall be drafted for use.

Several other policies, whose objectives affect water resources management, include:- National Community Development Policy, 1996; Sustainable Industrial Development Policy, 1996; National Land Policy, 1995; National Energy Policy, 2003; National Agriculture Policy, 2013; National Forest Policy, 1998; National Human Settlement Policy, 2000; and National Livestock Policy, 2006.

Legislation for Adaptation

The legislations governing water resources management in Tanzania are the Water Resources Management Act (2009), Water Supply and Sanitation Act (2009) and Environmental Management Act (2004). There exist several provisions in the Acts that provide for the implementation of several adaptations measures, which might reduce the negative impacts of climate variability and change on Tanzanian water resources.

These provisions include provision for groundwater exploitation, surface water resources conservation and protection and water pollution protection.

Water Resources Management Act, 2009

The Act include several provisions that could be used effectively to address climate issues related to adaptation of the water sector to impacts of climate variability and change. These provisions can adequately address issues related to implementation of adaptation options to reduce impacts of climate variability and change. However, issues related to generation of information that is important in relation to adaptation are weakly provided for in the Act.

Water Supply and Sanitation Act, 2009

The Act includes provisions only relevant to the implementation of measures for adaptation of the water supply to impacts of climate variability and change (Table 6.2). These include provision for centralized water supply systems (Parts IV and VII), which normally use a few well established water abstraction points that minimize environmental degradation.

5.2 Health Sector

Climate change is and will most likely affect human health in Tanzania. Already climate hazards have brought several serious diseases affecting various communities. For instance, due to climate change and global warming, there have been increased incidences of malaria in many parts of the country. The impact of climate change on human health in Tanzania may happen directly, as with the effects of heat extremes or flood injury, or indirectly, for example, through the changes in the transmission of vector, food or water-borne diseases. There are also wider indirect impacts from climate change on health, which are linked to other sectors, such as access to safe and clean water supply, food security and malnutrition (Yanda *et al*., 2006; URT, 2009b; URT/UKAID, 2011; Kangalawe, 2012).

Studies on the costs related climate change impacts on human health has estimated the potential increase in malaria and some other climate sensitive diseases indicating a potentially higher treatment costs to address the increased disease burden in Tanzania. It is estimated that about $20 to 100 million/year by 2030, rising to $25 to 160 million/year by 2050, will be needed for treating such climate sensitive diseases. In addition, the potential effects of more extreme high temperatures, e.g. exceeding 32°C, will have significant effect particularly in warmer locations like Dar es Salaam, leading to additional health impacts and reduced labour productivity (URT/UKAID, 2011).

For purposes of this Report, within the health sector, malaria and cholera have been considered in respect of vulnerability and adaptation to climate change being among the top ten leading cases and deaths in Tanzania Mainland.

5.2.1 Relationship between precipitation, temperature changes against disease spread

The tropical African climate is favourable to most major vector-borne diseases, including malaria, *schistosomiasis, onchocerciasis, trypanosomiasis, filariasis, leishmaniasis*, plague, Rift Valley fever, yellow fever and tick-borne haemorrhagic fevers (URT, 2012). Other health consequences are including of uncommon epidemic diseases such as unspecific diarrhoea, pneumonias and dengue fever which recently emerged and threatened Dar es Salaam community. Furthermore, the increase of dermatological diseases, unexplainable miscarriage, cancers, behaviour changes, neurological and cardiological disorders are shown to be associated with climate change. The continent has a high diversity of vector-species complexes that have the potential to redistribute themselves to new climate driven habitats leading to new disease patterns. These organisms have different sensitivities to temperature and precipitation. Vectors, pathogens and hosts reproduce within certain optimal climate conditions and changes in these conditions can modify greatly properties of disease transmission.

Global warming will increase the frequency of extreme weather events such as heavy floods and droughts, and increased health hazards through infectious diseases

(IPCC, 2007). It may also lead to food crisis resulting from depletion of water resources. Many developing countries particularly in Africa are regarded as being vulnerable to these adverse impacts of climate change.

In Tanzania, the impact of climate change on human health is increasingly becoming evident in almost all sectors of the economy, including health. Among the evidences in the health sector is the increase of incidences of malaria in highlands, for example, in places like Mbeya and Kagera regions. The similarity in the long-term temperature trends and malaria trends confirm the association between climate change and prevalence of malaria (URT, 2009b). In general, the observed positive temperature trends and the projected rise in ambient temperature due to climate change will probably increase leading to increased malaria vector habitats and longevity. These adverse climatic change impacts require sufficient and effective mitigation interventions.

Temperature favours growth of *Vibrio cholerae* and expression of violence. As predicted by climatologists, increased mean temperatures in the future years would therefore be expected to expand the range and increase the prevalence of *V Cholerae* both geographically and temporally, if effective public health measures are not implemented. In places with increased drought there will of course be lack of safe and adequate water supply. Also, in places subjected to increased floods there will be increased poor hygiene which will influence increased incidences of cholera outbreaks. In light of climatic and environmental drivers in cholera disease dynamics, it is necessary to take into account the capabilities of health systems, improved hygiene and sanitation systems. Therefore, if sufficient and effective sanitation strategies and measures can be implemented to protect the public health, then the disease will be preventable.

5.2.2 Malaria

Malaria is one of killer diseases that is highly climate-sensitive and is expected to worsen as the climate changes (WHO, 2013). Already some observational data show that malaria is moving to higher elevations where the disease is currently limited by temperature (Yanda et al., 2006; URT, 2009; URT/UKAID, 2011; Kangalawe, 2012).

Figure 5-1 presents an example of malaria diagnosed cases from a health facility in one of the highland areas of Tanzania while Figure 5-2 presents these cases expressed as percentage of total district population.

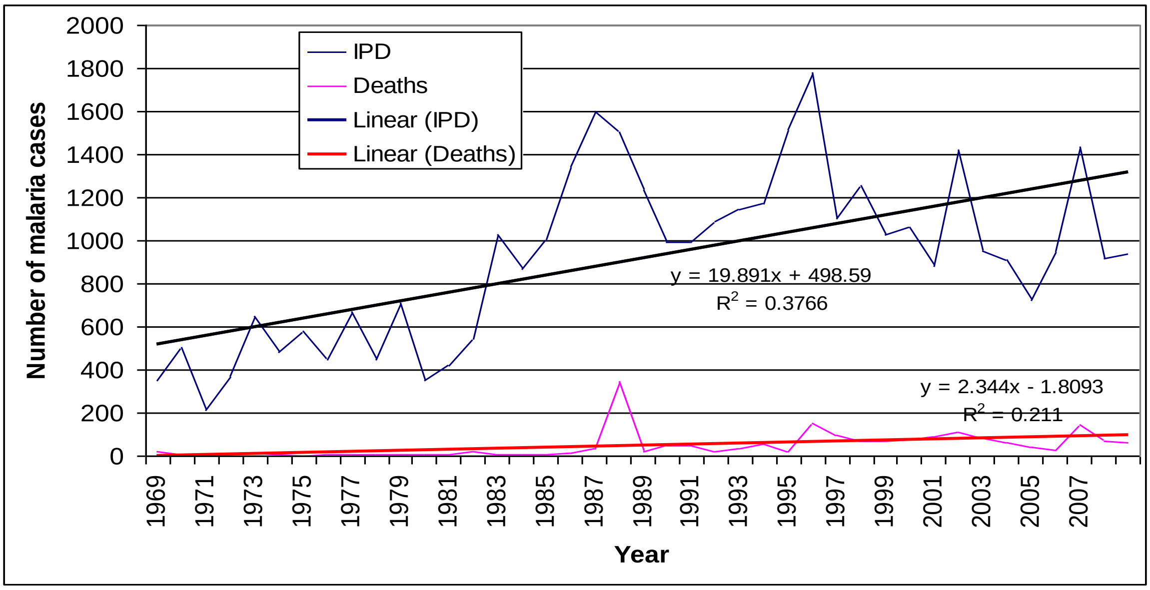


Figure 5-1: Long-term malaria trends from Igogwe Hospital records in Rungwe District (Source: Kangalawe, 2012)

This long-term data of malaria cases found at a highland hospital attests that malaria has steadily increased since the 1960s, especially for the inpatients (Figure 5-1). Even when taking into account the factor of increasing population, the same increasing pattern of malaria inpatients can be discerned (Figure 5-2). The number of deaths from malaria also shows a generally increasing trend (URT, 2009; Kangalawe, 2012). The peaks in number of malaria cases have coincided with climatic events such as El Niño, and warmer temperatures associated with droughts, for example, between 2002 and 2005. This confirms the association between increasing temperatures and increased risk of malaria. The latter therefore indicates that with global warming, and thus with climate change, such highland areas may face increased risk of highland malaria. Similar trends were reported for highlands in the Lake Victoria basin (Wandiga et al., 2006; Yanda et al., 2006).

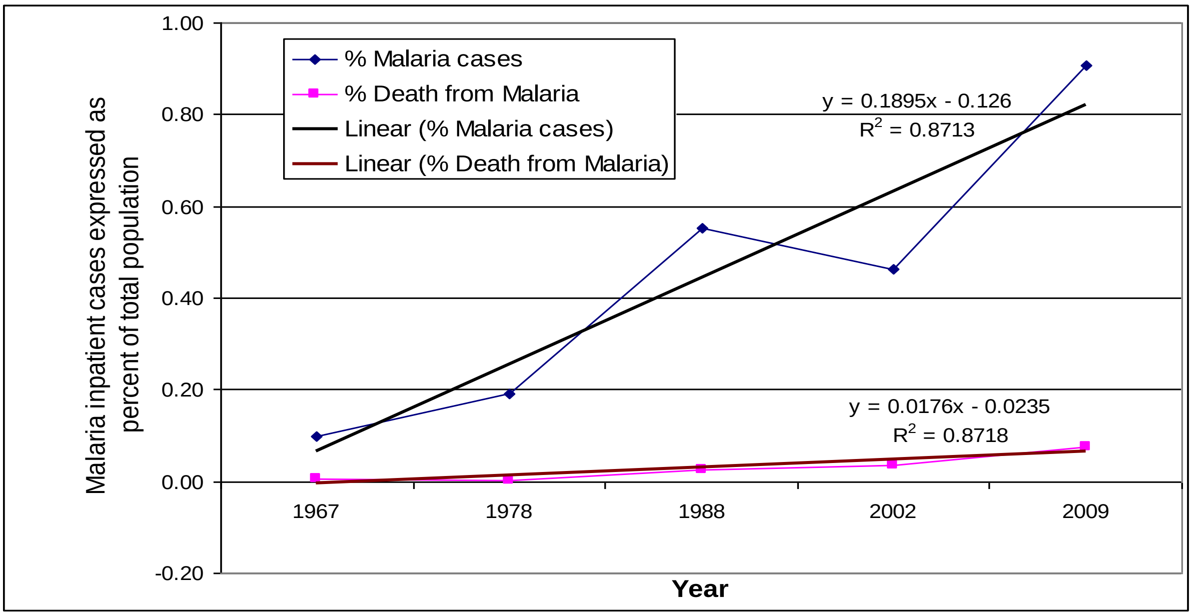


Figure 5-2: Long-term malaria trends from Igogwe Hospital records expressed as percent of total Rungwe District Population (Source: Kangalawe, 2012).

Malaria has been common in high temperature and humid lowland areas especially during and after rainy seasons but with changes in temperature and rainfall regimes, the disease has been observed in non-traditional malaria areas such as highland areas of Tanga, Kilimanjaro, Iringa, Kagera and Mbeya, among others, where it was not prevalent before. This is a dramatic increase in malaria spread in places it was not prevalent. The epidemics in these areas are mostly linked with El Niño events (URT, 2012). The communities in the highlands that have had less exposure to malaria are more vulnerable than their counterparts in the lowlands due to lack of immunity.

Malaria is a complex problem for which there is no "magic bullet," no quick or easy solution as its transmission with morbidity and mortality trends is on the increase. The virulence of both parasite and vector has thwarted control efforts, and emerging "drug resistant" parasite strains appear to be inducing an increasing human toll. Vector control measures are not sufficiently integrated and the available technologies for malaria adaptation and mitigation are diverse but inadequately disseminated due a range of factors, including some inadequacies in the some existing strategies, guidelines, and regulations to recognise the climate change impacts.

It is therefore recommended that policy framework for addressing climate change impacts, especially on human health vulnerability and adaptation need to be formulated, additionally, the government would need to set clear climate change policies, legislation and regulations and guidelines for disease control such as malaria in relation to vulnerability and adaptation to climate change. Further studies on the influence of temperature and rainfall variations on disease dynamics should be carried out to inform decision making and planning for surveillance and adaptation and mitigation measures. Additionally, an important investment to be made for malaria control is in human capital, that is, to build local capacity in Tanzania to develop solutions specific to the affected local environment and population as well as enhanced participation by communities in malaria programmes for ensured success and sustainability.

Other measures are to:

- Initiate integrated disease vector adaptation and mitigation technologies.
- Disseminate technologies - most of the health problems are area specific; some technologies may be suitable in one place but un-suitable in other areas. Therefore there will be a need for a situational analysis before any technology is imposed to an area.
- Develop mechanisms for monitoring and forecasting health effects due to climate change.
- Establish early warning systems where routine monitoring of meteorological data and their interpretation for predicting the risk of malaria epidemics is of paramount importance.
- Develop guidelines that will provide assistance to all stakeholders in the country on epidemic prone areas, malaria transmission, the different interventions and their implementation.

The floods that hit the low-lying areas in Dar es Salaam city in February 2014 is one example of the potential risk of contracting waterborne diseases as results of heavy rains and associated floods. Indeed, there is strong evidence that temperature and rainfall patterns affect the disease pattern. Recent studies have shown a significant relationship between cholera cases and temperature and predict an increase in the initial risk ratio for cholera in Tanzania in the range of 23 to 51 percent for a one degree Celsius increase in annual mean temperature (Trærup et al., 2010). The cost of reactive adaptation to cholera attributed to climate change impacts in Tanzania is projected to be in the range of 0.02 to 0.09 percent of GDP by year 2030. Total costs, including loss of lives are estimated in the range of 1.4 to 7.8 percent of GDP by year 2030, while the costs of additional cholera cases and deaths attributed to climate change impacts in Tanzania during the same period will largely exceed the costs of preventive measures (Trærup et al., 2010).

Additionally, weak institutional capacity in terms of coordination and collaboration as well as low public awareness on climate change impacts on cholera and associated adaptation and mitigation leave much to be desired in the country. Given cholera as an epidemic disease influenced by climate and hygiene, and the potential that development schemes have to influence the intensity of cholera transmission, requirements for cholera-specific adaptation and mitigation measures need to be instituted in the country. The following are among the ways to address this:

- Formulation and reviewing of policies to integrate climate change adaptation and mitigation;
- Promoting and ensuring community participation, which is critical to cholera programmes in adaptation and mitigation;
- Increasing public awareness of cholera adaptation and mitigation.

5.2.3 Initiatives to address climate change impacts on the health sector

The National Climate Change Strategy, 2012

The Strategy has provided essential directions on how climate change impacts on various sectors can be addressed. It specifically recognises that climate change is a significant and emerging threat to human health. Consequently, the Strategy has identified the need to build the capacity of key economic sectors and relevant institutions to address climate change adaptation and mitigation. The particular strategic interventions earmarked for the health sector include the following:

Enhancing resilience and climate change adaptation will reduce proliferation of infectious diseases and occupational health risks thereby ensure a healthier nation, which is particularly important for sustainable development. Thus the national goal is to increase resilience and adaptive capacity of people and health systems to address the impacts of climate change. This is envisaged to be addressed through three **Strategic objectives,** namely (a) To enhance public health care systems capacity to respond to climate change-related health risks; (b) To improve disease surveillances and design of diseases control programmes (e.g. preventive and curative procedures); and (c) To improve knowledge on climate change related occupational health risks. The currently identified **Strategic interventions** for climate change adaptation in the health are:

(i) Strengthening control systems related to health risks and diseases.
(ii) Ensuring availability of specialized trained staff and medical facilities for addressing climate-related diseases and other health risks.
(iii) Enhancing information sharing systems and cooperation with international community in addressing climate change – health related issues.
(iv) Enhancing health insurance system

The National Health Policy, 2007

The Policy recognises environmental health and sanitation, as an important area for preventive health. It is one of the best indicators for measuring social and economic developments which can be achieved by, among other things, enhanced environmental cleanliness, monitoring of water quality and safety, monitoring of food quality and safety of locally produced foods and imported foods at ports of entry, manufacturing, packaging and sales outlets. However, the link between health problems, environment and climate change is not directly addressed but the need to be incorporated in future policy reviews. The policy commitments indicate that the Ministry of Health will achieve these aims through:

- Provision of health education and promotion at all levels to individuals, families and communities.
- Giving priority to formulation of guidelines on different aspects of environmental health and sanitation.
- Continued collaboration with other stakeholders with the aim of achieving better environmental health and sanitation.
- Enforcement of solid and liquid waste management at each facility.

This policy as well as its predecessor, the National Health policy of 1990, does not directly address issues related to climate change. Indirectly, however, the policy addresses various issues related to environment and climate change, including the following:- (i) Improving malaria case management; (ii) use of insecticide treated mosquito nets (ITNs); (iii) Control of malaria in pregnancy; and (iv) Malaria epidemics prevention and control.

The National Adaptation Programme of Action (NAPA) (2007)

The NAPA has identified urgent and immediate adaptation options to combat climate change impacts, including issues relevant to the health sector. The NAPA already noted in 2007 that some of the climate-related health risks such as malaria were the largest cause of loss of lives in the country accounting for about 16% of all reported deaths. It notes that under the current trend in both rainfall and temperature, the frequency of occurrences and impacts of malaria will further rise. Other major diseases in Tanzania that are sensitive to climate are Dysentery, Cholera, and Meningitis (URT, 2007).

Health related legislation

Implementation of climate change issues in Tanzania is undertaken within the context of the National Environmental Policy, 1997 and the Environment Management Act (EMA), 2004 and other related sector policies and legislations. Section 75 of EMA describes how climate change issues can be addressed in Tanzania. Already, some of the health related legislations spell out clearly the need to address climate change adaptation in their sector activities. For instance, the Public Health Act No. 1 of 2009 demands in article 171 (3) (m) that programmes and facilities should be in place to ensure that the issues of climate changes are well addressed.

5.3 Agriculture Sector

Climate variability and long-term changes will impact the future growth and development of Tanzania's agriculture. Average temperatures will likely rise by at least 1ºC by 2050 which will impact food crops that are particularly sensitive to temperature, such as maize and rice. Some models suggest the already semi-arid zones in Northern Tanzania could receive up to a quarter less rainfall annually. While projected changes in average annual rainfall amounts vary considerably across models, there is higher confidence that both seasonal extremes of dry and wet conditions will intensify.

It has been indicated that changing climate has resulted in a general decline in agricultural productivity, including changes in agro-diversity (URT, 2009a). The prevalence of crop pest and diseases is also reported to have increased, posing more challenge to agriculture. The report also indicated that some of the previous highly productive areas such as the southern and northern highlands will continue to be affected by declining rainfall, frequent droughts and significant increase in spatial and temporal variability of rainfall with long term implications in the agricultural sector planning and resources allocation, such as seeds, pesticides and even the shifts in types of agricultural produce.

A study by the Ministry of Agriculture, Food and Cooperatives to establish strategies for addressing the negative effects of climate change in food insecure areas of

Tanzania indicated considerable changes in the types of crops grown in agro-ecological zones with declining production trends (URT, 2008). For instance, the study indicated a declining trend in productivity of maize and sorghum, which led to the introduction of drought tolerant crops such as cassava and Vanilla.

There is a general perception by the majority of farmers that incidences of crop pests have increased over the past few decades, and that the pests have become more prevalent with time. As a result, emerging diseases such as *batobato, banana xanthomonas wilt, panama, elihuka, coffee wilt, headsmuts, fusarium wilt, maize streak, cassava mosaic, cassava purple stripes, cassava root rot, and rust* particularly in green grams have become more prevalent (URT, 2008). Furthermore, increase in temperatures has led to increased incidences of some of plant species (for example, *striga spp*), a noxious weed particularly for cereal crops; insect pests (for example, *prostephanus truncatus*, and *bemisia tabacci*); and vermins such as the mole rats and an increase in the prevalence of crop pests and diseases which in turn has caused increased demand for pesticides and herbicides.

The National Food Security Policy (1997) recognizes food availability, accessibility and utilization as three major pillars of food security. Improved food security leads to improved human capital that leads to higher agricultural productivity and wages in the labour market. Food security is, therefore, a development issue that must be streamlined in the development agenda to ensure a healthy and productive nation. It has been noted however, that food availability is greatly affected by low production and productivity due to factors that are linked to climate change, e.g. high incidence of pests and diseases, and unreliable rainfall that leads to recurrent droughts or floods in some parts of Tanzania.

Tanzania’s NAPA ranked agriculture and food security as the most vulnerable and important sector that is severely impacted by climate change and advocated that studies on the impact of climate change in the sector and on food security be a priority activity.

The assessment of food security in the country revealed that semi-arid areas experienced more food shortages and insecurity compared to other districts (URT, 2008).

Climate related factors significantly contribute to the reported food shortages and insecurity, with much of the food shortage being experienced in years with drought and floods. Major causes for the food shortages included drought, crop pests and diseases, low soil fertility, livestock diseases, and low household incomes.

Evidence has shown that there is a shift of agro ecological zones (AEZ) as results of climate change (URT, 2007). Change in crop performance in some parts of the country may be considered as detective of AEZ shift. In general, there is need to undertake further studies aimed at rigorous review of the AEZ. Present evidence of climate change supporting the shift paradigm is the observed shift in rainfall patterns from bimodal to unimodal rainfall regimes in some areas. For example Manyara and some parts of Morogoro and Kigoma regions which have long been characterized by bimodal rainfall distribution are now experiencing a shift towards unimodal rainfall regime.

Productivity of most crops seems to have declined due to changing climate, particularly due to the increasing unreliability of rainfall. However, the production of some crops seems to have improved with the changing climate. For example, the productivity of mangoes and oil palm in the western plateau of Tanzania has increased considerably during the last 20 years, than in earlier years (URT, 2012). Warming of the environment has favored production of both mango and oil palm in these highland areas.

5.3.1 Agro-ecological zones

In general, based on weather, soil fertility and food crop production there are 7 main agro ecologies (AEZs) (Table 5-6). Based on main AEZs of Tanzania, a general perspective is made in respect of rainfall and temperatures (maximum) and implication to maize, normally a weather vulnerable crop and sorghum, normally a relatively weather stable crop with a reasonable contrast as far as rainfall and temperatures are concerned. This broad view of the existence of climate change effect is explored to reveal a variation over time and over season. Interest is to finally lay foundation for recommending best agricultural practices to adapt to looming climate change and boost production to ascertain food security.

Table 5-6: Agro-ecological zones

Zone	Sub-zone	Area	Characteristics of the zone
Coastal-I	North	Tanga	Infertile sands on gently rolling uplands
			Under 3000 m Above sea level; Bi-modal rainfall-750-1200 mm
			Growing season-December and March -June
Arid Lands-II	South	Dodoma	Rolling plains of low soil fertility susceptible
			to water erosion
			500-1500 m; unimodal and unreliable-400-600 mm
			Growing season-March to May
S/A lands-III	Central	Shinyanga	Undulating plains with rocky hills and low scarps.
			Well drained soils with low fertility etc;1000-1200 m
			Growing season-December to March
Plateau-IV	Western	Mbeya	Wide sandy plains and rift valley scarps; unimodal
			800-1000 mm; Growing season is November – April
S and W Highlands-V	Southern	Mbeya	Undulating plains to dissected hills and mountains.
			Moderately to fertile clay and volcanic soils
Northern Highlands-VI	Northern	Kilimanjaro	Granite Mts in Kilimanjaro; 1000-2000m; bi-modal
			and very reliable 1000-2000 mm; growing season is October - December and March – June
Alluvial Plains-VII	Coast	Rufiji	Wide mangrove swamp delta, alluvial soils, sandy upstream, loamy downstream in flood plain

5.3.2 Climatological and Environmental Factors

a) Rainfall analysis

Analysis of rainfalls performance over the past three decades 1975-1984, 1985-1994 and 1995 - 2004 in the Tanzania AEZ is shown in Tables 5-7, Table 5-8 and Figure 5-9.

Table 5-7: The AEZ of Tanzania – Environmental Factors (EF) and Food Crop Production

AEZ s/n	Name	Representative area	EF-1	EF-2	Crop 1	Crop 2
AEZ 1	Coastal	Tanga	Rainfall	Maximum Temperatures	Maize	Sorghum
AEZ 2	Arid land	Dodoma	Rainfall	Maximum Temperatures	Maize	Sorghum
AEZ 3	Semi-Arid lands	Shinyanga	Rainfall	Maximum Temperatures	Maize	Sorghum
AEZ 4	Plateau	Mbeya	Rainfall	Maximum Temperatures	Maize	Sorghum

Table 5-8: Analysis of rainfalls performance for 1975-1984, 1985-1994 and 1995-2004 in the Tanzania Agro Ecological Zones

AEZs	Study area	Estimated model
AEZ-I	Coastal	$y = -7.52x^2 + 26.367x + 92.463$
AEZ-II	Arid land-Dodoma:	$y = -0.8475x^2 + 7.235x + 37.722$
AEZ-III	Semi-Arid lands- Shinyanga	$y = -37.203x^2 + 183.09x - 145.89$
AEZ-IV	Plateau-Mbeya	$y = -7.268x^2 + 33.288x + 48.086$
AEZ-V	South Western Highlands- Mbeya	$y = -7.268x^2 + 33.288x + 48.086$
AEZ-VI	Northern Highlands -Kilimanjaro	$y = 1.4033x^2 - 10.47x + 87.756$
AEZ-VII	Alluvial-Morogoro	$y = 4.2733x^2 - 18.018x + 86.64$

In general, except for Morogoro and Moshi in Kilimanjaro region, all zones reflect negative sloping trends implying falling rainfall availability overtime. In view of this there is need to adapt to these rainfall shortages probably by adopting water conserving technologies. Water harvesting initiatives should not be taken for granted.

An analysis of long term means of monthly availability of rains across AEZ show that on average total rains for a typical crop season is normally highest in Tanga followed by Mbeya, Kilimanjaro, Shinyanga Morogoro and Dodoma. Rainfall intensity depends on bimodality tendency, which may be best described by proportionate contribution of each season to crop production. Thus Tanga ranks top in rainfall distribution over all 12 months followed by Mbeya, Kilimanjaro and Morogoro. Dodoma is the weakest distributed region with 4 months (June, July, August and September) having no rains at all followed by Shinyanga where 3 months (June, July and August) have virtually no rains.

An analysis of monthly rainfall maxima across AEZs over the 20 years (1984/85-2003/04) shows that only Dodoma did not receive any rains at all in September and July. All AEZs have rains in March and April

The range between highest and lowest rainfall values shows that highest range was found in Tanga followed by Mbeya, Kilimanjaro, Shinyanga, Dodoma and Morogoro. The implication to maize (vulnerable crop) and sorghum (relatively tolerant crop) has been worked out and presented later in this section.

b) Temperature analysis

An analysis of maximum temperature performance over the past three decades 1975-1984, 1985-1994 and 1995-2004 in the Agro-ecological zones shows that in general, except for Same in Kilimanjaro region, all areas indicate an increasing temperature of at least 0.02% per decade implying an increase of at least 2% in 100 years time.

Analysis of monthly long term means of maximum temperatures per AEZ across crop season shows that the hottest months with temperatures above 30^{o}C were October to March with peak values (33^{o}C) in February in Kilimanjaro. The situation was coldest (as low as 21.6 ^{o}C) in AEZ IV and V. Maximum temperatures over the 20 years of the study could reach 35.7 ^{o}C in AEZ IV. The result shows that the range between minimum and maximum temperatures was highest (reached 10.6) in February in AEZ VI

c) Area-wise Agro Ecological Zone (AEZ) trend analyses for rainfall and maximum temperatures and implication to crop production.

In each region representing an AEZ a zoom in analysis of maximum temperatures and rainfalls over the period of study (1984/85-2003/04) was undertaken. The analysis focused at monthly maxima over the period, the long term means calculated on the bases of 30 years (1974/75-2003/04) on the one hand. On the other hand the analysis focused at maize and later sorghum was made to ascertain the implication of climate factors to crop production at individual AEZ.

Accordingly, the following results are organized for Tanga (to represent Coastal zone-I) Mbeya (Plateau-IV, S and W Highlands-V), Shinyanga (S/A lands-III), Dodoma (Arid Lands-II), Kilimanjaro (Northern Highlands-VI) and Morogoro (Alluvial Plains-VII). In each representative region we explore changes in the two major climatic variables namely rainfall and maximum temperatures with implication to production of two major crops namely maize and sorghum.

In AEZ I represented by Tanga (Table 5-9) both maize and sorghum are positively correlated with climate factors influencing their production. Both have high parameters of association as reflected from the values of R^2, i.e. 66% for maize and 88% for sorghum.

In AEZ II represented by Dodoma (Table 5-9) maize and sorghum are positively correlated with climate factors influencing their production. However they are both not so strongly associated as reflected from the values of R^2 which are 46% for maize and 11% for sorghum. There may be other factors that share the strength of association with rainfall in particular.

Table 5-9: A Summary of trend analysis of maize and sorghum production under the influence of rainfall and maximum temperatures over the 20 years of study (1984/85-2003/04)

AEZ	Study area	Estimated model	R^2
AEZ-I	Coastal		
	Rainfall	$y = 0.126x^2 - 0.5176x + 31.191$	
	Temperatures	$y = -7.52x^2 + 26.367x + 92.463$	
	Maize	$y = 0.8485x^2 – 15.053x + 165.1$	0.6606
	Sorghum	y = 0.2226x2 - 2.7281x + 6.4275	0.8752
AEZ-II	Arid land		
	Rainfall	$y = -0.8475x^2 + 7.235x + 37.722$	
	Temperatures	$y = 0.1163x^2 - 0.407x + 29.131$	
	Maize	$y = 0.7277x^2 - 8.1387x + 59.586$	0.4606
	Sorghum	$y = 0.1556x^2 - 1.4146x + 78.008$	0.1106
AEZ-III	Semi-Arid lands- Shinyanga		
	Rainfall	$y = -37.203x^2 + 183.09x - 145.89$	
	Temperatures	$y = 0.2557x + 29.745$	
	Maize	$y = -1.2844x^2 + 29.418x + 128.07$	0.2295
	Sorghum	$y = -0.9046x^2 + 19.314x + 17.268$	0.4711
AEZ-IV	Plateau-Mbeya		
	Rainfall	$y = -7.268x^2 + 33.288x + 48.086$	
	Temperatures	$y = 0.1611x^2 - 0.4956x + 24.056$	

AEZ	Study area	Estimated model	R^2
	Maize	$y = 1.3517x^2 - 25.015x + 343.47$	0.3317
	Sorghum	$y = 0.0871x^2 - 1.7349x + 23.13$	0.0873
AEZ-V	South Western Highlands-Mbeya		
	Rainfall	$y = -7.268x^2 + 33.288x + 48.086$	
	Temperatures	$y = 0.1611x^2 - 0.4956x + 24.056$	
	Maize	$y = 1.3517x^2 - 25.015x + 343.47$	0.3317
	Sorghum	$y = 0.0871x^2 - 1.7349x + 23.13$	0.0873
AEZ-VI	Northern Highlands - Kilimanjaro		
	Rainfall	$y = 1.4033x^2 - 10.47x + 87.756$	
	Temperatures	$y = 0.033x^2 + 0.0168x + 29.314$	
	Maize	$y = 1.0458x^2 - 22.322x + 189.16$	0.2251
	Sorghum	$y = -0.0188x^2 + 0.534x - 0.3957$	0.1731
AEZ-VII	Alluvial-Morogoro		
	Rainfall	$y = 4.2733x^2 - 18.018x + 86.64$	
	Temperatures	$y = 0.0507x^2 - 0.0506x + 30.155$	
	Maize	$y = 0.7842x^2 - 12.681x + 153.19$	0.2991
	Sorghum	$y = -0.1266x^2 + 2.9289x + 16.389$	0.0656

In AEZ III represented by Shinyanga (Table 5-10) both maize and sorghum are negatively correlated with climate factors influencing their production. However they are both not so strongly associated as reflected from the values of R^2 which are 45% for maize and 23% for sorghum. There may be other factors that share the strength of association with rainfall and temperature.

In AEZ IV for plateau and V for SW Highlands represented by Mbeya (Table 5-10) both maize and sorghum are positively correlated with climate factors influencing their production. However they are both not so strongly associated as reflected from the values of R^2 which are 33% for maize and 9% for sorghum. There may be other factors that share the strength of association with rainfall and temperature.

In AEZ VI for Northern Highlands represented by Kilimanjaro (Table 5-10) Maize is positively correlated with climate factors influencing its production while sorghum is negatively correlated. However, they are both not so strongly associated as reflected from the values of R^2 which are 23% for maize and 17% for sorghum. There must be other factors that share the strength of association with rainfall and temperature.

In AEZ VII for Alluvial plains represented by Morogoro (Table 5-10) maize is positively correlated with climate factors influencing its production while sorghum is negatively correlated. However they are both not so strongly associated as reflected from the values of R^2 which are 30% for maize and 07% for sorghum. There must be other factors that share the strength of association with rainfall and temperature.

5.3.3 Evidence of Climate Change Impacts on crop sector under agro-ecological influence and adaptation efforts

Adaptation to the negative effect of climate change is being exercised here and there in different agro-ecologies. As a result, improvement observed in the production of cassava and potatoes, which are drought tolerant, has been attributed to continued government efforts to vigorously promote such crops. This has been a success story on the one hand. On the other hand, the falling trend in sorghum which is also normally drought tolerant and equally receiving Government promotional efforts needs further explanation. According to field reports, late long rain season (*Masika in Kiswahili)* onset is noted as the main reason for decreased production of sorghum due to serious effect of plant pests and diseases such as powdery mildew and head smut as observed during preliminary forecast of food crops in Mwanza region. During the same food crop assessment in Dodoma, excessive heat nearly drove most sorghum to permanent wilting point the situation that affected most of Dodoma rural and Dodoma Urban districts

Though maize is more vulnerable in drought prone areas compared to sorghum and millets the mixed status conditions encountered in sorghum and bulrush millets leaves out a strong issue that remains unaddressed. This is probably one of the potential issues that need to be studied under the climate change initiative.

Additional evidence of climate change supporting the Shift paradigm is the observed shift of some regions from unimodality to bimodality rainfall regime and vice versa. For example Manyara region which is mainly bordered by unimodal regions of Dodoma and Singida as well as the transition region of Morogoro has largely converted from bimodality tendency to unimodality. Also, Morogoro and Kigoma Regions which have been either wholly or partially conceptualized with transition features are increasingly transforming to Unimodal tendencies. Conversely, Mbeya and Shinyanga regions which have traditionally been unimodal are gradually developing bimodality tendencies, for the current status of various regions in Tanzania.

The result of trend analysis for rainfall, maximum temperature, maize and sorghum gives us estimates of the coefficients estimated through a polynomial function. The results ranked in order of time correlation

AEZ-VII ranks top followed by AIZ-VI then AEZ-II, AEZ-IV, AEZ-V, AEZ-I and AEZ-III. The positivity in top 2 AEZs shown that there is room for improvement in these AEZs in the shown order of ranks, likewise the negativity observed in Dodoma, Mbeya Tanga and Shinyanga shows the increasing negativity strength in that order.

Ranked according to descending a-coefficients AEZ-III ranks top followed by AEZ-IV, AEZ-V, AEZ-II, AEZ-VII and AIZ-VI, the trend values for maize crop are as per Table 5-10.

Table 5-10: Estimates for maize trend and predicted crop production

AEZ-Maize	Estimated 2004/05 (Tones)	Predicted 2014/15 (Tones)
Mbeya	414	867
Kilimanjaro	182	502
Tanga	223	514
Morogoro	233	514
Dodoma	210	507
Shinyanga	179	-194

Mbeya ranks top followed by Kilimanjaro, Tanga, Morogoro, Dodoma and Shinyanga. Except for AEZ-III, the values are all positive. Consistent with the fitted model, predicted maize production values are as per Table 5-11 for 2004/05 and for 2004/05, 10 years after. The forecasts are all positive in the year following years of observation. Likewise, it is all positive ten years after except for AEZ-III. However a critical look into this decadal interval forecasts shows that the forecasts are all increasing with topmost percentage increase in AEZ-VI, followed by AEZ-II, AEZ-I, AEZ-VII, AEZ-IV and AEZ-V. AEZ-III will fall off production and finally in 2009/10 at a calculated rate of approximately 21% per annum.

Based on trend analysis and the forecasts made thereafter, it is prospective to cultivate maize in the following AEZs (with percentage annual increase in brackets): AEZ-VI (17.6), AEZ-II (14.1), AEZ-I (13.0) and AEZ-VII (12.1) and AEZ-IV & AEZ-V (10.9). The policy recommendations go by the same order. As for sorghum the trend coefficients are as per Table 5-11.

Table 5-11: Estimates for sorghum trend and predicted crop production

AEZ-Sorghum	2004/05 (Tones)	2014/15 (Tones)	Percentage Change in Production
Dodoma	117	184	5.7
Mbeya	25	53	11.2
Tanga	47	136	18.9
Kilimanjaro	3	-2	-16.7
Morogoro	18	18	0
Shinyanga	24	-253	-115.4

According to a-coefficients, except for AEZ-2, AEZ-4 and AEZ-5, the rest of AEZs have negative a-coefficients showing that the latter have no definite chance of peaking up as future producers. The b-coefficients are negative for AEZ-2, AEZ-4 and AEZ-5 and positive values for others. The c-coefficients (values of y at 0-time (origin)) are positive except for AEZ-I and AEZ-VI where negative c-coefficients are recorded. Predicted values are all positive for 2004/05 (the first year after years of observation. Ten years later, the forecasts increase in AEZ-I (18.9%), AEZ-IV and AEZ-V (11.2%) and AEZ-II (5.7%). The forecasts decline in AEZ-III (115.4%) and AEZ-VI (16.7%) but stabilize in AEZ-VII.

Based on trend analysis and the forecasts made thereafter, it is prospective to cultivate sorghum in AEZ-I, AEZ-IV and AEZ-V and AEZ-II, and the policy recommendations go accordingly.

5.3.4 The Evidence of Agro Ecological Zone (AEZ) Shifts

Some of the evidences of climate change have been pointed out as shifts in agro-ecological zones (URT, 2007). Change in crop performance over a period such as a decade may be considered as detective of AEZ shift.

Based on estimated coefficients and the forecasts presented in Tables 5-11 and 5-12, re-ranking of AEZs has been undertaken on a decadal interval as shown in Table 5-12.

Table 5-12: Predicted values of maize and sorghum production demonstrating shifts in AEZs consistent with climate change effect

Maize	Decade 1	Decade 2	Decade 3	Decade 4	Maize crop performance demonstrating a shift in AEZs			
AEZ	1984/85	1994/95	2004/05	2014/15	AEZ-1984/85	AEZ-1994/95	AEZ-2004/05	AEZ-2014/15
AEZ-1	151	102	223	514	AEZ-4	AEZ-3	AEZ-4	AEZ-4
AEZ-2	52	58	210	507	AEZ-5	AEZ-4	AEZ-5	AEZ-5
AEZ-3	156	296	179	-194	AEZ-6	AEZ-5	AEZ-7	AEZ-1
AEZ-4	320	232	414	867	AEZ-3	AEZ-7	AEZ-1	AEZ-7
AEZ-5	320	232	414	867	AEZ-1	AEZ-1	AEZ-2	AEZ-2
AEZ-6	168	70	182	502	AEZ-7	AEZ-6	AEZ-6	AEZ-6
AEZ-7	141	109	233	514	AEZ-2	AEZ-2	AEZ-3	AEZ-3
Sorghum	**Decade 1**	**Decade 2**	**Decade 3**	**Decade 4**	**Sorghum performance demonstrating a shift in AEZs**			
AEZ	1984/85	1994/95	2004/05	2014/15	AEZ-1984/85	AEZ-1994/95	AEZ-2004/05	AEZ-2014/15
AEZ-1	4	3	47	136	AEZ-2	AEZ-3	AEZ-2	AEZ-2
AEZ-2	77	81	117	184	AEZ-3	AEZ-2	AEZ-1	AEZ-1
AEZ-3	36	120	24	-253	AEZ-4	AEZ-7	AEZ-4	AEZ-4
AEZ-4	21	15	25	53	AEZ-5	AEZ-4	AEZ-5	AEZ-5
AEZ-5	21	15	25	53	AEZ-7	AEZ-5	AEZ-3	AEZ-7
AEZ-6	0	3	3	-2	AEZ-1	AEZ-1	AEZ-7	AEZ-6
AEZ-7	18	18	18	18	AEZ-6	AEZ-6	AEZ-6	AEZ-3

Initially maize performance was in the order of AEZ-4, AEZ-5, AEZ-6, AEZ-3, AEZ-1, AEZ-7 and AEZ-2. Ten years later, the order changed to AEZ-3, AEZ-4, AEZ-5, AEZ-7, AEZ-1, AEZ-6 and AEZ-2. Except for AEZ-1 and AEZ-2 the rest of AEZs changed position. In these changes, AEZ-3 and AEZ-7 changed positions upwards while AEZ-4, AEZ-5 and AEZ-6 dropped. In second decade AEZ-4, AEZ-5, AEZ-7, AEZ-1 and

AEZ-2 moved up while, AEZ-3 dropped to lowest position leaving AEZ-6 in the same rank. Predicted 10 years later is seen to promote AEZ-1 only leaving AEZ-2, AEZ-3, AEZ-4 and AEZ-5 in the same position and demoting AEZ-7.

On the other hand, initially sorghum production ranked down in the order of AEZ-2, AEZ-3, AEZ-4, AEZ-5, AEZ-7, AEZ-1 and AEZ-6. Ten years later, the order changed to AEZ-3, AEZ-2, AEZ-7, AEZ-4, AEZ-5, AEZ-1 and AEZ-6. Except for AEZ-1 and AEZ-6 the rest of the AEZ changed positions. In these changes, AEZ-3 and AEZ-7 changed positions upwards while AEZ-2, AEZ-4 and AEZ-5 dropped. In second decade AEZ-1, AEZ-2, AEZ-4 and AEZ-5 moved up while AEZ-3 and AEZ-7 dropped leaving AEZ-6 in the same lowest rank. Predicted third decade is seen to promote AEZ-6 and AEZ-7 leaving AEZ-1, AEZ-2, AEZ-4 and AEZ-5 in the same position and demoting AEZ-3 to the lowest rank.

Based on rank order of climate factors and their influence on crop performance as perceived through modelled coefficients where aggregate ranks have been worked out and average positions ranked as shown in Table 5-13.

Table 5-13: Aggregate Rank Analysis for Regions representing AEZs

AEZ-Regions	Rainfall rank	Temp rank	+maize	+sorghum	Average
Kilimanjaro	2	1	3	4	2.5
Mbeya	4	5	1	2	3.0
Dodoma	3	3	6	1	3.3
Morogoro	1	2	5	5	3.3
Tanga	5	4	4	3	4.0
Shinyanga	6	6	2	6	5.0

Based on aggregate rank analysis (Table 5-12), Kilimanjaro area qualifies for further analyses of technological and policy options for adaptation to consequences of climate change followed by Mbeya, Dodoma, Morogoro, Tanga and Shinyanga. Furthermore, socio-economic value attached to Mt. Kilimanjaro adds weight to Kilimanjaro.

5.3.5 Adaptation Strategies for crop sector

The capacity to cope with impacts of climate change varies from one Agro-ecological zone to another. Crop growth, development and yield vary according to AEZ characteristics which are basically associated with changes in rainfall, temperature, humidity solar radiation and soil type.

Rainfall increase is expected in AEZ-VI and AEZ VII which are mainly in the bimodal rainfall regime. The fall which is mainly expected in the unimodal areas is in support of climate change scenarios as predicted under Initial Communication (URT, 2003). Temperatures are also expected to increase in all AEZs and apparently benefiting both maize and sorghum except for AEZ-III where both the crops suffer.

The crops that are expected to thrive better than maize with climate change should be encouraged for farmers to benefit from such changes. In the event of rainfall shortages drought tolerant crops such as sorghum or *stuka* type of maize should be encouraged, e.g. AEZ-3.

There is evidence of shifts in agro ecological zones. The switch from crops considered above implies changes in the allocation of land to different uses. In general, land use that shows a greater increase in productivity than others are likely to increase their comparative advantage over competing uses. Given adequate change in the pattern of comparative advantage decisions may then be made which will involve a change in its use.

Based on recent NAPA development process, a number of adaptation strategies were identified. These strategies are clearly defined in the National Climate Change Strategy (NCCS) 2013. The strategy has sets out strategic interventions for government-wide climate change adaptation measures and greenhouse gas emissions reductions. The NCCS outline objectives for the sector, proposing strategic interventions. The strategic interventions related to crop agriculture are stipulated in the sectoral climate resilient plan as outlined in Box 5-1.

Box 5-1: Strategic Interventions Related to Agriculture

a) Assessing crop vulnerability and suitability (including cropping pattern) for different Agro-ecological zones

- Promoting early maturing and drought tolerant crops, use of pest/disease tolerant varieties, and adoption of higher yielding technologies.

b) Water

- Promoting appropriate irrigation systems
- Protecting and conserving water catchments
- Enhancing exploration and extraction of underground and other supplemental water sources
- Facilitating and promoting water recycling and reuse and rainwater harvesting

c) On-farm practices

- Addressing soil and land degradation by promoting improved soil and land management practices/techniques.
- Strengthen integrated pest management techniques
- Promoting appropriate indigenous knowledge practices, agro-forestry systems, minimum tillage and efficient fertilizer utilization, and best agronomic practices such as conservation agriculture technologies
- Enhancing management of agricultural wastes.

d) Information

- Strengthen early warning systems for pest surveillance
- Strengthening weather forecast information sharing for farmers

e) Markets

- Assess trade comparative advantage on traditional export crops with changing climate
- Enhancing agro-infrastructural (input, output, marketing, storage) systems
- Strengthening post-harvest processes and promote value addition
- Development of crop insurance strategy

5.3.6 Conclusions

An analysis of rainfall trends and concurrent implication on crop production shows that AEZ-VII ranks top followed by AEZ-VI then AEZ-II, AEZ-IV, AEZ-V, AEZ-I and AEZ-III. The positivity in top 2 AEZs shows that there is room for improvement in these AEZs (AEZ-VII and AEZ-VI) in the same order of ranks. Likewise the negativity observed in AEZ-II, AEZ-IV, AEZ-V, AEZ-I and AEZ-III shows the increasing rainfall failure (increasing negativity strength) in that same order. The b-coefficients indicate the changing direction in opposition to a-values. Temperature analysis ranked according to descending a-coefficients shows that AEZ-III ranks top followed by AEZ-IV, AEZ-V, AEZ-II, AEZ-VII and AEZ-VI. The coefficients are all positive. However,the b-coefficients are all negative. The negative impact of climate change on maize and other seasonal crops suggests need for sustainable development policies.

Maize production trends up in all AEZs except for AEZ-III. Consistent with the fitted model, predicted maize production values show that the forecasts are all positive in 2004/05 (the year following years of observation). Likewise, it is all positive ten years after, except for AEZ-III. A critical look into this decadal interval forecasts shows that the forecasts are all increasing with topmost percentage increase in AEZ-VI, followed by AEZ-II, AEZ-I, AEZ-VII, AEZ-IV and AEZ-V. Following simulations, AEZ-III will keep trending negatively at a calculated rate of approximately 21% per annum and will finally fall off production in 2009/10.

As for sorghum production, a-coefficients are positive in AEZ-2, AEZ-4 and AEZ-5 but negative in the rest of AEZs. The negative values show that the corresponding AEZs have no definite chance of peaking up as future producers. Predicted values are all positive for 2004/05 (the first year after years of observation). Ten years later, the forecasts increase in AEZ-I (18.9%), AEZ-IV (11.2%) and AEZ-V (11.2%) and AEZ-II (5.7%). The forecasts decline in AEZ-III (-115.4%) and AEZ-VI (-16.7%) but stabilize in AEZ-VII (0%).

These simulation results suggest that the global 2xCO_2 may largely affect maize production. The fall in rainfall and rise in temperatures will negatively impact on maize production through decrease in water supply and shortening of the growing season. Implicitly yield will broadly fall in major maize producers which are mainly located in unimodal rainfall regime e.g. in the Southern Highland zone but will probably increase in the Northern bimodal regions . Although nothing can be done to reduce temperature under normal circumstances, irrigation can adjust water supply. Short term and drought tolerant crops such as sorghum, millets and cassava may be adopted to adapt. Adjustment in farmed area, changes in crop location, increased use of fertilizers, control of pests and diseases, better exploitation of weather and forecasts change in management practices such as change in planting dates.

5.4 Rangelands and Livestock Sector

Most of the livestock in Tanzania are concentrated in the semi-arid areas which are more suitable for livestock than any other form of agriculture. These areas are characterized by relatively low mean annual rainfall with stronger spatial and temporal variability, and therefore not very reliable for production of food and cash crops. Concentration of ruminant livestock in these areas is also attributed to low prevalence of tsetse flies and less competition for land for arable agriculture.

Changes in the mean temperature and rainfall, and the increased variability of rainfall, have resulted to prolonged length of dry seasons and increased severity of periodic droughts that reduces water and pastures availability for the livestock. It has been noted that warming shortens the growing seasons and, together with reduced rainfall, reduces water availability, and can also increase livestock diseases. On the other hand, this reduces the availability of crop residues, which are important sources of feed for livestock especially during the dry seasons. Limited availability of pastures and water has often resulted into resource use conflicts between crop cultivators and livestock keepers, particularly in the catchment areas and crater basins.

Availability of animal feed resources for poultry, non-ruminants and other nonconventional animal industry are affected by climate change due to extreme reduction in agricultural and industrial production for products such as seed cakes and molasses.

It has been noted in some parts of the country that climate change, particularly increasing temperature, increased frequency and intensity of wildfires inducing shifts in geographical distribution of biodiversity. For example, non-palatable and toxic plant species are replacing the palatable and nutritious plant species, thus affecting the livestock industry. The intensified wildfires also cause more damage to biomass growth, thereby reducing availability of both pasture and water for livestock. Also, savannah grassland is likely to replace forests and woodlands in many places. While this may have positive impacts on the availability of fodder for the livestock, the reported fires and species changes may limit the quality and productivity of these areas.

Warming is predicted to increase disease vectors which will consequently increase the incidences of vector-borne diseases of livestock, such as *trypanosomiasis*, East Coast Fever, and Rift Valley Fever. The increases of livestock mortality due to diseases and starvation (due to droughts) may have considerable impacts on the local economies and the overall community livelihoods, particularly given the shortages of livestock dips and low financial capacity of people to afford various livestock medications (URT,2013)

5.4.1 Plant Species Association

Vegetation cover associations had equal probability in conservation at 1xCO_2 as well as at 2xCO_2. However due to interacting factors, coupled with human activities, some plant associations which existed at 1xCO_2 succumbed to the projected ambient climatic conditions over the 100 year period.

The establishment of H23, C1 and PA1-type covers in North Eastern, Northern Western and Southern Eastern Tanzania, in Southern Western Tanzania and in Southern Western Tanzania and in Central Tanzania is explained by excessive evapotranspiration (of varying magnitudes), ambient temperatures and variation in seasonal mean maximum temperatures and rainfall. These climatic conditions have created favourable growing conditions of H23-type cover for MAGICC /SCENGEN ensembles model. These findings were different from those reported by Mwandosya et al. (1998). The authors reported that PA1-Type cover change in species composition for Northern Eastern (Tanga and Dar es Salaam), T10 and H24-Type cover for Southern Western Tanzania (Rukwa and Mbeya region respectively) and T11-type cover in Central Tanzania (Iringa) under General Circulation Models (GCMs) projections.

The highest DM (27.0 and 29.0 tonnes) yield produced in Kagera region under 1x CO_2 and under 2xCO_2 is related to mean annual rainfall received in the region. The region received the more mean annual rainfall than other regions used in the study.

The productivity of the mixed, intensive and extensive livestock production systems was related to mean annual rainfall received in the regions weighted by the productivity coefficients (0.02-1.4 tonnes/ha/100 mm rainfall received).The productivity was estimated under positive and negative effects of $2xCO_2$. These yields are lower (0.20 – 29.0 tonnes/ha) than those reported by Mwandosya et al. (1998) of 7.0 -100 tonnes/ha under both positive and negative $2xCO_2$ effects.

The high productivity of secondary mixed (444.6 million kg and 1,784.2 million litres), intensive (513. 2 million kg and 3,766.8 million litres) and extensive (588.0 million kg meat and milk under positive effect of $2xCO_2$ is probably due to the efficiency of C4 plants.

The projected consumption levels in different production systems (mixed-97.0 kg and 118.0 litres, intensive-13.0 kg and 98.0 litres and extensive-14.0 kg and 69.0 litres) under positive effects of $2xCO_2$ conditions is probably due to projected increase in human population and awareness creation on the role of animal protein in the diet.

Both reactive and pro-active adaptation measures have been proposed for adaptation to climate change. However, in so doing the government and the international community will have to remove barriers and constraints identified.

5.4.2 Conclusions

Effect of doubling CO_2 over 2100 would result into 96.7kg, 13.4kg and 13.6 kg, and 118.3 litres, 98.4 litres and 69.0 litres per capita consumption under mixed, intensive and extensive production systems for beef and milk respectively. On the other hand, negative effect of doubling CO_2 over 2100 would result into 74.7kg, 11.0kg and 21.4 kg and 54.2 litres, 38.3 litres and 36.0 litres per capita consumption under mixed, intensive and extensive production systems for beef and milk respectively.

Adaptation measures proposed fall under the responsibilities of both the farmer and the government agencies. However, in so doing the government and the international community will have to remove barriers and constraints identified, so that the farmer works without any impediments.

5.5 Forestry, Wildlife and Tourism Sectors

5.5.1 Anticipated Climate Change Impacts on Forest Ecosystem

Impact assessment on forest ecosystems has been done using literature review, expert judgement and the simulation model approach. Climate change scenarios developed above have been used to predict conditions at single and double levels of CO_2. From the Holdridge Life Zone Classification Model and Forest Gap Models, the actual Tanzania life zone base map at a single level of CO_2 has been developed. The result from the model shows that at 1x CO_2 there are three zones i.e. subtropical dry forest, subtropical moist forest, and subtropical thorn woodland. At 2 x CO_2 the Holdridge life model predicts potential changes in vegetation, for example, subtropical dry forest and subtropical moist forest life zone classes would change, as CO_2 doubles, to tropical very dry forest, tropical dry forest and tropical moist forest.

The model also predicts that subtropical thorn woodland currently in existence will be completely replaced. Subtropical dry forest and subtropical moist forest will decline by 61.4 % and 64.35 % respectively. There will be an increase in tropical very dry forest, tropical dry forest and tropical moist forest, which area likely to replace the current life zones. The Forest Gap Model predicted that some species are more vulnerable to climate change than others, particularly those: that are drought/heat intolerant, with low germination rates; that lie at boundaries of compatible climate regions at heat/drought tolerant limits; with low survival rate of seedlings; and with limited seed dispersion/migration capabilities (URT, 2003). The expert judgement also shows that there will be changes in forest type, species and distribution as CO_2 in the atmosphere doubles. Different vegetation types will experience changes as a result of temperature and precipitation variation.

Examples of such changes are:-

- In the area with well-drained soils, increase in precipitation and temperature along the Lake zone and the south-eastern, the miombo woodland would develop into closed woodland and evergreen forest;
- In areas with impeded soil characteristics, miombo woodland would be replaced by wooded grassland, which in severe cases would lead to

thickets/bush-land as most of the moisture would evaporate due to the high temperatures;

- In the southern highlands, an increase in precipitation of 30 percent and a general temperature increase would cause wetter upland woodland forest to become afromontane forest/vegetation type;
- In areas where there would be a slight decrease in precipitation and increase in temperature there would be higher evapo-transpiration. Woodland forest would be converted into wooded grassland or to thicket/bush-land if condition become severe;
- In the areas with imperfect-to-good excessively drained soils, where there would be increase in rainfall like in the north and north-eastern areas of Tanzania, the wooded grasslands would change to thicket/bush-land forest due to high evapo-transpiration and run off losses, and drought resistant species would dominate;
- In the southern areas like Mbeya, where rainfall would increase slightly and temperature would rise as CO_2 doubles, the upland wood forest would remain unchanged, as evapo-transpiration would be reduced due to the high altitude; and
- Areas with drought-resistant species like those available in the central Zone would, most likely remain unchanged, irrespective of temperature increase and a decrease in rainfall.

5.5.2 Climate Change Impacts on Wildlife

The UK89 model revealed that, as precipitation increase simultaneously vegetation cover will be enhanced in the Lake Victoria basin, the north and north-eastern zone and in Mikumi National Park. The number of breeding grounds for pests and locusts will also increase, as will incidence of ticks. In general, more diseases are likely to prevail. In the coastal, southern and western areas where precipitation has been predicted to decrease, rangeland conditions will be extended and the dry savannas will be free of parasites the quality of the grazing will be improved, as evapo-transpiration will pull up soil minerals to root zones for use by the plants.

It was further learnt that species that are vulnerable to drought will pave way for those that are more drought resistant. In this process, there will be loss in biodiversity. Such changes would be favourable to wildlife, as most of them are adapted to arid grazing conditions. Increase in temperature by 2°C to 4°C would also alter the distribution of the agro-ecological zones. Areas that are used to grow perennial crops would be suitable for annual crops; warming would tend to accelerate plant growth and hence reduce the length of growing season.

The negative effect of doubling of CO_2 would generally affect wildlife in Tanzania by affecting the availability of the foliage. This would influence the animal biomass in the protected areas and subsequently the cropping intensities.

5.5.3 Climate change Impacts on Tourism

Tanzania's tourism potential highly depends on Wildlife resources as a major attraction. National Parks, Conservation areas and Game reserves are main tourist destinations. Game viewing, tourist hunting resident hunting and ranching are the major wildlife utilisation in the country (URT, 1998). Most of the wildlife is found in national parks and game reserves, with forest and woodlands being the main habitat. The predicted impacts of climate change on forest habitats will have negative effects to the wildlife and tourist industries in Tanzania. It is predicted that climate change would result into fragmentation of the forests and woodlands leaving the wildlife exposed to other catastrophes.

Impacts of climate change on tourism are likely to manifest themselves in a number of ways according to local conditions. According to Viner and Agnew (1999), the most serious impacts will result from the effects of sea level rise on small island states. For Tanzania, an example could be sited on the famous tourist hotels at Zanzibar beaches, which are particularly vulnerable to sea level rise. Many of the impacts will develop indirectly through increased stresses placed on environment systems.

Climate change could affect vegetation and ecological zones, and ultimately the distribution of wildlife. The present tourism circuits (parks and reserves) are based on animal distribution and climate conditions, and in some areas, the adjacent areas of land are facing increasing pressure from human uses. Any redistribution in wildlife, therefore, could threaten population numbers which would, in turn, reduce the attraction for tourists.

Climate change will present both threats and opportunities for tourism and leisure in the region. Threats are likely to include:-

- Greater frequency and severity of intense rainfall, storms on coastal area and severe flooding in river areas. Both these events themselves and the increased precipitation of the associated risks will influence choices about activities and destructions. New development, including for tourism, should avoid vulnerable locations in flood plains and coastal areas wherever possible.

- Increased risks of summer drought could affect tourism and leisure choices and leisure activity could directly lead to higher demand for water at times when resources are under most pressure; water efficiency should be promoted in the sector.

- Pressure on both wildlife and agricultural crop and livestock as a result of changes to humidity, soil moisture, temperature, UV radiation etc. Such impacts could mean that characteristics that currently attract visitors to specific locations will be damaged or lost.

Climate change may increase the frequency of flooding, drought and land degradation, and subsequently reduce the viability of recreation activities and wildlife expeditions. The wildlife in both Lake Manyara National Park and the Masai Mara Game Reserve is closely connected to seasonality and climatic conditions. Some of the 380 bird species for which Lake Manyara National Park is renowned are seasonal (Viner and Agnew, 1999). It is predicted that changes in climate as well as changes in the lake and hydrological conditions may alter migration patterns, breeding of birds and other wildlife dependent on the lake. Flamingos, for example, have deserted their lake habitats due to their sensitivity to changed environmental conditions. The annual migration of wildebeest, zebra, and antelope in the Serengeti is one of the main tourist attractions in Tanzania. As the growth of grass and vegetation changes with altered rainfall patterns, migration will also shift. More frequent droughts may increase the pressure on the reserve by pastoralists. Changed local climate may also change the human use of land adjacent to the reserve, on which wildlife in the reserve interacts.

The importance of infrastructure in the tourist industry is well known. This is another area which could be affected by climate change. For example, Lake Manyara makes up to two thirds of the area of the park, and the rich bird and animal populations connected to the lake are among its chief attractions. Heavy rainstorms can cause temporary closure of tracks and make the lake shore inaccessible. Roads within many National Parks and game reserves for example, Lake Manyara National Park, Serengeti National Park and Selous Game Reserve as well as roads leading to the park and reserves deteriorate during heavy rains, and some roads and bridges may be temporarily difficult and expensive during prolonged heavy rains. Incidents of extreme heavy rains e.g. the 1997/98 El Niño rains, leave park roads impassable for long periods of time, and result in reduced tourist visits and loss of revenue.

5.5.4 Adaptation Measures in Forestry sector

In Tanzania, several adaptation strategies are already being employed at various levels in order to assist the local communities to adapt to climate change related impacts. Since local communities depend much on wood fuels (biomass) as the main source of energy, already some communities in Tanzania have developed affordable alternative source of energy such as rice and cotton husks, dry cow dung, and the use of non-wood products as fuel. Due to wood scarcity in some areas such as Shinyanga, Mwanza and Tabora, the local communities have increased the use of dry cow dung, crop residues (cotton, maize and cassava) as source of fuel (Moyo et al, 1993). In addition, the local communities in Sukumaland (Shinyanga and Mwanza) have developed Ngitili as their traditional conservation method to conserve and protect forests/woodlands for various purposes. Table 5-14 depicts the extent of Ngitili in Shinyanga Region.

Table 5-14: Known extent of Ngitili in Shinyanga region in ha

District	Communal	Individual	Total
Bariadi	13,696	6,191	19,887
Kahama	7,468	2,941	10,409
Maswa	2,632	4,336	6,968
Meatu	4,535	9,620	14,155
Shinyanga (Rural)	15,953	7,806	23,759
Shinyanga (Urban)	1,979	245	2,224
Bukombe	330	390	720
Total	**46,593**	**34,206**	**78,122**

Source: Kaale *et al.,* 2003.

Furthermore, the National Forest Policy (1998) provides and encourages for community based and participatory forest management in order to halt the current trend of forest degradation. Already success stories on community based and joint forest management have been reported such as Duru-Hai Temba forest (Babati, Manyara region), Mgori Community Based Forest Management (Singida region), and Amani Nature Reserve Joint Forest Management (Muheza, Tanga). In addition, the National Forest Policy gives provision for the local government or village government to establish, manage and declare forest reserves. Private and community based plantation are highly encouraged and supported by Forest Policy. Other good practice includes a Tree planting campaign that is being conducted on1st January of each year throughout the country. The national campaign serves as both a mitigation and adaptation strategy to the declining forest cover in Tanzania. In 2005, a total of 66,182,502 seedlings were raised compared to 65,558,138 in 2004, equivalent to an increase of 0.95 per cent. Due to community participation in tree planting, a total of 141,267,000 trees were planted in all regions compared to 133,271,038 trees in 2004. There was a decline in logs harvesting from 8,529.00 m^3 in 2004 to 5,867.48 m^3 in 2005 due to measures taken to control exportation of logs. In 2005, total export earnings from forestry and beekeeping products were Tshs. 27,463,472,500 compared to Tshs. 11,637,340.00 in 2004. The Fourth Phase Government has enhanced the Tree planting campaign by initiating a Tree Planting Presidential Award to be given on year basis. The main goal of the campaign is to plant at least 1.5 million trees in each region annually.

The Government has also embarked on a Strategy on Urgent Action to Conserve Land and Water catchments areas. The Government has emphasized on planting indigenous tree species and banned the use of tree building poles in construction (URT, 2006). The strategy also addresses the issue of bush fire, which is an annual event in most parts of the country especially during late dry season. Bush fire in Tanzania is generally caused by anthropogenic activities related to agriculture and hunting. Table 5-15 depicts wildfire situation from 2000-2011.

Table 5-15: Annual burned Area in Tanzania

Year	Km^2	Hectares
2000	108,386,7398	10,838,674
2001	82,870.3400	8,287,034
2002	118,402.1751	11,840,218
2003	129,433.3809	12,943,338
2004	131,462.6155	13,146,262
2005	124,544.5890	12,454,459
2006	93,190.5645	9,319,059
2007	110,603.8416	11,060,384
2008	110,012.1536	11,001,215
2009	112,396.8095	11,239,681
2010	122,008.7712	12,200,877
2011	85,709.5926	8,570,959
TOTAL		**132,902,157**
AVERAGE		**11,075,180**

Sources: FAO, 2013

Studies have revealed that, climate change impacts may in the long run cause changes in vegetation/forests and their distribution. Tanzania has undertaken an assessment of its forest resources and developed land use land cover (LULC) map as a baseline that would be used to monitor change in land use and cover change as a result of both climate change and human induced activities. The map below shows the current land use and land cover in Tanzania.

It is also known that some species will be more vulnerable to climate change than others. However, adaptation of forests to climate change, naturally and via human management, is still poorly understood. Therefore, adaptation of forests and species to a variety of stress (water stress, higher temperature, forest fires, pests and diseases), and their genetic adaptability needs to be more fully explored before adopting strategies to cope with Climate change (Mwandosya *et al*, 1998).

Previous studies (URT, 2003) suggest that there are various adaptation options/measures which could be deployed to adapt to the effects of climate change. Among the options include:-

a) Better forest management practices (gene management, forest protection, forest regeneration, silvicultural management, forest operations);
b) Afforestation programmes in degraded and non degraded lands using more adaptive species;
c) Improvement/change in the use of forests and forest products to reduce tree felling by the application of alternative materials;
d) Enhancement of forest seed banks and the development of new plant varieties;
e) Encouragement of multiple/diversity management practices in the case of plantations;
f) Reduction of habitat fragmentation;
g) Promotion of the development of migration corridors and buffer zones;
h) The application of technologies that use other materials instead of wood, for example recycled plastics in the production of furniture will lead to a litter-free environment and conserve trees for environmental purposes e.g. their use as sinks for CO_2. Likewise, greater recycling of waste paper will also reduce the volume of tree logs used to manufacture and paperboards; and
i) Encouraging private and community forestry to ensure sustainable management of forests, hence reduce pressure from illegal forest exploitation. Forest encroachment has been minimized in areas where people are involved in managing the surrounding forests.

Adaptation measures for maintaining biological diversity and ecological integrity in reserve systems include:

a) Protect existing forest through better forest management practices;
b) Afforestation of degraded lands with emphasis on plant species adapted to GHG-induced (adaptive species) changes of climate change as well as CO_2;
c) Change or Improve use of forests and forest products;
d) Improvement/change in the use of forests and forest products to reduce tree felling by the application of alternative materials;
e) Enhancement of forest seed banks and the development of new plant varieties;
f) Encouragement of multiple/diversity management practices in the case of plantations;
g) The application of technologies that use other materials instead of wood, for example recycled plastics in the production of furniture will lead to a litter-free environment and conserve trees for environmental purposes e.g. their use as sinks for CO_2. Likewise, greater recycling of waste paper will also reduce the volume of tree logs used to manufacture paper and paperboards;
h) Conduct research to identify plant species that can adapt or species adapted to climate changes for inclusion in afforestation programmes. However, the capability to adapt to climate change alone cannot be the basis for large scale forestry programmes centred on such species;
i) Enhanced forest seed banks and develop new plant varieties;
j) Encourage diversity management practices in case of plantations;
k) Establish flexible criteria for intervention; and
l) Reduce habitat fragmentation and prone development of migration corridors and buffer zones.

Tanzania is encouraging private and community forestry and it has proved to be a good practice to ensure sustainable management of forests, hence reduce pressure from illegal forest exploitation. Forest encroachment has been minimised in areas where people are involved in managing the surrounding forests.

Highly fragmented forest or species population will probably be more vulnerable to climate change. These parameters are characteristics of forest ecosystems that are most sensitive to climate change. The life cycles of forests range from decades to centuries. Most of the decisions made today are based on the assumption that the climate will remain relatively stable throughout a forest's life. This may have worked well in the past, but future climate change challenges this assumption. It has been reported that predictions of biological changes over the next century range from large-scale biome shifts to relatively less extensive disruptions in forest growth (Spittlehouse and Stewart, 2003).

An effective adaptation policy must be responsive to a wide variety of economic, social, political and environmental circumstances. Adaptation requires to: establish objectives for the future forest under climate change; increase awareness and education within the forestry community about adaptation to climate change; determine the vulnerability of forest ecosystems, forest communities, and society; develop present and future cost-effective adaptive actions; manage the forest to reduce vulnerability and enhance recovery; monitor to determine the state of the forest and identify when critical thresholds are reached; manage to reduce the impact when it occurs, speed recovery, and reduce vulnerability to further climate change (Spittlehouse and Stewart, 2003).

5.5.5 Adaptation Measures in Wildlife Sector

The primary objective of adaptive measures to protect wildlife and habitats is to maintain resilience in and among ecosystems. Resilience is simply the ability to absorb shocks and then return to the normal. As a rule, adaptive measures to climate change for protected areas should promote resilience in the protected area systems and the habitats that they protect (Markham and Malcolm, 1996).

In order to reduce the above threats and vulnerability, the government through TANAPA and Wildlife Division has established the so called Wildlife Management Areas (WMAs) whereby the local communities adjacent to the National Parks or Game Reserves are involved in the management of wildlife resources (URT, 1998). The government has also declared more areas to be National Parks. Among the recently established National Parks include Kitulo (Mbeya) and Saadani National Parks (Bagamoyo, Pwani). However, in some areas special migratory routes will be needed as an adaptation measure to enable wildlife to move freely and minimize human interference and threat. Licensed hunting in the game reserves is allowed except for specifically designated animals e.g. Giraffe, Rhinoceros, Elephant, Leopards, etc.)

On the same token, bushfires and human settlements remain the main bottlenecks in most of the wildlife areas; therefore strategies to stop deliberate fires and illegal hunting should be strengthened in order to reduce the current destruction of wildlife ecosystems and natural habitats. The Strategy on Urgent Action to Combat Land Degradation and Conserve Water Catchment areas (2006) addresses the issue of bush fire at length. Bush fire is among the twelve challenges that are addressed by the strategy. The Ministry of Natural Resource and Tourism has taken major steps to address the issue of fire by forming a National Task force that is tasked to come up with clear suggestions that will lead to a comprehensive fire strategy and action plan development.

A number of adaptation measures for maintaining biological diversity and ecological integrity in reserve systems are suggested by Markham and Malcolm (1996). These include:

a) **Reserve and choice**: In locations where it is still possible to plan for new protected areas, it would be important to site reserves near the range limits (in the direction of the expected migration or dispersal under changed climate) of species targeted for protection. It is suggested that altitudinal ranges within the reserves is important because species may be able to migrate up slope to avoid the consequences of warming.

b) **Connectivity and fragmentation**: Connectivity between reserves in human-dominated landscape is regarded as a key component of a well-planned protected areas network. Connectivity is the opposite of fragmentation in that it joins landscapes, thereby benefiting wildlife and ecosystems. Noss and Cooperrider (1994) define two major roles of landscape connectivity as (i) to provide dwelling habitat for plants and animals; and (ii) to provide a conduit role into three main categories. First, daily and seasonal movements; Second, facilitation of disposal and gene flow, and third, allowance of long-distance range shifts.

In times of rapid climate change, corridor systems may be of particular importance in that they allow the migration of species in response to bio-geographic range changes. Despite the clear need to increase connectivity to facilitate ecological adaptation to climate change, current scientific understanding of the utility of corridor systems is limited. Corridor plans often target the dispersal of a particular species, and little attention is given to the overall impacts on ecosystems. For example, corridors may aid the movement of invasive and alien species or provide a channel for the spread of diseases. Response to climate change will require more than just movement down corridors, because the biological range changes that will be occurring are expected to be rapid, with permanent loss of previously suitable habitat. For this reason, habitat will need to function as habitat rather than mere transit lanes.

c) **Habitat Management and Intervention**: Several habitat management and intervention techniques can become part of an adaptation strategy. Most of these techniques are already used in protected areas and managed reserves worldwide and these techniques can be adapted for use under a new set of climatic conditions. Although plans for managing and developing protected area systems are essential elements of an adaptive strategy to climate change, many nations find this approach limiting. In most developing countries, Tanzania included, the major cause of loss of biological diversity is (and is likely to continue to be for the foreseeable future) due to habitat destruction and degradation as a result of demographic and land - use changes. Human population growth is driving both the conversion of natural lands and the production of pollution (including GHGs). It is suggested that adaptive strategies/measures in the region of high human pressure (such as southern Africa) will have to take into account interactions among human populations, ecosystems and wildlife populations.

d) **Maintaining Ecological Resilience**: Ecological resilience is the single most important factor influencing the ability of wildlife and natural habitats to respond to climatic change. Conserving biological diversity, reducing fragmentation and degradation of habitat, increasing functional connectivity among habitat blocks and fragments, and reducing anthropogenic environmental stresses can increase resilience.

Some of the other adaptation options that could be applied to Tanzania include: i) Reduction of vulnerability and increased resilience; ii) Purposeful adjustments to reliable predictions of change; and iii) Promotion of the development of migration corridors and buffer zones.

Additional adaptation measures include: a) Fire control to minimize degradation and disturbances of the natural vegetation cover/forest and hence the cost of rehabilitation; b) The removal of impediments to migration (e.g. road systems) and colonization; c) The preparation of land for the establishment of the desired species; d) Assisted migration; e) The control of alien or invasive species to minimize disturbances; f) The control of diseases, the promotion of irrigation schemes to reduce drought impacts; g) The development of a multi-species animal production system; h) A comprehensive food and water provision programme aimed at ameliorating the impact of drought or famine is also recommended; i) Monitor changes in disease distribution and the expansion of the range of disease vectors as well as to plan their control strategies. j) A multi-species animal production system reduces the predicted vulnerability to the wildlife sector because of the various cropping options and hence increases resilience when management plans are implemented effectively.

Given the current uncertainty about the predicted impacts in the region, reducing vulnerability and increasing resilience is an attractive option. However, this option will encounter substantial challenges. Implementing some of the recommendations on protected areas management and planning, but perhaps an equally important step will be to develop strategies for landscape – wide management. Any measures that can reduce current pressure on ecosystems and minimise the development and expansion of those pressures in the future will provide a conservation benefit in a changing climate.

5.5.6 Adaptation Measures in Tourism sector

As already mentioned in the wildlife sector, the government has taken initiatives to reduce the threats on the highlighted areas. Such initiatives include establishment of new national parks (e.g. Saadani and Kitulo), forest, game and marine reserves to ensure the sustainability of tourism industry. The Ministry of Natural Resources and Tourism has formulated a National Tourism Policy, which is already operational. Furthermore, most of the national parks, game reserves and forest reserves have established buffer zones or wildlife corridors (such as the Derema corridor in Amani Nature Reserve and along Kilimanjaro National Park. These buffer zones are important in allowing movement of wildlife animals without much human interference. Public awareness and educational programme have been adopted by TANAPA, which reduces conflicts between national parks authority and local community. In some areas such as Kitulo National Park, communities at Kikundi Village have been re-located to other places to pave way for establishment of the national park. Where beach erosion threatens coastal and marine resources, efforts have been taken by both government and non-government organization to reverse the trend. The Environmental Management Act of 2004 supports such kind of initiatives.

Adaptation measures considered in the wildlife sector plays a great role in moderating the vulnerability of tourism (particularly wildlife-depended tourism) from climate change. For Tanzania this is crucial because of the fact that her tourism potential highly depends on wildlife resources as a major attraction. Adaptations in tourism sectors have not been widely and intensively studied in Tanzania and elsewhere, thus little information is available as regard to tourism adaptation measures. However, some measures are believed to contribute in reducing the impacts of climate change. These are:

a) **Robust interconnected habitats**: Creating robust interconnected habitats allow species and habitats to migrate and to take advantage of climate change. Moreover, opportunities would be constrained by the effects of climate change in specific areas and the need for other social, economic and environmental sectors to adapt. For example, it is likely that hotter, drier periods will lead to reductions in available water resources and to increasing demand for water among households, businesses, agriculture and the natural environment, through competition for resources. Tourism stakeholders will need to consider and plan for such changes.

b) **Diversification of tourist attractions**: Tanzania has a high potential of tourism attraction in many parts of the country. These potential sites are not well known to both local and foreign tourists. There is a need to diversify tourist attraction from the current main attraction i.e. national parks, conservation areas, game reserves and beaches to alternative attractions. This would maintain the flow of tourists to the country as well as continue receiving foreign earning. Climate change will have increased opportunities for environmental tourism as new habitats are created in compensation for lost wildlife areas. It is also possible that there will be niche opportunities as a result of lifestyle changes in a new climate. All these could be considered as new tourist attractions. Research should focus on potentially suitable areas as a result of climate change and plans to establish parks, game reserves and conservation areas. Changes are expected to occur steadily and animals might move to suitable places hence disturbance to the people and other activities in those areas.

c) **Reserves**: Studies should be conducted on the possible suitable areas as a result of climate change and plans to establish parks, game reserves and conservation areas. Changes are expected to occur steadily and animals might move to suitable places, hence disturbance to the people and other activities in those areas.

d) **Awareness creation**: Need to create awareness to the different stakeholders on the impacts of climate change to their resources. For example, Pastoralists/nomadic should be made aware of the impacts of climate change to their livestock and the resultant pressure that may occur to other resources.

The changes may be accompanied by change on human resource use of the land adjacent to the reserves on which wildlife and the reserves interact.

e) **Infrastructure development**: Transport to and from as well as around resorts and within destinations is another key area where changes could be made. The tourism industry should incorporate public transport and cycling infrastructure in resort plans as well as alternative low impact vehicle technology. Improved infrastructure especially roads would ensure access to tourist attractions that might be blocked due to climate change impacts such as flooding.

5.5.7 Constraints to Adaptation Options

Adaptation and technology needs are very important to sectors as they endeavour to cope with the impacts of climate change. One of the fundamental problems facing communities is transfer of relevant/appropriate technology. Previous studies have identified several barriers to technology transfer including market imperfection and institutional barriers. These are the main causes of lack of successive diffusion and implementation of technological innovations. Some of the most commonly cited barriers to transfer of technology between countries include:

i) *Shortage of technological information* because the developing countries lack access to information, they are not aware of what technologies fit their conditions and where they can find the suitable ones. The action to overcome this obstacle is to encourage the international technology exchange. This would be helpful in overcoming this barrier.

ii) *Shortage of information on the benefits of GHG emission reduction projects.* Information of the benefits of GHG emission reduction projects is not yet disseminated to the private sector and the financial institutions e.g. banks. Profit driven private companies are not only aware but also reluctant to implement such projects. Most of these companies are not aware of the “no-regrets” projects. To alleviate this obstacle, private companies and banks should be equally informed to help the possible projects proponents obtain loans for GHG emission reduction projects.

iii) *Limited technical and institutional capacity.* For developing countries, particularly African countries, it is clear that there is limited technical and institutional capacity regarding mitigation and adaptation to climate change. Since most of technologies are manufactured outside the country, their costs are high and financial capacities are limited. Activities should focus on technical and institutional strengthening of staff and institutions involved in climate change activities. There is a need to have an elite agency to certify the inward technologies soundness or safety, replicability and economical viability. The trained expert should be kept in their job through proper incentives, job security and motivation.

iv) *Shortage of capital (financial barrier).* Due to the long-term aspects of climate change, financial capital may also be a constraint to new technology. Capital constraint is seen as the main barrier to the diffusion of environmentally sound technologies and to the achievement of high standards of technological efficiency in Tanzania (CEEST, 1996). According to FAO (1990), technology transfer in developing countries involves some 550,000 staff; most of them in public extension services, and costs about US$ 4.5 billion annually. Under the influence of structural adjustment and declining public funding, extension services have in recent years tended to shrink. Governments and international organisations have the opportunity to encourage the private sector to promote effective modalities for the access and transfer, in particular to developing countries, through grants and concessional loans. Provision of funds through multilateral and bilateral co-operation should be emphasised. Technology providers need to ensure human and financial resources to transfer technology where as technology recipients need new investments to adopt new technologies.

v) *Decline of research funds.* There is a general decline in research funds. For example; agriculture is heavily dependent on climate in developing countries, so technology transfer is crucial for climate change adaptation and mitigation.

The slow of agricultural research funding will impede the generation and transfer of technology. The trend is observed across the natural resource sectors including forestry. It has been reported that funding from the Consortium of International Agricultural Research Centers (CGIAR) has declined as follows: Between 1971 and 1982 real spending for the CGIAR grew by 14.3 per cent per year. Growth in real spending decreased to 1.4 per cent per year from 1985 to 1991. It decreased further to 0.5 per cent per year between 1991 and 1996 (IPCC, 2001). Given the time lags between initial research and development investment and diffusion of technologies, it may be several years before the effect of this slowdown becomes noticeable on the availability of new technologies, but the negative effect seen certain. International co-operation through both multilateral and bilateral, and development agencies should be emphasised.

vi) *Absence of protection for intellectual property rights (IPR); Private sector*. The worry to the private sector is about the absence of protection for intellectual property. This might be the key barrier to more private sector involvement in technology transfer. It is therefore important to adopt stricter intellectual property rights so that to encourage greater private investment in research and involvement in technology transfer to increase research funding especially in agricultural R&D. Many developed countries have adopted stricter intellectual property rights regimes for agrochemical, agricultural machinery and biological innovations. Actions to alleviate this barrier is a rationale for adopting stricter IPRs, for the purpose of enhancing research benefits and encourage greater private sector investment in agricultural R&D and greater involvement in technology transfer.

Other constraints include:-

i) Distorted prices and limited competitive pressures; and
ii) Weakness of technological structure for generating and maintaining technical change in response to price signals and competitive environment. For Tanzania, this weakness has the following important features:

iii) Limited human and organizational resources needed to plan and manage the many situations technologies are operated at sub optimal levels and usually below the design levels and standards of efficiency;
iv) Low technological capability to operate and maintain reasonable efficiency levels. It is reported that in many situations technologies are operated at sub optimal levels and usually below the design levels and standards of efficiency.
v) Lack of a system of innovation that would allow maintaining or increasing high efficiency levels through incremental technical and organizational changes.
vi) Weakness of the services-supplier network which means that the operation of technologies stall when some spare parts or after sale service are lacking.

5.5.8 Recommendation

Global surface average temperature and sea level are projected to rise under all IPPC scenarios. This will strongly affect forestry, wildlife and tourism sectors. To address the situation, among the recommendations include:

i) Whether or not there will be significant climate change, inherent climatic variability makes adaptation unavoidable. These are embedded on issues such as sustainability of land productivity, changes in erosion, degradation and environmental quality, which also require due consideration.
ii) Improved management strategies are required for coping with increasing climate variability and change. These can be drawn from traditional /indigenous and new technologies.
iii) Standardization of natural resource models for wide spread agro-meteorological application are needed, with more modelling on the rainfall distribution and commencement for the rainy season in tropical and subtropical regions.
iv) Changes in management practices and methods of microclimatic modification, for example, to cool animal environments as climate warms.
v) Development of physiological based animal models with well developed climate components are needed urgently to cover gaps in knowledge and for future projections.

vi) Improvement of carbon sequestration is required from agriculture and forestry by adopting permanent land cover, utilising conservation tillage, reducing fallow periods, incorporating rotations of forage and improving pasture management in wildlife.

5.5.9 Conclusion

The vulnerability of forest, wildlife and tourism sectors is a clear indication that climate change will have significant impacts on the socio-economic and livelihood of the populations in Tanzania. This is due to the interdependence of the local community and the nation on these sectors. Natural and human systems are expected to be exposed to climatic variations such as changes in the average, range, and variability of temperature and precipitation, as well as the frequency and severity of weather events. Systems also would be exposed to indirect effects from climate change such as sea-level rise, soil moisture changes, changes in land and water conditions, changes in frequency of fire and pest infestation, and changes in the distribution of infectious disease vectors and hosts. The sensitivity of systems to these exposures will depend on system characteristics and includes the potential for adverse and beneficial effects. The potential for a system to sustain adverse impacts is moderated by adaptive capacity. The capacity to adapt human management of systems is determined by access to resources, information and technology, skills and knowledge to use them, and the stability and effectiveness of cultural, economic, social, and governance institutions that facilitate or constraint how human systems respond.

Because of the inter-relationship between sectors, climate change impacts will have a broad impact affecting both the ecological systems and human populations. In Tanzania, the impacts of climate change are already vivid in most sectors such as agriculture, forestry, energy, tourism, water and wildlife.

There is a need, therefore, for countries to take steps to study the adaptations as well as mitigation measures that would reduce or halt some of the effects caused by climate change. Without a planned strategy to deal with climate change impacts, ecological and socio-economical deterioration will affect not only Tanzania, but the entire world. For poor countries like Tanzania whose adaptive capacity is already constrained, it is imperative to come up with feasible adaptations and mitigation measures that would deal with those effects. The NAPA in Tanzania has just set a milestone towards these processes of setting priority areas for adaptation. While priority areas have been identified, it is therefore important for the international community to support the implementation of the same.

5.6 Coastal and marine environment

It has been projected that, global warming will accelerate sea-level rise, modify ocean circulation and change marine ecosystems, with considerable socio-economic consequences (IPCC, 2007). The warming will further cause expansion of ocean waters and some melting of glaciers and ice caps in the polar countries. Some deleterious effects associated with sea-level rise in Tanzania have been pinpointed as the likelihood of inundation of low lying coastal areas, accelerated coastal erosion, changes in sediment budgets, rising water tables, saline intrusion, damage to coastal structure and loss of coastal ecosystems and has already been disastrous in different coastal areas. The following are some of the global warming deleterious effects in the regions of Dar es Salaam, Tanga, Mtwara and Zanzibar.

5.6.1 Observed Incidences of extreme weather events over the coastal areas

Hurricanes, cyclones, and El Nino/Southern Oscillation (ENSO) patterns are extreme weather events. The 1997-1998 El Niño events was one of the strongest this century and in Tanzania was associated with floods and increased sea surface temperatures. Floods caused by rains have been disastrous for Tanzania. Various media sources reported deaths and hundreds of people left homeless following heavy rains that hit Tanzania’s coastal region during the El Nino Southern Oscillation (ESO) of 1982-83 and 1997-98 events. Flooding killed more than 100 people and left 155,000 people homeless. Over 128,000 agricultural hectares was flooded, leading to food shortages (UNEP/DGIC/URT/UDSM, 2001). Floods have damaged property and roads, and blocked drainage and sewer systems. On the other hand, cyclones have not yet affected Tanzanian coastal areas. The first cyclones to hit the country were in 1872 at Zanzibar/Bagamoyo and 1952 at Lindi though they were short-lived and did not cause much damage (Talbot, 1965). Another cyclone event was in 1994 which hit Zanzibar. The ENSO event caused significant ecological, social and economic impacts to the country. Some of the associated impacts are outlined in Table 5-16.

Table 5-16: Recorded cyclones in Tanzania

Date	Event	Affected places	No. of deaths
4 April 1872	Cyclone	Zanzibar, Bagamoyo	Not specified
15 April 1952	Cyclone	Lindi, Mikindani, Mtwara	34
1989	Tropical storm	Dar es Salaam	7
August 1994	Cyclone	Zanzibar	5 (children)

Source: UNEP/DGIC/URT/UDSM, 2001

5.6.2 Rising sea surface temperatures and coral bleaching

Coral bleaching refers to the loss of the *Zooxanthellae* by the host (i.e. the coral), or the loss of photosynthetic pigments within the algae itself, which make the coral transparent. Consequently, coral colony appears white due to the underlying skeleton. Some bleaching events are reversible and do not kill corals, however, extensive bleaching can cause mass mortality of corals and local extinction of coral species. The severity of the bleaching and coral mortality in the 1998 event differed among reef sites (Table 5-17)**.** Preliminary observations indicate that coral recovery has started on some reefs. However, some coral communities indicated to be affected more than the others.

Majority of marine species have an optimal physiological temperature range. Species that find themselves outside the tolerance range are energetically challenged. Coral bleaching presents an excellent example of these. The response of corals to such stress is exacerbated by increased solar irradiance levels (IUCN, 2004). Corals are highly sensitive to temperature and can only live in water between18 to 30 ^{0}C.

Table 5-17: The extent of damage due to coral bleaching event in 1998

Area or reef	Estimate of coral damage
Tanga	25% of corals bleached
Zanzibar area	25-50% of corals bleached
Changuu and Chapwani, Zanzibar	less than 40% survival after bleaching
Bawe, Zanzibar	60-80% survival after bleaching
Chumbe, Zanzibar	80-95% of *Acropora* spp. bleached, 60-80% survival of corals after bleaching
Mafia Marine Park	80-100% coral death
Chole Bay, Mafia	100% *Acropora* death
Tutia Reef, Mafia	more than 95% coral death
MnaziBay, Mtwara	15-25% of corals bleached, with 50% survival of corals after bleaching
KinasiPass	80-90% *Acropora* death

Source: (Wilkinson, 1998).

5.6.3 Sea Level Rise

a) *Coastal erosion and damage to coastal structures/properties*

Beach (coastal) erosion has been recognised as global environmental problem. Shoreline change and associated coastal erosion is a natural process of evolution of coastal areas. It may occur on different scales of time, from a very short time of a few days, to a long time of a few decades or several centuries. Beach erosion is caused by a complex interaction of various natural processes and in most cases is intensified by human activities. The natural processes include among others: the combined action of waves, tides, winds and currents, variations in the sea level, land subsidence, and storms. Human activities that could intensify beach erosion include manipulation of hydrological cycles through mainly dam construction, coastal structures such as jetties, groynes and vertical sea walls, mining of beach sand and live coral, river-bed sand mining, destruction of protective coral reef systems, destruction of coastal vegetation and building on beaches.

In Tanzania, the shoreline is dynamic and continually changing. It is obvious that the shoreline erosion is posing threats to tourist hotels, owners and their beneficiaries in the country. Processes of erosion, sediment transport and accretion are common along many beaches of Tanzania. Coastal erosion has threatened public and private property along the shores and many beachfronts and islands now affected. It has affected several areas along the Tanzania coast (including Zanzibar), causing significant social, economic and ecological impacts (Shaghude et al., 1994). These include: loss of beaches, arable and buildable land; damages to coastal property or infrastructure; and destruction of ecologically important ecosystems. The most affected areas include Mikindani Bay (Mtwara); Lindi Bay and Kilwa Masoko (Lindi); Kunduchi (Dar es Salaam); Kigombe and Mwambani (Tanga) and Maruhubi, Jambiani, and Nungwi (Unguja – Zanzibar) and Tumbe and Kisiwa Panza (Pemba – Zanzibar). The most researched and affected beach area is the one along Kunduchi, north of Dar es Salaam. Large areas have been lost either by erosion or accretion processes. This danger threatens even the tourist industry (Nyandwi et al., 2013; and Shaghude et al., 2013). For example, Africana hotel and Rungwe Oceanic hotels in Dar es Salaam have both been first class victims of shoreline change, particularly beach erosion. A study at Kunduchi-Manyema Creek by Makota *et al*. (2004) indicated that more erosion takes place in the northern part of the creek while deposition/accretion takes place in the southern part. This study further indicates some of the existed groins have been washed away and others stand far from the current shoreline. It is obvious that erosion removed the mangroves on the southwest side in which between 1981 and 1992 about 1 Acre of mangrove was washed away along the riverside near the river mouth at Kunduchi-Manyema creek.

b) Loss of coastal ecosystems and the associated habitats

In Tanzania, sea-level rise will have the most significant impact on coastal natural resources. Wave surge currents weaken the coastline and uproot coastal mangroves, which stabilize the shoreline. Excessive siltation and sedimentation occurs when there is deforestation as is the case for mangrove clear felling and cutting. In Tanzania sea-grass beds have been affected by many factors one of these being effects of sedimentation, which increase turbidity and reduce light penetration (Wells *et al*., 2003). Siltation and sedimentation mainly occur during heavy rains and monsoons. An excess of sediment can cover the aerial roots of mangroves (which are used for respiration) or change the water balance. This alteration in normal salt concentration can kill mangroves (Talbot and Wilkinson, 2001). The study by Wang *et. al.* (2003) indicated a decline in mangrove cover in some coastal districts on the mainland Tanzania between 1990 and 2000 which was attributed to erosion (Table 5-18).

Furthermore, a change in fish species composition can be attributed to siltation. For example, in the small pelagic fisheries of Zanzibar, the catch drastically declined from 600 t in 1986 to 91 t in 1997; and a drastic decline of sea cucumbers throughout the inshore waters of United Republic of Tanzania following the El-NINO (Whitney *et al*., 2003). Bwathondi *et al*. (2002) reported a decrease in prawn catch as in early 1988 where 13 trawlers were landing about 2000 t unlike now 25 trawlers are currently landing half of 2000. If this were to happen on a larger scale, fisheries would therefore be affected by changes in the breeding and migratory habits of most fish which causes year-to-year variability of stocks. This could further lead to planning and management problems. It has also been suggested that fishing yields will be reduced as reef viability decreases, leading to reduced yields of protein for the dependent human population.

Table 5-18: Comparison of mangrove areas between 1990 and 2000

Coastal Districts	**1990 Mangroves**		**2000 Mangroves**	
	Mangrove Vegetation	**If salt crust Areas added**	**Mangrove Vegetation**	**If salt crust areas added**
Tanga and Muheza	9,434	9438	9,662	9,662
Pangani	4,003	4,003	5,429	5,429
Bagamoyo	2,516	5,327	6,948	6,948
Dar es Salaam	2,494	2,494	2,516	5,327
Kisarawe	4,159	4261	4,092	4,167
Rufiji	49,799	50968	48,030	50,391
Kilwa	21,826	22,546	115,590	22,552
Lindi	4,034	4,055	4,044	4,065
Mtwara	9,226	9,409	9,458	9,860
Total	110,302	112,501	111,934	21,755

Source: Wang *et al*., 2003.

c) Submergence of coastal Islands

Maziwe Island situated 50 km south of Tanga and about 8km southeast of the mouth of the Pangani River completely disappeared in 1978. The island was originally famous for being the most important nesting ground in East Africa for three endangered marine turtles (olive ridley turtle, green turtle and hawksbill turtle). The entire island was submerged in 1978 as the Casuarina trees, which were common in the island, were uprooted following the disappearance of the turtles in 1960 to 1977. It was believed that, sea level rise was the main cause for the disappearance of this island (Fay, 1992). Although the study of Shaghude (2004) revealed that the island disappeared due to wave erosion after human clearance of the casuarina trees which used to protect the island.

d) Inundation of low-lying coastal areas

Inundation of low-lying coastal area has proven to have tremendous effect worldwide. Global climate change is likely to increase the strength and frequency of tropical storms. There are specific areas along the Tanzanian coast which would be most vulnerable by storm surge including Moa (Tanga region), Salale and Mbwera (Dar es Salaam/Coast Region), Nangurukuru and Mnazi bay (Mtwara and Lindi) (URT, 2003). In these areas, mangroves seem to be the most vulnerable resources followed by sand and mud flats. For the case of Zanzibar, it is projected that a sea level rise of 5 m would lead to a total loss of low-lying coastal areas of about 328 km^2 in Unguja and 286 km^2 in Pemba, which is equivalent to 19.7% and 28.9% of the total areas of Unguja and Pemba, respectively (Watkiss *et al.,* 2012). Currently, the percentage of populations living in these low-lying coastal areas are 29% for Unguja and 54% for Pemba, suggesting that a high proportion of the population and assets would be at risk.

e) Salt water intrusion

Sea level rise would cause salt-water intrusion in Tanzania's aquifers and deltas like the Rufiji. For example, Kasonta and Anthony (1999), upon groundwater investigation in Dar es Salaam city, found salt-water intrusion after values of less than 1-Ohm m of resistivity. Saline intrusion to ground water was even found around Zanzibar and perched aquifers which are relied upon as the main source of portable water. This is considered to be a natural phenomenon (Guard et al., 2004). During dry periods, the perched aquifer is separated from the supply wells that intersect the deeper contaminated aquifer. Increased water abstraction by the expanding population has led reporting of the increased salinity in water supplies by the Ministry of Water.

f) Changes in sediment budgets

Sediment budget is a concept that applies to sandy and muddy shores. It is only one of three factors (sediment budget, sea level and wave energy) that control most land loss. Sediment budget refers to the balance between sediment added to and removed from the coastal system; in this respect the coastal sediment budget is like a bank account. When more material is added than is removed, there is a surplus of sediment and the shore builds seaward. On the other hand, when more material is removed than is added, there is a deficit in sediment supply and the shore retreats landward. Coastal erosion is a physical expression of a deficit in the sediment budget where near shore processes remove more material from the shore than is added. The phenomenon quite agrees with the recent findings of shoreline erosion and accretion at Kunduchi - Manyema Creek in Dar es Salaam, which was attributed to natural processes or human activities. Upland sand mining activities often result in reduced sediment loading on beaches. This in turn, results in increased shoreline erosion, which puts at risk hotels being built along the coastline. Also, rivers and near shore currents, that transport sand onshore from the continental shelf, deliver sand directly to the beach. Humans have also contributed significantly to the deficit in sediment supply by damming rivers, building seawalls, groins, and jetties, and dredging tidal inlets. These natural and artificial reductions in coastal sediment supply have resulted in the erosion of many beaches, barrier islands, and deltas. Today the only remaining source of sediment for many coastal compartments is local erosion of nearby beaches and bluffs.

5.6.4 Current Analysis and Approach

Vulnerability and adaptation was assessed for Dar es Salaam, Tanga, Mtwara and Zanzibar. Assessment in Dar es Salaam and Zanzibar was for the second time therefore this assessment was based on the previous assessment done in 1998 as reported in Mwandosya *et al* (1998). Assessment in Tanga and Mtwara areas was done for the first time. In Dar es Salaam, the vulnerability and adaptation was verified by using both the analytical and Brunn Rule approaches. The area covered was from Ras Kiromoni to Mji Mwema i.e., the whole Dar es Salaam coastline. Analytical approach was applied in Tanga, Mtwara region and Zanzibar. The area covered was from 1 km north of the harbour/port to 1km south of the port. The whole coastline of Zanzibar Island was considered.

a) Coastal Characteristics

The coastal characteristics along the coastline were identified by using detailed topographic maps available. Assessment of mangrove forests, swamps, corals, seasonal swamps, cliffs, sand/mudflats, woodland, thicket, sisal estates, cashew-nuts, infrastructure, etc was conducted.

b) Analytical Approach

Topographic maps of 2 metres and 20 metres contour intervals were used to estimate the loss of coastal area and infrastructure in all the selected areas (Dar, Tanga, Mtwara and Zanzibar). This was done by considering first order approximations where the land is assumed to rise linearly from the sea level to the 2 metres and 20 metres contour intervals and approximation of the 1 metre, and 0.5 metres contours and their respective area coverage is made. The areas have an error of 5%.

c) Sea level Rise Scenarios

The global sea level rise scenarios that have been widely adopted (IPCC, 1990) was be used in the study. The scenarios of eustatic sea level rise are 0.5 m and 1.0 m per century has been applied to study the selected areas of the coastline of Tanzania. Future erosion rates or land loss estimates was projected using Bruun Rule (Bruun, 1962; and Hands (1983) in response to global warming and accelerated sea level rise of 1 m to about 9 m km^2. The ground truthing was conducted for Dar es Salaam, Tanga, Mtwara and Zanzibar to help reveal the characteristics of the coastlines if they consist of erodible materials, hard rock, sand, mangroves, tourist hotels, populated areas, urban areas etc. This ground truthing exercise made several visits to various representative coastal types (hard rock, sand, muddy etc). Interview with local communities was also conducted. Topographic information together with information concerning land property values, buildings, agriculture, future plans for development, etc was recorded. Land loss estimate due to erosion caused by sea level rise was applied by Bruun Rule (Bruun, 1962 given by Hands, 1983) for Dar es Salaam only. Other parts (Tanga, Mtwara and Zanzibar) were assessed by analytical approach.

5.6.5 Adaptation options and Cost Implications

In Tanzania, efforts have been made towards management options to produce guidelines and reports (Kunduchi Beach Erosion Monitoring Committee, 1987; Kairu and Nyandwi, 2000; Mwandosya *et al*., 1998; Francis *et al*., 2003; and URT, 2003). Following the United Nations Framework Convention on Climate Change (UNFCCC) Technical Paper on Coastal Adaptation Technologies (FCCC/TP/I/1999), a number of strategies and adaptation options have been put forward. This is supported by the in-depth report on technology needs assessment (URT, 2010). Moreover, the technology needs assessment reports identified all types of technologies, gaps, cost implications and suggested recommendations for the specific sector. Other guidelines and reports covered structural methodology for assessment of impacts and addressed both immediate and long-term information and technological needs. Adaptation measures addressed were those which enforce protection and conservation of coastal and marine areas. These measures were classified as (1) “managed retreat”- the abandonment of the land and structures in vulnerable areas and the resettlement of inhabitants (2) “accommodation”- the continued occupation and use of vulnerable areas which may involve changes in land use and (3) “protection”- building of a barrier wall around the vulnerable areas, whereas this option was identified as the most favoured measure in coastal areas and it is comprised of a variety of options as illustrated by Hansen (2003). Apart from adaptation options, policy issues are key to management and conservation of coastal resources and also development of the technologies. Several key policy issues are outlined below.

The damage and loss can be extremely expensive, for example, along the Dar es Salaam coastline the estimated loss of important structures is about 49.83 billion and 85.97 billion Tanzanian Shillings for a sea level rise of 0.5 m and 1.0 m respectively (URT, 2003). This therefore, translates into loss of property worth millions of Tanzanian shillings including reduced employment opportunities, decrease in revenue to the government, and decrease in market for the fishermen.

5.6.6 Policies, strategies and measures that are key to the adaptation options

Legal and institutional frameworks are among the important mechanisms in deterring the degradation of the coastal and marine environment. Effective implementation of policies at the national level largely depends on effective institutional mechanisms. Different management responses have been or are being undertaken in management of coastal and marine resource and therefore coastal tourism in Tanzania. These include traditional management systems, enforcement of policies and laws through regulatory mechanisms such as collaborative management arrangements, and conservation initiatives by private sector.

A number of environmental regulations exist in Tanzania. Such efforts notwithstanding, serious gaps remain in policy, law and practice. There is also a shortage of reliable information to guide implementation of both policy and legislation. However, previous experiences clearly show that enacting environmental laws with the accompanying penalties is one thing, enforcing and implementing them is another. More often than not, the problem lies in enforcement. Limited financial and human resources, lack of technological capacity as well as the practical problems of administering environmental regulations are the main factors contributing to weak enforcement. Also there has been minimum translation of the national legislation dealing with coastal and marine environment to district and local levels. An attempt has been made in translating laws related to agriculture, land use planning and forestry. By-laws exist at district level in the named sectors but these are very few.

5.6.7 Conclusions and Recommendations

Many sector policies recognize the need for a participatory resource management approach to resolve issues and take advantage of development opportunities. Some policies and strategies, however, address the need to develop technologies and adapt the existing ones to conserve resources, and to develop a scientific knowledge for understanding ozone layer depletion and other components of the stratosphere that are detrimental to public health and the environment. Others do address climate change, based on socio-economic and sustainable development which need not be pursued at the expense of the environment. Legislation, coastal related sector policies and other regulatory frameworks including the mangrove management plans need to be assessed and improved to reflect the problems encountered today.

This lies to the fact that, managing coastal and marine resources will minimize impacts caused by climate change and also safe guard the tourism sector and life of coastal communities. In fact, the complex ecology of coastal and marine ecosystems is well appreciated but not fully understood by the public or decision-makers. Considering this fact, the coastal ecosystems will continue to be vulnerable to rising temperatures and changing sea levels. Also monitoring of individual sites to determine what strategies to be implemented; legislation, coastal sector policies and other regulatory frameworks including the mangrove management plans need to be assessed improved and /or implemented to reflect the problems encountered today; gaps existing in these policies need to be restructured to cover components like awareness on climate change, training and human capacity building, establishment of climate related software, libraries and data banks and research development is important towards identification of species that are adaptable to climate change. Local participation and management of coastal and marine resources is emphasized as it will contribute positively towards economic and social development.

6. TECHNOLOGICAL AND OTHER OPTIONS FOR GREENHOUSE GAS MITIGATION

A number of technological and other options for the mitigation of greenhouse gases in Tanzania have been identified in various sectors including energy, forestry and land-use, agriculture and livestock, industry, household energy use and transport. This chapter looks into the assessment of the GHG mitigation options in the various sectors. Table 6-1 summarizes the GHG mitigation options for Tanzania.

6.1 Greenhouse Gas Mitigation in the Energy Sector

Based on literature survey, expert judgement and experience and the limited consultation with stakeholders, in a nutshell the identified energy sector related greenhouse gases' mitigation options include the following:

i) Efficiency improvement of existing energy systems including retrofitting thermal power plants, use of efficient wood, charcoal stoves and electric cookers, efficient charcoal production and efficient bio-waste stoves, boilers and furnaces;
ii) Enhanced deployment of renewable energy technologies such as biomass co-generation using bagasse and saw dust or wood waste, poly-generation, geothermal, biomass briquetting, biogas from animal waste, bio-latrine, sisal waste and municipal waste, biomass gasification, alcohol form ethanol and methanol, biodiesel, solar, and wind. Appropriate use of non renewable such as Fossils fuel(natural gas and coal);
iii) Energy efficiency and conservation by applying cleaner energy technologies and techniques in all sectors of economy including industries and households and
iv) Power trading with neighbouring countries to allow for optimised use of electricity. Fuel switching to alternative environment benign energy resources; and
v) Energy pricing with due regard to social and environmental costs including the application incentives to encourage effective energy use.

6.2 GHG Mitigation Options in Waste Management

Four greenhouse gases mitigation options were considered for Tanzania waste sector. They include landfill gas capture, incineration, composting, and anaerobic digestion. The maximum technical potential for mitigating the greenhouse gases by the technologies are evaluated and compared and thus forming the basis for their choice for application.

a) Landfill Gas Capture

By capturing the landfill gas, which contains a large proportion of methane offers both environmental and economic benefits. The captured gas can thereafter be combusted for providing thermal or electrical energy. Available capturing technologies can achieve an efficiency of about 60% of the generated landfill gas.

Time series on the extent of landfill gas recovery from Tanzania municipal solid waste dumpsites is shown in Figure 6-1.

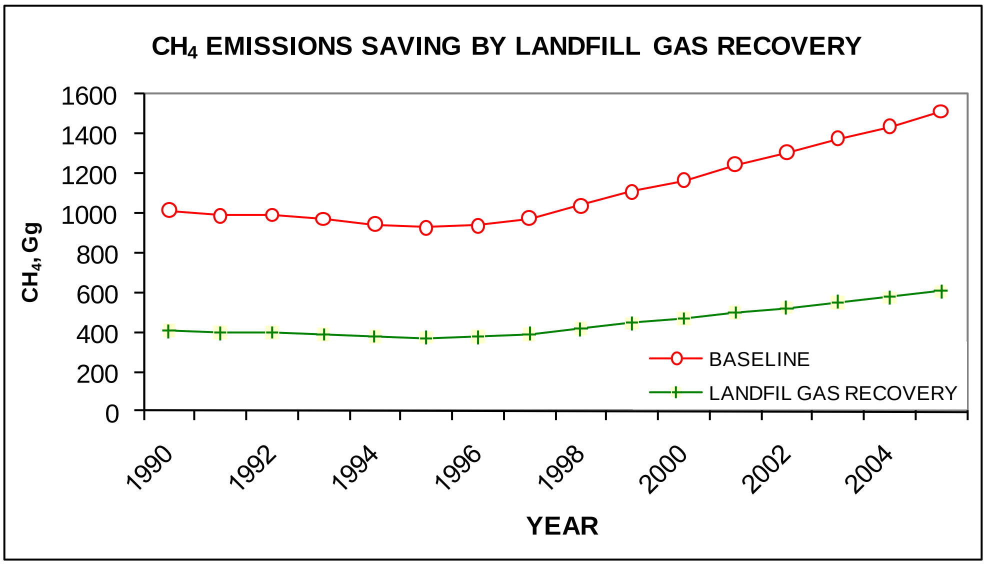


Figure 6-1: Landfill gas recovery time series

b) Incineration

Estimation of greenhouse gases emissions mitigation by incinerating the waste was done according to the IPCC 2006 guidelines. Figure 6-2 shows that a tremendous

CO_2 (equivalent) reduction is achieved by incinerating the municipal waste. This is because incineration avoids the production of methane, which has a high global warming potential. Though incineration produces other emissions like N_2O (Figure 6-3), it results in mitigating over 97% of the CO_2 emissions.

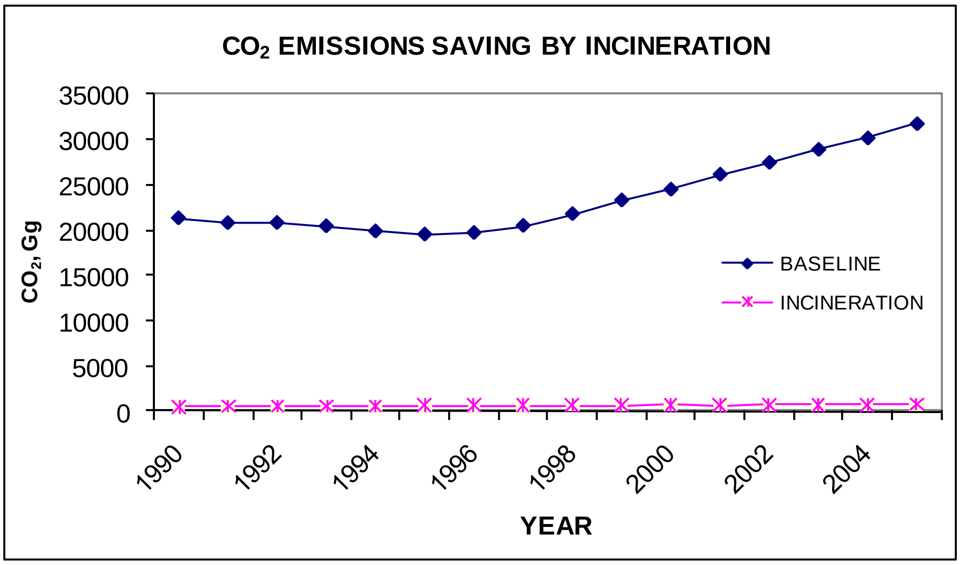


Figure 6-2: CO_2 mitigation through waste incineration

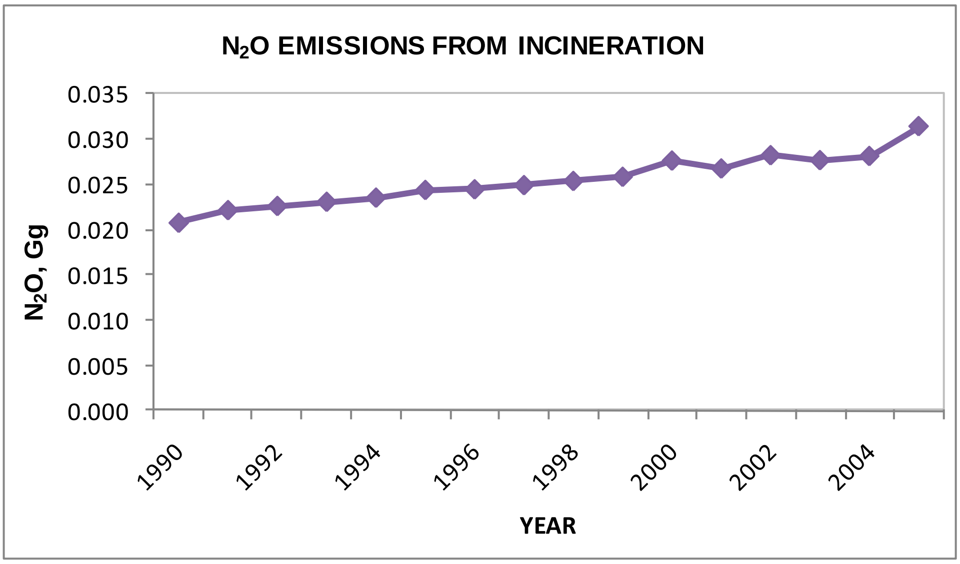


Figure 6-3: N_2O emissions from waste incineration

c) Composting

Compared to the baseline CH_4 emissions presented in Figure 6-4, composting offers an opportunity of mitigating over 99% of methane gases. Gas leakage from the compost is the main contributor to the final CH_4 emissions.

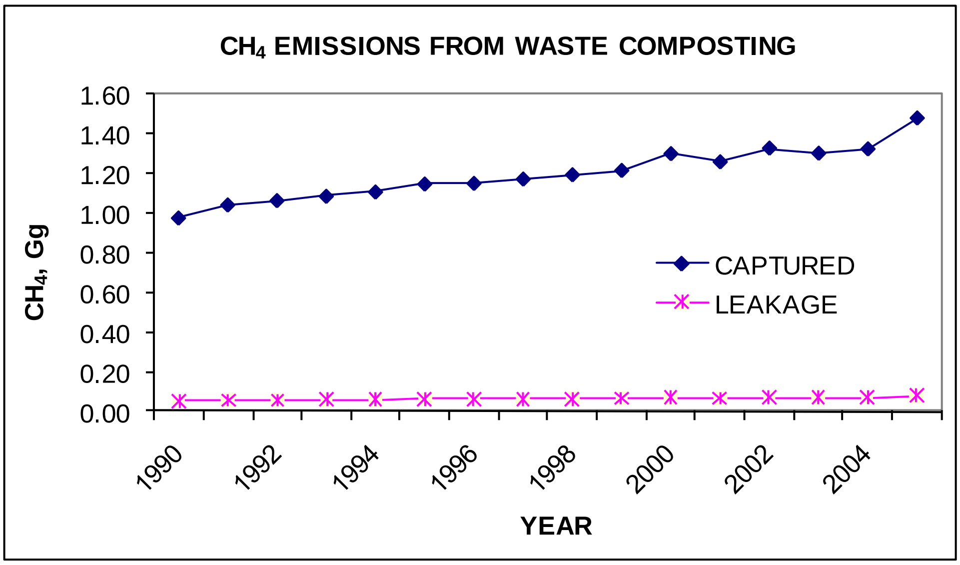


Figure 6-4: Methane emissions from composting

d) Anaerobic Digestion

Besides the high methane savings from anaerobic composting (over 99% CH_4 reduction), the process also offers nearly negligible N_2O emissions. Furthermore, the process produces effluents that can be used to stabilize and maintain soil fertility.

6.3 Greenhouse Gas Mitigation Technologies for the Transport sector

Mitigation technologies for the transport sector can be grouped into 4 main categories. These are vehicle technology improvement, fuel technology improvement, fuel substitution and infrastructure and system changes. The first three measures, which base on efficiency improvement and fuel substitution are said to have more impact on greenhouse gases mitigation compared to measures that are addressing travel demand (Patterson, 1999; and Yoshida *et al*., 2000).

a) Vehicle technology improvement

Contemporary vehicle technology, which is associated with electromechanical control, is geared towards fuel economy while achieving pollution reduction. Some of these technologies include: -

- Lean burn engines
- Exhaust gas recirculation (EGR)
- Light weight materials
- Exhaust after treatment devices

b) Fuel technology improvement

Improving gasoline and diesel fuel result in improved performance with reduced emissions. Methanol can be blended with gasoline in the ratio of 85 to 15 to form a fuel known as M85 and similarly, E85 is a blend of ethanol with gasoline. Such fuels are effective in reducing emissions of smog-forming volatile organic compounds.

On the other hand, low sulphur gasoline and diesel fuels reduce sulphur oxide emissions from vehicles. Unleaded gasoline has the ultimate effect of reducing the risks of brain, kidney and the central nervous system damage caused by lead.

c) Fuel substitution

Alternative fuels for motor vehicles such as natural gas, hydrogen, solar, biofuel and electricity have a number of inherent properties that make them cleaner than conventional petroleum fuels. These fuels emit less hydrocarbons, and the emitted hydrocarbons are less reactive (slower to form ozone) and less toxic.

Apart from reduced emissions, these fuels increase the use of natural resources from the localities they are found and are therefore potential for socio economic development.

d) Transport infrastructure and system changes

Transport infrastructure and system changes include the following:-

i) Use of Mass Transit where increasing use of public transport is an effective means of achieving significant energy savings and environmental gains. This can be achieved without putting much pressure on the scarce resources. Travel by public transportation will produce, on average, 95% less carbon monoxide, 90% less volatile organic compounds, and about 45% less carbon dioxide and nitrogen oxide, per passenger per kilometre. People will embark on the public transport given the system is reliable and efficient.

ii) Improving roads condition affects the operating characteristics of motor vehicles by influencing the speed of travel and rolling resistance. A wider road allows a free flow of vehicle fleet whereas narrow ones reduce speed limits with a danger of congestion. To ease traffic flow road capacity need be increased to meet the volume. This involves introducing flyovers at critical intersections, widening roads, improving functions, linking roads and providing sidewalks. Road signs and lane marking is necessary for directing traffic flow whose absence may result in unnecessary jams.

iii) Traffic management techniques are developed at a local level aiming at addressing economic, social and environmental priorities. In a long run they are important strategies for GHGs mitigation in the transport sector. Some of these techniques are: -

(a) Computerized and linked traffic signals;

(b) One way streets;

(c) Improved facilities and layout in favour of pedestrians, cyclists, and public transport (exclusive bus lanes);

6.4 Greenhouse gas mitigation in the industry sector

6.4.1 Cement Industry

Cement manufacturing is a highly energy-intensive process. During the production of cement, CO_2 is generated from three sources:

- Combustion of fuel in the kiln, to maintain the required kiln temperature;
- Decarbonation of limestone within the kiln; and
- Indirectly from the use of electricity in installations such as grinding mill.

Of the three sources, the decarbonation of limestone generates the greater proportion (60%) of the CO_2 emissions liberated from the kiln. Emissions of CO_2 from cement kilns are closely linked with both the process and energy efficiency. Approximately 51% of the CO_2 comes from the limestone, 37% comes from fuel used in the combustion process, and 12% is related to electricity use. About 0.8 tonnes of CO_2 are released for each tonne of cement produced.

A summary of technologies and measures that can be adopted in cement industry to limit or reduce greenhouse gas emissions is provided hereunder.

a) Fuel switching

A reduction of up to 18% in CO_2 emissions can be realized by switching over to natural gas. Switching to a fuel with lower carbon content will reduce emissions of CO_2 but may involve a structural change in the energy supply system. The cost of retrofitting is about US$ 750 per GJ of energy (CEEST, 1997).

b) CO_2 recovery system

This option involves recovering CO_2 from the flue gases during or after the production process. Typical concentrations of CO_2 in the flue gases may reach up to 18% (CEEST, 1997). When gas recovery system is installed it reduces the amount of CO_2 emitted to large extent. A preliminary calculation indicates that a reduction of about 65% in CO_2 emission would be possible. It is expensive because of high dust load in flue gases. The cost for installing CO_2 recovery system if natural gas is the primary fuel is US$ 760 per GJ. Uses of the recovered CO_2 include: use in food processing (carbonated soft drinks and carbonated alcoholic beverages); oil field tertiary enhanced oil recovery; use as pure CO_2 gas; and use in fire extinguisher.

c) Waste-derived alternative fuels

An important opportunity to reduce the CO_2 emission is the application of waste-derived alternative fuels. Types of alternative fuels include: Gaseous alternative fuels (Coke oven gases, refinery gases, pyrolysis gas, landfill gas and natural gas); Liquid alternative fuels (Halogen-free spend solvents, mineral oils, distillation residues, hydraulic oils, insulating oils); and solid alternative fuels (Waste wood, dried sewage sludge, plastic, agricultural residues, tyres, petroleum coke, tar). The use of waste-derived fuels in the cement industries is a feasible alternative and is practical, with potential to reduce CO_2 emissions by 20 to 40% (CEEST, 1997; Hendriks *et al,* 1998).

d) Production of blended cements

The production of clinker is the most energy-intensive step in the cement manufacturing process and causes large process emissions of CO_2. One of the options is to replace a portion of the clinker with industrial by-products such as coal fly ash (a residue from coal burning) or blast furnace slag (a residue from iron-making), or other pozzolanic materials (e.g. volcanic material). This reduces the amount of fuel used for calcinations and the amount of lime per a given quantity of cement production rate. The potential for reducing CO_2 emissions through production of blended cement is estimated to be 20% (Freund, 2001; and Gale *et al,* 2001).

The potential for application of blended cements depends on the availability of blending materials, and on standards and legislative requirements.

e) Recovery of waste heat for co-generation

Cement production processes generate large amounts of waste energy that simply pass out of plant stacks and into the atmosphere hence lost. Therefore, waste heat recovery offers a great opportunity to productively use this energy, reducing overall plant energy consumption and greenhouse gas emissions. Common methods of recovering heat include direct heat recovery to the process, recuperators/regenerators, and waste heat boilers. This option is feasible but needs resetting most of the downstream equipment and thus costly. Recovery of waste heat, including co-generation, has a payback period of up to 3 years.

The amounts of CO_2 emissions from the flue gases for two cement industries in Tanzania are about 18% v/v and 13.5%v/v. These values are within suitable range for CO_2 recovery, however, feasibility studies are needed to provide convincing basis for adopting this option Gaseous emissions originating from the cement manufacturing process are to a large extent determined by the characteristics of the available raw materials.

6.4.2 Beer Brewing Industry

The GHG emissions from beer brewing industry are produced directly during production process and indirectly due to electricity consumption. However, the CO_2 from the production process is utilized in a closed cycle, therefore the focus here is on the energy-related CO_2 emissions only primarily due to electricity and fuel consumption. The sources of GHG emissions that are energy related may include:

a) Energy inefficiency and poor power factor in the process chain; and
b) Fuel combustion in boiler to generate steam as well as its poor efficiency

The following mitigation options are recommended for adoption in breweries to minimize generation of GHGs:

a) Fuel switching

Use of alternative energy sources that can result in less GHG emissions provides a useful option. This includes use of natural gas, solar and wind energy *b) Wort boiling using thermal vapour recompression*

Thermal vapor recompression is an established technology for reducing energy costs in evaporation. In thermal vapor recompression, a portion of the evaporated water vapor is compressed by high-pressure steam and reused. The wort expands in the kettle at 100°C. Vapor-condensate is collected in the condensate tank and the heat (used to preheat water) is recovered through a plate heat exchanger. These systems work best when operating under constant running conditions for long periods.

c) Wort boiling using mechanical vapor recompression

Vapor recompression is an established technology to reduce energy costs for evaporation. In a vapor recompression system, the wort is boiled to 102°C externally using compressed vapours up to 1.25 bar. The wort expands in the kettle at 100°C. Vapor condensate is collected in the condensate tank and the heat (used to preheat water) is recovered through a plate heat exchanger. Mechanical vapor recompression (MVR) systems can achieve energy savings because the generated useful heat contains more energy than the electricity required to compress the steam. MVR systems work best when operating constantly for long periods.

A reduction in evaporation requirements can be achieved from 9.9% for conventional boiling to 8.7% for MVR. In MVR the evaporator is generally more costly than in thermal vapor recompression, but has significant lower operating costs. Estimates for operating costs are around 2-7% of the investment costs.

d) Brewing at high specific gravity

Specific gravity is the “heaviness” of a substance compared to water. Beer may be brewed at a higher specific gravity and diluted with water after final filtration to bring it to the desired alcohol concentration. Estimates of energy savings vary between 18% and 30% in the brew-house. High gravity brewing can defer capital expenditures, may increase brewing capacity and improve product quality (although the impact on flavour is an obvious concern) and reduce water use. Disadvantages, in addition to possible flavour changes, include decreased brew house material efficiency and reduced kettle hop utilization. However because of the many additional benefits that accompanies this option, payback period can be rapid.

e) Low pressure wort boiling

In low pressure wort boiling, the boiling vessel is designed for a maximum operation pressure of 0.6 bar, which corresponds to a temperature of 113°C. Lower temperatures and pressures are also used. In brew houses with large cast wort quantities (e.g. 8-12 brews/day), investment in these systems becomes more cost-effective. Steam consumption is estimated to range from 26-28 kBtu/barrel cast wort for mashing and boiling. Compared to conventional systems, fuel savings range from 43 to 54%, depending on the amount of evaporation. Electricity use, however, doubles for these systems to 0.02 kWh/hl from 0.01 kWh/hl.

f) Wort stripping systems

This is a modification of the wort boiling system into two-part system. In the first phase, wort is kept at wort boiling temperature in a conventional kettle without significant evaporation. In the second phase, after clarification and before wort cooling, the wort is sent to a wort stripping column. In counter flow with the falling wort, live steam is injected at a flow rate of 0.5-2.0% of the wort flow rate. Total evaporation of the wort is generally kept below 2% of the total wort volume while cooking time of the wort is reduced from 65 to 40 minutes with no changes in colour, foam stability or flavour. The system has significant reductions in evaporation requirements accounting for energy savings of 46%.

g) Emerging CO_2 recovery systems

In the fermentation process, the yeast feeds on the wort to produce carbon dioxide and alcohol. This carbon dioxide can be recovered with closed fermentation tanks and used later in the carbonation process. The fermentation process generates about 3-4 kg CO_2/hl. Typical CO_2 scrubber operations require 2 kg of water per kg of carbon dioxide.

Of recent a new CO_2 recovery system has been designed that combines the dryer and deodorizer tower, which could be applicable for medium and large breweries. The new systems reduces water consumption by 50% for the scrubbing systems, requires less capital and have much lower Operation & Maintenance costs although, payback period based on energy savings are greater than three years compared to older technology.

h) Flue gas heat recovery

Heat from boiler flue gasses can be used to preheat boiler feed water in an economizer or to preheat boiler air intake. However, this measure is fairly common in large boilers. As a rule of thumb, 1% of fuel use is saved for every 20-25°C reduction in exhaust gas temperature. Capital costs for such systems are likely to have a payback greater than 3 years (Galitsky *et al,* 2003)

i) Combined Heat and Power (CHP) or Co-generation

For industries such as breweries that have process heat/steam or cooling and electricity requirements, the use of combined heat and power systems can be an important energy efficiency measure as well as reduction of pollution. A thermal to electric ratio of 2:1 is typically a good candidate for CHP. CHP is most likely to be economically viable when a unit can run at full load for at least 5,000 hours annually (Galitsky *et al,* 2003). Waste heat exhaust from CHP systems can be used to operate cooling systems. A study of the application of a CHP absorption cooling system to cooling spaces found a payback period of 4.5 years (Galitsky *et al,* 2003).

j) Power factor correction

Application of recommended power factor reduces GHG emission that may arise from thermal production as additional power to fill the gap. Poor power factor and use of inefficient motors have been cited to be a common practice in Tanzanian industries (CEEST, 1996). The desirable power factor is 0.9, however, previous studies by TIRDO indicated that the power factor in most of the Dar es Salaam industries is between 0.76 and 0.94.

k) Use of Efficient motors

Electrical motors are used in industrial applications such as pumps, compressors, fans, and blowers, agitators crushers, pulverize, and conveyors. If motors are oversized as the case in most industries they operate at lower efficiency than expected. Since electric motors comprise a single relatively homogenous end-use category, small amount of savings results in significant energy conservation within the industrial sector. Replacing these motors with efficient ones will result in significant energy savings and reduced CO_2 emissions.

6.5 GHG Mitigation in the Forestry Sector

The objective of mitigation measure is to attempt a gradual reversal of the effects caused by increased CO_2 concentration, primarily through a more effective Carbon sequestration. Table 6-1 indicates some forest disturbances that contribute to reduced sequestration capacity

Table 6-1: Forest disturbance by zones during 5-years period (2005/07-2010/12)

Forest disturbance	Eastern	Southern	Southern Highlands	Central	Lake	Western	Northern
Fire	23%	19%	19%	15%	8%	30%	6%
Disease	2%	3%	1%	1%	1%	5%	4%
Lumbering	16%	13%	11%	22%	7%	22%	4%
Encroachment	13%	9%	9%	26%	9%	27%	3%
Grazing	9%	2%	14%	31%	15%	28%	9%
Charcoal making	17%	7%	9%	32%	16%	21%	9%
Other	8%	4%	4%	10%	3%	8%	2%

Source: URT, 2013b

In Tanzania the GHG emission analysis in forestry sector suggests a number of ways in which the sustainable management of forest resources can be achieved (URT, 2003). The suggested ways are grouped into two categories as follows:

- Interventions that would create public good; such as forest protection and conservation; conservation activities which create private good e.g.

steep slope farming and tree cutting restrictions in private farms, or a combination of both public and private good.

- The establishment and management of forest plantations including the sustainable harvesting of the forestry products, timber or inputs for bio-energy production.

Apart from two categories identified above, Tanzania National Forest Policy and National Forest Programme have been reviewed in view of adapting REDD+ as a mitigation and adaptation measures.

Potential forestry projects/forests that would lead to CO_2 sequestration from the basis of the forestry mitigation assessment have been identified. These include:

i) Commercial/industrial forest plantation e.g. Sao Hill Forest;
ii) Extension and replanting of other industrial forest plantations;
iii) Small holder or village tree growing for multiple purposes;
iv) Natural/catchment forest protection; and
v) Bio-energy from forest waste.

Other related mitigation measures proposed are as follows:

a) Reforesting immediately after harvest.

This measure has several features. First, the forest coverage should be restored to every surface that was previously covered by forest, after harvest, to maintain an active and almost continued Carbon sequestration function. Secondly, from the Carbon sequestration view point, this is an occasion when the forest composition can change by introducing new species that may be better adapted to changes in ecological conditions. In this case, priority has to be given to species and silvicultural methods that will result in productive new forests, therefore having high sequestration efficiency. Thirdly, reforesting immediately avoids long interval with the forest soil exposed, which could result in decomposition of soil organic matter with the area becoming a CO_2 source.

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b) Restoring the productive forest cover

This relates to bare areas that can sustain, and have sustained forest production, thus re-establishing the CO_2 sink function, as well as stopping erosion, where it is a problem. In many forest zones, large areas exist where the forest has been harvested, but, for various reasons, regeneration did not succeed. Such areas have been degraded, or are simply abandoned and bear some pioneer, low-productivity forest types, with marginal agricultural use. . In terms of land area, this is probably the largest area on the planet that could be covered with active CO_2 retrievers, estimated at over 200 million hectares (Papadopol, 2001).

c) Expanding existing forest carbon sink

It is believed that large areas of forest at all latitudes are not storing carbon at their potential. This is due to activities such as grading which is repeatedly applied to the forests, resulting in secondary forests. Forests could sequester considerably more carbon in future decades, especially if management practices to expand forest sink would be applied, thus favouring soil carbon pools such as:

i) reforesting to arrest erosion;
ii) adding chemical amendments to boost fertility;
iii) reducing shifting cultivation;
iv) reforesting marginal agricultural lands, and
v) retaining litter/debris after logging operations.

In the special cases of poor soils, intensive management practices (soil preparation, weed control and fertilization) can increase greatly the carbon storage in timber biomass and soils, either directly or by shortening the rotation. Measures such as improving soil fertility by the application of nitrogen fertilizers may expand the pool of carbon in forest soils, provided the carbon costs of fertilizer production do not exceed the gain in soil organic matter (Papadopol, 2001). Comparing with natural regeneration, this practice implies additional costs, or can have secondary effects such as leaching fertilizers/pesticides to groundwater or other water courses.

d) Establishing new plantations

Establishing plantations of productive species, including mono-species, industrial plantations, managed on the basis of economic principles, on all suitable sites will satisfy both the requirements of traditional timber-related industries, especially for pulpwood and the CO_2 retrieval function.

It was reported by McCarl *et al.,* (2001) that afforestation and timber Management and grassland conversion can contribute to CO_2 emissions reduction Forest based carbon sequestration can be stimulated by afforestation of agricultural lands, increasing rotation length, or changing management intensity through improved silvicultural practices. Revision of cropland back to grassland generally increases soil carbon and, in addition, affects nitrous oxide emission by displacing fertilizer used in crop production.

e) Shifting species

Based on various studies carried out in Tanzania, there will be changes in forests types, species and distribution as CO_2 in the atmosphere doubles (URT, 2003). Studies from other parts of the world indicate that some plant ranges could shift naturally by as much as 500 to 1000 km during the next 200 to 500 years (Papadopol, 2001).

f) Replacing drought sensitive species

The GCMs predict potential consequences of climate warming, some of the most important affecting the water cycle. Annual temperature will increase in different parts on Tanzania ranging from 2.1°C to 4°C. The scenario also indicates that there will be increased rainfall in some parts while other parts will experience decreased rainfall. In areas experiencing decreased rainfall, drought sensitive species will be replaced with drought resistant species so as to keep the carbon sink.

g) Substituting wood fuels for fossil fuel

Substitution of a renewable resource, biomass energy for fossil fuel combustion is very rewarding in terms of carbon conservation. This measure does not change the carbon balance in the atmosphere, since CO_2 released from burning wood or biofuels is cycled back to forest biomass through photosynthesis. Short-rotation woody crops have the greatest potential in this case. The productivity of the specialised crops can be further enhanced using the latest genetic progress related to fast growing species, particularly Eucalypts *(Eucalyptus spp.).*

h) Increasing protection measures

It is a known fact that the population dynamics of potential insect pests are highly dependent on temperature. Insect pest outbreaks result in considerable economic losses and accumulation of combustible material (dead biomass) in the forest. Because the virulence of insect pest outbreaks is affected by the physiological state of trees, forests should be well tended to ensure vigorous forest stands. Before chemical means are used to fight the outbreaks, it is important to maintain, through silvicultural practices (sanitary operations), a state of active stand growth and to remove declining trees. This can be affected through periodic thinning and removal of diseased trees.

i) Increasing fire prevention measures.

Fires in Tanzania occur mostly during dry season and with increase in temperatures, increased risk of forest fires is expected where more fire protection measures will be needed in forests and wildlife areas as well. Technology options to mitigate GHG in wildlife sectors would include increasing fire prevention measures and early warning systems.

Fire risks in forests are increased by the amount of dead biomass left after logging, or litter found in the forests. The more the dead biomass and litter become dry, the more they are vulnerable to fire.

In Tanzania, fire damage to the vegetation is more wide spread than damage caused by pit sawing or fuel wood and pole cutting. Areas with drier climate due to the climate change will have higher frequency of fires. More fire protection measures therefore will be needed for reducing or stopping fire instances.

j) Establishing surveillance systems.

With the development of advanced (spatial) surveillance technology, it is conceivable that such systems will be expanded to address forest heath and productivity, monitoring biotic vectors and natural elements, as well as tree and stand responses. In the future, the main objective of the surveillance activities will be to minimize the loss of carbon from biomass to the atmosphere, likely to be caused by either fire or insect outbreaks. In the absence of surveillance and prompt intervention with modern fighting means, fires and insect outbreaks will represent positive feedbacks to CO_2 atmosphere concentration.

k) Ecological resilience

On ecological resilience, possible technological options include:- reserve and choices, connectivity and fragmentation, habitat management and intervention, maintenances of the ecological resilience. Since wildlife and tourism sectors are closely related, technology options recommended in the tourism sector will also hold in wildlife sector. These include fuel switch from diesel to natural gas, renewable energy options e.g. hydro electricity generation; biomass energy e.g. biogas, solar energy; wind energy e.g. wind generators and windmills. All these are significant technology options to mitigate GHG in wildlife sector.

l) Energy management

Improvements in energy efficiency will be possible if opportunities to improve energy efficiency and appropriate resources are made available. Effective implementation requires well-designed combinations of financial incentives and other government policies in human settlements, including energy pricing strategies, regulatory programs, utility demand-side management programs etc. Strategies to reduce emissions likely will prove more effective if they use well-integrated mixes of policies, tailored for local situations and developed through consultation with and participation by those most affected.

m) REDD+ Mechanism

The mechanism for reducing emissions from deforestation and degradation (REDD+) has been put forward as a mitigation measure to reduce emissions from forests. It is agreed that recent initiatives to curb the loss of forests have not resulted in significant changes; deforestation is continuing at an alarming rate and is impairing vital Ecosystem Services at the global and at the local level. Without strong political will, international cooperation and new policy instruments, forest resources are expected to continue to decline for the next 30 to 50 years (van Bodegom *et al.*, 2009). According to NAFORMA report, Tanzania is losing 1.1% of its forests annually which is about 400,000 ha. The past management experience in forestry and natural resources at large, calls for changes in global forest management, postponing changes may be fatal for the coming generations because the value of the destroyed ecosystem services is irreversible. Effective investments to reverse this depletion of natural resources can considerably reduce the future costs of adaptation. In this context, the REDD process created momentum for reducing emissions from forest destruction while simultaneously addressing other urgent environmental and development objectives.

Tanzania is among the few countries that have piloted REDD+ activities. Preparations for REDD+ in Tanzania began in 2008. Since that time, the National REDD+ Task Force (NRTF), developed and produced both a National Framework for REDD+ and the National REDD+ Strategy and Action Plan (2013). While REDD+ has the potential to deliver significant social and environmental co-benefit, there are also some serious risks, particularly for forest dependent and local communities and for the environment. In cognizant of this, Tanzania has prepared a draft REDD+ Social and Environment Safeguard which is to be finalized soon. REDD+ is a new climate change mitigation policy instrument which need to be advocated among different stakeholders especially people at local levels. A REDD+ Information and Communication Strategy (2013) have also been prepared.

Through the implementation of the pilot projects, Tanzania has gathered enormous experience in the areas of Governance, Benefit Sharing, Gender, Land and carbon tenure and ownership, Capacity building, Activities to address drivers of D & D, Monitoring, Reporting and Verification (MRV) and issues on REDD+ sustainability. The information and experience from REDD+ pilot projects is key for the successful REDD+ implementation in Tanzania. The existing forestry programs have the potential to reduce forest degradation and enhance carbon stocks inside and outside the forest. Governments must ensure that these programs continue to benefit local people when integrated into a REDD strategy.

Table 6-2: Summary of some Sector specific GHG Mitigation Options

Sector	Option	Description
Energy Supply	• Advanced electricity generation technologies • Efficiency improvements • Charcoal production • Coal mining • Renewable technologies	• Installation of combined-cycle power plants instead of simple cycle power plants • Increase the efficiency of existing power generation systems, mproving transmission and distribution systems • Improve the conversion efficiency of charcoal kilns • Optimize methane release from coal mines • Use solar collectors, photovoltaics, wind turbines, geothermal and biomass energy sources
Industry	*Cement Production* • Production management • CO_2 recovery system • Fuel switching • Production mix *Pulp and Paper* • Efficiency improvements • Recovery of CO_2 *Other Industries* • Energy efficiency improvements	• Install automatic control systems for reducing the amount of fuel used and improving production efficiency • Install CO_2 recovery systems. Recovered CO_2 can be used for other industrial applications • Substitute natural gas for fuel oil in two production plants • Produce blended cements such as pozzolanic cements, blast furnace slag cement, and Portland cements in order to reduce the amount of fuel used for calcination and the amount of lime used per unit of cement produced • Optimize the recovery boiler in order to reduce both the amount of lime and energy used • Recover CO_2 from calcination by the absorption of CO_2 • Improve efficiency in existing plants through maintenance, improved steam production and management, improvements to motor drive systems,

Sector	Option	Description
		co-generation, and power factor correction
Transportation	• Vehicle efficiency • Improve system efficiency • Modal split • Urban transport • Fuel switching	• Improve the technical efficiency of vehicles • Improve traffic flows, increase vehicle load factors, improve vehicle maintenance, traffic operations, training and management • Rehabilitate and expand the rail system • Implement mass transit systems in cities and fast growing urban centers • Use of natural gas as fuel
The Household and Service Sector	• Electrical appliances • • • • Cookstoves • Waste management	• Create awareness on the use of energy efficiency standards and labelling. • - • Use of energy efficient appliances – e.g. energy saving bulbs • Increase the efficiency of biomass cookstoves and use of LPG • Improve waste management including landfills and waste water treatment
The Agriculture and Livestock	• Agricultural practices • Livestock husbandry	• Reduce methane and carbon emissions through better practices related to fertilizer application, rice cultivation, and loss of organic carbon from cultivated soils • Better husbandry, including better breeding and feeding practices
The Land Use and Forestry Sector	• Forest management • Grasslands and rangelands	• Maintaining existing stocks through forest protection and conservation; and expanding carbon sinks by means of afforestation, reforestation, and enhanced regeneration and agroforestry practices • Maintaining or increasing carbon sequestration through better soil management and sustainable agricultural practices

7. OTHER INFORMATION RELEVANT TO THE CONVENTION

7.1 Systematic Observations

Weather and climate affects every aspect of human activity. The socio-economic well being of most Tanzanians are very sensitive to severe weather and extreme climate events. The country experiences loss of life and destruction of property as a result of severe weather and extreme climate events such as heavy rains, resulting in floods and landslides, destruction of road, buildings, bridges and houses, loss of properties and peoples life. Likewise less rainfall result into droughts and a prolonged drought affects agriculture production and hydroelectric power production. A large population in rural areas in Tanzania lives below the poverty line since rain-fed agriculture, on which they depend for their livelihood, has become more sensitive to severe weather and extreme climate events that are prevalent. Skilful and timely weather and climate forecasts can help the government and local communities mitigate the negative impacts of severe weather and extreme climate events through proper planning of the anticipated weather or climate events; however these can only be achieved through well organized systematic observation, monitoring and analysis of weather and climate parameters. Advance weather information and seasonal outlook forecasts given; helps farmers in planning their farming activities, mitigation of water bone disease and national food security. It is important, therefore, that the Meteorological Service be improved so as to be in a position of giving better services not only to agriculture but also to other sectors of the economy.

Climate monitoring, detection, attribution and climate change research and applications require historical observational data from sources that are well distributed across the country. In particular, it is of major importance that data from different locations and times are comparable or can be made comparable. This calls for:

a) ***Homogeneity*** of the data time-series relating to observing practices: This ensures data to be inter-comparable over the entire record, especially for data from the same location for different times. Changes in observing practices, including instrumentation can cause problems for climate research and many applications though they may improve operations and other real-time uses. Homogeneity of environment is basic for quality time-series data. It should consider observing practices, instrumentation and the environment in which the measurements are taken. Since observing sites are often established where people are living, the environment has a tendency to change continuously.

b) ***Representativeness*** of the environment: Observing sites need to provide the best representation for the climate in the area of concern. Current observing stations are located in habitable areas.

Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems. Tanzania network of stations is integrated into the global weather and climate-observing network under the World Meteorological Organization (WMO), World Weather Watch (WWW) and GCOS programmes.

7.2 Current Observation and Monitoring capacity

The available instrumental meteorological observations in Tanzania measure all common parameters including air temperature, precipitation, air pressure, surface radiation budget, wind speed and direction and water vapour. Since 1982, the number of rainfall stations, has expanded considerably and today there are more than 2056 rainfall stations in the country of which only about 1650 are still open and about 600 are operating. Rainfall is the most extensively measured element because it is considered to be the most crucial meteorological factor in the country. There are about 150 climatological stations in the country mainly with measurements of rainfall and temperature.

TMA does collaborate with other players such as Ministries responsible for water, Agriculture and Food Security, Natural Resources, Infrastructure and Education; and private institutions in weather observation. The public institutions have stations that measure other elements apart from rainfall, while private institutions such as churches and schools operate most of the single-element rainfall stations. The existing monitoring /observation networks were described as follows;

a) Synoptic Stations

At present TMA operates 28 Synoptic meteorological stations, most of which are located at airports. Synoptic stations make 24 hourly observations of various elements: including wind direction and speed, solar radiation, relative humidity of the air, wind run, and cloud type.

The hourly observations are telecommunicated to the National Meteorological Centre daily at prescribed times and monthly records are submitted to the Data Section (DS) of TMA. These include manually filled forms, cards and charts records from automatic instruments, such as sunshine recorder, automatic rain-gauge, thermo-hygrographs and anemographs. Fourteen Automatic Weather Stations (AWS) have been installed in various parts of the Country for improving data availability.

Synoptic stations are equipped with telecommunication facilities which include: Radio telephone (single side band), landline leased telephone, cell phones and facsimile machines. With a few exceptions, all synoptic stations are located in airports. Synoptic stations also make observations of upper air winds using pilot balloons that are tracked with theodolites, however, the operational costs for running synoptic stations are very high.

b) Agro-meteorological Stations

There are 15 agro-meteorological stations that are operated by TMA in collaboration with Ministry of Agriculture, Food Security and Cooperatives (MAFS). Agro-meteorological stations make meteorological observations twice daily, at 06.00 hours and at 12.00 hours UTC. Observations made include: daily rainfall, wet bulb and dry bulb temperatures, maximum and minimum temperatures, hours of bright sunshine, air relative humidity, class-A pan evaporation, soil water, soil temperature and the crop growth and development.

These stations send monthly returns of observations to Data section and Agro-meteorological Section of TMA. In addition, rainfall reports are communicated to Agrometeorological Section by phone and on weekly cards to MAFS-Food Security Department. Automatic instrument charts, cards and hand filled forms are sent monthly to the Data section. Office and residential accommodation for station staff is provided by MAFS. TMA provides professional observers and services the meteorological enclosures and instruments. Efforts are being made to improve these stations by providing them with basic equipment and expand the network to 70 stations. The main constraint facing TMA on this is insufficient financial resources.

c) Climatological stations

These stations measure the rainfall, temperature, humidity and sunshine. There are about 150 ordinary climatological stations in Tanzania, of these only 60 provide regular and continuous records (Table 7-1). These are operated by various institutions such as Ministry of Water, National Parks, Universities, Sugar plantations etc. TMA has plans to rehabilitate many of these and increase them to more than 200.. It is important that all stations adhere to and maintain the required standards.

d) Automatic Weather Stations (AWS)

There are 14 Automatic Weather Stations (AWS) located at various stations in the country. However, due to the vastness of the country, the actual requirement is about 80 AWS according to the minimum requirements from the WMO standards.

e) Upper-Air Observation Network

Upper air data has always been necessary in weather forecasting and climate monitoring. Upper air data are also vital input to global circulation and climate models (GCMs). Generally surface movements of weather systems are controlled by upper level systems including horizontal and vertical motions.

TMA used to have four such systems located at Dar es Salaam, Mtwara, Kigoma and Tabora. They have since stopped working due to lack of resources, old age and change of technology. However, Dar es Salaam has since acquired new upper air system under the Global Climate Observing System (GCOS) of WMO and is now operational. There is a need to revive the other three if we are to enhance the quality of forecasting and improve safety regularity and efficiency of aviation. It is planned to operate a radio theodolite station at Tabora.

f) GCOS Surface Network (GSN) and Upper Air Network (GUAN) Stations

There are 4 operating GSN stations in Tabora, Dodoma, Dar es Salaam and Songea. GUAN stations are currently not operating but are in the process of being revived. They are located in Kigoma, Dar es Salaam and Mtwara. These stations are important for upper surface and atmospheric observations.

g) Other Observation Stations

Tanzania is not connected to any of the global programmes for systematic terrestrial observations such as Global Terrestrial Network–Glaciers (GTN-G), Global Terrestrial Network-Permafrost (GTN-P), Global Terrestrial Network-Ecology (GTN-E), Global Terrestrial Network-Hydrology (GTN-H), Global Terrestrial Network-Carbon (FLUXNET) and other networks which monitor land-use, land cover, land-use change and forestry, wild fire distribution, CO_2 flux, and snow and ice extent. These observations would be appropriate for Tanzania since the phenomena to be observed do exist in the country, e.g. glaciers and permafrost on Mount Kilimanjaro, wild fires and/or loss of land cover and forestry. Such observations would provide information and data essential for implementation of Multilateral and Regional Environmental Agreements related to biodiversity and desertification and drought.

h) Remote sensing

Two weather Radars have been installed in Dar es Salaam and Mwanza and they are being operationalized. The optimum Radar coverage for the country is seven. Radar observing systems help to detect and track microsystems such as severe storms, tropical cyclones, tornadoes, wind shear etc. Recently the government purchased one new radar, this could enable TMA to enhance accuracy in the provision of weather forecast and warnings of impending disasters and improvement in now-casting.

i) Satellite

METEOSAT data are at the Dar es Salaam TMA Central Forecast Office. There is need to have a satellite receiver for polar orbiting satellites to enable TMA to provide better forecasts and rainfall estimates. The METEOSAT which use the satellite technology it is estimated to cost US$ 0.5 million. Table 7-1 shows the existing network of TMA stations in the country.

Table 7-1: TMA station network

Description	Number of stations		
	Current	Operational	Needed total
Surface synoptic stations	26	26	70
AWS	14	5	80
Agromet stations	15	15	35
Ordinary climate stations	150	60	250
Rainfall station	2056	600	2500
Marine weather station (offshore)	-	-	15
Lake weather station (offshore)	-	-	16
Upper air stations	4	1	4
Radiowind	-	0	1
Pilot Balloon	5	-	5
Wind profiler	-	-	
Weather Radar	0	0	7
Lightning	0	0	
GAW	0	0	-
Radiation	8	3	3
Ozone	-	-	1
Bouys	-	-	15
Bouys with meteorological obs.	-	-	15
Tidal with meteorological obs.	-	-	5
Seismic station	-	-	8
Satellite receiving station MSG	1	1	1

7.3 Constraints to systematic monitoring/ observations network in Tanzania

a) Inadequate Financial Resources

Inadequate financial resources affect the implementation of some of the activities highlighted in the TMA strategic plan. Operational and developmental activities in the meteorological sector are mainly funded by the Government. Other sources of funds includes loans from banks and grants from donors, revenue collections from the Tanzania Civil Aviation Authority (TCAA) and the Tanzania Airports Authority (TAA) also contribute to the funds. Unfortunately the current funding does not adequately address the required need for climate services. The need and demand for climate services is increasing and will continue to increase further under climate change, while the current funding level still fall short of the optimum requirements.

b) Low Network Coverage

The distribution of the network of stations in Tanzania is less than the WMO recommended density of 2.5 degrees of Longitude Square between stations. The distribution of these stations is not even, some parts of the country have a very high concentration of stations and others having very few. This is because distribution of stations is based on the human population. Areas with high density of population distribution have relatively high concentration of stations. There are areas with concentrated activities of agriculture basically in the north eastern and southern highlands and Lake Victoria basin which requires high network coverage of the observation systems.

c) Shortage of Essential Meteorological Instruments and Equipment

Many of the instruments and equipment were installed more than 30 years ago thus aged, obsolete and beyond repair due to non-availability of compatible spares. Recording instruments are worse-off than ordinary instruments as they lack charts, ink, pens and spares for unserviceable clock mechanisms. There is no single station with a complete working automatic rain-gauge. Meteorological enclosures for most stations are not of WMO standard form.

d) Poor Telecommunication Facilities

For real-time data, HF-radios, telephones and dedicated teleprinter lines are used. These unfortunately experience frequent breakdowns. Besides, the operational costs for the present telecommunication system are very high. There is, therefore, a need for modernization through adoption of the most up to date, cost effective and efficient way of receiving and transmitting meteorological data and information within the country and internationally through the GTS.

e) Replacement of analog telecommunication system with digital system

The current telecommunication which uses the analogy system has 3 automatic links. The one for Dar es Salaam and Nairobi, is outdated, fragile and subject to frequent failure resulting in unacceptable breaks in transfer of data and products. There is need to switch from analog to digital system.

f) Lack of Maintenance, Calibration and Inspection

TMA has shortage of technical workforce to service its instruments and equipment. In addition, it lacks modern maintenance and repair workshop to service meteorological instruments and equipment. Instrument calibration laboratory is also lacking.

Corrective and preventive maintenance is a key in ensuring quality meteorological data. It is important to enhance regular preventive maintenance. Due to the budget constraint, corrective and preventive maintenance are not carried as required.

7.4 Cooperation with Global and Regional Institutions

Tanzania like any other developing country is prone to extreme climate events such as droughts and floods, as well as to climate change impacts. These extreme events have severe negative impacts on key socio-economic sectors in the country and other countries in the sub-region. In view of this Tanzania through TMA is cooperating with various regional and international organizations in monitoring the extreme events and climate change.

In 1989, twenty four countries in Eastern and Southern Africa established a Drought Monitoring Centre with its headquarters in Nairobi (the DMCN) and a sub centre in Harare (Drought Monitoring Centre Harare – DMCH) in response to the devastating weather related disasters. In October 2003, the Heads of State and Governments of the Intergovernmental Authority on Development (IGAD) held their 10th Summit in Kampala, Uganda, where DMCN was adopted as a specialized IGAD institution. The name of the institution was at the same time changed to IGAD Climate Prediction and Applications Centre (ICPAC) in order to better reflect all its mandates, mission and objectives within the IGAD system.

The ICPAC is responsible for seven member countries namely: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda as well as Burundi, Rwanda and Tanzania, while DMCH is responsible for all SADC member states. Both centres, ICPAC and DMCH were formulated with the vision of becoming the viable regional centres of excellence in climate prediction and applications for climate risk management, environmental management, and sustainable development. Tanzania because of its location and climate it belong to both centres. TMA cooperate with ICPAC and SADC-Drought Monitoring Centre (DMC) in following areas:

- Development of Regional Climate forecasting on seasonal time scale.
- Expert attachment program
- Capacity building and training
- Greater Horn of Africa Climate Outlook Forum (GHACOF)
- Data exchange

TMA also cooperates with other regional and international organizations and institutions which include the following:

- Pretoria Regional Specialized Meteorological Centre (RSMC) - Severe Weather Forecasting and capacity building
- Re-Union RSMC on tropical cyclone matters
- National Oceanic and Atmospheric Application (NOAA) and National Centre of Environment Prediction (NCEP): Cooperation on expert attachment program through African Desk.
- TMA and NCEP (NOAA) are cooperating through data and product exchange. Generally the cooperation is in three areas (training, operations and research).
- African Centre for Meteorological Application and Development (ACMAD) - Development of Climate forecasting on seasonal time scale, expert attachment program, capacity building, training and data exchange

- WMO – All meteorological and related issues
- ICAO - Aviation
- UNEP - Environment
- ISDR – Disaster management
- Agricultural and hydrological Institutions - Data collections and exchange including rainfall and soil moisture

7.5 Early Warning System

Tanzania is affected by frequent weather related natural disasters, the main ones being droughts, floods, severe storms, tornadoes, strong winds, and tropical cyclones. These cause big losses of human life and livestock, property destruction and damage of roads and rail systems. The droughts in 1983, 1987, 1993, 2003 and 2005 were the worst having affected millions of people. Earthquakes happen and they have caused death of several people. The Indian Ocean tsunami in 2004 caused the death of 10 people while unknown number went missing. Epidemics occurs frequently affecting thousands of people. Losses caused by the above disasters could be minimized by accurately monitoring and forecasting these extreme events, and issuing timely warnings and advisories so that mitigation and contingency measures are taken. Relief operations also require weather information.

TMA operates on 24/7/365 basis. It is responsible for weather monitoring, data analysis, prediction of extreme or adverse weather events likely to endanger life and property and issue of corresponding warnings. TMA is a designated focal point for tsunami, and is responsible for issuing warnings for tsunami. TMA currently receives international tsunami warnings for tele-tsunamis from the Pacific Tsunami Warning Centre and from the Japan Meteorological Agency. The messages are received by the meteorologist on duty (analyst) at TMA through Global Telecommunication System of WMO, fax and email.

7.6 Climate Change modelling

TMA is in its infancy stage on issues of Climate Change Modelling in terms of technical staff capacity where only 4 TMA staff have participated in short-term courses on climate change modelling. TMA also lacks computer facilities for running climate change GCMs.

7.7 Possible Areas for Improvement

In order for TMA to perform its duty efficiently, the following are the proposed areas for improvement:

a) Capacity Building through basic and specialized meteorological training e.g. in Numerical Weather Prediction modelling computers for modelling laboratory
b) Institutional capacity to monitor the weather and climate of Tanzania through increased surface station network (Synoptic and Automatic weather Stations), upper air observing stations and efficient telecommunication system
c) Satellite Remote sensing capability
d) Weather Radar network
e) Data Rescue - Digitization and archiving of original old manuscripts
f) Training school expansion (class rooms, hostel, library)
g) National Meteorological Centre (TMA Headquarters) building

In general there is an urgent need to enhance the capacity of the Country in weather and climate observation and Monitoring involving both meteorological infrastructure and human resource capacities. Moreover the capacity in data management (Digitization) and dissemination of weather and climate information including Early Warning information to the wider public including those in remote areas.

8. POLICIES AND MEASURES TO ENSURE THE FULFILMENT OF THE UNFCCC OBJECTIVES

8.1 Institutional Framework

Implementation strategy and coordination of climate change issues in Tanzania are guided by an institutional arrangement as provided by the EMA (2004) and the National Climate Change Strategy (2012). In that context, the overall coordination rests in the Division of Environment under the Vice President's Office while implementation is undertaken at different levels by respective sectors. The implementation takes into account the need for an economy-wide holistic approach to mitigation and adaptation as stipulated in Article 4 paragraph one, sub-paragraph (c) of the UNFCCC.

Efforts are being made to establish an institutional framework to conduct National Communications (NCs). Thematic groups were established and enabled carry out activities of the NC in their respective areas. In addition, training for conducting GHG inventories for some experts and climate projections were conducted. However, most of trained officers no longer work for their former institutions. Thus, need for continued capacity building on greenhouse gas inventories in different institutions is necessary. Another challenge under GHG inventory is unavailability and access of accurate data in the sectors and the performance of QA/QC and therefore more attention will be paid in to the same in the Third National communication. With regard to mitigation measures, the Energy and transport Sectors are relatively well structured than other most of the sectors such as Waste and Land Use and Forestry. The two sectors have put in place institutions which help to capture some data related to GHGs inventories. Other sectors such as health and industries still need more attention as they are lagging behind, mainly because of lack of understanding and use of appropriate models.

8.2 The Division of Environment

The institutionalisation of climate change issues and processes is mandated to the Division of Environment, under the office of the Vice President, is a focal point for all matters related to environment. The Division of Environment has also been a link between the government of the United Republic of Tanzania and the United Nations Environment Programme (UNEP) on the development of the Second National Communication. The Division of Environment is the National Focal Point for the UNFCCC and the Designated National Authority (DNA) for the Clean Development Mechanism (CDM). The responsibilities of the DNA among others include assessing potential CDM projects, issuing written approval for such project and functions as a one-stop-shop for CDM project developers interested in developing CDM projects in the country. The Division of Environment commissioned the preparation of the Initial National Communication and second National Communication (SNC). However capacities in those institutions which were commissioned to undertake the preparation of the national communications have continued to decline following staff turnover.

To assist the Division of Environment, a range of key informants covering a range of climate change related expertise was assembled to investigate and prepare advisory information to Government. This team of experts were responsible for the technical studies required to inform both the initial and second national communications. Three technical Working Groups have been established – one with the responsibility for the GHG Inventory, another for assessing vulnerability and adaptation, and one for mitigation assessment.

8.3 National Climate Change Committees

At national level climate change issues are guided by two committees namely: National Climate Change Technical Committee (NCCTC) which provides technical advice to the National Climate Change Steering Committee (NCCSC). The NCCSC provides the overall policy guidance on all issues related to climate change and ensures coordinated action and participation within various sectors. The implementation of specific strategic interventions and activities is done by the respective Ministries, Department and Agencies (MDAs); and local government Authorities (LGAs) according to their roles and responsibilities under EMA and mandates. NGOs, civil society organisations, religious organisations, educational institutions etc also participate in the implementation of various specific adaptation and mitigation projects at a community level. There are also three thematic working groups on adaptation, mitigation and means of implementation that serve the NCCTC.

8.4 Implementing Adaptation Measures

Adaptation to climate change remains at its early stage of development due to a number of reasons such as financial resource, skilled people on climate change issues, development of a national adaptation plan etc. Stakeholders consulted during the preparation of this Communication suggested that the low levels of awareness on climate change issues and availability of the financial resources to address climate adaptation are the main reasons. Although the country is implementing a wide range of projects to overcome socio-economic challenges, all were not designed with climate adaptation in mind and thus mainstreaming of climate change issues is still required.

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8.5 Climate Change Mainstreaming

Since the publication of its Initial National Communication, Tanzania has undertaken a number of activities that can broadly be presented as the first steps towards addressing the needs of climatic change and these include:

- The establishment of National Climate Change Committees which will strengthen climate change mainstreaming and coordination in the country.
- Formulation of a National Climate Change Strategy (2012).
- Preparation of National Adaptation Program (2007).
- Engaging in REDD+ piloting activities

Moreover, Tanzania has put in place initiatives and policy measures which facilitate mainstreaming of climate change issues. For example the National Vision 2025 and Zanzibar Vision 2020 both aim at reducing vulnerability of Tanzanian people to poverty so as to foster sustainable development. The MKUKUTA is the short- to mid-term development plan to support the overarching national vision. MKUKUTA-I, which was approved in 2005, ended in December 2010 and was followed by MKUKUTA-II (2011-2015) as a continuation of the government and national commitments to accelerate economic growth and fighting poverty. MKUKUTA-II is considered the national vehicle for achieving Tanzania's international commitments on social development, including the UN's 2015 Millennium Development Goals. Climate change is highlighted in the national development plans in the context of growth and poverty reduction; specifically with respect to ensuring food and nutrition security and environmental sustainability and addressing climate change adaptation and mitigation.

Furthermore, Tanzania has been implementing a project to mainstream environmental and climatic concerns into the main policies and sectors. Both of these have shown a positive influence on the mainstreaming of these concerns.

9. CONSTRAINTS GAPS AND RELATED FINANCIAL, TECHNOLOGICAL AND CAPACITY NEEDS

9.1 Financial, Technical and Capacity Needs

Addressing climate change in Tanzania largely depends on financial support from international community such as the development partners. Domestic funding from government budget, private sector, as well as individual contributions complements this effort. However, an integrated approach and coordinated working system is highly required to ensure that funds to address climate change are raised and used to meet the intended objectives.

Tanzania faces a number of challenges which constrain her ability to set aside adequate resources for implementing climate change projects in many sectors. Given this challenge, it is critical that technical capacity and skill to develop sound project proposals is developed, data collection and packaging (according to the UNFCCC standards), research in climate change including downscaling are strengthened and maintained at various levels. . Moreover, baseline information to model, analyse or interpret climate impacts still need to be further developed. Hence, national research institutions need to develop their capacities to ensure that future National Communication Reports are done based on readily available, useful, relevant data and information. Issues that need to be addressed include the development of a climate change policy and legislation to coordinate and consolidate climate change activities at national level so that climate change issues are mainstreamed in national development priorities and plans.

9.2 Proposed Technology Needs in Various Sectors

In order to address climate change, appropriate mitigation and adaptation options and strategies that are based on appropriate technologies are required at all levels so as to reduce greenhouses gas emission and build the resilience of communities to adapt to climate change. **Annex 2** presents priority technological needs and measures for addressing climate change for various sectors in Tanzania.

9.3 Proposed Projects for Financing

Priority intervention addressing climate change directly or indirectly are stipulated in national climate change strategy, national adaptation programme of action (NAPAs), as well as national REDD+ strategy. Other cost-effective measures to reduce emissions of greenhouse gases and adapt to climate change to be considered include:-

- energy efficiency measures, including the removal of institutional barriers to energy efficiency improvements;
- fuel switching measures in industry, energy and other sectors;
- improved forest management and land use practices;
- reducing methane, nitrous oxide and other greenhouse gas emissions;
- Promoting the development and implementation of national and international energy efficiency standards;
- Promoting voluntary actions to reduce greenhouse gas emissions at different levels;
- Promoting awareness, education and training, implementing information and advisory measures for sustainable development and consumption patterns that will facilitate climate change mitigation and adaptation; and
- Capacity building activities to public and private sectors on issues related to climate change.

9.4 Conclusion

Addressing climate change requires the implementation of various projects relevant to the GHG Inventory, Vulnerability and Adaptation (V&A) Assessments and Mitigation Analysis. Presented in this Chapter are some priority intervention which can be considered for addressing challenges and concerns on climate change in Tanzania. It is envisaged that the implementation of these project activities will help to address adverse effects of climate change on various sectors of the economy and promote sustainable development of Tanzania.

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ANNEXES

ANNEX 1: SHARES OF GROSS DOMESTIC PRODUCT (%) BY KIND OF ECONOMIC ACTIVITY

ECONOMIC ACTIVITY	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture, Hunting and Forestry	**29.0**	**2 8.6**	**28.7**	**29.5**	**27.6**	**26.2**	**25.8**	**2 5.7**	**24.6**
Crops	2 1.4	2 1.4	21.8	22.4	20.5	19.2	19.0	1 9.0	18.4
Livestock	5 .0	4 .8	4.7	4.8	5.0	4.8	4.7	4 .7	4.0
Hunting and Forestry	2 .5	2 .4	2.3	2.3	2.2	2.2	2.1	2 .0	2.2
Fishing	**1 .7**	**1 .7**	**1.6**	**1.5**	**1.4**	**1.3**	**1.3**	**1 .2**	**1.4**
Industry and construction	**1 8.0**	**1 9.6**	**21.0**	**20.8**	**20.8**	**20.8**	**21.2**	**2 1.0**	**22.0**
Mining and quarrying	1 .8	2 .1	2.4	2.6	2.9	3.2	3.5	3 .4	3.3
Manufacturing	8 .4	8 .3	8.3	8.1	7.9	7.8	7.8	7 .8	8.6
Electricity, gas	2 .2	2 .0	1.9	1.8	1.7	1.5	1.6	1 .7	1.7
Water supply	0 .5	0 .5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Construction	5 .2	6 .8	8.0	7.9	7.8	7.8	7.8	7 .7	7.9
Services	**4 5.5**	**4 4.2**	**42.7**	**42.0**	**42.5**	**43.3**	**43.3**	**4 3.8**	**43.6**
Trade and repairs	1 3.0	1 2.4	12.0	11.4	11.0	11.4	11.5	1 1.6	11.8
Hotels and restaurants	2 .8	2 .6	2.4	2.3	2.5	2.6	2.7	2 .6	2.3
Transport	5 .4	5 .0	4.8	4.6	4.4	4.3	4.2	4 .2	5.0
Communications	1 .2	1 .2	1.3	1.5	1.7	2.1	2.3	2 .5	2.1
Financial intermediation	1 .5	1 .7	1.7	1.6	1.7	1.7	1.6	1 .6	1.7
Real estate and business services	1 0.3	9 .7	9.4	9.1	9.5	9.6	9.5	9 .6	9.0
Public administration	7 .0	7.2	7.2	7 .7	8.0	8.0	7.9	8 .2	8.1
Education	2 .1	2 .0	1.8	1.7	1.6	1.5	1.4	1 .3	1.4
Health	1 .3	1 .5	1.4	1.4	1.5	1.5	1.6	1 .5	1.6
Other social and personal services	0.9	0 .8	0.7	0.7	0.7	0.7	0.6	0 .6	0.6
Gross value added before adjustments	9 4.2	94.1	94.0	93.7	92.3	91.7	91.6	9 1.6	91.6
Less FISIM	- 0.9	- 0 .9	- 0.9	- 0 .9	- 0 .9	- 0.9	- 1.0	- 1 .0	- 1 .2
Gross value added at current basic prices	9 3.3	9 3.3	93.1	92.8	91.4	90.7	90.7	9 0.6	90.4
Add Taxes on products	6 .7	6 .7	6.9	7.2	8.6	9.3	9.3	9 .4	9.6
GDP (At current market prices)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: URT (2010a)

ANNEX 2: PROPOSED TECHNOLOGICAL NEEDS AND MEASURES FOR VARIOUS SECTORS

Sector	Proposed Technological Needs and Measures
1. Agriculture	1.1 Production • use of irrigation efficient technologies • Appropriate fertilizers applications • Changes in planting dates
	1.2 Mechanization • Application of tractor and drought power • Conservation tillage
	1.3 Seed • Use of improved cultivars • Integrated weeds, pests and diseases control • Use of biotechnology • Direct seedling of rice
2. Water	2.1 Water supply options • Development of new and rehabilitation of water supply infrastructures • Development of water storage facilities (large storage tanks and dams) • Rain water harvesting • Promotion of water conservation programmes • Promotion of conjunctive use of water sources • Inter-basin water transfers • Desalination • Recycling of domestic and industrial water • Development of groundwater resources
	2.2 Water end-use • Water conservation as well as sustainable utilization • Setting up of tariffs at an economic cost • Metering and regulation for efficient water uses especially • Leakage control • Development of water allocation mechanisms

Sector	Proposed Technological Needs and Measures
3. Energy	3.1 Fuel switching to alternative environmental friendly energy resources such as switching from using diesel to natural gas
	3.2 Efficiency improvement of existing energy systems including retrofitting thermal power plants, use of efficient wood and charcoal burning stoves and use of efficient electricity appliances
	3.3 Enhanced deployment of appropriate renewable energy technologies such as biomass co-generation, tri-generation (generating steam, electricity and a second generation fuel like fuel cells), biogas, biodiesel, solar, wind, hydropower and geothermal
	3.4 Energy efficiency and conservation by applying cleaner energy technologies and techniques in all sectors of the economy including industries and households.
	3.5 Power pricing with due regard to social and environmental costs including the application of polluter pays' principle so as to discourage wasteful behaviours in energy use
4. Livestock	4.1 Husbandry • Intensive Livestock Stocking (diversity, mobility and high density)
	4.2 Grazing management by intensive livestock stocking:- • Fodder Bank and pasture development • Supplementary Feeding and feed manipulating • Alley cropping and grass legume mixture • Ammoniating straw and use of feed additives for animal Feed
	4.3 Animal breeding and related technologies • The hybrid and back- crossing • Veterinary animal health services • Ex-situ conservation of semen from improved bulls • Traps and targets for insect control • Embryo transfer
	4.4 Animal waste management • Covered lagoons • Small and large digester

Sector	Proposed Technological Needs and Measures
5. Forestry	5.1 Mitigation options • Commercial/industrial forest plantation • Extension and replanting of other industrial forest plantations • Small holder or village tree growing for multiple purposes • Natural/catchment forest protection • Bio-energy from forest waste. • Reforesting Immediately After Harvest • Establishing New Plantations • Replacing Drought Sensitive Species • Establishing Surveillance Systems and Increasing Fire Prevention • Promote agro-forestry practices
	5.2 Adaptation options • Sustainable forest management practices (gene management, forest protection, forest regeneration, silvicultural management, forest operations) • Afforestation programmes in degraded and non degraded lands using more adaptive species; • Improvement/change in the use of forests and forest products to reduce tree felling by the application of alternative materials • Enhancement of forest seed banks and the development of new plant varieties • Encouragement of multiple/diversity management practices in the case of plantations • Reduction of habitat fragmentation • Promotion of the development of migration corridors and buffer zones • Promotion of use of non-timber products • Promote private and community forest management system • Promote agro-forestry practices
6. Transport	6.1 Vehicle Technology Improvement • Lean burn engines • Exhaust gas recirculation (EGR) • Light weight materials • Exhaust after treatment devices

Sector	Proposed Technological Needs and Measures
	6.2 Fuel Technology Improvement • low sulphur gasoline • leaded gasoline • liquid bio-fuels
	6.3 Fuel Substitution • Natural Gas • Hydrogen and Solar • Electricity-Hybrid Electric Vehicles, Electric Vehicles and Efficiency
	6.4 Bio-fuels • Ethanol • Bio-diesel • Bio-gas
	6.5 Transport Infrastructure and System Changes • Use of Mass Transit • Improving Roads Condition • Traffic Management Techniques
	6.6 Locomotives • New modern locomotive engines with less emission • Electronic locomotive engines
7. Coastal Resources	7.1 Coastal protection options • Establishment of marine protected areas • Establishment of networks of marine reserves • Identification and protection of climatic *refugia* • Protection of physical and biological heterogeneity • Control of soil erosion • Integrated coastal zone management
	7.2 Restoration of degraded habitats (beach nourishment) • Mangrove replanting/restoration • Vertiver grass planting • Coral reef restoration and conservation

Sector	Proposed Technological Needs and Measures
	7.3 Building artificially (beach nourishment) • Artificially placing sand on the beaches • Coastal drain beach management system
	7.4 Line structures • Construction of concrete groins/seawalls • Integrated coastal protection system • Rehabilitation and construction of coastal infrastructures
	7.5 Reductions or elimination of non-climate stresses and monitoring • Elimination of destructive fishing practices and over-fishing • Reduction/control of damaging extraction • Coastal ecosystem monitoring
	7.6 Managed retreat and accommodation • Implement/enforce building Regulations and Modification of Land Use • Desalination
8. Industry	8.1 Fuel Switching 8.2 CO_2 Recovery System 8.3 Waste- derived Alternative Fuels 8.4 Recovery of Waste Heat for Co-generation 8.5 Cleaner production technologies and techniques
9. Waste management	9.1 Solid waste management • Recycling technologies to ensure waste reduction • Composting facilities • Engineered/sanitary landfills with appropriate leachate and gas recovery • Waste to energy technologies
	9.2 Wastewater management • Water conservation technologies to ensure reduction in wastewater generation • Wastewater reuse and recycling technologies • Wastewater treatment technologies incorporating methane recovery units