THE STATE OF ERITREA

MINISTRY OF LAND, WATER AND ENVIRONMENT
DEPARTMENT OF ENVIRONMENT

Third National Communication Under The United Nations Framework Convention On Climate Change (UNFCCC)

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List of Acronyms and Abbreviations

Acronyms	Description
AD	Activity Data
ADB	African Development Bank
AF	Adaptation Fund
AFOLU	Agriculture, Forestry & Other Land Use
AMSC	Asmara Mines Share Company
AOGCMs	Atmospheric Oceanic Global Circulation Models
ASARECA	Association for Agricultural Research in Eastern and Central Africa
AWSD	Annual Water flow Simulation on Dams
BHCP	Basic Health Care Package
BMSC	Bisha Mining Share Company
BRT	Bus Rapid Transit
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CFL	Compact Flourcent Lamp
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of the Parties
DANIDA	Danish International Development Agency
DoE	Department of Environment
ECMIB	Eritrea's Coastal Marine and Island Biodiversity
EF	Emission Factor
ENDA	Environment Development Action
EPHS	Eritrean Public Health Survey
ET	Evapotranspiration
FAO	Food Agricultural Organization of the United Nations
FNR	Facilitating National Reporting
FReMP	Fish Resources Management Program
FSS	Food Security Strategy
FWA	Forestry and Wildlife Authority
GCCM	Global Circulation Climate Models
GCOS	Global Climate Observing System
GDI	Gender Development Index
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GER	Gross Enrolment Rate
GFRA	Global Forest Resources Assessment
Gg	Gig gram

Acronyms	Description
GHG	Greenhouse Gas
GIS	Geographical Information System
GoSE	Government of the State of Eritrea
GOOS	Global Ocean Observing System
GPG	Good Practice Guidance
GTOS	Global Terrestrial Observing System
GWP	Global Warming Potential
ha	Hectare
HCS	High Climate Sensitivity
HDI	Human Development Index
HFCs	Hydro fluorocarbons
HSD	Horizontal set back dam
HSS	Health Sector Strategy
ICAM	Integrated Coastal Area Management
ICPAC	IGAD Climate Prediction and Applications Centre
IDP	Internally Displaced People
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IFPRI	International Food Program and Research Institute
IGAD	Intergovernmental Agency for Development
IHEs	Institutions of Higher Education
IMCI	Integrated Management of Child Illness
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
I-PRSP	Interim Poverty Reduction Strategy Paper
IWRMP	Integrated Water Resources Management Plan
KP	Kyoto Protocol
LDCF	Least Developed Countries Fund
LDCs	Least Developed Countries
LEAP	Long Range Energy Alternative Planning
LPG	Liquefied Petroleum Gas
LULUCF	Land Use Land Use Change & Forestry
M &E	Monitoring & Evaluation
MAED	Model for Analysis of Energy Demand
MAR	Mean Annual Rainfall
MAT	Mean Annual Temperature
MDG	Millennium Development Goals
MEAs	Multilateral Environmental Agreements
MHDG	Millennium Health Development Goals

Acronyms	Description
MIHAP	Minimum Integrated Household Agricultural Package
MoA	Ministry of Agriculture
MoEM	Ministry of Energy and Mines
MoFND	Ministry of Finance and National Development
MoH	Ministry of Health
MoI	Ministry of Information
MoLG	Ministry of Local Government
MoLWE	Ministry of Land, Water & Environment
MoMR	Ministry of Marine Resources
MOP	Montreal Protocol on Substances that Deplete the Ozone Layer
MoPW	Ministry of Public Works
MoTC	Ministry of Transport & Communication
MoTI	Ministry of Trade and Industry
MSW	Municipal Solid Waste
MSY	Maximum Sustainable Yields
N_2O	Nitrous Oxide
NAMAs	National Appropriate Mitigation Actions
NAP	National Agriculture Programme
NAPA	National Adaptation Programmes of Action
NAPDD	National Action Plan for Drought & Desertification
NARI	National Agricultural Research Institute
NBSAP	National Biodiversity Strategy & Action Plan
NC	National Communication
NCSA	National Capacity Needs Self-Assessment
NCSP	National Communication Support Programme
NDC	Nationally Determined Contribution
NDHS	National Demographic and Health Survey
NDIP	National Development Indicative Programme
NEIAPG	National Environmental Impact Assessment Procedures and Guidelines
NEMP-E	National Environmental Management Plan-for Eritrea
NEPFP	National Economic Policy Framework and Program
NERTC	National Energy Research and Training Centre
NGAP	National Gender Action Plan
NGHGI	National Greenhouse Gas Inventory
NGHGITEWG	National Greenhouse gas Inventory Technical Expert Working Group
NHCP	National Health Care Policy
NMHOA	National Meteorological, Hydrological and Oceanographic Agency
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen oxides
NUEW	National Union of Eritrean Women
NUEYS	National Union of Eritrean Youth and Students

Acronyms	Description
ORS	Oral Dehydration Solution
PEM	Protein-Energy Malnutrition
PFCs	Per fluorocarbons
PIF	Project Identification Form
POPs	Persistent Organic Pollutants
PPs	Project Profiles
PRECIS	Providing Regional Climate for Impacts Studies
PRRD	Post Recovery and Rehabilitation Development
QA	Quality Assurance
QC	Quality Control
RCM	Regional Climate Model
RD	Research and Development
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goals
SEI	Stockholm Environment Institute
SF_6	sulphur hexafluoride
SGP	Small Grant Programme
SimCLIM	Simulation of Climate
SNC	Second National Communication
SO_2	Sulphur dioxide
SoER	State of Environment Report
SPA	Strategic Priority on Adaptation Fund
SPM	Summary for Policy Makers
SRS	Southern Red Sea
SSA	Sub-Sahara Africa
SST	Sea Surface Temperature
SWC	Soil and Water Conservation
T	Ton
TAR	Third Assessment Report of the IPCC
TED	Technological and Environmental Data
TNA	Technology Needs Assessment
TNC	Third National communication
ToRs	Terms of References
TVET	Technical and Vocational Education Training
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention on Combating Desertification
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework on Climate Change

Acronyms	Description
VATWG	Vulnerability and Adaptation Thematic Working Group
WEAP	Water Evaluation and Planning
WG	Working Group of the IPCC
WHO	World Health Organization
WMO	World Meteorological Organization
WRD	Water Resources Department

Foreword

By virtue of its geographical location and low adaptive capabilities, Eritrea is among the hardest hit countries by climate change impacts. It is prone to climatic variability, which is manifested in the form of recurrent drought, shortage and spatial and temporal variability of rainfall which resulted to frequent crop failure, livestock and wildlife mortality, genetic erosion, extinction of endemic species, emergence of climate sensitive diseases, degradation of habitats and disequilibria in ecosystem structure and function.

Nowadays, increased climate variability is becoming evident throughout the country and the increase in temperature is being felt and is more noticeable during the summer season (July, August and September). Since early 20th century, historical meteorological data show that rainfall has been declining by about 0.4 mm/year in central and southern highlands of Eritrea.

In an effort to assess and update climate change impacts and comply with the reporting requirement under the UNFCCC, Eritrea hereby presents its third national communication (TNC). As required from Non-Annex I Parties the TNC encompasses information on climate and climate change background of the country, GHG inventory, GHG mitigation assessment and analysis, climate change impacts and adaptation assessment, as well as information on constraints, gaps, technical and capacity needs.

The results of the national greenhouse gas inventory, which covers 2006, 2010 and 2015 base years reveal that Eritrea's GHG emission contribution is negligible and accounts to only 0.013% of the global GHG emission. On the other hand the climate vulnerability assessment indicates that agriculture, water and forestry are the most severely affected sectors which require intensive climate smart adaption interventions.

Climate change is a global challenge. It can effectively be tackled only through collective action of all Parties as clearly declare in the tenets of the Convention. Eritrea expresses its commitment to the achievement of the ultimate objectives of the Convention and the Paris Agreement. To this end and in order to ensure effective transfer of technology and knowledge, Eritrea insists that financial and technological commitment made by developed country parties be secure and accessible to all eligible countries, particularly the LDCs.

In conclusion, on behalf of the Government of the State of Eritrea and myself, I am pleased to present the Eritrea's Third National Communication to the UNFCCC Secretariat, and acknowledge to all those who contributed for the successful completion of this report. Special words of appreciation also go to GEF and UNEP for their financial and technical support respectively.

Tesfai G. Selassie Sebhatu
Minister of Land, Water and Environment

Acknowledgment

First of all, I am honoured to thank H.E. Mr.Tesfai G.Selassie, Minister of Land, Water and Environment for his valuable support, encouragement, and continuous guidance and advice throughout the preparation processof the Third National Communication.

The Third National Communication is prepared through active involvement of various key stakeholders. In this regard, I would like to extend my gratitude to the Ministries of: Local Government, Energy and Mines, Trade and Industry, Transport and Communication, Health, Agriculture, Marine Resources and other institutions such as well as Forestry and Wildlife Authority, Segen Construction Company, Regional Administrations, Eritrean Institute of Technology, Hamelmalo Agricultural College, Adikeih College of Business and Social Sciences for providing reliable data and information.

Furthermore, my thanks go to the Bureau of Standard and Evaluation of the Higher Education and Research Institute consultants for preparing this document in accordance with the guidelines provided by UNFCCC secretariat. My special words of appreciation also go to the team of experts emanated from the key stakeholder institutions for gathering and synthesising data and information from their respective institutions and for reviewing the document meticulously.

I am also grateful to all UNEP and GSP Experts for their relentless efforts in providing technical support, guidance and for their efficient facilitation of the financial transaction for the preparation of the TNC document.

Kibrom Asmerom
Acting Director General,
Department of Environment

Executive Summary

1. Introduction

Eritrea has taken a number of steps to enhance its resilience against the risk hazards emanating from climate change and hence ensure sustainable development. In this connection, the country acceded to the UNFCCC on 24 April 1995 and has been actively participating in the UNFCCC process to ensure the implementation of the convention. The Third National Communication (TNC) to the UNFCCC is prepared in accordance with the guidelines on the national communications from non-Annex I Parties. The report builds up on the Initial National Communication (INC) and the Second National Communication (SNC) and presents the overall climate change situations of the country since the last report was submitted. The preparation of Eritrea's TNC has been motivated not only to comply with the reporting commitment to the Conference of Parties (COP) of UNFCCC, but also to support the rapidly evolving process of mitigation and adaptation policy making process, which at the moment lacks a clear roadmap. Virtually, all communities and various sectors in Eritrea have been adversely impacted by the effects of climate change. As a result, climate change mitigation and adaptation strategies, and hence reducing vulnerability remain at the centre of the country's sustainable development agenda. Nevertheless, a number of traditional climate change coping mechanisms exist, which need to be considered seriously in knowledge management strategies.

2. The National Circumstances

The National Circumstance is one of the main components of the Third National Communications and the first Biennial Update Report (BURI, which Eritrea has to report to the UN Framework Convention on Climate Changes (UNFCCC). The document is prepared in accordance with the guidelines developed and adopted by the Conference of the Parties (COP). It is the most effective tool and means of providing country context information to the COP. It helps Eritrea and other non-Annex I Parties to meet their reporting requirements, and serves as a medium for the presentation of information in a consistent and transparent manner.

Eritrea possesses a geopolitically significant location covering a total of 124,320km^2. Its climate is most influenced by altitude and topography, which cause variations in temperature. Based on the climatic parameters, the country is divided into six agro-ecological zones. There are two rainfall regimes, summer (June-September) in the highlands and western low lands; and winter rains (Nov-February) in the eastern and coastal areas, and the main feature of rainfall is the extreme variability within years and variations over short distance. The country is vulnerable to the adverse effects of climate mainly, due to its geographical location.

The major land-use/land-cover types in the country are categorized as grazing land, woody vegetation, cropland and barren land. Grazing land and woody vegetation, account for the largest proportion of the land cover system. Depletion of land productivity, caused by overgrazing, infertile soils, and poorly established incentive measures for sustainable land management, is a major problem. In general, soils with the highest agricultural potential are found in the southern part of the central highlands and south-western lowlands of the country. However, shallowness, which is the result of continuous cultivation and soil degradation, is the major constraint to productivity in agriculture.

The immediate development priority of Eritrea is to meet the basic needs of its population through achieving economic stability, and rehabilitating and expanding infrastructures. The Government formulated Macro Economic Policy in 1994, which clearly sets out the path for enhanced national development. In this respect, Eritrea has made significant efforts to provide educational services to all its citizens. The National Gender Plan of Action which addresses the

critical constraints of girls' education and training, and outlines key strategic objectives and plans of action to address the problems. Similarly, the country has made a remarkable progress in the health system through improvement in longevity and the general wellbeing for all citizens. The progress in the health sector is mainly attributed to increased number of medical personnel and expanded facilities and services. Eritrea is one of the few countries to have achieved the Millennium Development Goals (MDGs) in health before the given deadline date.

Eritrea is a pre-industrial society where a large proportion of its population is rural, directly depending on land resources for its livelihood. The country's economy is based on the extraction of natural resources such as agriculture, fishery and mining. Agriculture is the main source of income and food security for the great majority of the population. It plays a significant role in reducing poverty and supports industrialization at a national level. The Government is pursuing a policy that aims at increasing farm productivity in recognition of the significant role agriculture plays in the national development. Eritrea has the potential to harvest a large amount of fish annually, though the current fish catch is known to be very low. Moreover, the country has an excellent opportunity for developing tourism industry particularly along its coastal area. In recent years, the economy has been driven by the mineral resources, especially with the start-up of commercial mining activities and the export of copper and zinc at the *Bisha* mine.

Eritrea is one of the most vulnerable countries of the world to the adverse effects of climate changes due to its geographic location in the *Sahelian* Zone. The problem has been further aggravated by human activities such as over-cultivation and excessive fuel wood collection. Anthropogenic factors are thus the main driving forces of the changes in climate. Land degradation is prevalent throughout the country, but is particularly manifested in the central, northern highlands and southern plateau. The Eritrean Red Sea and coastal beaches remain relatively clean as there are no serious pressures from industrial and other related activities.

3. National Greenhouse Gas Inventory

The GHG national inventories include anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. These inventories have been produced, to the extent of the countries capabilities, using recommended methodologies of the IPCC 2006 guidelines. The inventory is prepared for (i) Energy (i) Industrial Processes and Product Use (IPPU) (iii) Agriculture, Forestry and Other Land Use (AFOLU); and (iv) Waste sectors. It covers both direct greenhouses: CH_4, CO_2, and N_2O gases (GHG) and indirect precursor gases, CO, NO_x SO_x.

Inventory Estimates of Aggregated Emissions: Eritrea's net total GHG emissions by year; 2000, 2006, 2010 and 2015 of all sectors were respectively 3286.76, 3293.31, 3433.05 and 3866.76 Gg of CO_2 eq coming from the four key category sectors. Over the period 2000 – 2015, total GHG emissions have increased by 17.65% from 3286.76 Gg CO_2eq in 2000 to 3866.76 Gg CO_2 eq in 2015. Although the contribution to the aggregated GHG emission from, the IPPU and Waste remained low, the % increment observed in the years 2000-2015 was drastic mainly due to the establishment of new Cement Factory. The emission from the waste sector is attributed to the increase in urban population growth and change in living habits.

The GHG emission revealed that CH_4 has the highest GHG emission contribution for all the inventory periods followed by CO_2. However, the change in CO_2 emission of 41.7% increase is much higher than that of CH_4 emission change of 14.34% increase between the year 2000 and 2015. Looking at the GHG emission trend, it shows that Eritrea is a net GHG emitter in which

the change GHG emission between 2000 to and 2010 was gentle, and showed an abrupt increase from 2010 onwards; and remains to undertake appropriate mitigation actions.

Between 2000-2015, the GHG emissions by year and gas in Gg of CO2-eq show fallowing: i) CO_2 increased by 41.70% i.e. 401.24 to 568.55 ii) CH_4 by 14.34% (2759.26 – 3154.89) iii) N_2O increased by 13.51%. Looking at the trends of the various gases emission, in 2015, GHG inventory year, methane gas followed by CO2 were the highest. Majority of methane emissions came from enteric fermentation and manure management sub-sector. The second highest direct gas emission, is CO2 from Energy sector which indicates that the country has not adopted a full-fledged energy efficient and renewable energy technologies.

Anthropogenic emissions by sources of Per-fluorocarbons (PFCs) and sulphur hexafluoride (SF6) from production activities were not accounted due to lack of data availability. But for anthropogenic emissions by sources of hydro fluorocarbons (HFCs) in Gg CO_2 eq. for the 2000, 2006, 2010 and 2015 are 0.10, 2.66, 6.41 and 14.23 respectively.

Quality Assurance and Quality Control: Quality Assurance (QA) procedures, as defined in the IPCC 2006 Guidelines, were implemented. As per the Guide 2006 guidelines, the GHG data and information were collected and compiled by NGHGITEWG. QC of the GHG inventory was performed the project coordinator and the lead experts. In case of inconsistencies, and transcription errors, the responsible institutions were consulted with the aim of instantly solving the problem. Although capacity is limited. The QA of the GHG i.e., consistency, completeness, accuracy and transparency and comparability of data was carried out by two independent GHG experts who had prior training in the IPPCC 2006 guidelines; and who were registered in the UNFCCC expert group.

Uncertainty analysis: has been performed using the tool available within the IPCC 2006 software model version 2.691. Based on the quality of the survey data and whether the EFs used were defaults or nationally derived, uncertainty levels were allocated for the two parameters and the combined uncertainty calculated for the latest inventory year 2015. For the national inventory, the level and trend assessment uncertainties show 11.29% and 11.75% respectively. Looking at the categories it is noted that the highest uncertainties was in the 3.A Livestock followed by biomass consumption in Energy sector.

Key Category Analysis: The level assessment shows that nine categories; These are i) Enteric Fermentation, ii) Forest land Remaining Forest land, iii) Road Transportation, iv) Cement production, v) Energy Industries - Liquid Fuels, Other Sectors – vi) Biomass, Other Sectors – vii) Liquid Fuels, viii) Manure Management (CH4) and ix) Manure Management (N2O) that account for the cumulative total of 95.1%.

In the trend assessment the following ten categories are the key category of Eritrea based on the 2015 inventory year and GHG emissions. These are: i) Cement production, ii) Enteric Fermentation, iii) Energy Industries - Solid Fuels, iv) Other Sectors - Liquid Fuels, v) Manufacturing Industries and Construction - Liquid Fuels, vi) Road Transportation, vii) Solid Waste Disposal, viii) Forest land Remaining Forest land, ix) Energy Industries - Liquid Fuels and x) Refrigeration and Air Conditioning.

4. National GHG Mitigation Assessment & Analysis

Eritrea is committed to stabilize and mitigate greenhouse gas concentrations. The mitigation assessment covers five sectors/subsector : i) Energy, ii) Public and Commercial, iii) Industry

and Road Transportation, iv) Agriculture, Forestry and Other Land Uses (AFOLU) and v) Solid Waste.

The population size which stood 3.2 million (70% Rural) in 2010 is expected to reach 6.52 million in 2035. In 2035, the proportion of the rural population is expected to decline to about 49.8% which is equivalent to 3.25 million. The energy demand in the energy sector increased from 767.6 in 2016 to 977.9 thousand tons in 2035. The breakdown of the various sub sectors was as follows: i) household from 602.9 decreased to 545.5; transport 79.3 increased to 251.4; public and commercial 72.8 increased to 142.6; and industry 12.7 to 38.9. Corresponding GHG emission based on BAU scenario increased from 739.8 in 2016 to 17,717 in 2035.

Emission Estimates scenario: In 2016, the household sector, as the main GHGs contributor, accounted for 40.8% in the reference scenario, its contribution is expected to be reduced to 30.8%. Within the sector, from 2016 data rural households accounted for an average of 60.9% contribution of the total emissions which is mainly from wood, dung and agricultural residue consumption. This is followed by emissions from urban households 35.9% mainly from the use of LPG, kerosene and wood fuel for cooking. The BAU projection shows that the expected emission contribution from household category by 2035 is 529.13 $GgCO_2$ eq. Therefore, GHGs emission form household sector shows a decreasing trend throughout the scenario years.

Transportation will be the major CO_2 emission contributor in 2035 in which the share of transport sector GHG emission in GWP CO_2-eq was projected to increase from 32.6% in 2016 to more than 44.5% of which emissions from road transport will account for more than 80% of the sector's emissions.

Public and Commercial Services, based on BAU scenario analysis, GHGs emission from the services sector are projected to increase from 167 $GgCO_2e$ in 2016 to 335.2 $GgCO_2e$ in 2035; whereas, its share will decrease from 22.6% in 2016 to 19.52% in 2035. Thus, the industrial sector shows increasing trend from 29.09 $GgCO_2$ eq in 2016 to 87.84 $GgCO_2$ eq in 2035. Its share in the demand sector also increases from 3.9% in 2016 to 5.11% in 2035.

The fuel derived from the electricity demand of the various scenarios and BAU were fed in the Long Range Energy Alternatives Planning (LEAP) modelling tool to compute emissions. The difference in emissions between the BAU and each individual mitigation scenario provides its abatement potential. The mitigation scenario shows household sector will remain the main emitter up to 2025; the transport sector will outmanoeuvre the household accounting for 440.54 $GgCO_2eq$. In addition, the mitigation scenario reveals household emission will be reduced from 40.85percent to 32.61percent emission contributor. Transport sector will increase from 30.62percent to 39.92percent GWP CO_2 eq emission contributor in Eritrea.

During the scenario period emission from transport sector grows faster and bypasses the household sector due to the fact that the transport sector depends only on oil. Thus, thus, by 2035 the main emission contributors within the energy demand sector are transport (45%), household (30%), and services (20%). Although industry is forecasted to grow; it will only contribute about 5% to the total emission by the same year. Based on the BAU scenario, by 2035 total GHGs emission is expected to rise by 2.32 times.

Key Barriers to GHG Mitigation: GHG mitigation involves the introduction, adoption and adaptation of appropriate new technologies. In this endeavour, shortage of skilled human and financial resources still remains a major constraint for installation and maintenance. These constraints should be alleviated through human capacity building focusing on the various

emitting sectors; which would require linkage partnership at the national and regional levels. In this regards, the role of higher Education and Research Institutes, civil societies and professional associations and beneficiaries is crucial. Harmonization of the existing land uses practices, policies and legal frameworks is required to yield the desired level of outcome in mitigating GHGs; the financial constraints must be addressed through domestic and international financial resource mobilization.

Opportunities GHG mitigation: There are a number of opportunities for GHG Mitigation upon which the strategy should capitalise. These are, among others, community participation, Integration of Climate Change in to the Curricula, Continuous Education, and the Contribution of the Mass Media. Participation of local communities is critical to the success of the proposed mitigation projects and/or programs. The commitment of the local stakeholders is guaranteed as these projects/ideas were generated from the various sectors including energy, agriculture, transport, land water and environment as well as the various municipalities involved in the management of wastes in the six administrative regions of Eritrea. The emergence and advancement of the renewable energy sources, such as solar, wind, and geothermal are key drivers for shifting from fossil fuel energy generation to more clear energy production and energy efficiency technologies.

Institutional Capacity-Building to Sustain Mitigation Work: To sustain GHG mitigation works, it is important to strength the national institutions to enable them design and implement projects. Consistent technical and human capacity building should be designed, implemented and regularly evaluated and improved. Further retention of trained and experienced expert in the paramount importance and mechanism need be developed for ensuring effective transfer of knowledge and skills to younger and junior. To this effect strategy for the transfer of knowledge needs to be developed.

5. Vulnerability, Impacts, and Adaptation Assessment

Rainfall: Analysis of rainfall data for the years 1900 to 2018 was used for the current scenario in which there is a decreasing trend in the mean annual precipitation that amounts from 17% to 30%. Overall, the long term precipitation showed that rainfall is decreasing during the past 28 years whereas in some localities (southern red sea) an increasing trend was observed in the mid red sea region. The rate of decrease of rainfall in south-eastern coastal areas of Eritrea is much smaller compared to the inland parts. The degree of uncertainty in future projections of rainfall patterns very high. None of the models showed a reduction in mean annual rainfall patterns, though the probability for drought occurrence is very high. Drought has long been a significant natural phenomenon in the past and it will continue in the future, which is a matter of great concern.

Temperature: Data on temperature for the years from 1961 to 2018 was applied for the current scenario. Result of the analysis showed a significant increase in the maximum average temperature of 1.85℃ in the Eritrean plateau and a modest increase of minimum average temperature of about 1.64℃. The result did not significantly differ from the analysis carried out by IPCC, which mentioned an increase of 1.7℃. However, in the coastal areas of the country, a significant decrease of maximum average temperature of about 2.5℃ was observed from 1960 to 2018.

Vulnerability and impact assessments: Vulnerability is a combination of exposure and sensitivity in which decrease in vulnerability implies reduction of exposure to hazards, sensitivity of their effects and build capacity for adaptation action. The agricultural sector is the

most vulnerable sector to the effects of climate change as it is highly dependent on the natural system. Drought, epidemic pests, diseases and parasitic weeds are the major threats that hamper crop and livestock production systems. Subsistence farmers, rural dwellers, pastoralists, urban poor and fishermen are, in particular, form the most vulnerable groups. Among Eritrea's regions, the Northern Red Sea and Southern Red Sea are much more vulnerable compared to the other parts of the country.

Sectoral vulnerability and Impact assessment: Eritrea is highly vulnerable to drought being the most important single climate related natural hazard impact. The major adverse impacts of climate change includes decline of agricultural yield (food insecurity), depletion of water resources, land degradation, loss of biodiversity outbreak of diseases associated with climate change, and loss of livestock and property due to wind storm accompanied by heavy rainfall.

Crop subsector: In general crop production is dwindling as the result of climate change. Some crops have either decreased in diversity or extinct. Sorghum is the most important crop which occupies 49% of the total cultivated area and accounts for 46.4% of the total production. Barley stands second to sorghum in total production based on the 1992 to 2018 data. Sorghum, pearl millet and barley are early maturing and drought tolerant crops grown by majority of farmers. Productivity for sorghum and barley is 0.55 tons/ha and 0.75 tons/ha, respectively though there were fluctuations of yield in different years. Based on the impact of climate change scenarios, although yield loss would be significant for all crops its impact is more pronounced for wheat in which it is expected to be reduced by more than 25%.

Livestock subsector: Livestock production is mainly affected by drought, which contributes to poor animal feed, lack of water points and decreased food intake as the result of heat stress. Livestock are important sources of milk, meat, manure and draught power. Income from the sales of livestock and their products is also an important means of a coping mechanism in time of food shortages. Droughts that occurred between 1992 and 2004 have led to massive death of cattle and camels and such environmental stress in the future might result in similar trends.

Forestry: A century ago, 30percent of Eritrea's land surface was covered by forest, which dwindled to less than 1% now. Deforestation for the expansion of agriculture, cutting of trees for fuel-wood and construction of materials-intensive traditional houses are the main causes. The overwhelming dependence on biomass (charcoal, firewood, agro-residues etc.) and cow dung for domestic energy contributes significantly to clearing of forests and woodlands. Land degradation is one of the most serious environmental concern following inappropriate land management, unsustainable agricultural practices, overgrazing and deforestation resulting in clearing of vegetation cover and increased soil erosion. The annual rate of soil loss from cropland is estimated at 12-20 tons/ha and crop yield is declining at the rate of 0.5% per annum owing to soil erosion.

Water resources: Climate change reduced surface water and groundwater resources in most dry regions of the country intensifying competition for water among different sectors. There is a decreasing order of stream flow series in almost all river basins except in the *Anseba* River. The water quality in the Central Highland region and the Western lowlands is good with respect to chemical quality, while that in the Red Sea coastal area is mostly saline. The bacteriological analysis indicated that on the average 59.7% were found to be biologically contaminated.

Human Health: In Eritrea, climate change has evident effects on public health. Consequent to prevailing climate change some areas have been infested with new diseases. This are related directly or indirectly linked with the expansion of irrigated agriculture or increased temperature

due to climate change. Habitually malaria infestation was common in lowlands; with increased temperature, the disease expanded to highlands where the disease was unknown in the pasts. Nonetheless, as the result of the effective government intervention, morbidity and mortality due to malaria have declined by more than 86% and 82% respectively.

Period of drought are usually followed by torrential rains that cause tremendous floods thereby contaminating water points. Under climate change scenarios associated with flooding, drought, and rise in temperature, diarrhoea incidence increase and remain to be one of the major killers of the poor and children under the age of five. In response to droughts, a number of dams, reservoirs and ponds have been constructed for irrigation and these water bodies are believed to favour the development of snails, the intermediate host of Schistosomiasis. Consequent to climate change new diseases emerged during the past few decades some of which included Chikungunya and dengue fever.

Adaptation Assessment, Strategies and Policies

In order to withstand the impacts of climate change, policies and other related programs should aim at promoting drought-resistant breeds of livestock so that opportunities for income diversification are created, and effective rural finance institutions along with extension service are established. These polices should focus at ecosystem enhancement by promoting soil and water conservation structure, afforestation and reforestation, drought resistant crop varieties, integrated pest management and disease control etc. Policies should also be tailored coastal area management to prevent coastal erosion.

In the crop subsector, the adaptation activities carried out are distribution of inputs, utilizing smart agriculture practices: choice of crops and varieties, inter tillage cultivation, intercropping/mixed cropping, minimum tillage, irrigation, soil and water conservation and water harvesting in crop fields. Similarly in the Livestock subsector, the current adaptation measures that are implemented are conservation of standing hay and crop residue; building water harvesting structures and distribution of breeds that are resistant to feed shortages, diseases and heat. The farming community are utilizing various livestock breeds for production.

Natural Resource management/forestry: The adaptation activities commonly carried out in some parts of Eritrea are soil and water conservation, afforestation, reforestation, enrichment using indigenous plants or mixing with selected exotic varieties programs and area closure. In addition, considerable number of trees has been planted through green campaigns. Moreover, distribution of energy saving stoves has helped in conserving a large track of forested area.

Water resources: A climate smart water use system is being adopted that includes reducing flooding through maintaining ground water recharge; sustainable use of river basins; introducing new technologies in irrigated agriculture and dissemination of knowledge in the protection of water resources. In addition water conservation activities and techniques such as terracing, check dams, bunding and water harvesting structures have been constructed.

Health: The key adaptation strategies would be to focus on climate smart health system, which is integrated in the health service provision.

Malaria: Integrated vector control includes environmental management, larveciding, indoor residual spray; bed net distribution; malaria case management composed of early diagnosis and treatment; training community health agents; ensuring availability of drugs for treatment; operational research such as malaria surveys, drug sensitivity and drug resistance are the adaptation measures that are undertaken.

Malnutrition: The activities include therapeutic feeding and supplementary feeding program. In addition, appropriate and high quality complementary food for infants accompanied by appropriate micronutrient intervention have helped to address the problem of malnutrition and stunting.

Diarrhoea: The adaptation activities are feeding and supply of ORS which helps to reduce dehydration and minimize the adverse consequences of diarrhoea; the stool disposal has also prevented the spread of diseases that is if faeces are not properly disposed the disease (diarrhoea) may spread with direct contact or through animal contact.

Yellow fever: Travellers coming to Eritrea from a country with risk of yellow fever virus transmission are required to have international vaccination certificate.

Coastal areas and island: Adaptation activities carried out along the Eritrean coast includes distribution of fishing nets and polyethylene ropes, mangrove reforestation programs in the mainland and. A major adaptation activity also includes strengthening inland fisheries with a potential to produce around 100-150 tonnes per year. Fisheries management measures are also in place to avoid over-exploitation of marine resources and habitat destruction. The conservation and management efforts include activities such as not allowing fishing any marine mammals and turtles but if caught accidentally they are released immediately.

Urbanization: The major adaptation strategies for urbanization include building cities and towns with proper waste management and providing suitable conditions for residents, investment, tourism and development. Urban development consider public space such as parks, sport places, road dividers, roadsides and roundabouts, festival areas, and water shed areas and urban agriculture. Furthermore, woodlots and green belts near cities and compounds need to be planted with different types of vegetation, fruits and ornamentals so that the cities could become green at all times.

Review on selected Adaptation Projects: Several climate resilient adaptations activities have been undertaken throughout the country. Examples of these adaptation projects among others include: *Gash Barka* Livestock and Agricultural Development project, Post Recovery and Rehabilitation Development (PRRD) add on Development Program in *Gash Barka* and *Zoba Debub* 2010-2014; Climate Change adaptation program in water and agriculture in *Anseba* region, Eritrea; Semenawi and Debubawi Bahri, Buri-Irrori and Hawakil protected areas, The Conservation Management of Eritrea's Coastal, Marine and Island Biodiversity (ECMIB) Project.

Policy issues related to adaptation: The adaptation activities that are mentioned in various policies are briefly described in this report. The policies where adaptation programs to climate change are documented includes the National Economic Policy Framework and Program (1998-2000), Food Security Strategy, The Interim Poverty Reduction Strategy Paper,(IPRSP2004), National Adaptation Plan of Action (NAPA, 2007) National Biodiversity Strategy and Action Plan for Eritrea,(NBSAP-2015) , National Environmental Assessment Procedures and Guidelines (NEAPG, 1999), National Action Program (NAP) to Combat Desertification, Environmental Management Plan for Eritrea (NEMP-E,1995), Water Policy and Proclamations,(2010), Health Policy, Coastal Areas Policy and Marine Protected Areas (MPA) and Land use policy are fully specified to show that the policy reflects the adaptation activities to be implemented.

6. Information Relevant to the Achievement of the UNFCCC

Adaptive measures to tackle climate-related challenges require mobilizing national resources including economic, social capital, information, technology, education, and wealth. Resources have to be used effectively so as to realize effective coping mechanisms. In this regard, Eritrea has mobilized substantial amount of resources to promote development and enhance enabling environment for achieving goals under UNFCCC.

Formation of technical Expert Groups and committees: In its endeavours to mitigate climate change and adapt to it Eritrea has involved various stakeholders to take part in the design and development of climate change projects. As a result, relevant stakeholders have been organized as technical expert groups; and offered their expertise. Such arrangement helps to develop sense of belongings on the on-going and planned climate change or related activities.

Level of integration of climate change into National Development priorities: Eritrea has issued a number of environmental laws, proclamations, directives and legal notices to address climate change. Committed to the international endeavours, today, Eritrea is party to a number of international conventions and protocols including the UNFCCC. To that end, the Ministries of Agriculture, Health, Land Water and Environment, and Marine Resources have issued climate change related polices laws and guidelines.

Extent of the development and transfer of environmentally sound technologies: The UNFCCC has created a platform to promote transfer of technologies for mitigating and/or adapting impacts of climate change. In this regard, Eritrea is involved in technology transfer through technology needs assessment, technology development, creating enabling environments, capacity building and setting mechanisms for technology transfer.

Extent of climate change awareness and systematic observations: There is increased public awareness about climate variability in Eritrea. However, climatic data is highly constrained because of lack of modern instruments. Besides, most of the attributes including location, geographical distribution, and type of instruments used in some stations do not satisfy the requirements for a national observation network and WMO standards. Thus, there is need for upgrading and calibrating the weather stations to meet international standards.

Assessment of the Educational Training Programmes and Public Awareness: The educational policy underlines the need for building human resources as one most important resources of the country. In recognition of the critical role education plays, structural changes have been introduced in the educational system. A number of short -term training and workshops were carried out with the aim of providing knowledge and skills on specific aspects of climate change mitigation and adaptation.

Public Awareness: The MOLWE is preparing a robust environmental awareness programs targeting all levels of the public. It prepared several environmental awareness packages such as video shots on environmental challenges and solutions associated with climate changes. The mass media is playing crucial role in raising public awareness with regard to mitigation and adaption programmes. Interviews with experts and dissemination documentary films highlighting climate change are broadcasted on opportune times.

Gender main streaming: Climate change affects the most vulnerable segment of the population including women -headed households, children and the old. To increase the copping capacity of women to climate change, it has increasingly become necessary to stream line

climate change issues. In this connection, the distribution of energy saving stoves has been the right step in the right direction. The improved stoves not only reduce GHG emission but also improve the health of women and children at household level.

Capacity Building efforts: Climate change is multifaceted challenges; which requires institutional and human capacities to respond to the needs. Up to now, Eritrea has limited capacity to cope - up with the requirement for climate change mitigation and adaptation programmes and projects. It is vital that Eritrea alleviate the constraints related to capacity building through training, institutional strengthening, awareness raising, technology transfer, and knowledge management and sharing of experiences. The implementation of capacity building requires an uninterrupted development and strengthening of the country's capacities in various aspects of GHG mitigation activities.

Extent of information sharing and networking: Eritrea has enhanced the level of involvement of stakeholders in preparing the Intended Nationally Determined contributions (INDC and Nationally Determined Contributions (NDC). The information acquired from the UNFCCC regarding capacity building (training workshops and seminars) are disseminated and shared with stakeholders at the national and sub-regional levels. This would be boosted by the steady expansion of the telecommunication in the country.

7. Constraints and Gaps Related to Financial, Technical, and Capacity Needs

Eritrea has a number of constraints and gaps that need to be addressed to produce better quality reports for planning and reporting to the Convention. Climate change study has been constrained by limited institutional capacity, in most sectors, coupled with limited financial resources. Further, there is lack of central point for data management, storage and retrieval or data unavailability and low quality. The main technical and capacity constraints and gaps identified were low level of knowledge, skills and awareness of the climate change issues among the national stakeholders. In the greenhouse gases inventory the major problems were i) Inconsistent data and Information formats ii) Sectoral data unavailability iii) Lack of solid waste characterization data iv) Lack of country specific emission factor and v) inadequate of institutional memory.

Constraints and Gaps in Implementing Adaption Projects: In line with the NAPA, Eritrea has implemented a number of pilot projects in the various regions of the country with the aim of promoting increased food security through ecologically sustainable and climate-resilient agricultural production system. These projects also aim at enhancing resilience of communities and adaptive capacity to climate change through integrated water management and agricultural development approach. The main beneficiaries were vulnerable small-scale farmers, agro-pastoralists, pastoralists and a rural woman that is anticipated to up- scale its outcomes of the project to other regions of Eritrea.

The inadequacy of the financial support can be analysed from two perspectives. First, the number of climatic change projects is small because climate change is viewed as a global issue linked with the emission of GHG from the industrial countries. Second, the immediate environmental problems in the developing countries are related with land degradation that attracts less financial resources.

Measures taken to alleviate the gaps and constraints: To address gaps and constraints described above and to strengthen adaption to climate change, Eritrea has prepared National Action Plan (NAP) with the following objectives: i) Establishment of an innovative and effective NAP consultative framework at the various levels involving key stakeholders ii)

Enhance the national capacity in climate data collection, analysis and modelling of climate change projections, and risks and vulnerability assessments iii) Streamline climate change adaptation issues into sector strategies and budgets and monitoring systems iv) Secure and sustain climate change financing mechanisms for NAP implementation.

The outcome of the NAP is expected to facilitate a consultative process, utilize downscaled global climate, determine risks and vulnerabilities to climate change, prioritize the best adaptation approaches, ensure sustainable budget for the implementation and strengthen monitoring and evaluation systems in the country.

CHAPTER ONE

1 NATIONAL CIRCUMSTANCES

1.1 Introduction

The preparation of the National Communications in Eritrea has been carried out as part of the country's commitment to the United Nations Framework Convention on Climate Change (UNFCCC). The National Communication is thought to be the most effective tool and means for evaluating the implementation of the convention as it enables parties gain information on the overall aggregated effects of the implementation of the convention. That far, Eritrea has submitted the Initial National Communication (DoE, 2000) and the Second National Communication (DoE, 2012).

This TNC presents information on the trend of the national GHG emissions, impacts and vulnerability, mitigation and adaption policies and plans as well to use the information to develop project addressing climate changes. The preparation and reporting processes of TNC was prepared under the auspice of the MOLWE which guides and oversees the preparation process; and facilitates access to additional technical assistance when and if required. The DoE is the executing body as well as the Focal Point for UNFCCC. The Global Environment Facility (GEF) through its implementing agencies including UNEP and UNDP plays crucial role as source of financial resources.

Eritrea, for most of its history, has been a victim of expansionists as a result of its strategic location along the sea route between Europe and Asia. The country suffered invasions from the Bejas and the Turkish beginning from the early to the medieval periods. With the opening of the Suez Canal in 1869, the European powers showed increased interest in the Red Sea region. Italians captured the port town of Massawa in 1889 with the aim of establishing a permanent place of residence for their settlers. They invested heavily in Eritrea, viewing it as a staging ground for further conquest of East Africa. Italian entrepreneurs confiscated land with high potential for agriculture from the indigenous population and transformed it into large-scale commercial farms. After the defeat of the Italians in 1941, the country was put under the British military administration from 1941 through 1951. This was the time of popular uprising among the Eritrean people for independence. Despite the call for a free nation, the UN, however, adopted a resolution in 1952 that brought an end to the autonomous administration, which was followed by the Ethiopian annexation. The armed struggle for independence began in 1961and ended in 1991, after years of peaceful protest against Ethiopia's violation. In 1993, Eritrea became an independent nation; and was admitted to a full membership in the UN as the 182nd member state.

By virtue of its geographical location in the *Sahelian* region of Africa, Eritrea is prone to drought since time immemorial (MoLWE, 2012). Throughout the country, drought remains one of the major threats to the rural livelihoods as well as urban dwellers. Since recent past, risks associated with climatic variability have intensified thus accelerating land degradation. The mean annual temperature has increased by 1.7°C over the last few decades, which is a clear manifestation of climate change at the local level (MoLWE, 2018). Adaptaion Plan of Action (NAPA, 2007) indicated that increased temperature has detrimental effects on crops, livestock and the marine ecosystems. In most cases, periods of droughts are followed by intensive torrential rains that trigger flooding particularly in areas adjacent to the seasonal rivers basins. Moreover, recent studies (Waithaka *et al.* , 2012) using Global Circulation Model (GCM)

projections indicate that in the medium to long-term periods of drought and flooding contribute to future risk and vulnerability of the rural livelihoods in sub-Saharan Africa.

In view of the complexity of the problems highlighted in the previous paragraphs, the extent to which Eritrea will effectively mitigate and adapt climate changes depends on the country's coping capacity to the adverse effects. Undoubtedly, such endeavours require mobilisation of local communities, financial support and transfer of knowledge and technology which necessitates the establishment of a reliable climate change database to generate information needed for mitigation and adaptation activities in the country.

1.2 Geographical Setting

Eritrea is geographically located between 12°22' and 18°02' north and 36°26' and 43°13' east. It is bounded by the Sudan to the north and west, the Red Sea to the east and northeast, Djibouti to the southeast and Ethiopia to the south (Figure 1.1). It covers an area of 124,320 km^2, with two major physiographic zones identified as highland and lowland. The country has a mainland and island coastline of approximately 3300 km (ECMIB, 2007). The elevation ranges from 120m below sea level, in the southern arid region, to over 3000m in the central highlands. The country is divided into six administrative regions (Figure 1.1).

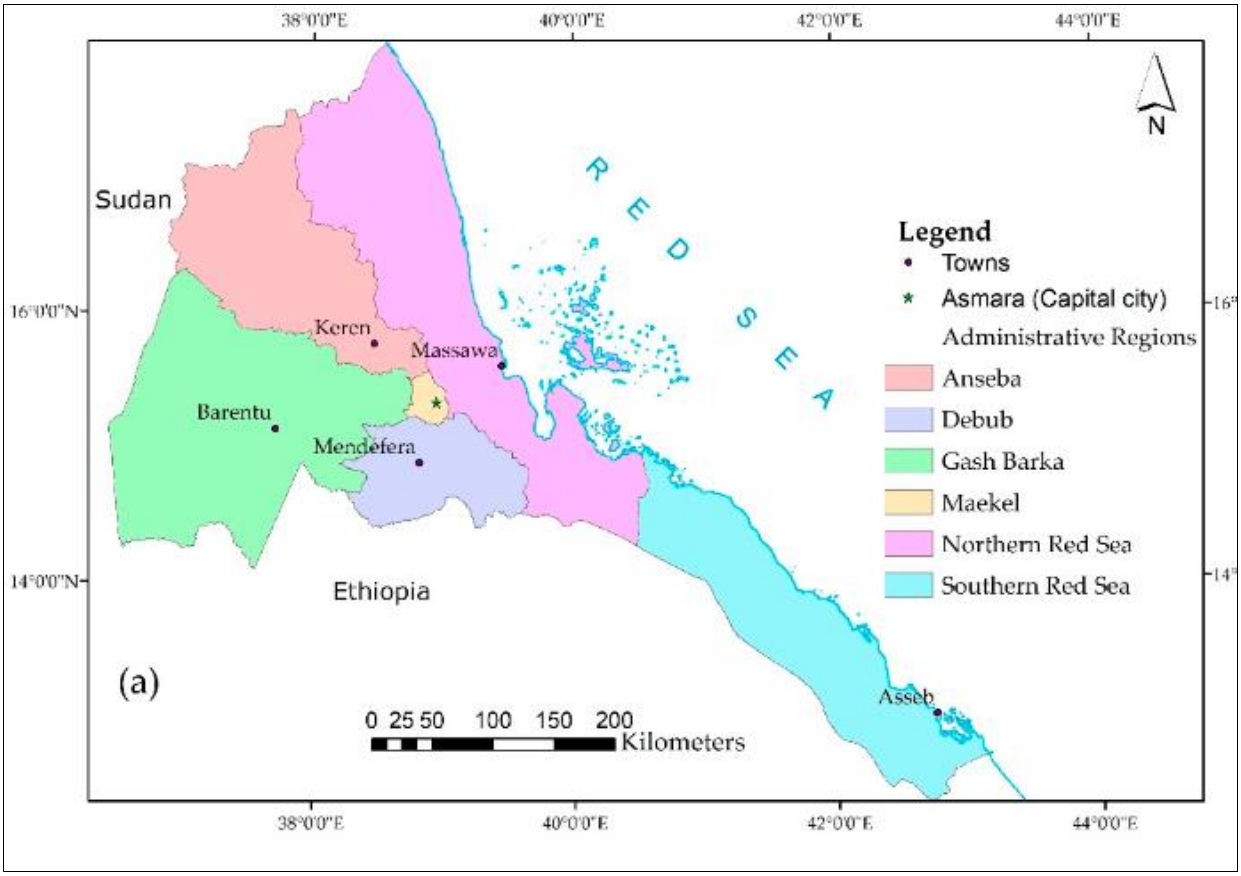


Figure 1.1: Location and administrative regions of Eritrea
Source (Measho *et. al*., 2019)

1.3 Climate

Temperature: The temperature in Eritrea is most influenced by altitude and topography. Average temperature varies considerably in space and time. The average annual temperatures in the eastern lowlands and western lowlands are 31°C and 25°C respectively. In the highlands, the annual mean is 21°C (Figure 1.2). Temperature fluctuates with change of altitude; moving

westward from the Red Sea towards the highlands, temperature reduces by around 1^0C for every 200 m of elevation increase. According to Eritrea Second National Communication under the United Nations Framework Convention on Climate Change (MoLWE, 2012.); since 1960, the mean annual temperature has increased by 1.7°C; a clear manifestation of climate change.

Rainfall: there are two major rainfall regimes: the summer and winter rains. The summer rains occur from June to September; and covers the Highlands and the Western Lowlands with mean annual rainfall ranging from 400 to 700mm. The Eastern Lowlands receive winter rains, from October to March, ranging between 50mm and 200mm. The amount of rainfall in the Sub-humid eastern escarpment, with bimodal rainfall regime, reaches about 1000mm. Precipitation is constantly changing with unpredictable patterns. In general, rainfall declines both in amount and intensity from south to north and from the highlands to the lowlands (Figure 1.3).

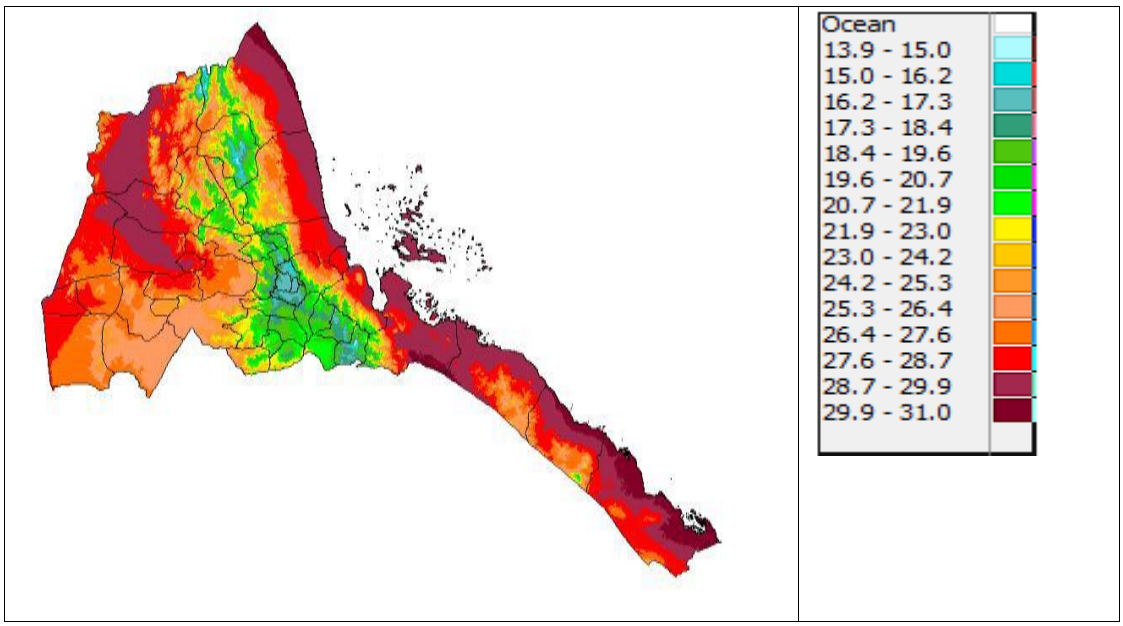


Figure 1.2: Mean Annual Temperature in ^{o}C of Eritrea (**Source**: SNC, 2012)

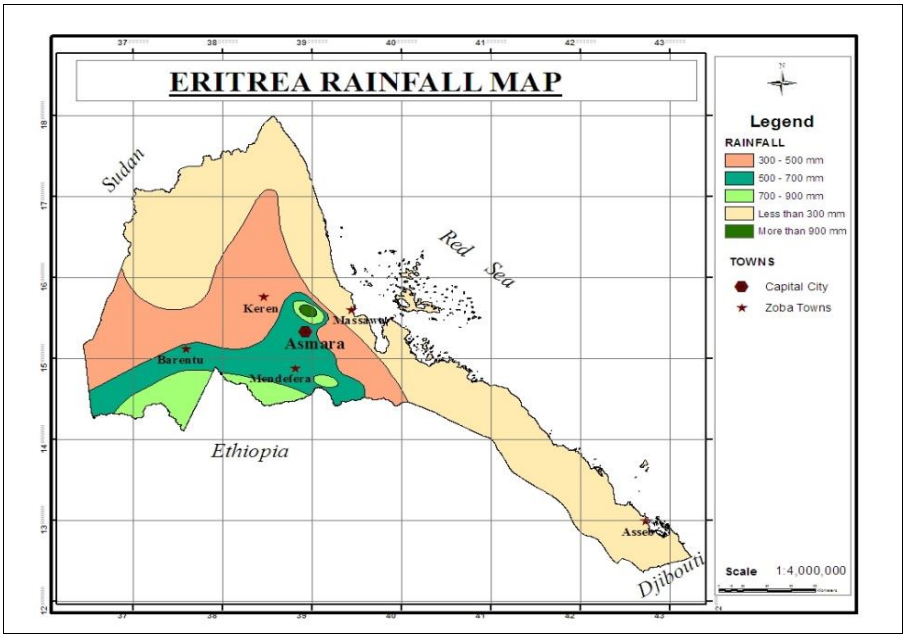


Figure 1.3: Rainfall Map of Eritrea

1.4 Agro-Ecological Zones

Based on combination of parameters such as slope, altitude, rainfall, temperature, Potential evaporate-transpiration, and length of growing period, Eritrea is divided into six agro-ecological zones, (MoLWE, 1997). The characteristic features of these zones is summarised in Table 1.1. The map depicting the six zones is given in (Figure 1.4).

Table 1.1: Description of the Agro Ecological Zones of Eritrea

	Agro Ecological Zone					
Parameters	**Sub-Humid**	**Arid Highland**	**Moist Highland**	**Moist Lowland**	**Arid Lowland**	**Semi-Desert**
Area (km^2)	1006	3143	9302	20363	43115	48772
Total area (%)	1	3	7	16	34	39
Slope (%)	8-100	2-100	2-30	2-30	0-30	0-30
Altitude (m a.s.l.)	600 - 2600	1600 2600	1600 - 3018	500 – 1600	400 - 1600	<100 - 1,355
Rainfall (mm)	700-1100	200-500	500-700	500-800	200-500	<200
temperature (^oC)	16-27	15-21	15-21	21-28	21-29	24-32
Potential Evapotranspiration (mm)	1600 - 2000	1600 - 1800	1600 - 1800	1800 – 2000	1800- 2000	1800 - 2100
Dependable Length of Growing Period (days)	60-210	0-30	60-110	50-90	0-30	0
Median Length of Growing Period (days)	90-240	30-60	90-120	60-120	30-60	<30

Source: MoLWE, 1997

From Table 1.1, it becomes evident that the vast majority of the land surface areas of Eritrea are occupied by the Semi-Desert (39%) and arid lowlands (34%). The dominant farming system in these areas is spate irrigation supported agro pastoralism and nomadic pastoralist. High temperatures and irregularity in precipitation characterize the climatic conditions of these zones. Both the Moist Lowland (16%) and Moist Highland (7%) cover the south-western and highlands; and both are the most productive agricultural lands suitable for rain-fed and irrigated agriculture; and account for the majority of annual crop production and cultivable lands. Contrary, the Arid Highland (3%) is a sparsely populated; and characterized by deficiency in rainfall and a short growing season. Consequently pastoralism is the basis of the livelihoods of the population in the area. The Sub-Humid Zone, small stretch of land in the Eastern Escarpment covering (1%) receives bi-modal rainfall with diversified ecological niches.

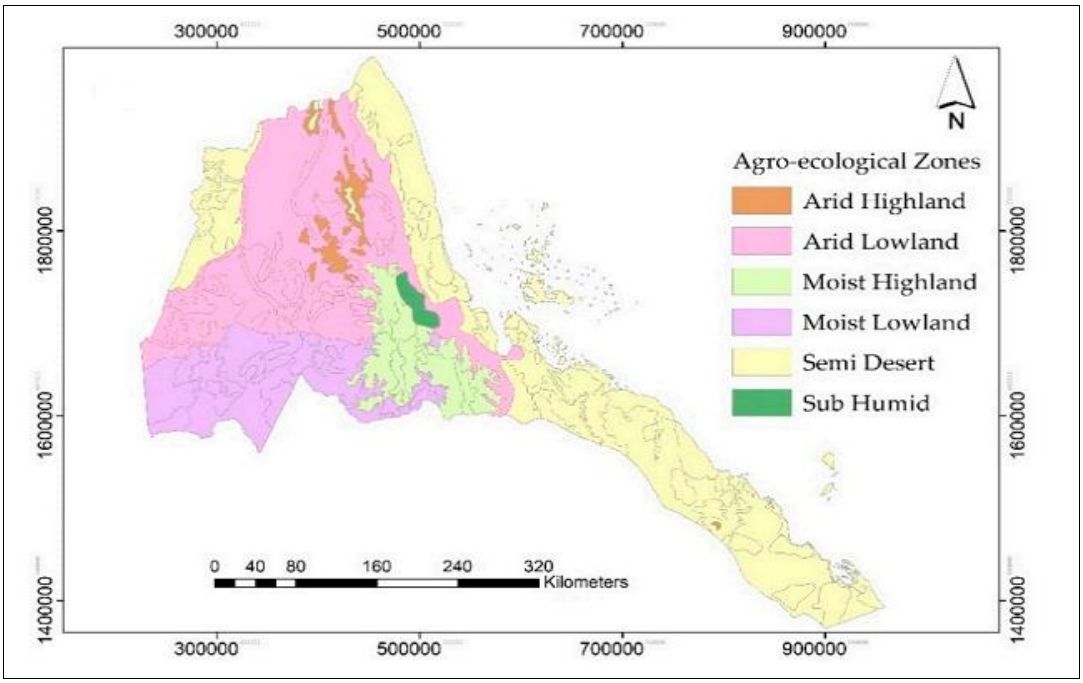


Figure 1.4: Agro ecological zones of Eritrea

1.5 Land Use and Land Cover

To date, there is no comprehensive land use plan covering the whole country. Nevertheless, the Land Proclamation No.58/1994 (MoLWE, 1998), and Land Use Planning Regulatory Framework, (MoLWE, 1999) form the basis for the country's land use policy. Based on these Proclamations, a pilot project on sustainable land management was carried out in the central region (Zoba Maekel) using remote sensing data; and discussion with key local informants. The pilot project has proved to be successful and is expected to expand throughout the country in order to generate a much extensive land use plan.

The main land uses in Eritrea are crop production (agriculture) and livestock production (pastoralism). According to the MoA (2002), the major land uses are cropland (3.5%), Grazing land (56.3%), Grass and Shrub Land (5.4%), Settlement land (0.1%) and Bare and Other land (34.1%), Forest Land (0.4) and Wetland (0.1). Grazing land and Barren Lands and other land account for the largest proportion of the land use in the country (Table 1.2).

Table 1.2: Land Use Types of Eritrea

Major Land Use Types	**Sub - category**	**Areas (000ha)**	**%**
Cropland		**439**	**3.5**
	Rainfed	417	3.4
	Irrigated	22	0.2
Grazing Land		**7000**	**56.3**
Woody Vegetation		737	5.9
	Highland Forest	53	0.4
	Plantation	10	0.1
	Wood land	674	5.4
	(Dry)	664	5.3
	(Riverine)	5	0.0
	Coastal	5	0.0
Urban land		**13**	**0.1**
Barren Land		**4243**	**34.1**
Total		**12,432**	**100.0**

Source: The National Adaption Plan of Action (MoA, 2002)

A large proportion of the population in Eritrea depends on traditional subsistence farming. Hence, agriculture plays a crucial role in the livelihoods of the population. Nonetheless, it is highly constrained by decline of land productivity caused by human induced land degradation including overgrazing, over cultivation, deforestation and overall inadequate land resource management practices. To mitigate and adapt the adverse effects of climate change; the GoE is undertaking efforts to create a green economy. Strategies for environmental reclamation are incorporated into the National Action Programmes (NAP). Despite the positive moves, however, land and forest degradation still pose a major environmental problem (MoA, 2017a).

1.6 Soil

The Harmonized World Soil Database (FAO, 2012) identifies 13 soil types out of which Leptosols and Arenosols covers most parts of the country (Figure 1.5). Solonchak, soils with high salinity, are mostly found along the coastal regions. In general, soils with the highest agricultural potential are found in the southern central highlands and south-western parts of the country.

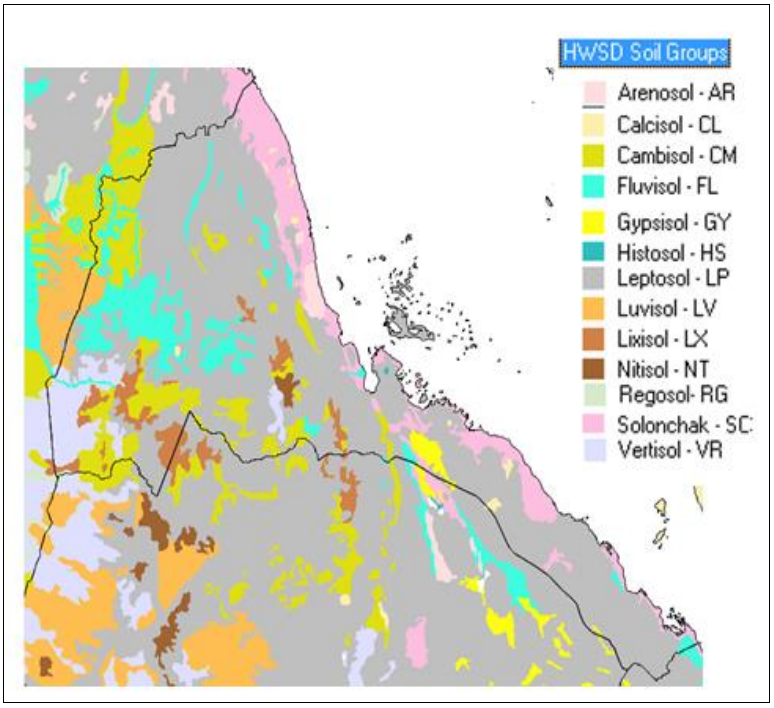


Figure 1.5: Soil map of Eritrea – extracted from Harmonized World Soil Database (version 1.2). (**Source**: FAO, 2012)

1.7 Socio- Economic and Development Context

Eritrea's development objective is to attain rapid, widely shared and regionally balanced growth with macroeconomic stability and sustainable reduction in poverty. In 1994, the Macro Economic Policy of Eritrea clearly set out the path for enhanced national development. Important measures to address development challenges in the country, among others, include the Interim Poverty Reduction Strategy Paper (I-PRSP, 2004), the Food Security Strategy (FSS), Education Sector Development Program, the National Water Supply Emergency Action Plan and the 2003-2008 national Gender Action Plan, and the National Health Policy. For instance, the I-PRSP aims to promote economic growth and development through the following measures:

- creating favourable conditions to achieve sustainable growth,

- attracting investment in high potential growth centres mainly in fisheries, tourism, construction, manufacturing and regional trade,
- investing in human resources development with priority to health and education, and
- expanding and modernizing the country's basic infrastructures (UNDAF, 2006).

1.7.1 Population and Demographic Profile

In Eritrea, there are nine ethnic groups namely *Tigrigna, Tigre, Afar*, *Bilen*, *Bdawet*, *Kunama, Saho*, *Nara*, and *Rashaida*. These groups differ in language, customs, and exhibit diversified land management practices with noble indigenous knowledge regarding climate change. According to the Population and Health Survey (NSO, 2010), the total population of Eritrea was estimated at 3.2 million people. The majority of the population (65%) lived in rural areas. The population density is approximately 26% per km^2. At a national level, the geographic distribution of the population shows that highlands with mild temperatures are densely populated than the hot and arid lowlands.

The country's population is essentially young, with children below age 15 years accounting for 41 %. Dependency ratio, which indicates fertility rates, is high. The rate of population growth is generally higher in rural areas than in the urban areas. There are strong inclinations among both men and women, in the countryside, for having as many children as possible, with no preference of one sex for another. Significant improvements in early childhood mortality rates have been observed in both rural and urban areas, which as a result, Eritrea's population is expected to grow rapidly in the coming decades. The rapid population growth rate, in turn, will have implication for the country's development.

1.7.2 The Education Sector

Eritrea made significant stride to ensure equitable access of education across all regions of the country. Many areas, previously unreached and disadvantaged benefited from investments in infrastructure. Curriculum improvement and deployment of trained teachers has been improved. The number of students, teachers and schools increased at all levels (MoE, 2004).

As part of global commitment for gender, special attention has been given to ensure that the gender gap is closed at different levels of education. Promotional activities have been conducted in various administrative zones to help females and disadvantaged children attend school. Children from poorer families received incentives including school feeding, waiving of registration fees and supply of stationery materials. Besides, increasing enrolment at the formal primary education system, a complementary primary education program has been developed to provide catch-up education for children who missed the opportunity for formal education. Thus, a large number of over-aged children have been given the opportunity to attend school through non-formal education.

Though Eritrea had made quite a remarkable progress in terms of increasing school enrolment, the Gender Parity Index is skewed towards male students. The most critical challenges that limit girls' education are related to economic and social conditions (MoE, 2004). Community attitudes towards females' enrolment in school, early marriages and heavy domestic loads are among the major factors that contribute to the gender disparity at all levels of education. Nevertheless, a major strategy to enhance women's participation in education should, focus on alleviating these social barriers. The National Gender Plan of Action (2003-2008) identified critical constraints to girls' education; and outlined strategic objectives and plan of actions to address the problems (MoE, 2004). Awareness raising campaign a key approach to tackle the negative attitudes towards educating females. Female teachers help assure parents regarding

safety of girls at schools and hence increase enrolment rate for female students. Besides expanding education at the primary and secondary levels, the Government recognizes tertiary education as a key to social and economic development. Accordingly, student enrolment rate in the Institutes of Higher Education is steadily growing with increased female enrolment in various colleges.

As part of the country's basic education system, Eritrea expanded adult literacy. Adult literacy is equivalent to five years of the elementary education; and is composed of literacy and post literacy for persons 15 years old and above. As the result of relentless and collaborative efforts, a total of 700,000 adult learners have been enrolled since 2000 (MoE, 2013). In addition to the basic education, Information and Communication Technology (ICT) became an important variable in enhancing quality education. The introduction of ICT into the Eritrean school system since 2005 laid foundation for improved school system. More importantly, it has created extensive awareness and common understanding in preparing the young generation of learners for today's globalized world of knowledge and information.

1.7.3 The Health Sector

The goal of the health system, in Eritrea, is improvement in the general wellbeing, and economic productivity of all citizens. The country adopted the National Health Care Policy (NHCP) and Health Sector Strategy (HSS) to provide basic health services to the wider sections of the population. The outcome has been an increase in accessibility to the health facilities within 10km radius from 46 % in 1991 to 80% in 2018. In addition, over 60% of the population is now living within 5 km from health facilities (MoH, 2017). Health indicators such as longer life expectancy and reduction in child and maternal mortalities are among the major achievements in the health sector. In general, the main contributing factors for the progress in the health sector of the country are increased number of workers and expanded facilities.

Health Facilities and Personnel: Eritrea made extensive progress in terms of building health infrastructure with the aim of promoting access to health services. At independence in 1991, the country which had only 16 hospitals, and 106 health stations; today possess 391 facilities of which 29 are hospitals, 56 centres, 193 stations and 113 clinics. The national care network is three times bigger than what it had been in 1991. There are 74 laboratories categorized under five different levels, namely: National Health Laboratory, National Referral Hospital Laboratory, Regional Hospital Laboratory, Hospital Laboratory and Community Hospital Laboratory. There National Medicine and Food Administration (NMFA); an agency that monitors the safety and availability of medical and pharmaceuticals supplies at affordable prices is established. Besides, the number of health professionals increased over the years. According to the World Health Organization (WHO), a country needs to have at least 2.5 health workers per 10,000 inhabitants to achieve the MDG (WHO, 2017). Eritrea has achieved beyond the WHO requirement by having 15.9, 17.9 and 18.2 workers/ 10,000 for the years 2015, 2016 and 2017, respectively (MoH, 2017).

Trends in Morbidity and Mortality: Eritrea achieved the Millennium Development Goals (MDGs) for health before the timeline set. Maternal Mortality Rate (MMR) is reduced from 998/100,000 in 1995 to 486/100,000 in 2010. Similarly, Figure (1.6) depicts the infant and child mortality was reduced from 72/1000 in 1995 to 34/1000 in 2015 (MoH, 2019). Building on the progress to date, infant immunization showed remarkable success with coverage standing at 85% at a national level (Tekie, 2019). The reduction in child mortality places Eritrea among the ten countries in sub Saharan Africa that have achieved the MDG4. A further improvement in the health sector is the reduction in the prevalence rate of HIV, TB, and

Malaria. The rate for HIV infection decreased substantially, while malaria is put under control as the country moves toward pre-elimination phase. Morbidity and mortality from measles have gone down to less than 90% of the 1991 level. The country is heading towards achieving the polio-free status (WHO, 2017). Although, Eritrea is classified as having low potential for yellow fever virus (YFV), the principal vector that transmits the disease (*Aedes aegyptiaca*) still prevails in the country. Moreover, the country shares border with countries that have higher risk of yellow fever transmission. As part of the progress made in the sector, major preventable diseases no longer pose significant public health threat. Currently, non-communicable diseases such as heart and hypertensive diseases and diabetes are among the leading causes of morbidity and mortality in the country.

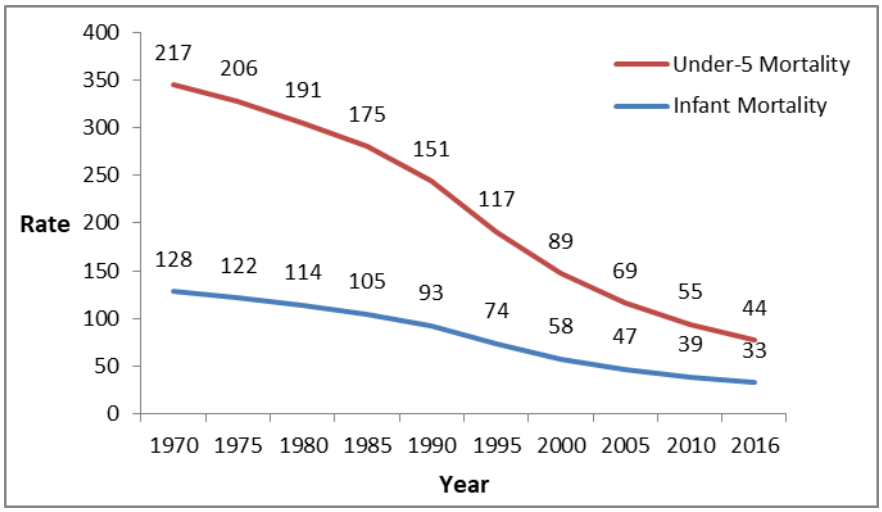


Figure 1.6: Infant and under-5 mortality rates per 1,000 live births (1970 - 2016)
Source: MoH, 2017

Safe Water and Sanitation: Eritrea made tremendous effort over the years to increase access to clean drinking water and improved sanitation (UNDAF, 2006). This effort has reduced the threat from waterborne diseases; and; enhanced hygienic behaviour of the public. The improvement has been significant particularly for rural communities; though access to sanitation facilities still lag behind. In spite of Eritrea's huge success in the health sector, there are emerging challenges that adversely influence the availability of clean drinking water. The challenges, among others, include the effect of climate change and unplanned expansion of urban areas. The changes in climate pattern have, in particular, resulted in new disease epidemiology. Lack of Public Health Act has been identified as the main gap in the country's health system.

1.8 Economic Sectors

Eritrea's immediate development priorities have been set to meet the basic needs of the population. To this effect, the Government formulated Macro Economic Policy, which stipulates the need to enhance national economic development and to monitor the changes in the natural environment. The Government has also prepared the National Economic Policy Framework to optimize resource use and sustain human development. Moreover, the country's Interim Poverty Reduction Strategy Paper (I-PRSP) has been a milestone in directing development interventions (MoND, 2004). The long-term objective of the I-PRSP is to attain rapid and widely shared economic growth with a steady and sustainable reduction in poverty. I-PRSP is based on the following four pillars. (i) Provide strength to economic growth; (ii) Create income earning opportunities for the poor; (iii) Enhance access to essential services for human development; and (iv) Promote economic, social and political participation of the population by

creating an enabling environment. The I-PRSP further states that the private sector, non-governmental and community-based organizations all have vital roles to play in meeting the challenges of poverty reduction. Immediately after independence in 1993 and up to 1997, the socio-economic polices and strategies led to notable rise in economic growth averaging 7.4 % (UNDAF, 2006). There were marked improvements throughout key sectors until the outbreak of the border war with Ethiopia (1998-2000), which reversed positive post-independence achievements.

1.8.1 Agriculture

Crop production: Agriculture has been and still remains the cornerstone of the Eritrean economy food security for the largest proportion of the population. It plays significant role in reducing poverty and support industrialization. It is critical for achieving export growth, employment generation, and supply of raw materials for agro-industrial processing. Agriculture sector contribution to the country's Gross Domestic Product (GDP) estimated at 20.30 (MoA, 2016).

The farmers produce cereal crops, oil crops, pulses, fruits and vegetables primarily for subsistence use, but they also sell a small portion of their produce at the local markets. The farm sizes are small and highly fragmented, particularly in the densely populated Central Zone of the country. Farming practices remain traditional; and the use of mechanization and modern agricultural inputs are highly limited. In addition, agriculture suffers from unpredictable weather conditions and wide seasonal price fluctuations of outputs. Consequently, domestic food production, even in good years, remains well below the requirements forcing the country to rely on commercial imports. Other critical challenges impeding the development of agriculture includes limited availability of water resources, insufficient modern farming inputs, poor marketing channels, and limited access to credit. Female-headed households represent a typical group within the vulnerable segment largely because they lack sufficient labour and own fewer assets.

Livestock Production: Livestock occupy a place of significant importance in the economic and social lives of rural communities in Eritrea. They are important sources of food in the form of meat and milk. Livestock also play a crucial role in agriculture as plough animals and as a means of transport in rural areas. They acquire cultural significance as important indicators of a person's social status. Skins and hides provide major raw materials for local industries and important sources of foreign currency. Besides, the country generates significant revenue through export of live animals and frozen meat. Since recent times, Eritrea suffered from sharp fluctuations in livestock production. The causes are linked to human factors and to the changes in climate. Livestock are kept in traditional grazing systems with low level of productivity. Shortages of pasture and water points, caused mainly by climate change and deteriorating land quality also hamper livestock economy of the country. Droughts that occurred between 1992 and 2004, for example, have caused deaths to a large number of small and large ruminants. The climatic stress is expected to exceed the thresholds that animals can tolerate, leading to reduced feed intake, lower animal productivity, and increased exposure to pathogens.

The Veterinary Institute of Asmara, though it went through a gradual decline during the colonial times, is currently playing crucial role in tackling animal health problems. Veterinary facilities have been expanded and a large number of assistant veterinarians trained during post-independence period. The outcome has been a substantial reduction in the outbreaks of major livestock diseases. The veterinary institute at present is engaged in diagnosis services to plant and animal diseases; and monitoring food safety and quality services. It also provides research

support to prospective graduates from the various colleges in the country. At present the institute is working hard to come up with viable vaccine production.

1.8.2 Fishery, Marine and Coastal Resources

Eritrea has substantial and underexploited marine and fishery resources. With its long coastline, Eritrea has very high potential to exploit fish and other marine resources. The coastal beaches are relatively pristine and provide an excellent opportunity for developing tourism industries. The MoMR has a regulatory mechanism for monitoring fishing activities. The Ministry's policy prohibits fishing during the months of July to October to avoid over-exploitation of the marine resources; and to allow sufficient time for breeding. Presently, Eritrea's marine ecosystems are vulnerable to the adverse effects of climate changes, as a result of which, it has experienced temperature rise causing tremendous losses of biodiversity, sea level rise and coral bleaching (MoMR, 2020). The MoMR has set a plan for adapting climate smart technologies to counteract the adverse impacts of climate changes. Relevant intervention strategies including Integrated Coastal Zone Management, Marine Protected Areas and Mangrove Afforestation Program have been established.

Extensive continental shelf and the coral reefs along the coastline and islands are rich in marine biodiversity. There are about 1,000 known species of fish of which 250 are of commercial importance. Small pelagic fish account for 62% of the total fish catch. The Maximum Sustainable Yield (MSY) of Eritrea Red Sea fisheries is estimated at about 80,000 tonnes per year (MoMR, 2018); but presently, the annual domestic fish production is much lower than the potential.

The Macro-Economic Policy of Eritrea provides wider legal context for the development of the fishery sector. The policy goal for this sector includes a long-term sustainable utilization of fishery resources for the benefit of the Eritrean people. The policy, more specifically, aims to attain the following strategic objectives:

- Increase the profitability of artisanal fisheries by strengthening the fishers' cooperatives;
- Enhance food security and the provision of employment opportunities for the coastal population;
- Increase foreign exchange earnings through the export of fish and fish products, and
- Encourage domestic fishing market through promoting local fish consumption.

Problems concerning lack of data about the precise fishery stock and inadequate market linkages are the main challenges that constrain the development of the sector. The MoMR in collaboration with its partners including IFAD is working to enhance the productivity of the artisanal fishery.

1.8.3 Tourism

Eritrea's pristine marine waters, spectacular coasts and islands, diverse marine-life and colourful coral reefs, numerous historical, archaeological sites, mountain sceneries, and pleasant climatic zones are the basis for a dynamic tourism industry. The country's relative proximity to the major tourist markets in Europe and the Middle East is a key feature to the development of the sector. The decision by the Government to pursue a strategy for developing tourism potential is based on the industry's positive economic impacts, which fall into two broad categories namely: wealth generation and employment creation. It is widely argued that success in the tourism industry depends mainly on building infrastructure, and protecting the natural environment. In this regard, the country has laid the basis for environmental protection through its National Environmental Management Plan (NEMP-E, 1996) which has outlined

specific activities for an integrated coastal zone management. At present, the major bottleneck for the development of the tourism sector remains to be the inadequate hotel facilities and transport infrastructure.

1.8.4 Trade and Industry

Manufacturing industries in Eritrea are dominated by light industries shown in Table 1-3. These industries have great potential to become important contributor to Eritrea's growth and development thanks to the country's strategic location along the world's busiest shipping route which offers opportunity for accessing export markets, while there is large potential for import substitution. The country, in the past, had a well-developed industrial economy in Africa. The long war for independence and the border conflict that followed, however, had an adverse effect on the country's manufacturing sector. Eritrea possesses manufacturing sectors that range in type from food and textile to chemicals and construction materials. However, the industries operate below capacity for reasons including lack of raw materials operate below capacity due to a number of reasons including among others lack of foreign currency, unsustainable power supply, non-competitive products and shortage of skilled manpower. The country imports a wide range of agricultural and industrial items from Asian, European, African and the Middle East countries. The import values for food and, textile and garment account for the largest amount of expenditures compared to all other items imported. Similarly, the country earns substantial amount of revenue from its exportable items that mainly include textile, and leather and shoe. Since recently, the mining sector is increasingly becoming a driving force to the economic growth of Eritrea.

Table 1.3: Manufacturing Sectors of Eritrea

Sub-sector	**Number of establishment**	**Capacity in %**
Food and beverage	83	41
Textile and leather	33	42
Paper and printing	15	29
Chemicals, paints and pharmaceuticals	23	27
Rubber and plastic	11	39
Construction materials	32	48
Metal	17	26
Furniture	32	41

Source: Ministry of Trade and Industry, 2019

1.8.5 Transport and Communication

The modes of transport in Eritrea comprise road, railway, water and air. The road transport, in particular, is critical as it meets much of the demand for passenger and freight services and hence it has a significant contribution to the overall development of the country. Road transport has undergone improvement as a result of the rehabilitation work and the opening up of new routes and terminals. In addition, proclamations on compulsory third party insurance, road traffic safety and legal notice on technical specifications and standards of vehicles have been issued and enforced to ensure public safety. The Eritrean highway system is categorized into primary, secondary and tertiary levels. The tertiary level is the lowest level in the road category, and serves mainly the rural areas. It is a dry weather road that makes travel during the rainy season difficult. The next higher level in the road classification system is secondary, which is an all-weather gravel road that connects district centres with the regional capital centres. Primary roads are those that are fully asphalted throughout their entire length. They carry traffic

between all the major towns in the country. At present, there are a total of 15,000 km of road in the country of which 36 % consist of asphalt and paved roads (MoTC, 2016).

The railway transport system of Eritrea began in the 1930s, carrying both passengers and freight at a limited capacity. In the past, there was a total of 317 kilometres narrow gauge rail line linking Asmara with towns of Massawa and Akordet. However, it remained non-operational starting from 1978 until it was reopened in 1994. Some rehabilitation works took place in recent years, and as result, the line from Massawa all the way through Asmara had been restored. Currently, there are no railway links with adjacent countries.

1.8.6 Energy and Mines

Eritrea has favourable geology for mineral resources, but largely remained unexplored. The country is made up of tertiary geological formation. As a result, several high-grade volcanic massive sulphide (VMS) discoveries were made in the past few years. It is well endowed with significant precious minerals, base metals and, industrial and construction materials that can support the development of a viable mining industry. There are rich deposits of gold, copper, iron ore, lead, magnesium, nickel, potash, silver, zinc and chromium. The country also possesses reserves of industrial and construction materials that include basalt, cement, clay, coral, granite, gravel, gypsum, limestone, marble, salt, sand, and silica. Moreover, there is a potential for large reserves of natural gas and petroleum. Several companies including Nevsun, Sub-Sahara, Sanu and Sun ridge Corporation took part in the exploration of minerals in the country, while Bisha, Zara and Asmara mining companies are currently involved in the actual operational activities. The development of the mining sector is believed to have a good prospect to the economic development of Eritrea (MoEM, 2018).

Presently, the largest proportion of the total energy consumption of the country is met from biomass sources followed by oil and electricity. The various biomass sources that account for 83% of the total energy consumption show the following estimates: Fuel wood 76 %, charcoal (11 %), dung (10%) and agricultural residues (3%) (MoEM, 2018). Excessive dependence on biomass has significantly contributed to the clearing of forests and woodlands. Such unsustainable practices have led to the overall reduction of Eritrea‘s terrestrial biodiversity. As part of a long term development strategy, the GoE together with its partners piloted a wind energy project in 2010 in the Southern Red Sea region, which consists of a wind farm with a capacity of 750 kilowatts (MoEM, 2018).

Five small stand-alone decentralized wind turbines were installed in the villages of Rahayta, Gahro, Barasole, Edi, and Beylul. The Government has also embarked on solar projects that provide modern, affordable and sustainable energy to the previously off-grid villages and rural towns. A good example is the solar power project that aims to serve over 40,000 residents in Areza area in the southern part of the country (MoEM, 2019). This is expected to improve the livelihoods of the rural population through increased income and access to social services. The project will contribute to the Sustainable Development Goal 7 (affordable and clean energy) and will contribute to the reduction of fuel-wood dependence. In addition, the project is anticipated to reduce carbon emission substantially. Besides wind and solar energy, the country has huge prospect for the development of geothermal energy.

1.9 Environmental Context

Eritrea suffers from intense environmental degradation as a result of a complex set of factors including long and short-term climate changes, expansion of settlements, agricultural encroachments and excessive use of fuel wood. Loss of vegetation cover through continued

deforestation affected the hydrological conditions making the water supply unreliable. The problem is further aggravated by the use of animal dung for domestic fuel and absence of input replacement for the nutrient loss. Land degradation is prevalent throughout the country, but is particularly manifested in the central, northern highlands and southern plateau. The degraded area covers 2.4 million hectares, constituting around 19% of the total land area of the country (MoA, 2017a). The most visible impact of such environmental crisis is reflected in the decline in crop yield; consequently, the country is incapable of meeting its annual food requirement. The long term changes in the country's ecosystem are expected to have serious adverse impacts on the human health, forestry, and coastal and marine environments.

1.9.1 Climate Changes

Eritrea is one of the most vulnerable countries of the world to the adverse effects of climate changes due, primarily, to its geographic location in the Sahelian Zone. Human activities have led to unsustainable land use practices such as clearing of land for farming. Moreover, heavy dependence on wood for energy needs had adversely impacted the forest cover of the country, which, in turn, has reduced crop yield and livestock production. There is a widely accepted proposition that climate change has brought about an increase in the mean annual temperature of 1.7^{o}C since 1960 (MoLWE, 2018). As a consequence, the country faces recurrent droughts and associated problems of food insecurity and poverty. Overall, the changes in climate have seriously impacted livelihoods and socio-economic systems of the country.

1.9.2 Water Resources

Eritrea is not endowed with rich water resources due to its exposure to vulnerable environments such as drought. The country's water supply coverage is estimated at 75% and 93% for the rural and urban areas, respectively (MOLWE, 2007). In order to meet the demand for clean potable water, the present per capita consumption for the rural population should increase from 15lt/day to 20lt/day. Similarly, clean water supply for the urban population has to increase from 40lt/capita/day to 50lt/capita/day. In 2020, the overall domestic water needs for the rural population and for the urban population were expected to be 27.0 Mm^3/yr and 40.8 Mm^3/yr, respectively (WRD). A survey to determine the future water demand for livestock is based on the assumption that herd size increases by 1% annually. A large quantity of clean water is also needed for agriculture sector with a projected amount of 2396.5 Mm3. Nevertheless, the mining projects that are on the operational phase are expected to demand a considerable amount of water in the future. The water resource of the country faces major challenges including lack of regulatory mechanism for proper water use allocation and severe environmental degradation.

Surface Water: There are five major river basins that drain a significant proportion of the country's land surface. Table (1-4) presents Major drainage basins of Eritrea and estimated runoff contribution (Mm^3/yr) where the largest share of the total annual runoff flows to the west, while the remaining flows to the east entering into the Red Sea. The total estimated mean annual runoff from the five rivers basins is 9967Mm^3/year (IWRMP, 2009).

Table 1.4: Major drainage basins of Eritrea and estimated runoff contribution (Mm3/yr)

Drainage Basin	**Basin surface area within Eritrea (km^2)**	**Total surface area of drainage basins**	**Estimated Mean Annual Runoff**
Red Sea	44,376	44,376	961.2
Barka-Anseba	41,920	41,920	932.2
Mereb-Gash	17,256	23,176	1422.7
Danakil	8,905	10,485	421.9
Setit	7,292	68,255	6229.0
Total	**119,749**	**188,212**	**9967.0**

Source: Integrated Water Resources Management Plan (IWRMP, 2009)

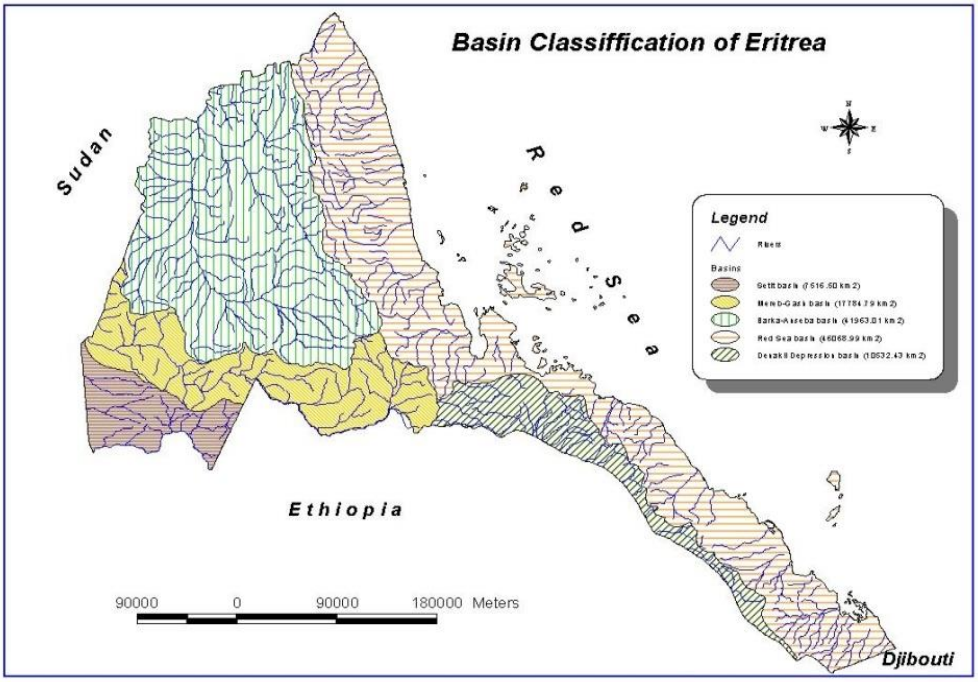


Figure 1.7: Drainage Basin Classifications of Eritrea (Source: MOLWE, 2007)

The government has constructed many strategic dams in recognition of water demand for a rapidly growing population. Currently, there are about 340 reservoirs with total capacity of 400millon M^3. In general, the surface water in Eritrea is fresh with no serious problem of pollution. The dams are suitable for irrigation and with proper filtration and bacteriological treatment; they can further be used for drinking purposes.

Ground water: In Eritrea, ground water is the major source for domestic, agricultural and industrial purposes. The total amount of ground water in the major drainage basins is estimated to be 1,664.4 Mm^3/yr (IWRM, 2009) Table 1.5. An in-depth study is required to verify this data to plan for a proper resource management. Technical papers indicate that water sources in the central highland and the western lowland are in good standing with no serious problems of contamination. On the other hand, the ground water along the Red Sea coast and the eastern escarpment are generally classified as saline with high concentrations of fluoride. The pollutants that affect groundwater are likely to originate from agricultural chemicals and infiltration of effluent from sewage treatment plants. The current status regarding Eritrea's water resource management is not up to standard as there is no comprehensive development. In addition, constraints associated with human capacity have emerged as a key concern in the water sector, which acts as bottleneck to the development of the sector (IWRM, 2009).

Table 1.5: Ground water sources of Eritrea (million M3)

Source	Quantity	%
Barka-Anseba	479.6	28.9
Mereb Gash	261.6	15.7
Red Sea	558	33.6
Danakil Depression	26.2	1.6
Setit	339	20.4
Total	**1664.4**	**100.0**

Source: Water Resource Sector Study, 1998

1.10 Waste Management

The volume of solid waste produced is increasing as a result of the growth in urban populations, concentration of industries, and consumption patterns of residents. In the developing countries, municipal solid wastes constitute a serious health problem to the local community. Illegal sites for dumping also bring serious threats to environmental sanitation. In Eritrea, a total of 539.2 tonnes of municipal solid waste are generated from major towns and cities each day. Out of this, 283.4 tones (52.5 %) (MOLWE, 2007) were collected and disposed at the dumping sites through municipalities of respective towns and cities. Organic waste accounts for almost 70 % of the total generated from households, commercial and agricultural activities. Limitations in finance and technology are the main constraints that force people to dump wastes using inappropriate means such as burning, burring and throwing in drains or open places along the streets. Additionally, wastes collected through municipalities are poorly managed with no proper means of segregation. Accordingly, the economic and environmental benefits that could have been generated from wastes are not realized. Absence of proper disposal mechanism also makes the level of methane gas emission difficult to estimate.

1.11 National and Regional Policies and Strategies

Eritrea, as a member state of the Intergovernmental Agency for Development (IGAD) shares, common understanding about the environmental challenges in general and climate change induced hazards such as drought, rainfall variability, temperature fluctuation, sea level rise, locust infestation, and human diseases (IGAD-Regional Climate Change Strategy (IRCCS, 2016)). The IGAD platform is also used as hub for exchange of data and information pertinent to climate change. Eritrea‘s seasonal forecasts for climate information is done through the IGAD Climate Prediction and Applications Centre (ICPAC).

Besides the aforementioned regional engagement, Eritrea, as member state of COMESA, will participate in the “Regional capacity building of COMESA member states in Eastern and Southern Africa for enhanced transparency in Climate Change Monitoring, Reporting and Verification(MRV) as defined in the Paris Agreement. This has to be specifically oriented towards addressing towards consistent, transparent and comparable regular reports.

Towards achieving Eritrea‘s environmental goals, the five years Indicative Development Plan of Eritrea (IFYIDP) stipulates the following measures to be undertaken during the plan period and beyond: (i) comprehensive national baseline data on the environment shall be prepared; (ii) legal provisions reviewed to determine their adequacy and supplemented if needed; (iii) land use classification and land use maps developed to promote sound land use management; (iv) alternative renewable energy sources, such as wind and solar, shall be harnessed and developed; (v) non-wood construction materials developed to prevent further depletion of forest

resources; (vi) establishment of appropriate vehicle emission standards, inspection procedures, and enforcement capacities; and (vii) environmental protection, restoration and enhancement measures shall be mainstreamed in all investments and development programs by requiring appropriate environmental impact assessments, provision of mitigation measures and effective enforcement mechanisms for compliance with established national standards. Details about specific environmental policies and prioroties is summarised in chapter 5 wich specifies about information relevant to the achievement of UNFCCC.

Eritrea has prepared its NDC in 2018 and thrives to implement the programmes and projects as well as evaluate the extent of the impacts of its implementation. Indeed, the NDCs presents measures and steps that need to be taken in the implementation of projects and programs to address climate change issues in the country; and include, capacity building, technology transfer, financial support and partnership with regional and international agencies involved in climate change.

1.12 Institutional Arrangement for National Communication

The Technical Committee guides and oversees the technical issues for the preparation of the Third National Communications (TNC). The Committee comprises sub-technical committees for the National Communication including sub-technical committees for the preparation of four major components: i) National Circumstances, ii) National Greenhouse Gas Inventories, iii) National Greenhouse Gas Mitigation and Analysis, iv) Impacts, Vulnerability and Adaptation Assessment, and v) Constraints and Gaps and Related Financial Technical and Capacity needs.

The current working institutional arrangement for the preparation of national communications is shown Figure 1.8. The Ministry of Land, Water and Environment, in consultation with the relevant institutions has established Technical Expert Working Groups composed of representatives of the line ministries and academic institutions. Each institution has a clear role and a set of responsibilities as described in Table 1.6. Nonetheless, these roles and responsibilities are not mutually exclusive; instead they overlap across components and activities that will enable the various sub-technical committees to work in complementary manners to bring integrated and consistent results.

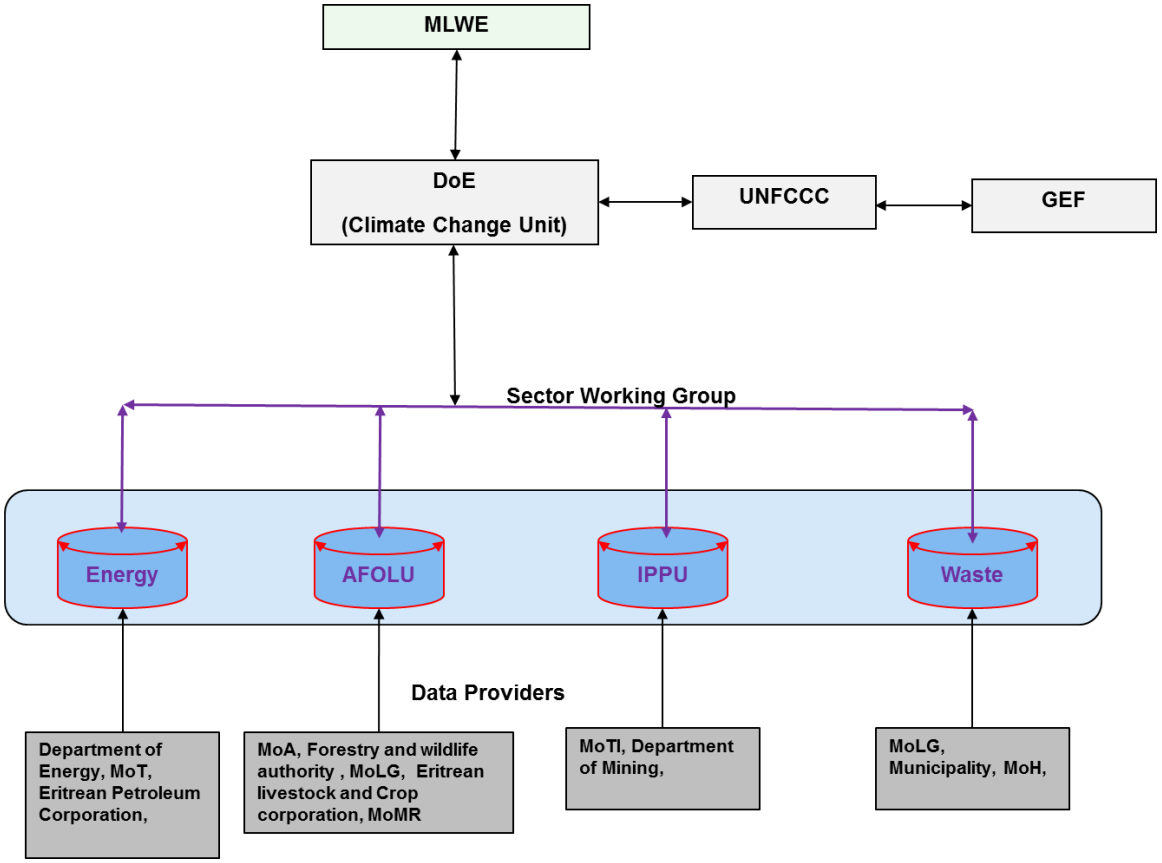


Figure 1.8: Institutional Arrangement

Table 1.6: Roles and Responsibilities of each institution

Agency/Sector	Roles and responsibility
MLWE	The MLWE is the representative of the convention that approves the budget allocation of the projects. It also leads the Department of Environment for any designated project coordinator and communication with the line ministries.
DoE (Climate Change Unit)	The Department of Environment is the focal point of the UNFCCC and responsible to manage and supervise the implementation of the project and financial disbursement. It also contracting for any consultancy when accept and approved implementation of the project by the MLWE and UNFCCC convention. The climate change unit also responsible to coordinate the project and compiled data relevant to GHG emission and modelling and quality control of the project.
Energy Hub	The department of Energy and MoTC are the responsible agencies for providing data related to fuel and biomass consumption in power plants, road transport, civil and marine aviation also in commercial and residential consumption. These agencies also have responsibility to assess the status of mitigation action and its effects in the country.
AFOLU Hub	MoA is the main responsible sector to provide the overall agriculture information relevant to mitigation and adaptation programmes and GHG relevant data. The crop and livestock corporation and forest and wildlife authority are the two institutions to provide the relevant information on crop, livestock, forest and wildlife of the country. These institutions have also responsibility to assess the status of mitigation and adaptation progress on agriculture.
IPPU Hub	MoTI is the responsible sector to provide the industrial information including the production, consumption, and import and export volume of the industrial material. It also has responsibility to assess the status of industrial mitigation action.
Waste Hub	MoLG is the lead agency of the Municipalities to provide the waste generation of the country and other relevant information in use and change of wastes.

CHAPTER TWO

2 NATIONAL INVENTORY OF GREENHOUSE GASES

2.1 Introduction

Since its establishment in 1988, the Intergovernmental Panel on Climate Change (IPCC) has, provided conclusive evidence that greenhouse gases (GHGs) concentration in the atmosphere are increasing beyond tolerable levels; and thus, causing global climate change; where these climate changes are negatively impacting the globe. Eritrea, having appended her signature and ratified the UNFCCC is required to fulfil its obligations. Accordingly, Eritrea decided/committed to produce and regularly update national Greenhouse Gas (GHG) inventories. This will enable the country to work in coordination and close cooperation with the international community to tackle climate change and associated challenges. Thus, Eritrea, to comply with the obligation under Article 4, paragraph 1(a), and Article 12, paragraph 1(a) of the (UNFCCC), takes its responsibility to develop, periodically update and publish national inventories of anthropogenic emissions by sources and removals by sinks of all its greenhouse gases not controlled by Montreal Protocol to the extent its capacities permit, using comparable methodologies and following the provisions of Decision 17/CP.8.

The INC and SNC, the national GHG inventories were carried out for the years 1994 and 2000 respectively and submitted to COP in 2000 and 2012 respectively. In this chapter, GHGs emissions inventory for the years 2006, 2010 and 2015 are elected as part of TNC. It covers anthropogenic activities representing the main economic sectors that contribute to the release and/or capture of greenhouse gases. These sectors are Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste. The GHGs emissions are grouped into two categories: direct and indirect GHGs. While the direct GHG include (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); the indirect GHG precursor gases are carbon monoxide (CO), oxides of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOC).

2.1.1 Objectives

The main objective of undertaking this inventory is to identify and quantify the major anthropogenic sources of greenhouse gas emissions and sinks in Eritrea. Among the specific objectives are to:

- Develop of baseline data to understand the relationship between GHG emissions and climate change;
- Develop the capacity of Eritrea to identify, monitor, document update and report the national inventories of GHG sources and sinks;
- Develop baseline information for possible identification of national technological and policy options that could reduce and/or avoid future national GHG emissions in Eritrea; and
- Build institutional capacity and information sharing on climate change issues.

2.1.2 Institutional Arrangement for TNC preparation

The DOE of the MOLWE, as the focal point of UNFCCC and the executing agency for the preparation of National Communications in Eritrea, has established a National Greenhouse Gases Inventory Technical Expert Working Group (NGHGITEWG) in order to facilitate and institutionalize the national GHG inventory process. This group is composed of more than 15 experts from eleven public institutions and academia. While the ministries of Energy and Mines

(MoEM), Agriculture (MoA), Trade and Industry (MoTI), Transport and Communication (MoTC), Marine Resources (MoMR), Health (MoH) and Local Government (MoLG) and the Forestry and Wildlife Authority (FWA) represented the public sector; the National Higher Education Institutions and Research Institute (NHERI) was represented by three higher education institutions namely Hamelmalo Agricultural College (HAC), College Business and Social Sciences (CBSS), College of Science -Eritrean Institute of Technology (EIT). The NGHGITEWG has been entrusted with the mandate of data collection planning and execution, and preparation of documentation and activities necessary for the completion of national GHG inventory.

Consultation with Technical Expert Working Group:
The flow chart of the institutional arrangement for NGHGITEWG is given in Figure 2-1. The working group had specific ToR to enhance the national endeavours aimed at sustaining the GHG inventory process. In addition to being members of the working group also officially represented their respective institutions which are custodians of data and information as specified in Table 2-1. TEWG meet regularly to discuss and exchange experiences regarding climate change mitigation and adaption to climate change. Data gathered were validated through regular meeting arranged at the Bureau of Standards and Evaluation of the National Higher Education and Research Institutes (NEHRI); as well as identify the gaps, constrains affecting the climate adaption and mitigation projects. The inputs of the expert opinions in addition to data gathered from the respective institutions are integrated in the document as part of the national report.

Table 2.1: Members of the NGHGITEWG and their respective mandates

Institution	**Mandate related to GHG inventory**
Ministry of Land, Water and Environment	Formulation of environmental information relevant to policies, rules and regulations
Department of Environment	• Overall coordination for the national GHGI, • Monitors adequacy and review of reports/GHGI • Prepare, progress, financial and audit reports • Communicate with UNEP on technical and financial matters, • Data and information archiving • Data source for land use planning, • Hire National Consultant
Ministry of Energy and Mines	Provide data and information of the energy sector (Type and Quantity of Fuel Consumption for energy production, national electrification and energy efficiency including renewable energy at national level)
Ministry of Transport and Communication	Provide data and information of the transport sector (existing and trends of number of vehicles and fuel consumption)
Ministry of Trade and Industry	Provide data and information of the IPPU sector (Type of industrial installation, raw material used and fuel consumption, etc.))
Ministry of Agriculture	Provide data relevant to AFOLU (Land management practice, Fertilizers used, Crop production and manure management of livestock population)
Forestry and Wild life authority	Data source for forest cover (Forest cover, afforested/.reforested, Wood and Charcoal, consumption,)
Ministry of Local Government	Provides data and information on Municipality wastes, Administrative Structure information pertinent to the GHGI
NHERI	Provide technical consultant service by leading the different Technical Expert Working groups and Prepare, Compile and submit the TNC report to the DOE

The institutional arrangement for the preparation of the GHGI is shown in Figure 2.1.

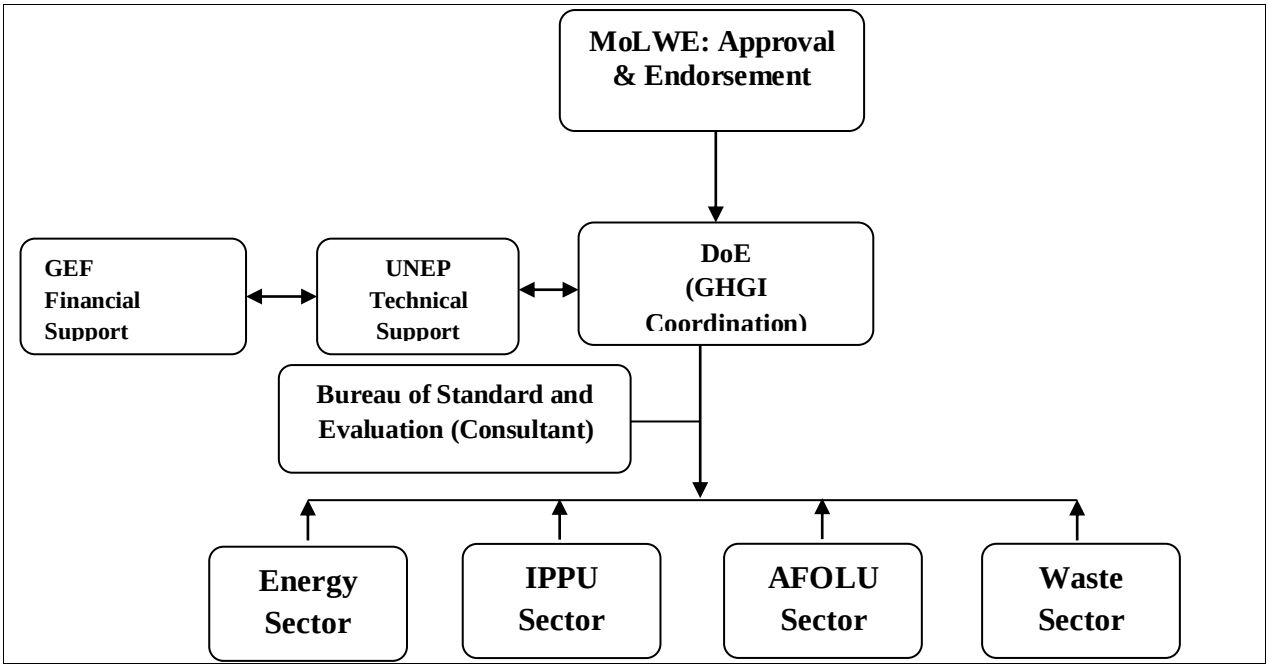


Figure 2.1: Institutional arrangements for the GHG inventory preparation

2.2 Methodologies

The emissions' inventory has been conducted in series of steps using a diverse data sources. They were estimated through the application of methodologies that link emissions to data on observable economic activities in the country. Eritrea's GHG emissions inventory report was prepared according to the UNFCCC convention in compliance with the IPCC, 2006. The use of the IPCC Guidelines was enhanced by the inventory software (version 2.691 GHG software) developed for use in calculating and estimating emissions. As there are no site specific emission factors for Eritrea that can be utilized to establish emissions for the sectors, IPCC Tier 1 methodology was applied to estimate emissions of direct GHGs (CO_2, CH_4, and N_2O) and indirect GHGs (N_2O, CO, NO_X and NMVOC) from all sectors.

In the subsections that follow, GHG emissions are reported both in absolute units of carbon dioxide, methane and nitrous oxide emissions, as well as in units of global warming potential of CO_2 equivalent (i.e., 1 for CO_2, 21 for CH_4, and 310 for nitrous oxide) as recommended by the IPCC in its Second Assessment Report. Generic emission factors from the IPCC guidelines have been used, due to lack of sufficient available source-category and technology-based inventory. The detailed data and calculations used to estimate these emissions are available within the IPCC software employed in the inventory.

2.2.1 Activity Data

A. **Data Source:** The NGHGITEWG identified all data needs and the custodian institutions. Hence, the GHG inventory was prepared using data from national data sources. Thus, national activity data were collected through questionnaire and survey for the key category sectors: Energy, Industrial Processes Product Use (IPPU), AFOLU and Waste. The Ministries of MoEM and MoTC were the activity data sources for the energy sector. MoTI provided the activity data source for the IPPU. MOA provided the activity data source for GHG emissions from the Agriculture. The Municipalities of the cities and towns were data source for GHG emissions from the waste sector. The last forest resources assessment has been carried out by MoA in 1997 through support from FAO. Hence, the most recent data on Eritrean AFOLU has

been obtained from the FWA and customised by the Global Forest Resources Assessment (FRA, 2015) reported to the World's Forests FAO is used as official government document.

B. **Emission Factors:** When using the IPCC default emission factors for the respective sectors, the NGHGITEWG assessed the applicability of these factors to national circumstances as per requirements of the good practice guidance i.e. an evaluation of national conditions compared to the context under which the IPCC default emission factors were based. When there was insufficient information on the context of the IPCC default emission factors, the NGHGITEWG put into consideration the uncertainty of the national emissions estimates based on the IPCC default emission factors. Hence, the activity data, emission and conversion factors were recorded directly into the sector and sub-sector worksheets of the 2006 IPCC Inventory Software.

2.3 Emission of GHG by Source and Removals by sink

2.3.1 Aggregated GHG Emissions and Trends

Eritrea's GHG emissions and removals by sinks for the years 2006, 2010 and 2015 are given in Table 2.2 by sectors and Table 2.3 by gases including 2000 base year. The report includes the direct GHGs are (Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O)) on gas-by-gas basis aggregated values and trends in units of Giga-gram CO2-eq (GgCO2-eq); and the percentage increase for the period 2000-2015 were presented by gas and sector. The Table 2.2 shows that Eritrea remained a net GHG emitter throughout the specified period which the majority comes AFOLU sector. This is mainly due to inadequate livestock and manure management, deforestation. Moreover, the energy sector is the highest GHG contributor as biomass remains main source of domestic energy in most part of the country.

Eritrea's total GHG emissions by year; 2000, 2006, 2010 and 2015 of all sectors were respectively 3286.76, 3293.31, 3433.05 and 3866.76 Gg of CO_2 eq coming from the four key category sectors. Over the period 2000 - 2015 total GHG emissions has increased by 17.65% from 3286.76 Gg CO_2eq in 2000 to 3866.76 Gg CO_2 eq in 2015. Although the contribution to the aggregated GHG emission from, the IPPU and Waste remained low, the % increment observed in the years 2000-2015 was drastic mainly due to the establishment of new Ghedem Cement Factory that has high production capacity. The emission from the waste sector is attributed to the increase in urban population growth and change in living habits.

Table 2.2: Direct GHG Emissions and removals by year and sector

Year	2000	2006	2010	2015	Percent change b/n 2000 and 2015
Sector	**Gg of CO2-eq**				
Energy	757.70	649.95	663.71	784.15	3.49%
IPPU	18.37	21.88	24.28	169.56	823.05%
AFOLU	2510.04	2608.52	2725.02	2884.80	14.93%
Waste	0.66	12.97	20.04	28.26	4184.16%
Total	**3286.76**	**3293.31**	**3433.05**	**3866.76**	17.65%

The GHG emission by Gas CO_2 eq (Gg) is given in Table 2.3 in which CH_4 has the highest GHG emission contribution for all the inventory periods followed by CO_2. However, the change in CO_2 emission of 41.7% increase is much higher than that of CH_4 emission change of 14.34% increase between the year 2000 and 2015.

Table 2.3: Direct GHG Emissions by year and Gas

Year	2000	2006	2010	2015	Percent change b/n 2000 and 2015
Gas	Gg of CO2-eq				
CO_2	401.24	307.43	313.02	568.55	41.70
CH_4	2759.26	2859.14	2986.10	3154.89	14.34
N_2O	126.26	126.75	133.93	143.33	13.51
Total	**3286.76**	**3293.31**	**3433.05**	**3866.76**	17.65

Looking at the GHG emission trend, it shows that Eritrea is a net GHG emitter as indicated in Figure 2.2 which illustrates that change GHG emission between 2000 to and 2010 was gentle, and showed a sharp increase from 2010 onwards; and remains to undertake appropriate mitigation actions.

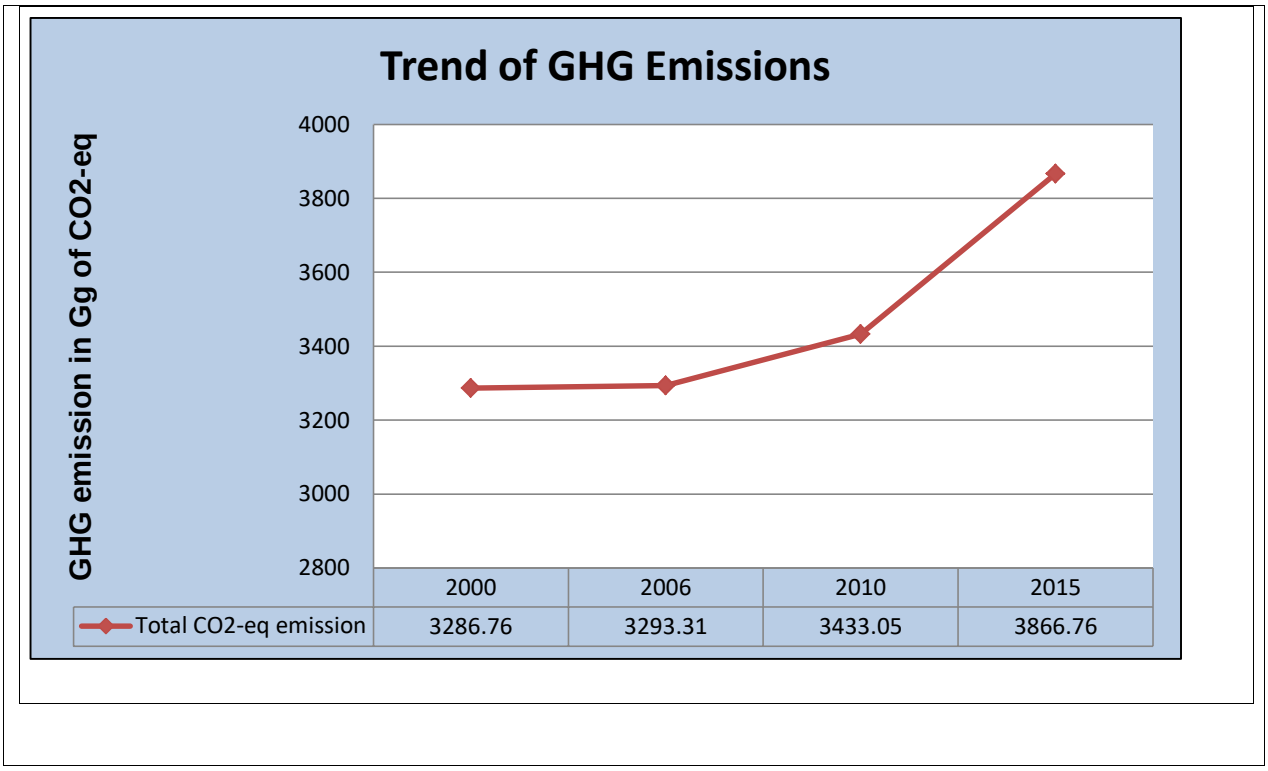


Figure 2.2: Trend of total GHG Emission by year CO_2 eq (Gg)

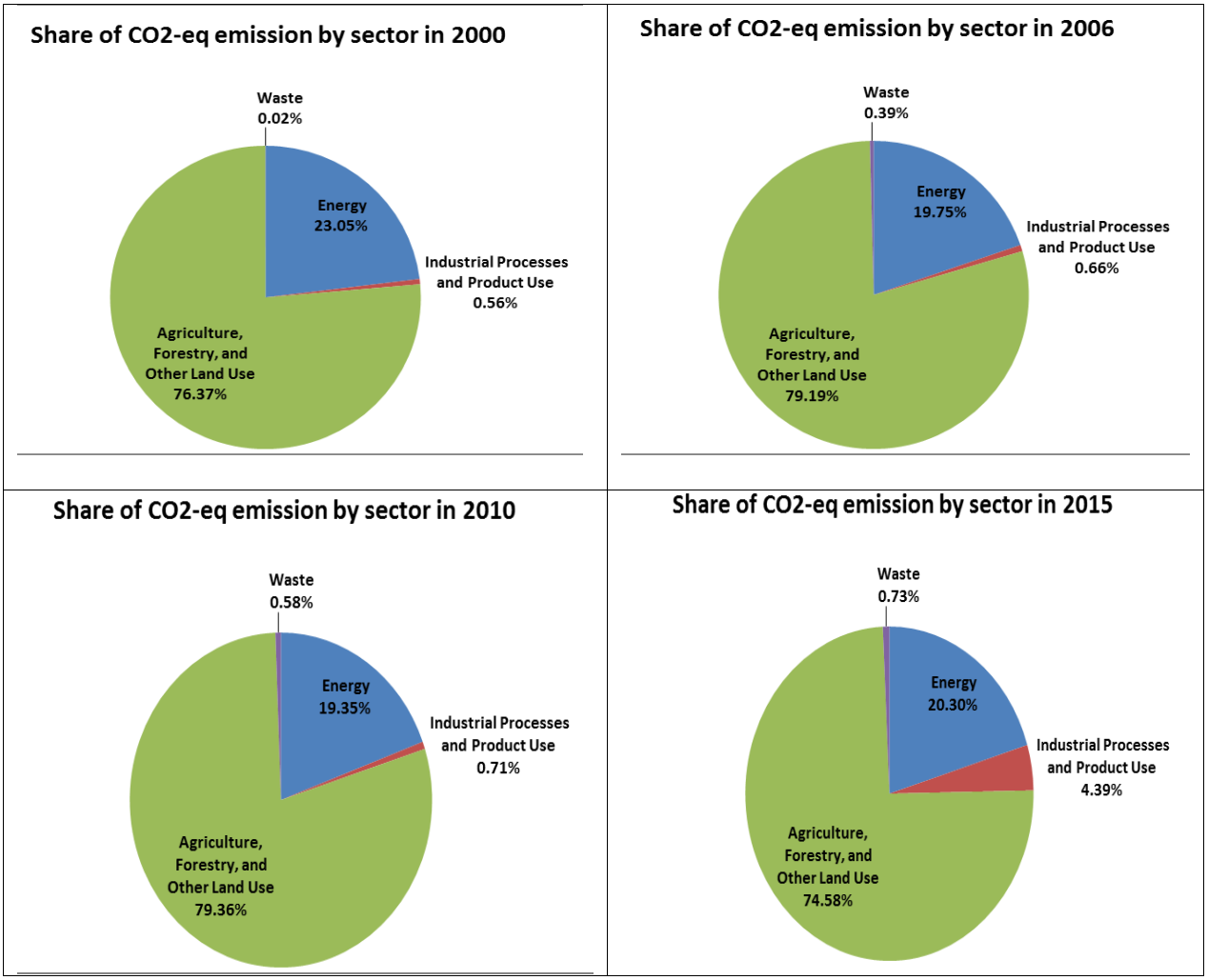


Figure 2.3: GHG emission contributions by sector 2000-2015

The figure 2.3 shows that GHG emission in $GgCO_{2e}$-eq for the direct greenhouse gases; and the contribution by each sector in the GHG emission through the selected years has changed over the years. Throughout the selected inventory years, although there is some fluctuation, it is clear that the AFOUL sector followed by Energy have been the major contributors.

Looking at the share of the various gases emission in 2015, Methane gas followed by CO_2 was the highest (Figure 2.4). Majority of methane emissions came from the livestock (enteric fermentation) and manure management sub-sector. Methane emission is mainly due to inadequate manure management; and farmers/herders preference on quantity (more livestock with less productivity) rather than quality (less but productive) of livestock. The second highest direct gas emission, in the country, is CO_2 from Energy sector which indicates that the country has not adopted a full-fledged energy efficient and renewable energy technologies.

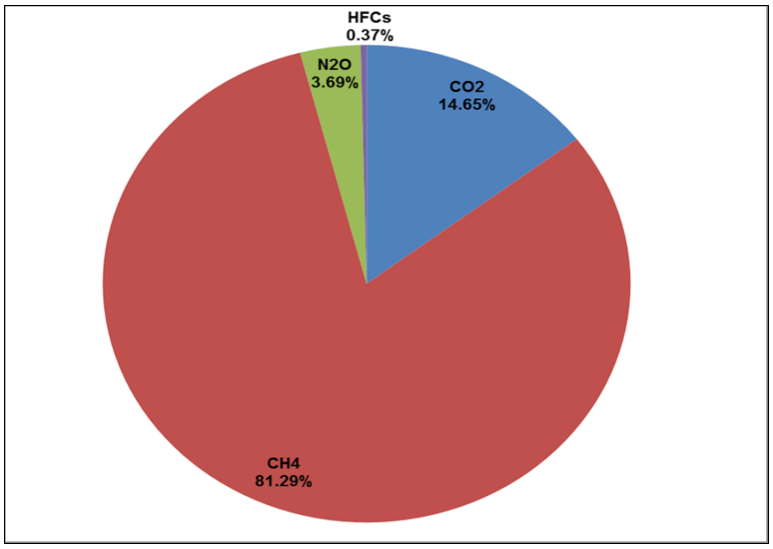


Figure 2.4: Share of GHG emission by gas in 2015

Table 2.4: Summary report for national direct GHG emissions (Gg) (2000, 2006, 2010 and 2015)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES							
Year			GgCO2-eq				% Contribution
			CO_2	CH_4	N_2O	Total GHG emission	
		Total Gas Emissions	**401.24**	**2759.26**	**126.26**	**3286.76**	**100.00**
2000	1	Energy	613.08	117.78	26.83	**757.70**	23.05
	2	IPPU	18.37	0.00	0.00	**18.37**	0.56
	4	AFOLU	-230.88	2641.48	99.43	**2510.04**	76.37
	6	Waste	0.66	0.00	0.00	**0.66**	0.02
		Total Gas Emissions	**307.43**	**2859.14**	**126.75**	**3290.89**	**100.00**
2006	1	Energy	509.93	114.95	25.07	**649.95**	19.75
	2	IPPU	21.88	0.00	0.00	**21.88**	0.66
	4	AFOLU	-227.59	2732.00	101.67	**2606.09**	79.19
	6	Waste	0.78	12.19	0.00	**12.97**	0.39
2010		**Total Gas Emissions**	**304.39**	**2986.10**	**133.93**	**3424.41**	**100.00**
	1	Energy	506.46	129.13	28.12	**663.71**	19.38
	2	IPPU	18.37	0.00	0.00	**18.37**	0.54
	4	AFOLU	-221.32	2837.81	105.80	**2722.30**	79.50
	6	Waste	0.88	19.16	0.00	**20.04**	0.59
2015		**Total Gas Emissions**	**565.41**	**3154.89**	**143.33**	**3863.63**	**100.00**
	1	Energy	607.16	144.87	32.12	**784.15**	20.30
	2	IPPU	169.56	0.00	0.00	**169.56**	4.39
	4	AFOLU	-212.32	2982.78	111.20	**2881.66**	74.58
	6	Waste	1.01	27.25	0.00	**28.26**	0.73

A. Emission of Carbon Dioxide (CO_2)

The total national net CO_2 emission in the years 2000, 2006, 2010 and 2015 were 401.2 Gg, 307.43 Gg, 304.39 Gg and 565.41 Gg respectively (Table 2.4). The highest contributor of CO_2 emission is Energy sector in all the years. In the energy sector, during the period during the period 2000 - 2010 the CO_2 emission showed a decreasing trend, and later increased in 2015 (Table 2.4) following border conflict with Ethiopia in which there was fuel rationing and low

level of economic development. The net CO_2 emission in 2000 is higher than the years 2006 and 2010 and this is attributed to the high level of land use change for agriculture, and resettlement which lead to massive tree clearing. The categories considered in the energy sector are 1.A.1 energy industry, 1.A.2 manufacturing industry and construction, 1.A.3 transport & 1.A.4 other sector. The net CO_2 emission from industrial sector was attributed to the emission from 2.A.1. Cement and 2.A.2 lime production in the country which was very small prior to the establishment of the new Ghedem Cement Factory. The AFOLU sector remains net sequester in all the years. The CO_2 emission from waste sector was solely from 4 C incineration & open burning of waste.

B. Emission of Methane (CH4)

CH_4 is primarily removed from the atmosphere through a chemical reaction with hydroxyl radical (OH) which is ultimately converted to CO_2. Increasing emissions of CH_4 reduces the concentration of OH, a feedback that increases the atmospheric lifetime of CH_4 (IPCC, 2003). Incomplete combustion of hydrocarbons in fuels results in methane emissions. The amount of CH_4 emitted is also a function of the methane content of the fuel, the amount of hydrocarbons un-burnt in the engine, the engine type, and any post-combustion controls (IPCC, 1996). CH_4 emissions from fuel combustion are relatively small on a national scale and the uncertainty in estimating it is high.

The total national methane emission in 2000, 2006, 2010, and 2015 were 2759.26 (83.96%), 2859.14 (86.88%), 2986.10 (87.2%) and 3154.89 (81.65%) Gg CO_2-eq respectively. Table 2.4 shows that, in 2015, the AFOLU sector had the lion share (94.54%) of methane emissions followed by energy sector (4.59%) and waste sector (0.86%). In the AFOLU sector, methane emission came from enteric fermentation from ruminant animals and manure mismanagement. In the energy sector, the residential, Energy industry and the road transport were the major sources and to some extent the solid waste disposal also contributed to the CH_4 emission to a limited extent.

C. Nitrous Oxide (N2O)

Generally, the anthropogenic sources of N_2O emissions include agricultural soils, especially production of nitrogen-fixing crops and forages, the use of commercial fertilisers and farm yard manure, and manure deposition by livestock; fossil fuel combustion, especially from mobile combustion; adipic (nylon) and nitric acid production; wastewater treatment and waste incineration and biomass burning.

Emission of Nitrous Oxide (N_2O) in 2000, 2006, 2010 and 2015 was 126.26, 126.75, 133.93 and 143.33 Gg CO_2-eq respectively. In most cases, agricultural activities particularly sub category of manure management has high N_2O emission contribution in the country, whereas the energy sector is the second highest emitter due to fuel combustion and the low engine efficiency in transport and electricity generation sub-categories Overall, Nitrous Oxide emission in 2015 was estimated at 143.33 GgCO2-eq coming exclusively from the AFOLU (Manure management) and Energy (Electricity generation, Transport, Commercial and Residential) sectors.

D. Emissions of HFCs, PFCs and SF6

Hydro Fluorocarbons (HFCs), Per-Fluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are direct GHGs. Anthropogenic emissions by sources of Per-fluorocarbons (PFCs) and sulphur hexafluoride (SF6) from production activities was not accounted due to lack of data availability. But for anthropogenic emissions by sources of hydro fluorocarbons (HFCs) in Gg

CO_2 eq. for the 2000, 2006, 2010 and 2015 are 0.10, 2.66, 6.41 and 14.23 respectively (Table 2.5). However, the data from 2000 to 2010 are estimated by the extrapolating the 2012-2015 data from the Eritrean ODS alternative survey report (2017).

In 2015, a comprehensive assessment on the consumption of ODS and use of ODS-related equipment in the country has been conducted by the DoE. The data was formatted, refined and used as an input to the National GHG Inventory in these inventory years. The GHG inventory for the emission incurred by the HFCs and PFCs is shown in Table 2.5. The report covers mainly emissions from consumption activities, mainly, from the use of refrigerator and air-conditioning units.

Table 2.5: Emissions of HFCs, PFCs and SF_6

Categories	CO_2 Equivalents(Gg)		
	HFCs	PFCs	SF_6
2.F - Product Uses as Substitutes for Ozone Depleting Substances	14.234	0	0
2.F.1 - Refrigeration and Air Conditioning	14.234	0	0
2.F.1.a - Refrigeration and Stationary Air Conditioning	13.528		
2.F.1.b - Mobile Air Conditioning	0.706		

2.3.2 Emissions of Indirect Greenhouse Gases by Sources

The emission of carbon monoxide (CO), Nitrogen oxides (NOx) and NMVOCs in the presence of sunlight contribute to the formation of the greenhouse gas Ozone (O_3) in the troposphere and are therefore often called Ozone precursors. Furthermore, NO_x emission plays an important role in the earth's nitrogen cycle. Sulphur Dioxide emissions led to formation of sulphates particles which also play a role in climate change. All indirect greenhouse gases could be emitted from all source categories. The methodologies contained in the EMEP/ CORINAIR Emission Inventory Guidebook is the basis used for the estimation of emission from CO, NO_x, NMVOCs and SO_2. However, the 2006 IPCC software version used for this GHG inventory of those gases are estimated to be negligible or not occurring as shown in Annex-C1 (key Summary of GHG emission)

2.4 Sectoral GHG Emissions

2.4.1 Energy Sector

Energy industries in Eritrea are mainly based on thermal power plants that utilize fossil fuels for electricity generation. Consequently, the country is a net importer of refined petroleum products. The main secondary energy sources are from liquid, gaseous and biomass fuels. Liquid fuels consist of petroleum products: diesel, gasoline, heavy fuel oil, Jet-kerosene, LPG and lubricants that were used for combustion and non-energy activities; and the biomass include wood fuel, charcoal, dung and agricultural-residue. Biomass is the main sources used to support household, certain commercial and small - scale industries. Emissions arise from these activities by combustion and as fugitive emissions (e.g. escape without combustion). Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the GHGs emitted from combustion of fuels. In addition, the GHG precursors: carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs) are released in the process.

The IPCC 2006 guideline provides two ways of estimating CO_2 emissions from fuel combustion. These are the top-down (reference approach), and the bottom-up (sector approach). In this case, in the GHGs inventory, both top-down and bottom-up analyses were carried out for comparison. Ideally there should not be much of a difference in the emission calculations using these methods.

A. Reference (Top-Down Approach)

In the reference approach, the primary level of energy supply and distribution is considered. It enables calculations of CO_2 emissions by considering the overall national inventory of fuel supply. The basic data requirement is an overall inventory of the national fuel supply including information on fuel qualities for each fuel type utilized in the following activities: i) production ii) imports iii) exports iv) international bunkers (the amount of fuel used for international aviation and marine transport) and v) stock change or the variation in the quantity of fuel in stock. Fuels that are imported and/or used for international bunkers (i.e. aviation) are subtracted from the overall apparent consumption and hence are not included in the total national net GHG emissions. CO_2 emissions from international bunkers, nonetheless, are still computed as a separate memo items as recommended by IPCC, 2006 guidelines in section 2.4.1 D.

Calculating the Apparent Fuel Composition

The data for fuel consumption were provided by the MoEM and Petroleum Corporation of Eritrea. The data on fuel type, production, import, export, transport through international bunkers and stock change are used in kilotons of oil equivalent or Giga grams (Gg). The apparent consumption of fuel was estimated using the *equation 2.1*.

Apparent Consumption = (Production + imports) – (international Bunkers – Stock change) Eq. 2.1

The Reference Approach does not distinguish between different source categories within the energy sector. It only estimates total the CO_2 emissions from Source category 1A, Fuel Combustion. National total carbon dioxide emission from fuel combustion, based on reference approach apparent emission of CO_2 was estimated disaggregated by fuel type (Table 2.6). The Table show a difference in energy consumption and carbon dioxide emission of -4.97% and -4.77 % respectively. The Reference Approach and the Sectoral Approach often have different results because the Reference Approach is a top-down approach using a country's energy supply data and has no detailed information on how the individual fuels are used in each sector.

Table 2.6: Fuel consumption disaggregated by fuel type reference versus sectoral approach for 2015

	Reference Approach				Sectoral Approach		Difference	
Fuel	Apparent Consumption (TJ)	Excluded consumption (TJ)	Apparent Consumption (excluding non-energy use and feedstock) (TJ))	CO_2 Emissions (Gg)	Energy Consumption (TJ)	CO_2 Emissions (Gg)	Energy Consumption (%)	CO_2 Emissions (%)
Other Kerosene	0.00	0.00	0.00	0.00	520.78	37.44	-100.00	-100.00
Gas/Diesel Oil	3448.60	0.00	3448.60	255.43	3184.58	235.98	8.29	8.24
Residual Fuel Oil	2103.63		2103.63	162.75	2103.63	162.82	0.00	-0.04
Liquefied Petroleum Gases	237.97	0.00	237.97	15.01	238.87	15.07	-0.38	-0.43
Bitumen	229.14	229.14	0.00	0.00	135.88	10.97	-100.00	-100.00
Lubricants	113.36	0.00	113.36	8.31	111.69	8.19	1.50	1.55
Coking Coal	1068.47		1068.47	101.08	1068.47	101.08	0.00	0.00
Total	**7714.87**	**229.14**	**7485.73**	**578.17**	**7877.85**	**607.16**	**-4.97**	**-4.77**

Based on the assessment the difference energy consumption and CO2 emission into the coking coal sub-sector is zero which indicates that data recording system at the Ghedem Cement factory, the sole coking coal consumer is efficient. On the contrary for all other type of fuels, except Gas/Diesel Oil and Lubricants, the difference in energy consumption and CO_2 emission show negative results. This difference may be due to inadequate data management and recording system of the sectors which could have led to double counting or there be over estimation of sectoral energy consumption.

B. The Sectoral (Bottom-up Approach)

This sectoral approach looks at the actual energy consumption of the specific subsectors. The subsectors are the energy industry (Power generation or energy production), transportation, manufacturing industry and service sector (public and commercial), and residential. Being more detailed in the sense that; it is applied for each specific end-use category. This approach identifies the specific sector consumers of fuel, including major emitters of energy-related GHGs, and thus provides a more detailed inventory of the CO_2 emissions from fuel combustion. Compared with the reference approach, nevertheless, requires a much more detailed disaggregated data and analysis. Correspondingly, the estimated CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users, which may not always be complete. Thus, there is a persistent problem of incompleteness of data submitted by end- users due to recording errors and biases in addition to data collection challenges.

Calculating Apparent Fuel Consumption for Each Fuel Type

In order to calculate the emissions from fuel consumption, the following parameters are required: the fuel type, its consumption figures for every sub-category, and the carbon emission factors and conversion factors extracted for the fuel type are subdivided in to CO_2 and non-CO_2 categories. The Tier 1 approach was used to compute GHG emissions where default emission factors were used to estimate emissions as there are no country specific emissions factors. The GHG emissions from the stationary combustion are calculated using *equation 2.2*, from volume 2 of the IPCC 2006 guidelines.

$$\text{Emissions}_{(\text{GHG Fuel})} = \text{Fuel Consumption}_{\text{Fuel}} * \text{Emission Factor}_{\text{GHG, Fuel}} \qquad \text{Eq. 2.2}$$

Where:

- Emissions $_{GHG,\ fuel}$ = emissions of a given GHG by type of fuel (kg GHG)
- Fuel Consumption *fuel* = amount of fuel combusted (TJ)
- Emission Factor $_{GHG,\ fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

The CO_2 emission factors mainly depend on the carbon content of the fuel in units of kg CO_2/TJ on a net calorific value basis which reflect the carbon content of the fuel and the assumption that the carbon oxidation factor is 1. Emission factors for CH_4 and N_2O for different source categories differ due to differences in combustion technologies applied in the different source categories. The default factors presented for Tier 1 is applied to technologies without emission controls.

The contribution GHG emission in Gg of CO2-eq by sub-sectors in the energy sector is shown in Figure 2.5 which synthesises the major clusters (sub sectors) of the energy sector. In this pie chart, although the other sectors (include commercial/institutional, Residential and stationary agricultural activities) account for 39% of the emission, it is clear that the energy industries particularly electricity generation (33%) followed by the transport (25%) are also in the picture. The manufacturing industries and construction accounted for only 3% of the total emission. For more clarification and details of the GHG emissions from energy sector refer (Annex-C2, GHG emission from Energy Sector).

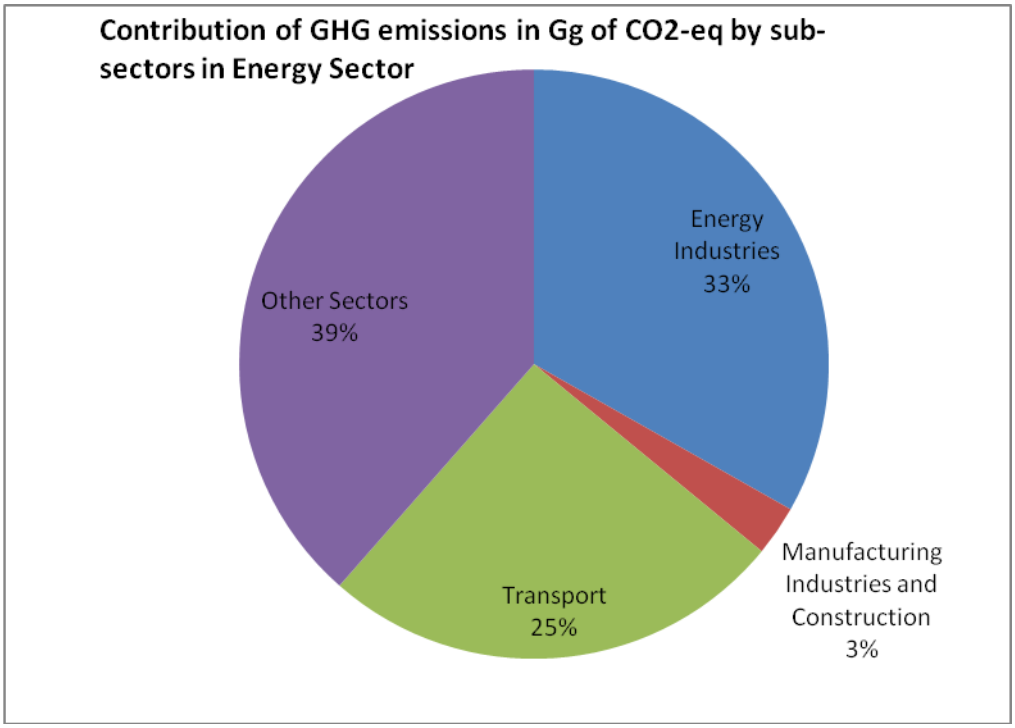


Figure 2.5: GHGs emissions in Gg of CO_2 equivalent by sub-sector in the energy sector, in 2015

C. Bunker Fuels

Bunker fuels are categories included international aviation and marine bunker fuels. Emission estimates from these sources were not included in the national total in accordance with the Revised 2006 IPCC Guidelines. The CO_2 emission from International Aviation Bunker came in from the use of Jet Kerosene; and the estimated emissions are shown in Table 2.7. Emission from International Marine Bunker was not estimated as there was no sufficient supporting data in the country for this purpose. Thus, in order to improve the completeness of the inventory, Eritrea will include in the improvement plan to estimate those emissions in future inventory submissions. The total GHG emission from international aviation were estimated around 4.396 Gg of CO2-eq in which 99% is CO2 and the remaining 1% are Methane and Nitrous Oxide. Table 2-7 shows that there is almost the same GHG emission in 2000 and 2006 where as in 2010 and 2015 substantially reduced. . This is mainly due to the economic sanction imposed of 2008 which continued until 2018 which have affected most of the international flights.

Table 2.7: Emissions from Bunker fuels in absolute unit of Gg, 2000- 2015

GHG	2000	2006	2010	2015
CO_2	21.1	21.13	4.04	4.35
CH_4	2E-4	1.5E-4	2.8-5	3E-5
N_2O	8E-4	6E-4	1E-4	1E-4

D. CO2 Emission from Biomass Combustion for Energy Production

As described in the previous sections, majority of the population of Eritrea, particularly rural communities, the energy demand mainly rely on biomass combustion for cooking and heating purposes. The overall CO_2 emission from the biomass combustion in 2015; GHG inventory year is estimated 2553.663 Gg that shows there is still high fuel wood consumption in the country leading to deforestation and hence land degradation. Thus, there is dire need for an urgent action to shift to more energy efficient fuel and adoption of renewable energy to reduce communities' dependence on biomass energy.

E. Fugitive Emissions from Fuels

Fugitive emissions came from all intentional and unintentional emissions from extraction, processing, storage and transport of fuel to the point of final use. According to the 2006 IPCC guidelines, in fugitive emissions the following categories should be considered: i) CH_4 emissions from coal mining and handling, ii) CH_4 emissions from oil and natural gas activities, iii) emissions of ozone precursors and SO_2 from oil refining (Tier 1 or Tier 2). These emissions were not applicable in Eritrea in all the inventory years because of the fact that there was no extraction and/ processing facilities. Nonetheless trace may exist in filling stations and transportation.

2.4.2 Industrial Processes and Product Use (IPPU)

The IPPU category covers the processes that transform materials, chemically or physically to make certain desired products. The energy inputs for process heating are covered under the energy sector section. The IPCC 2006 broadly classifies this sector into seven industrial processes and others as indicated in Annex-C3 (GHG emission from IPPU sector). These are A) Mineral Industry B) Chemical industry C) metal industry D) Non-Energy Products from Fuels and Solvent Use E) Electronics Industry F) Product Uses as Substitutes for Ozone Depleting Substances G) Other Product Manufacture and Use and, H) others. Of these categories, only the mineral products (e.g. cement and lime production) and the Product Uses as Substitutes for Ozone Depleting Substances (Refrigeration and Stationary Air Conditioning And Mobile Air Conditioning) were relevant to Eritrea. Other subcategories (2B-Chemichal industry, 2C-Metal production) were not there in the country within the inventory years. Thus, the whole of CO_2 emission by this sector is attributed to cement industry. Share of the CO_2-eq emission from this sector in the years 2000-2015 are shown in Table 2.8 which shows an increase from 0.56% in 2000 to 4.3% in 2015

Table 2.8: GHG Emissions from Industrial Process & percentage share Inventory Year 2000-2015

Direct GHG	**2000**	**2006**	**2010**	**2015**
Gg CO_2-equ	18.37	21.88	24.28	169.6
Share of CO2-eq	(0.56%)	(0.66%)	(0.54%)	(4.39%)

The higher emission value in 2015 is because of the start of a new cement plant in 2013. However, the low level of the share contributed by industrial sector indicated the low level of industrial development and limited production activities at this point in time.

2.4.3 Agriculture, Forestry and Other Land Use (AFOLU)

The AFOLU sector comprises activities responsible for emissions and removals linked to Agriculture, Forestry, and Other Land Uses. Agriculture comprise of emissions from crops and livestock which generate GHG emissions through decomposition and other biological processes. In this sector, the main GHG emissions are of methane and nitrous oxide associated with agricultural practices, enteric fermentation of livestock, manure management etc. Methane is produced through the processes of enteric fermentation, and manure management. Nitrous oxide is produced from cultivated soil by direct and indirect mechanisms. Therefore, methane and nitrous oxide in the country remain the most significant emissions resulting solely from Livestock rearing resulting in enteric fermentation and manure management as indicate in (Annex-C4- GHG emission from AFOLU Sector). All domestic livestock have been considered in this assessment and information from the MOA was used in the estimation of methane and nitrous oxide gases. Accordingly, the corresponding emissions are described in the following sections.

A. Methane (CH_4) Emission from Enteric Fermentation and Manure Management

Methane emission from agriculture categorised by main source is shown in Figure 2.6. The Figure shows that emissions from the sector shows increasing trend from 2000 mainly as a result of livestock related activities. The results further, further shows that enteric fermentation remains the main source of methane emissions while manure management produce both Methane and Nitrous Oxide emissions in the Agriculture sector. The low level of emission of methane directly corresponds to the livestock population. Methane and Nitrous Oxide emissions in the 2015 inventory year were 2982.77GgCO2-eq and 111.205 GgCO2-eq respectively. While enteric fermentation accounts for 95.91% of the total methane emissions 100% of the N_2O emission came from Manure management (livestock sub-sector). Compare to the 2000 level, Methane and N_2O emissions in 2015 increased by 12.9% and 13% respectively.

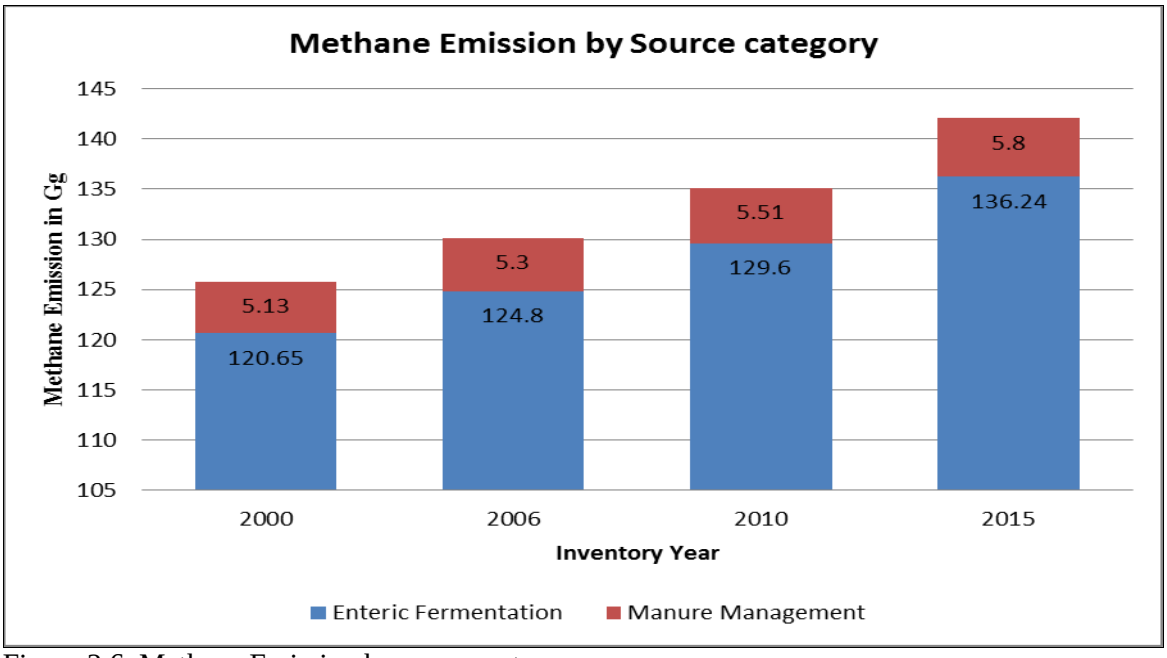


Figure 2.6: Methane Emission by source category

B. Agricultural Soils - N_2O

The following emissions subcategories were assessed under "N_2O Emissions from Agricultural Soils" category: i) Direct N_2O Emissions from agricultural fields, excluding cultivation of Histosols, ii) Direct N_2O Emissions from cultivation of Histosols, iii) Nitrous Oxide Soil emissions from grazing animals, pasture range and Paddock, IV) Indirect Nitrous Oxide emission from atmospheric deposition of NH_3 and NO_x and V) Indirect Nitrous Oxide emissions from Leaching. However, based on the 2006 IPCC Software the value of N_2O emission could not be observed and hence it is considered zero.

Land Use and Land Use change

Land use affects the ability of the natural environment to absorb (sequester) carbon, thus removing it from the atmosphere. When carbon is sequestered in a given area, the area is referred to as an "emission sink." The AFOLU sector differs from the other sectors in that; it functions as source of atmospheric emissions and a sink of emissions through the removal of atmospheric CO_2. The balance of the two is net emissions or removals in the AFOLU sector.

According to Land Degradation Neutrality report carried out by the MOA (MoA, 2017); it become evident that 8% of the Eritrean land mass showed declining trend in terms of land productivity, and 16% showed early signs of land productivity and 12% of the land covers

remains stable but stressed. Hence, about 36% of the land shows clear indications of land degradation due to a number of factors including the conversion of forests and woodlands into crop fields; and grazing pressures. These areas are located in the western lowlands between the Gash and Setit Rivers, and the southern part of Eritrea where intense farming is carried out due to population density. The eastern escarpment where the remnant afromontane forest is located as well as coastal area experience early signs of declining of productivity. As it was not possible to get data on the area covered by plantation forests, unmanaged grassland, and perennial cropland the available ancillary data was insufficient to delineate the classes satisfactorily. However, the data from the (MoA 2002) from 1992-2002 10000ha of land planted and area under cropland; the rainfed and irrigation are 417000ha and 22000ha respectively. Based on these data, interpolation and extrapolation methods were applied to calculate the missing data for the entire inventory years. Furthermore from the total irrigated are in 2002, 10% is considered as perennial crops (technical expert assumption) and was applied in the toolkit. The section on Land Use, Land-Use Change and Forestry (AFOLU) accounts for emissions and removals resulting from managed forestland (that displays some human intervention), cropland, wetland, settlements and other lands.

The key greenhouse gases of concern in the AFOLU sector are CO_2, CH_4, N_2O, NO_x and CO. The emissions and removals were determined using the default methods and emission parameters included for this sector in the 2006 IPCC Guidelines. This sector is turning out to be the net sink of CO_2 during 2000 - 2015. However, the sink capacity is in decreasing trend over this period and that was attributed to the adverse effects of land use change occurred for agricultural and resettlement use (Figure 2.7). In 2015, the net GHG emission from Land use and land change and Forestry is estimated -209.2 Gg which indicated that there was CO_2 sequestration. The forest land and wetland sub-sectors account CO_2 sequestration/removal of 212.139 Gg and 0.017 Gg of CO2 respectively while Cropland and Settlement CO_2 emission contribution were estimated to be 2.575 Gg and 0.398Gg of CO2 respectively.

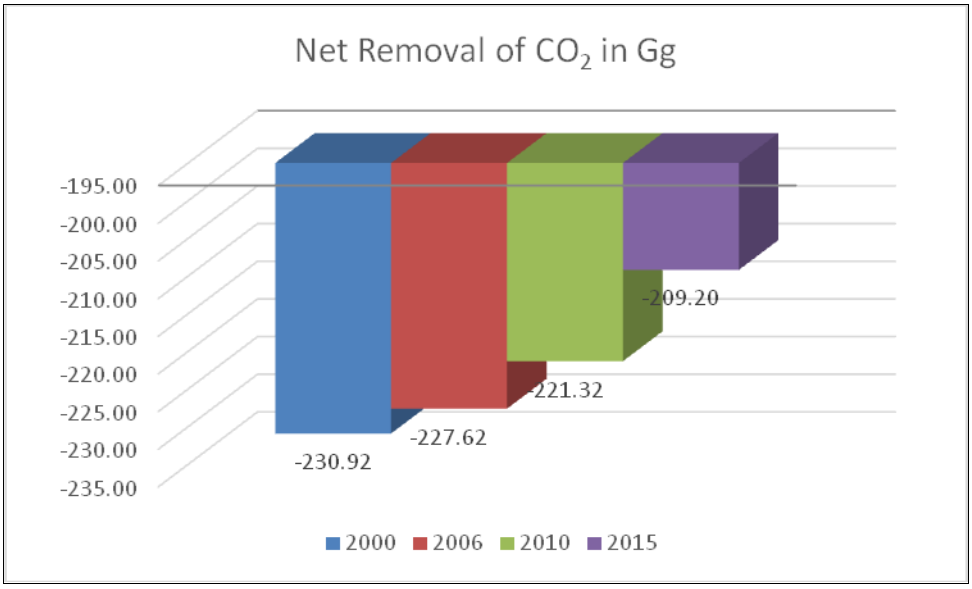


Figure 2.7: Land net CO_2 removal in Gg through the inventory years

The level of change in forest and other woody biomass stock and land conversion is very significant; as a result, the contribution of this sector to the GHG emission is considerably high. Specific emission factors in AFOLU sector should be researched on at country level to reduce uncertainty in GHG inventory results. In this regard, Research institutions and universities

should be encouraged to conduct research on the existing gaps to develop local emission factors to enable Tier 2 computation of GHG emissions.

2.4.4 Waste Sector

The IPCC 2006, guidelines categorise waste sector into five categories: 4A solid waste disposal, 4B Biological treatment of solid wastes, 4C Incineration and open burning of wastes 4 D wastewater treatment discharge and 4E any other waste that must be specified. In Eritrea, the solid wastes included three types of waste generated from domestic, clinical, and industrial wastes. The composition of solid waste in the capital city Asmara and other major towns is increasing rapidly. There are some medical incinerators installed at the referral hospitals to incinerate medical waste; but most of these incinerators are not operational due to technical constraints. Solid waste (domestic, clinical and industrial) is collected and transferred to municipal disposal sites in the major towns where it is left to decompose or burned in open air.

Each year, about 320,948 tons (MoLG, 2019 archives) of municipal solid waste are generated from major towns and cities. Approximately 57.7% of the solid waste is collected for dumping at the landfill and the remaining is managed in various ways including open burning, burying, or left unattended. Organic waste accounts for nearly 70% of the total solid waste generated from households, commercial and agricultural activities. Limitations in finance and technology are the main constraints compelling people to dump wastes using inappropriate means: burning, burring and throwing in drains or open places along the streets. Solid wastes collected through municipalities are poorly managed with no proper classification. As a result, the economic and environmental benefits from solid wastes are not realized. Absence of proper disposal mechanism also makes the level of carbon dioxide and methane gas emission difficult to estimate.

In the current inventory the subcategory 6A Solid Waste Disposal; 4C Incineration and open burning of wastes are considered; and the level of carbon dioxide and methane gas emission are estimate. All calculation and estimation for waste sector in this inventory is based on the data based on survey on solid waste management status of the major cities and towns of Eritrea. The data and expert assumption made for use in the 2006 IPCC software are as indicated in Table-2.8. All waste in rural communities is discards at farmland or any other open area; and it is assumed zero open burning for this inventory. The waste generated from the urban area is estimated based on the given data in Table 2.8 including assumptions by considering the solid waste management status of the major cities and towns of Eritrea.

Table 2.9: Data and assumption used for waste sector.

Waste generated per capita (kg/can/year)	146
Rural population in %	65
Urban population in %	35
Waste collected in urban areas in %	53.5
Assumption of waste burning from collected waste in %	30
Assumption of waste open burning for unmanaged in %	40

According the above data and assumption, the total GHG emission from waste sector in Eritrea is estimated to be 28.26 GgCO2-eq in 2015 inventory year and around 96% of the total GHG emission is methane. The GHG Emission from waste accounted for about 0.02%, 0.39%, 0.58%, and 0.73% relative to overall anthropogenic GHG emissions in CO_2-eq during the inventory years (2000, 2006, 2010, and 2015 respectively) which may be attributed to the expansion of dumping sites in medium towns. The CO_2 and CH_4 emissions in Gg from the sub

categories considered are shown in Figure 2.9. For more information see (Annex-C5 GHG emission from Waste Sector).

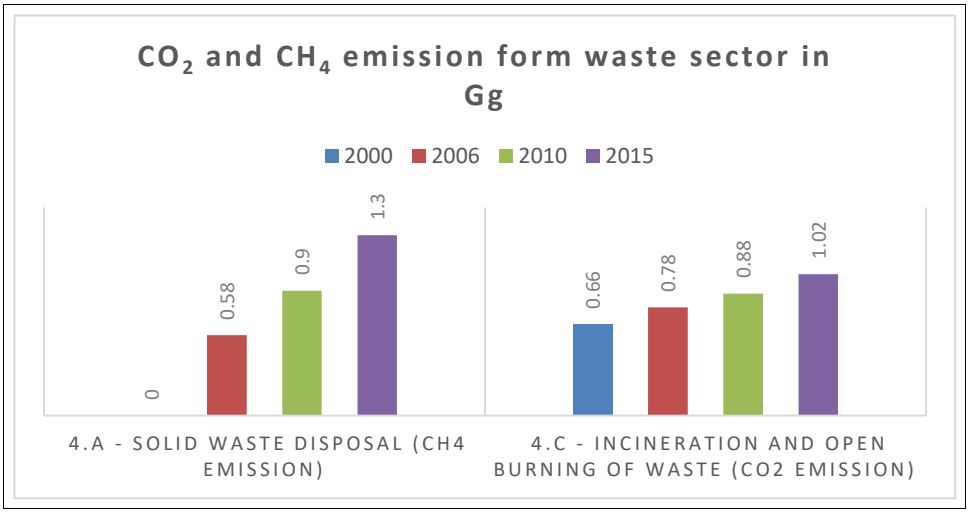


Figure 2.8: Emission from waste sector in Gg

2.5 Quality Assurance (QA) and Quality Control (QC)

2.5.1 Quality Assurance (QA)

The QA GHGs inventory constitutes an important part of inventory development cycle. This was carried out at two different steps. The first the QA/QC system is set - up to ensure routine and consistent checks of data completeness, correctness (accuracy) consistency, comparability, transparency of data sources and emission estimates; and data was checked by NGHGITEWG. The second step was to check the data analyses and information generated by independent reviewers who were not involved in preparation of the inventory, and had prior training in the IPPCC 2006 guideless, and UNFCCC expert group. Thus, review process had the following objectives.

- Confirm data quality and reliability;
- Review the activity data and emission factors adopted for each source category as a first step;
- Assess and check the calculation steps in the software; and
- Ensure consistency over the time series.

2.5.2 Quality Control (QC)

During the TNC, Eritrea has set up a quality control QC system for GHGs inventory. The NGHITEWG chaired by the project coordinator and the lead experts undertakes the QC. QC focuses on the overall quality of data collected from the various institutions. In the event when inconsistencies and transcription errors arise, responsible institutions were consulted to recheck the quality of their databases; which was conducted at all steps of the inventory. The consistency of the data was checked by comparing the total annual consumption figures with the production (imports data). In addition, the data used were verified/validated during meetings of stakeholder's representatives. Thus, data collected from the different institutions was first validated; and checked before undertaking detailed analyses. The outcome of the validation discussion was presented to the various stakeholders to check its appropriateness for inclusion in the GHGs inventory report. Whenever inconsistencies and possible transcription errors were noted, the data providing institution were consulted to recheck the validity of their

data. Accordingly, QC was implemented through combination of the following techniques and processes:

- Routine and consistent checks to ensure data integrity, reliability and completeness;
- Routine and consistent checks to identify errors and omissions;
- Accuracy checks on data acquisition processes and calculations;
- Use of approved standardized procedures for emissions calculations; and
- Technical and scientific reviews of data used, methods adopted and results obtained.

2.6 Uncertainty Analysis

Uncertainty assessment was an essential element of the GHG emission inventory to help prioritize efforts to improve the accuracy of future inventories. For estimates of GHGs from different sources, the amount of GHG emitted, in principle is directly proportional to the amount of activity data and emission factors. For the national inventory the level and trend assessment uncertainties shows that 11.29% for the 2015 inventory year where as the trend assessment 11.75% uncertainty between the 2000 and 20015 and is this is considered as being acceptable given the existing data gaps in the various sectors.

Based on the quality of the data and whether the EFs used were defaults or nationally derived, uncertainty levels were allocated for the different subsectors and the combined uncertainty calculated for the latest inventory year 2015. For details for more clarification of the level and trend uncertainty of all sectors (See annex-6).

2.7 Key Category Analysis

In this inventory, key categories and corresponding key gases were identified based on tier 1 methodology of the 2006 IPCC guidelines at both level and trends analyses were conducted. These deserve special attentions in the national inventory system as their GHG estimate emissions have significant contribution to the country's total direct GHG emissions, in terms of both absolute level and trends in GHG emissions. This is done to enable the government to prioritize efforts in the reduction of GHG emission and undertaken appropriate mitigation/adaptation measures for the Key category. The percentages of contributions to both levels and trends in GHG emissions were calculated and sorted in descending manner using the 2006 IPCC software; and 95% cumulative contribution threshold has been applied as an upper boundary for key category identification.

2.7.1 Level Assessment

The level assessment for the latest inventory year (2015), Table 2.9, shows that nine categories namely Enteric Fermentation, Forest land Remaining Forest land, Road Transportation, Cement production, Energy Industries - Liquid Fuels, Other Sectors – Biomass, Other Sectors - Liquid Fuels, Manure Management (CH_4) and Manure Management (N_2O) accounted for 95.1% of the total cumulative emission.

Table 2.10: Level Assessment 2015

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2015 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
3.A.1	**Enteric Fermentation**	**METHANE (CH4)**	**2860.96**	**2860.96**	**0.66**	**0.66**
3.B.1.a	**Forest land Remaining Forest land**	**CARBON DIOXIDE (CO2)**	**-212.14**	**212.14**	**0.05**	**0.71**
1.A.3.b	**Road Transportation**	**CARBON DIOXIDE (CO2)**	**196.53**	**196.53**	**0.05**	**0.76**
2.A.1	**Cement production**	**CARBON DIOXIDE (CO2)**	**163.02**	**163.02**	**0.04**	**0.80**
1.A.1	**Energy Industries - Liquid Fuels**	**CARBON DIOXIDE (CO2)**	**158.21**	**158.21**	**0.04**	**0.83**
1.A.4	**Other Sectors - Biomass**	**METHANE (CH4)**	**143.85**	**143.85**	**0.03**	**0.87**
1.A.4	**Other Sectors - Liquid Fuels**	**CARBON DIOXIDE (CO2)**	**129.84**	**129.84**	**0.03**	**0.90**
3.A.2	**Manure Management**	**METHANE (CH4)**	**121.82**	**121.82**	**0.03**	**0.93**
3.A.2	**Manure Management**	**NITROUS OXIDE (N2O)**	**111.20**	**111.20**	**0.03**	**0.95**
1.A.1	Energy Industries - Solid Fuels	CARBON DIOXIDE (CO2)	101.08	101.08	0.02	0.97
1.A.4	Other Sectors - Biomass	NITROUS OXIDE (N2O)	27.81	27.81	0.01	0.98
4.A	Solid Waste Disposal	METHANE (CH4)	27.25	27.25	0.01	0.99
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CARBON DIOXIDE (CO2)	21.50	21.50	0.00	0.99
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	14.23	14.23	0.00	1.00
2.A.2	Lime production	CARBON DIOXIDE (CO2)	6.54	6.54	0.00	1.00
3.D.1	Harvested Wood Products	CARBON DIOXIDE (CO2)	-3.14	3.14	0.00	1.00
1.A.3.b	Road Transportation	NITROUS OXIDE (N2O)	3.08	3.08	0.00	1.00
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO2)	2.55	2.55	0.00	1.00
4.C	Incineration and Open Burning of Waste	CARBON DIOXIDE (CO2)	1.01	1.01	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	NITROUS OXIDE (N2O)	0.50	0.50	0.00	1.00
1.A.3.b	Road Transportation	METHANE (CH4)	0.49	0.49	0.00	1.00
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO2)	0.40	0.40	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	NITROUS OXIDE (N2O)	0.38	0.38	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH4)	0.35	0.35	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N2O)	0.30	0.30	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	METHANE (CH4)	0.13	0.13	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	NITROUS OXIDE (N2O)	0.05	0.05	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO2)	0.03	0.03	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	METHANE (CH4)	0.02	0.02	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	METHANE (CH4)	0.02	0.02	0.00	1.00
3.B.4.a.i	Peatlands remaining peatlands	CARBON DIOXIDE (CO2)	-0.02	0.02	0.00	1.00

2.7.2 Trend assessment

In the trend assessment (Table 2.10) for the inventory years (2000-2015) ten categories contributed 95.9% of the GHG emission. These are, Cement production, Enteric Fermentation, Energy Industries - Solid Fuels, Other Sectors - Liquid Fuels, Manufacturing Industries and Construction - Liquid Fuels, Road Transportation, Solid Waste Disposal, Forest land Remaining Forest land, Energy Industries - Liquid Fuels and Refrigeration and Air Conditioning. Most of the sub-category identified in both level and trend assessment are key category that require specially intervention (Table 2.9 and 2.10).

Table 2.11: Trend Assessment

A	B	C	D	E	F	G	H
IPCC Category code	IPCC Category	Greenhouse gas	2000 Year Estimate Ex0 (Gg CO2 Eq)	2015 Year Estimate Ext (Gg CO2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
2.A.1	**Cement production**	**CO2**	**14.92**	**163.02**	**0.04**	**0.21**	**0.21**
3.A.1	**Enteric Fermentation**	**CH4**	**2533.81**	**2860.96**	**0.03**	**0.19**	**0.40**
1.A.1	**Energy Industries - Solid Fuels**	**CO2**	**0.00**	**101.08**	**0.03**	**0.15**	**0.55**
1.A.4	**Other Sectors - Liquid Fuels**	**CO2**	**181.18**	**129.84**	**0.02**	**0.12**	**0.67**
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO2**	**82.13**	**21.50**	**0.02**	**0.11**	**0.78**
1.A.3.b	**Road Transportation**	**CO2**	**201.41**	**196.53**	**0.01**	**0.06**	**0.84**
4.A	**Solid Waste Disposal**	**CH4**	**0.00**	**27.25**	**0.01**	**0.04**	**0.88**
3.B.1.a	**Forest land Remaining Forest land**	**CO2**	**-230.89**	**-212.14**	**0.01**	**0.03**	**0.91**
1.A.1	**Energy Industries - Liquid Fuels**	**CO2**	**148.37**	**158.21**	**0.00**	**0.02**	**0.94**
2.F.1	**Refrigeration and Air Conditioning**	**HFCs, PFCs**	**0.10**	**14.23**	**0.00**	**0.02**	**0.96**
1.A.4	Other Sectors - Biomass	CH4	116.52	143.85	0.00	0.01	0.97
3.A.2	Manure Management	N2O	99.43	111.20	0.00	0.01	0.98
3.A.2	Manure Management	CH4	107.67	121.82	0.00	0.01	0.98
3.B.2.b	Land Converted to Cropland	CO2	0.00	2.55	0.00	0.00	0.99
2.A.2	Lime production	CO2	3.45	6.54	0.00	0.00	0.99
3.D.1	Harvested Wood Products	CO2	-2.04	-3.14	0.00	0.00	0.99
1.A.4	Other Sectors - Biomass	N2O	22.65	27.81	0.00	0.00	1.00
1.A.3.b	Road Transportation	N2O	3.16	3.08	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	N2O	0.00	0.50	0.00	0.00	1.00
3.B.5.b	Land Converted to Settlements	CO2	0.00	0.40	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	CH4	0.51	0.35	0.00	0.00	1.00
4.C	Incineration and Open Burning of Waste	CO2	0.66	1.01	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	N2O	0.45	0.30	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N2O	0.20	0.05	0.00	0.00	1.00
1.A.3.b	Road Transportation	CH4	0.56	0.49	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH4	0.07	0.02	0.00	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	N2O	0.36	0.38	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	CH4	0.00	0.02	0.00	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	CH4	0.12	0.13	0.00	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CO2	0.03	0.03	0.00	0.00	1.00
3.B.4.a.i	Peatlands remaining peatlands	CO2	-0.02	-0.02	0.00	0.00	1.00

2.8 Consistency

The actual activity data for each source category in the inventory year of 2000, 2006, 2010 and 2015 were collected from the relevant sectors. Interpolation method was applied to estimate missing activity data of the years in between to allow consistent comparison of GHG emission across time. The same emission factors were also used for all the time series in line with 2006 IPCC Guidelines. The emission trends from 2000 to 2015 were estimated as shown in Figure 2.11 for consistency and that indicates to some extent GHG emission has been increasing.

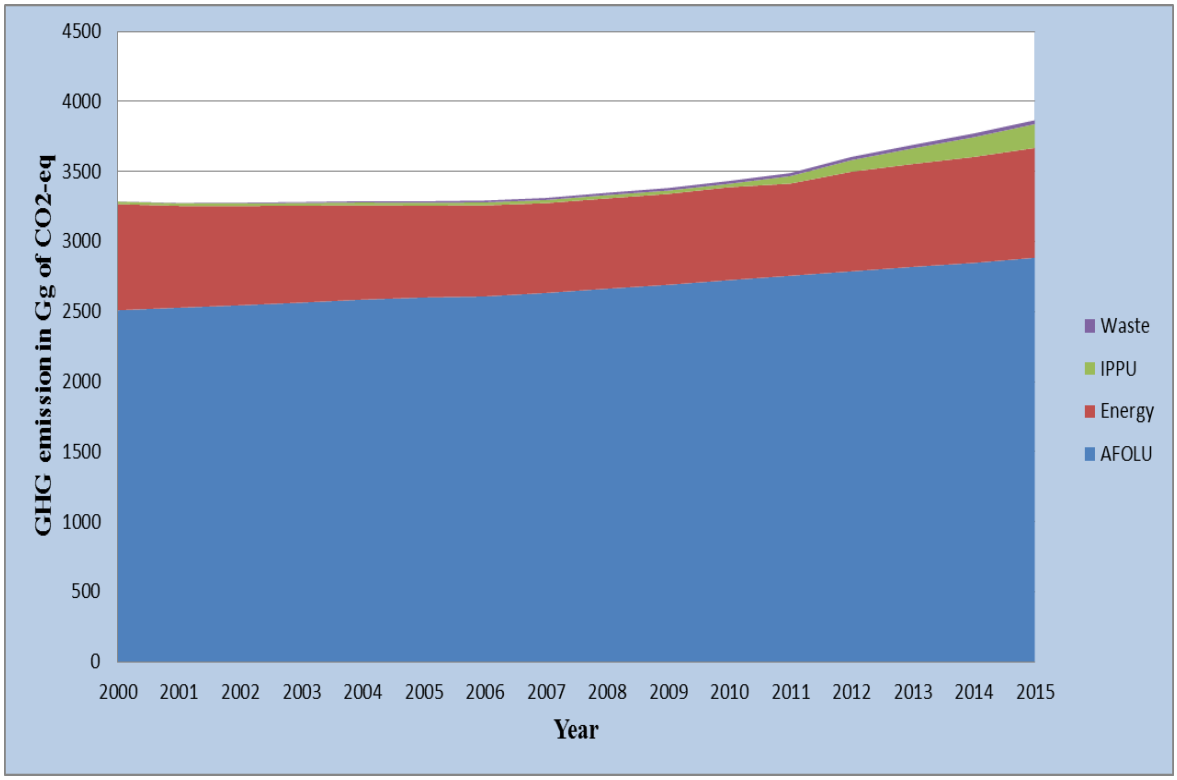


Figure 2.9: GHG emission consistency

2.9 Completeness of the 2000 to 2015 Inventories

All the direct and indirect GHG emissions for all the source categories were included. The sectors are energy, IPPU, Agriculture, AFOLU and waste sectors. Completeness of data for those categories considered is provided in details in Table 2-12. Despite the efforts made, GHG emissions from some categories and subcategories like the International water born navigation, Waste water Treatment, Non-Energy Products from Fuels and Solvent Use were not included mainly owing to lack of data sources.

Table 2.12: Completeness of the 2015 inventories of Eritrea

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	603.894	154.34	0.474	21.236	NO	NO	NO	NO	NO	NO	NO	NO
1 - Energy	617.243	6.4870	0.097	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A - Fuel Combustion Activities	617.244	6.4870	0.097	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.1 - Energy Industries	330.148	0.0095	0.003						NO	NO	NO	NO
1.A.2 - Manufacturing Industries and Construction	12.881	0.0005	1E-04						NO	NO	NO	NO
1.A.3 - Transport	160.343	0.021	0.008						NO	NO	NO	NO
1.A.4 - Other Sectors	113.871	6.455	0.085						NO	NO	NO	NO
1.B - Fugitive emissions from fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C - Carbon dioxide Transport and Storage	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2 - Industrial Processes and Product Use	190.558	NO	NO	21.236	NO	NO	NO	NO	NO	NO	NO	NO
2.A - Mineral Industry	190.558	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.A.1 - Cement production	185.317								NO	NO	NO	NO
2.A.2 - Lime production	5.241								NO	NO	NO	NO
2.A.3 - Glass Production	NA								NA	NA	NA	NA
2.B - Chemical Industry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.C - Metal Industry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.D - Non-Energy Products from Fuels and Solvent Use	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.E - Electronics Industry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NE	NE	NE	21.236	NE	NE	NE	NE	NE	NE	NE	NE
2.F.1 - Refrigeration and Air Conditioning				21.236				NE	NE	NE	NE	NE
2.F.2 - Foam Blowing Agents				NE				NE	NE	NE	NE	NE
2.F.3 - Fire Protection				NE	NE			NE	NE	NE	NE	NE
2.F.4 - Aerosols				NE				NE	NE	NE	NE	NE
2.F.5 - Solvents				NE	NE			NE	NE	NE	NE	NE
2.G - Other Product Manufacture and Use	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
3 - Agriculture, Forestry, and Other Land Use	-205.011	146.33	0.378	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.A - Livestock	0	146.33	0.378	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.A.1 - Enteric Fermentation		140.36							NO	NO	NO	NO
3.A.2 - Manure Management		5.9760	0.378						NO	NO	NO	NO
3.B - Land	-205.011	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.B.1 - Forest land	-207.981								NO	NO	NO	NO
3.B.2 - Cropland	2.590								NO	NO	NO	NO
3.B.3 - Grassland	NO								NO	NO	NO	NO
3.B.4 - Wetlands	-0.017		NO						NO	NO	NO	NO
3.B.5 - Settlements	0.398								NO	NO	NO	NO
3.B.6 - Other Land	0								NO	NO	NO	NO
3.C - Aggregate sources and non-CO2 emissions sources on land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.1 - Emissions from biomass burning		NE	NE						NE	NE	NE	NE
3.C.2 - Liming	NE								NE	NE	NE	NE
3.C.3 - Urea application	NE								NE	NE	NE	NE
3.C.4 - Direct N2O Emissions from managed soils			NE						NE	NE	NE	NE
3.C.5 - Indirect N2O Emissions from managed soils			NE						NE	NE	NE	NE
3.C.6 - Indirect N2O Emissions from manure management			NE						NE	NE	NE	NE
3.C.7 - Rice cultivation		NA							NA	NA	NA	NA
4 - Waste	1.104	1.5220	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A - Solid Waste Disposal	NO	1.5220	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.B - Biological Treatment of Solid Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
4.C - Incineration and Open Burning of Waste	1.104	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D - Wastewater Treatment and Discharge	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
International Bunkers	13.084	9.1E-05	4E-04	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.3.a.i - International Aviation (International Bunkers) (1)	13.084	9.1E-05	4E-04						NO	NO	NO	NO
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	NE	NE	NE						NE	NE	NE	NE

NO = Not Occurring; NE = Not Estimated; NA = Not Available

2.10 Comparability and Recalculation of GHG emission

The last national GHG inventory submitted to the UNFCCC, as part of the second national communication, was in February 2012. The methodology used for this inventory was the revised 1996 IPCC Guidelines for estimating and reporting national GHG inventories except for the LULUCF which was estimate based on the IPCC guidelines of 2006 Volume 4 and Good Practice Guidance (GPG) 2003 and the reported GHG emission, excluding the biomass emission was 7501 Gg CO2-eq. On the other hand, GHG inventory in the TNC report is estimated/calculated using the 2006 IPCC software version 4.691. To provide consistent data series, recalculation was performed using the 2006 IPCC guidelines for the 2000 inventory data. Moreover in the second national communication, it was erroneously indicated that the country forest cover was 12.7% of the total area. It is now evident that the actual Eritrea's forest cover is less 1%; and accordingly round wood and fuel wood removal is prohibited. Therefore, data on annual round and fuel wood removal as well area forest cover are improved at this stage. Based on the data improvement and application of revised 2006 IPCC guideline under, the GHG emission for the 2000 inventory year is 3286.76 Gg CO2-eq and which is 43.8% of the valued reported under the second National communication.

2.11 Archiving

All raw data collected for the inventory have been stored in a database; and in the 2006 software database after being processed and formatted for making estimates of emissions and removals. All documentation on the data processing and formatting have been kept in soft copies in the excel sheets with the summaries reported. These versions will be managed in electronic format in copies, at the MoLWE, the Department of Environment as reference for future use and comparison the dynamics of GHG emissions in Eritrea.

2.12 National Inventory Improvement Plan

Based on the constraints and gaps and other challenges encountered during the preparation of the inventory, a list of improvements has been identified. The following list provides highlights of the major activities that need to be addressed prior to the preparation of the upcoming 4th National Communication. These are outlined in the following bullet points.

- **Refine data collection norms and procedures**: Eritrea is endowed with diversified breeds of livestock adapted to agro-ecological zones of the country. Determining country - specific factors is increasingly becoming necessary to establish national norms i.e. weights for livestock as country - specific data is better than using default IPCC values.
- Improve data collection from the IPPU,
- Much remains to be done on the waste sector specially to categorize the various components of wastes not covered in this inventory;
- **Introduction of national Quality Control mechanism**: Adequate and proper data collection including QC, validation, and storage and retrieval mechanism to facilitate the compilation of future inventories is required. There is a need for a shift from an ad-hoc basis of QC approach to an organized institutional set - up so as to take over the task and coordination of data sources from various stakeholders involved in GHG inventories.
- **Implement fully the QA/QC system**: in order to reduce uncertainty and improve the inventory quality, fully-fledged QA and QC need to be institutionalized at the national level. International support is needed to adapt an effective, efficient and sustainable QA/QC mechanisms and procedures.

The collection and providing of data are a challenging issue for compiling and estimation of GHG inventory in Eritrea. The previous and current procedure for collecting of data used were in aggregated form that inappropriate for the data quality and identify the sectoral key category of GHG emission in the country. To avoid this problem the next GHG inventory could include the disaggregate data and national emission factor and clearly defined the roles and responsibility of the national institution as described in Table-2-14.

Table 2.13: Improvement Plan

Category Code and name	Issue	Improvement Option	Priority	Responsible Sector	Implementation period
National Circumstance	Lack of updated national statistics on (population and population growth rate, Economic contribution and population distribution)	The national statistics office will update the information relevant to population; if necessary take a survey and updated the national statistics documents. The other economic sectors/Institutions will identify and calculate the contribution of their respective sector contribution to the national economy.	High	NSO of the MoND, MoA, MoTI, MoH, MoMR, MoEM, MOT etc.	2022
National Meteorological Information	There is no complete national on ground measurements of temperature fluctuation during the day and seasonal variations, rainfall, wind direction and speed as well as information relevant changes to Ambient air quality (State of air pollution)	Installation of appropriate and representative Meteorological Instruments across the country; and take measurements of the relevant parameters. Data obtained from global sources could be calibrated using ground truth.	High	MoLWE, MOLG, MOTC (Aviation)	2023
Institutional Arrangement (IA)	Limited coordination and network of communication among the relevant national institutions.	Develop coordination and network of communication with national institutions and establish Domestic MRV system at national level for accuracy, transparency, consistency and completeness of the GHG inventory; which would be helpful for QA/QC system. In this venture, the national UNFCCC focal point, in collaboration with relevant stakeholders will revitalise the technical committees to periodically monitor the effectiveness and efficiency of the system on a sustainable manner. Establish a well-equipped and staffed GHG inventory unit within the DOE responsible for GHG inventory compilation and coordination of activities among the various stakeholders.	High	DOE (MoLWE)	2022

Category Code and name	Issue	Improvement Option	Priority	Responsible Sector	Implementation period
IA	Strengthened existing institutional framework:	More than ever, there is increasingly becoming necessity to further build capacity and strengthen the existing institutional framework to improve a coordinated action for reliable data collection and accessibility. Hence, institutionalize the archiving system is imperative.	High	DOE (MoLWE)	2021
1.A.4.c-ii Off-road vehicles and other machinery	Activity data not included separately in this inventory	For accuracy, and completeness of the GHG inventory, the activity data should be gathered separately from transportation statistical data; and include it in the National communication.	High	MoA, FWA, MoTC, MOLG, MOH etc.)	2023
1.A.3.d.i - International water-borne navigation (International bunkers)	The consumption of fuel and technology used were not considered in this inventory	It is understood the international water borne navigation is reported separately from the National GHG inventory; but for meeting the reporting requirement efforts will be made to gather relevant information to fill the gaps.	low	Ministry of transport and communication, Eritrean Maritime, MOMR	2024
1.A.3.d.ii-domestic water-borne navigation	The consumption of fuel by the domestic water-borne is important to the national GHG inventory but due to lack of data; it could not be included in this report.	The consumption of fuel will be included in the next inventory; and the technology used with the domestic water-borne will be assed.	medium	MOTC, MOMR, Eritrean Maritime	2023
2.D.1 lubricant use	The consumption and use of Lubricants are not included in this inventory.	Inclusion of the lubricant consumption and use would make the nation national GHG inventory complete; and hence efforts will be made to include the information on lubricants in the next inventory.	low	MoTI, Custom office	2023
2.D.2 Paraffin wax use	The consumption and use of paraffin wax were not consider in this inventory	Although small, it would important to include the consumption and use of paraffin in the national GHG inventory.	low	MoTI, Custom office	2024

Category Code and name	Issue	Improvement Option	Priority	Responsible Sector	Implementation period
2.G.1.b-use of electrical equipment and 2.G.1.c-disposal of electrical equipment	Due to inadequate data recording and management system, the use and disposal of electrical equipment were not considered in this inventory.	The department of energy responsible for the data recording especially out of use equipment and disposal. Adequate data recording and management system shall be developed for the out of use and disposal of electrical equipment	low	Department of Energy	2024
3.A.2 - Manure management	The characterizing of national manure management in this inventory was not clearly identified as there are data gaps in livestock management.	Develop appropriate mechanism to identify and characterize the national manure management system to include in the national GHG inventory.	High	MOA, Eritrean Crop and livestock Corporation	2023
3.B.1.a Forest land	The national land classification used in the inventory is out dated (MoA, 2002). The likelihood of land use change over the last 19 years is very high; and this should be captured in FNC inventory.	It is important that updated and current land use classification report is prepared for forest land. This needs the application of spatial and temporal remote sensing data and GIS application tools and expertise to analyse and detect the change.	High	MOLG, MLWE (DOL) MOAFWA, Crop and Livestock Corporation (CLC),	2022
3.B.2.a-Cropland	Reclassification required	More accurate and transparent GHG inventory.	High		2022
3.B.4 Wetlands	Up-to-date assessment	More accurate and transparent GHG inventory.	High		2022
3.B.5-Settlements	Land use change	More accurate and transparent GHG inventory.	Medium		2022

Category Code and name	Issue	Improvement Option	Priority	Responsible Sector	Implementation period
Forest Resources Inventory:	The last forest cover map of Eritrea was carried out in collaboration with FOA in 1997; and has not been updated in view of the subsequent changes in the forest cover of the country.	There are evident changes in the forest resources in the country due to climate change particularly climate change. Hence, there is a need for a comprehensive forest inventories to supplement the available data on the LAND category. Review and correct inconsistencies that exist for the recent land cover maps with additional overlays with previous maps and ground referencing.	High	FWA	2022
4.A - Solid Waste Disposal	Due to inadequate activity data on waste compositions; the IPCC default factor is used in this inventory; and this could have led to some errors in the GHG inventory report. Insufficient data on the type and amount of waste disposed at the landfill is another area where improvement is required.	Develop national waste data and information recording system especially on the composition and type of waste generated and disposed at the landfills (industrial commercial/domestic). The solid, liquid waste disposal and management needs to be assessed to generate suitable data.	High	Municipality	2022
4.C.1-Waste Incineration	The Ministry of Health uses inclinators to incinerate medical wastes, however, due to lack of data; this has not been included in this inventory.	Appropriate data and information on the amount of medical waste incinerated at each premise shall be recorded and documented on a regular basis (daily, weekly monthly and yearly.	High	MoH and Municipalities (MoLG)	2022

Category Code and name	Issue	Improvement Option	Priority	Responsible Sector	Implementation period
4.C.2-Open Burning of Waste	There is insufficient data and information about open burning of waste and fraction of population that practice open burning.	Classify and identify the amount of open burning waste (Clinical, Hazardous and industrial) and estimate fraction of population that use open burning of waste	High	Municipality and MoH	2022
4.D.1 - Domestic Wastewater Treatment and Discharge	Generally there is no waste treatment at national level; but discharges of domestic wastes directly to the sewer system; and were not include in this inventory due lack of data.	The municipality estimates the daily waste drainage to the sewer and identify the final ends and usage of sewage.	High	Municipalities of cities with liquid waste discharges	2023
4.D.2-Industrial Wastewater Treatment and Discharge	Industrial wastes generated at each facility are discharged to the sewer system without pre-treatment. However, due to lack sufficient data and information, it has not been included in the inventory	Appropriate data and information recording and management shall be developed to support the estimation of GHG from the sub-sector	High	MoTI, MoLWE (DoE and WRD). Relevant Municipalities	2025

CHAPTER THREE

3 NATIONAL GHG MITIGATION ASSESSMNET AND ANALYSIS

3.1 Introduction

In order to stabilize greenhouse gas (GHG) concentration in the atmosphere, Article 4.2 (a) of the convention stipulates that parties shall adopt national policies and take corresponding measures on mitigation of climate change by limiting their anthropogenic emissions of GHG, and by protecting and enhancing GHG sinks and removal. Unlike developed country parties, less developed countries such, as Eritrea, have no specific mandatory targets set for them, but their participatory role is considered important because these countries are striving for economic expansion which will eventually lead to higher GHG accumulation in the atmosphere. Apart from meeting, the UNFCCC requirements, the GHG mitigation process presents every country with a challenge to achieve economic development in harmony with environmental protection.

The energy sector is one of the highest emitters of the global CO_2 emissions. Hence, many mitigation studies have justifiably focused on this sector. This chapter presents mitigation options of the energy sector; despite Eritrea not being expected to be among the major emitters of GHGs for the reason that both its population and level of economic development are low. Eritrea is also expected to report on the GHG emission levels and mitigation strategies in compliance with the UNFCCC to which it is a party. Eritrea's economic base is expected to grow resulting in increased emissions. Thus, it is important to incorporate GHG abatement technologies in the growing economic infrastructure now to benefit from the energy and cost savings associated with the mitigation measures.

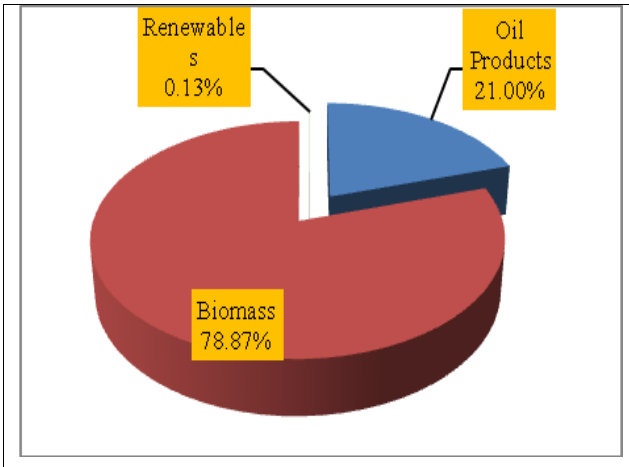
Energy production through fossil fuel heavily contributes to GHG emissions. Thus, GHG mitigation measures in this sector play an important role in achieving positive environmental, economic, and social impact through both demand and supply side management and clean energy production. The implementation of mitigation measures helps in reducing the country's GHG emissions by reducing and improving the efficiency of supply and end- use consumption by various intervention activities in the energy sector. Therefore, Eritrea is committed to contribute to its maximum capability towards meeting Article 2 of the UNFCCC which states "the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The two major principles in this mitigation assessment are to meet the ultimate objective of the Convention and promote socio-economic development as per the policies and strategies in place presently and mapping the medium term strategic plans and actions of the country.

In view of the above background, this mitigation assessment and analysis provides a description of Eritrea's efforts in understanding its options in reducing greenhouse gas emissions within the context of key sustainable development initiatives. It too provides an overview of the reductions that could be achieved in critical emitting sectors and a forward-looking set of recommendations for overcoming current challenges and barriers. This analysis addresses options which present the highest potential for mitigation for their abatement potential based on the year 2016 up to the 2035-time horizon.

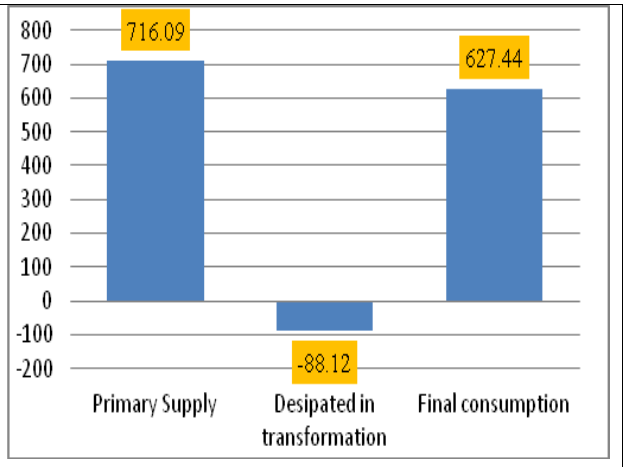
3.2 Energy Sector Background

Energy plays vital roles in the economic, social and political development of a nation. Inadequate supply of energy restricts socio-economic activities, limits economic growth; and adversely affects the quality of life of citizens. Every nation needs access to modern energy sources to improve the lives of its citizens, by increasing labour productivity, improving the health of the population, lowering transaction and transportation costs, facilitating information sharing and educational activities, increasing living standards, advancing new technologies, and a host of other socio-economic factors.

The energy sector of Eritrea is dominated by massive dependence on traditional biomass fuels to cover domestic energy requirements. Wood, charcoal, animal waste and agricultural residue accounts for more than 90% of the household energy mix. Lack of access to modern energy by the majority of the country's population (3/5), only 38%, of the population has access to electricity at national level (88% urban and 12% rural. Total reliance on imported oil as a source of modern energy, 92.5% of electricity is being produced from thermal generators firing oil products which are an indication of poor level of market penetration of Renewable Energy Technologies (RETs). It reliance on imported oil makes the country's energy supply and economy extremely vulnerable to international oil price rises. Despite these, Eritrea is considered to have very high potential sources of renewable energy resources, especially wind, solar and geothermal. The share of energy supply mix as of 2018 and primary supply dissipated in transformation and final consumption is shown in Figure 3.1.



Share of primary energy supply by fuel type



Primary supply, dissipated in transformation and final consumption ('000'toe)

Figure 3.1: Share of the Energy Supply and Primary supply, dissipated in transformation and final consumption ('000'toe) in 2018

The Interconnected System (ICS) and the Self Contained System (ICS + SCS) electricity generation GWh, sales and losses is shown in Figure 3.3.The figure shows that while power generation grew by 3.5%, sales grew by 4% indicating a gap between supply and demand sides.

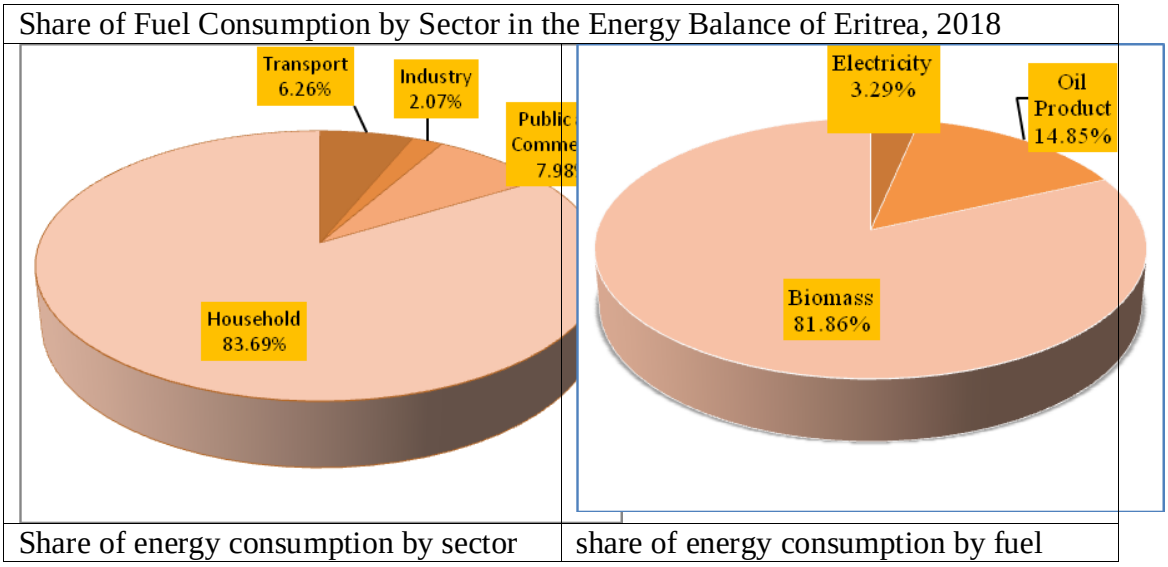


Figure 3.2: Share of Fuel Consumption by Sector in the Energy Balance of Eritrea, 2018

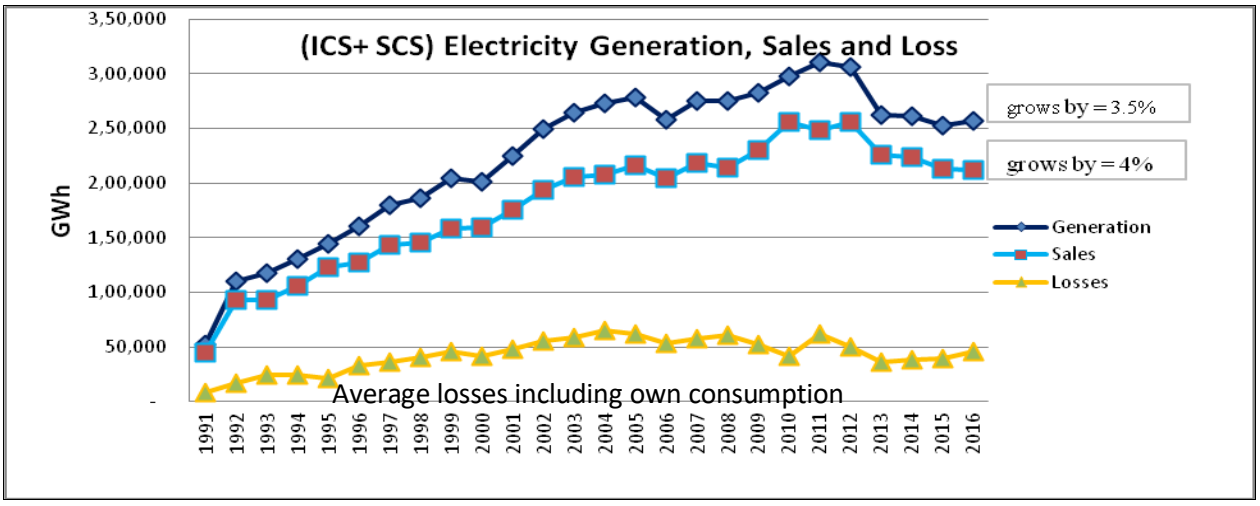


Figure 3.3: ICS + SCS) electricity generation GWh, sales and losses

In Eritrea, there are a number of Potential Renewable energy sources: wind, solar and geothermal to meet the demands of the population. The wind energy (high potential of wind electricity generation and wind mechanical water pumping) is given in Figure 3.4.

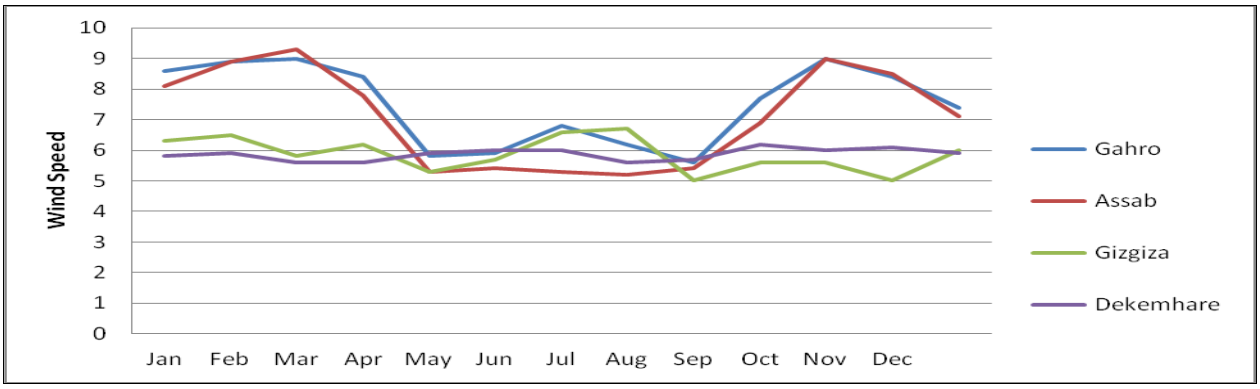


Figure 3.4: Wind potential at 10 Meter height in different regions

The solar Energy (high potential of solar energy more than 10 hours sun shine a day with 7kWh/m^2) is shown in Figure 3.5.

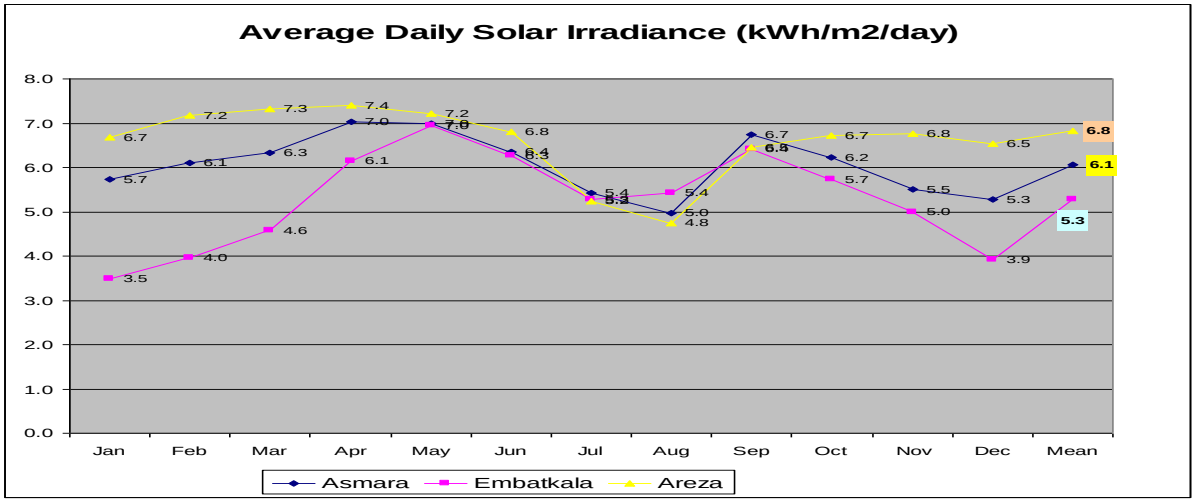


Figure 3.5: Average daily solar irradiance

Eritrea is part of the red sea rift valley and geothermal energy source has very high potential provided the requisite technical capacity and investment are put in place to harness it.

A. Policy initiative

Energy Sector Policy is striving to provide an efficient, economic, reliable and sustainable supply of affordable energy throughout Eritrea, with due regard to the preservation and improvement of the environment. This can be achieved through exploiting or promoting the potentials of renewable energy resources, energy efficiency conservation, promote incentives for private investors to develop and utilize renewable and efficient energy technologies. According to the policy statement of the MoEM, in the energy sector, the primary objective focuses on availing ample, dependable and sustainable energy for the growing needs of all economic and social sectors in Eritrea at an affordable price which includes the following key issues:

- increasing access to affordable energy services,
- improving energy governance,
- stimulating economic development,
- managing energy-related environmental impacts, and
- Securing supply through diversity.

The specific targets corresponding to above stated objectives include:

- Expansion of electric power system to a yearly growth rate of at least 2% higher than the overall economic growth rate and not less than 10% annually;
- Within five years increase rural electricity access level to 15% from current access level (12%) through provision of stand-alone renewable power systems or through interconnection to the main grid. Increase the electricity access level in the rural population to 30% by 2030 and achieve universal access by 2050. This implies electrification of about 50 villages per year;
- Within five years, reduce the technical losses from the power systems of the Eritrean Electric Corporation to less than 10% (Implement power distribution rehabilitation);

- Initiate bilateral or multi-party discussions with neighbouring countries on joint energy and development and interconnection in the vicinity areas. To achieve the above targets, the MoEM has prepared following short and medium - term development programs:
- Consolidation and expansion of the existing power plants in both the ICS and SCS;
- Consolidation, expansion and rehabilitation of transmission and distribution systems including substation; and
- Promotion of renewable energy applications and energy efficiency and conservation programs.

To this effect, actions in progress to address energy problem in the country are:

- refurbish the generators at the national power plant to their normal condition;
- install additional modular solar PV systems to back the national grid;
- rehabilitate the distribution system to reduce the line losses; and
- Expanding access of electricity to rural areas through grid extension and standalone systems.

Prioritized development programs waiting for financing are the following.

- Exploitation of wind and solar resources:
  - 20-30 MW Grid connected wind power (Dekemhare and Asseb area);
  - 10-20 MW Grid Connected solar power (Asmara, Adi Keih Dbaruwa Barentu area), Kerkebet Wind and Solar or Gerset hybrid system;
- Feasibility study and development of geothermal energy;
- Reactivating and rehabilitation of Asmara power distribution;
- Construction of 220kV transmission line (Hirgigo-Tesenay) including corresponding substation and distribution lines;
- Expansion of rural electrification through solar systems; and
- Establishment of assembling plant for RETs and batteries.

Challenges

There is excessive and inefficient consumption of wood fuel for domestic usage, which has caused the degradation of forest cover and negatively affecting the environment. The ever escalating oil prices on the international market imposes heavy burden on the economy and making the country energy insecure. Lack of access to electricity by majority of the population, especially the rural people on one hand; and limited resources to increase access to affordable, efficient, reliable, clean and modern energy services for the majority of Eritrean on the other is a daunting endeavour. As the result of limited skilled personnel and spare parts, power plants operate for an extended period without regular and timely maintenance. Old energy infrastructure, including power plants, transmission and distribution systems are with high level of losses involved in conversion, transmission and distribution of energy (about 22% loss).

There is low level of awareness and information about energy conservation practices and improved energy technologies among energy users which is aggravated by lack of developed indigenous or proven energy resources for commercial energy production. Adequate capital investments are necessary to address the urgent need for energy infrastructure development. This is compounded by insufficient incentives and financing mechanisms for the private sector to invest in modern efficient energy technologies. High capital cost of RETs relative to income of the majority of the population compounded by the absence of financing instruments/ mechanisms for RETs. These limitations are compounded by inadequate institutional capacities are manifested in the following three bottlenecks.

- Inadequate energy information management system that is necessary for energy supply and demand analysis and planning purposes.
- There is low level of co-ordination and information sharing between or among various government institutions, private sector and civil society organizations.
- Lack of planning and appropriate research and development (R&D) capacity.

Besides, efforts are also underway to introduce 2.25 MW solar PV- Diesel hybrid systems to enhance rural electrification. For instance, two of 4MW grid tides PV system to feed the national grid (Figure 3.6, Figure 3.7) and 16MW to back generators of mining sector.

Figure 3.6: Solar PV Diesel Hybrid Mini-grid system (Mai – Dma)

Figure 3.7: Solar Home system and solar water pump

In order to optimize firewood consumption and minimize smoke emissions traditional stove of *Mogogo* has been developed Figure 3.8. Through promotional campaign, as of 2018, it has been possible to install improved *Mogogo* in over 250,000 rural households which constitutes about (30%) of the country.

Figure 3.8: Traditional Improved stove (Adhanet Mogogo) training and demonstration

3.2.1 Scope of the Assessment

All activity areas concerned with emissions, in a country can be targeted for mitigation analysis. However, this is very resource demanding and very often, it is not worth evaluating the minimal contributors of GHGs for their mitigation potential seeing that it is not cost effective. Based on this principle and available data, the following three categories were prioritized for assessment namely

- Energy sector (Energy industry, Household, Public and Commercial, Industry & road transportation),
- Agriculture Forest and Land Use Change (AFOLU) and
- Solid waste categories were prioritized for the assessment.

The following sections provide details about mitigation assessment and abatement measures (mitigation scenarios) for Eritrea in energy supply and demand sectors: Electric Power Generation, Domestic, Public & Commercial, Manufacturing Industry, and Transport. Mitigation scenarios have been informed and aligned to existing Government sector policies, strategies and programs. In order to ensure consistency, the level of emission reductions has been aligned with the national targets outlined in the NDCs set for 2030 (MoLWE, 2018). The mitigation scenarios are presented by explaining the underlying assumptions and the methodology used to develop mitigation options. It includes energy outlooks (forecasting), integrated resource planning, greenhouse gas mitigation analysis and environmental loading inventories for the energy industries, household /residential, road transport, public and commercial and manufacturing industries and construction sub sectors.

3.2.2 Mitigation Assessment Methods and Approaches

Technical Working group representing the Energy, Transport, Industry, Agriculture and Waste sector was established. Each team member was responsible to provide relevant information and future development programs and projects of the respective sectors. Mitigation assessments were done based on a combination of two alternative approaches namely an activity-based approach, and an outcome-based approach (Figure 3.9).

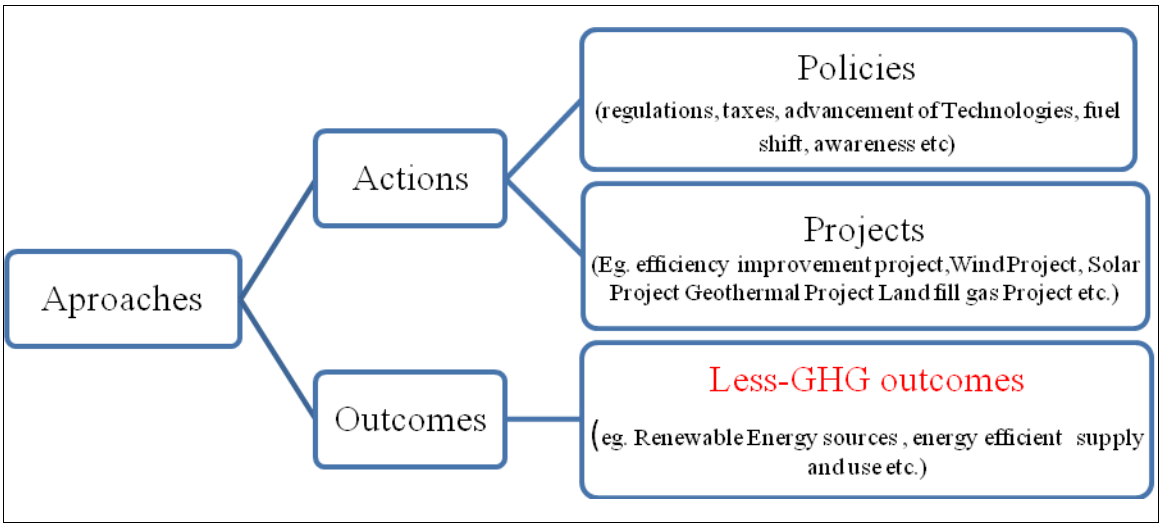


Figure 3.9: Mitigation assessment approaches

A. **Use of LEAP modelling tool:** In order to conduct GHG mitigation assessment and analysis in the Energy sector, a bottom-up and integrated system approach has been utilized using the Long Range Energy Alternatives Planning (LEAP) modelling tool This tool was found to be useful for strategic integrated energy-environment scenario studies including energy outlooks (forecasting), integrated resource planning, greenhouse gas mitigation analysis and energy balances and environmental inventories.
B. **Time Frame:** The goal of the assessment was to establish annual and cumulative GHG emission reductions following the introduction of several energy efficiency and renewable energy options. Ideally, a mitigation assessment should be long - term assessment, in order to reflect economic lifetimes and the potential for the stock turnover of major technologies. However, establishing long-term projections can be difficult owing to uncertainties over future development pathways and limited statistical data. Shorter-term assessment based on national plan and sector assessment was more practical. Hence, in this report, GHG emissions projections from 2020 to 2035 following a business-as-usual and mitigation scenario were made taking 2016 as base year due to relative demand supply stability.
C. **Data Sources:** Most of the data required to undertake the assessment was acquired through the technical expert group representing the key ministries involved in GHG mitigation activities. Additional data was also obtained from experts who participated in the preparation of the report. Physical properties of fuels (e.g., GHG emission factors, energy densities) are based on IPCC 2006 default factors used in the development of the GHG inventory. Basic parameters and assumptions regarding future development in Eritrea (e.g., population growth, GDP, electric capacity expansion, transport sector characteristics, etc.) were obtained from official sources. In the event when data and information were wanting it was necessary to apply a combined approach in which expert judgment was used.
D. In the mitigation assessment, two scenarios were considered. These are the Business-as-Usual (BAU) and Mitigation Scenarios (MS). In the BAU scenario, it was assumed that there would be steady growth in the economy accompanied with urbanization increasing energy demand and prevail fuel shift. Furthermore, increase access to modern energy sources was certain. In the MS, it was assumed that the on-going government policy to increase efficiency in all sectors of the economy would result in the reduction in energy consumption and accordingly reduce the greenhouse gas emissions in the energy supply and demand sectors. Furthermore, diversification of energy supply mixes with indigenous Renewable energy Sources was imperative.

E. Key assumptions for projecting energy demand and estimating GHG emission for the BAU and mitigation cases include drivers of emissions in the energy supply and demand sectors including economic development, population growth and changes in household size. Urbanization, efficient end-use devices and fuel shift and diversified indigenous sources.

3.2.3 Socio Economic Scenarios

A. Population Size and Growth

The population which stood at 3.0 million in 1991 grew slowly to 3.2 million in 2010. With a population growth rate of 2.8%, the projected population will reach 6.52 million in 2035 as shown in Figure 3.10. During this period the estimated household size is expected to be about 5 with household growth rate of 2.8%. As shown in Figure 3.10, in 2016, the household size was 782,200 and it is projected to grow to 1,329,600 by the year 2035.

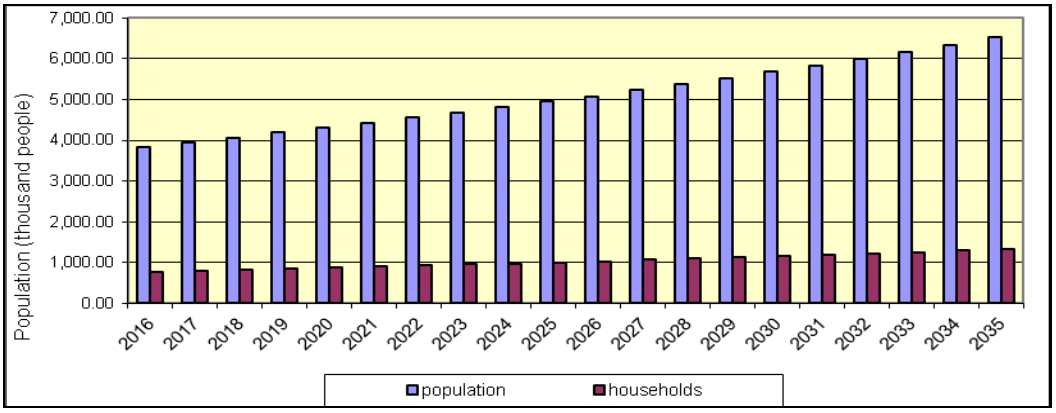


Figure 3.10: Projected population statistics of Eritrea

B. Urbanization

For urbanization, a short-term profile i.e. until the year 2035 was developed on the basis of past recorded trends. Between 2016 and 2035, the projected urbanization (Figure 3.11) shows that urban & semi urban population will be 50% of total population. Thus, by 2035 the urban population is projected to reach 44% of the total population will be 2.86 million living in cities and towns. Hence, the proportion of the rural population will progressively decline to 3.25 million in 2035, which accounts for about 50% of the total population. The remaining 6% (0.39 million) will be semi urban dwellers.

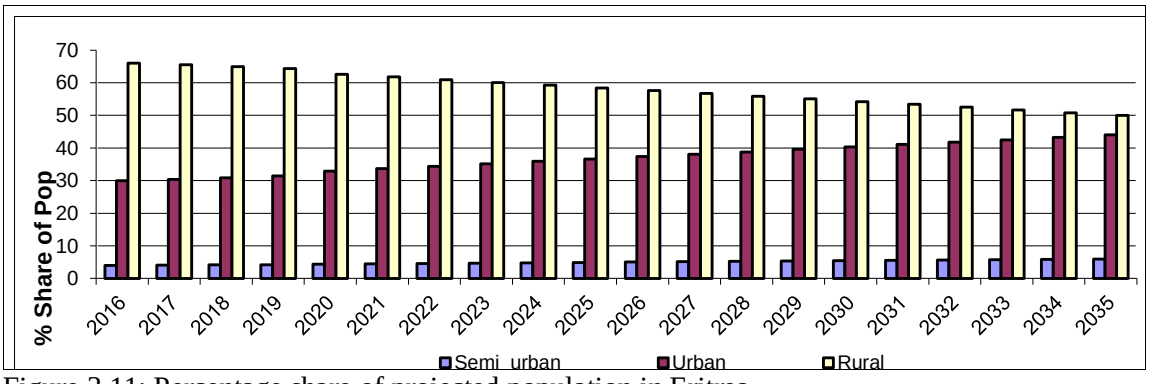


Figure 3.11: Percentage share of projected population in Eritrea

C. GDP and GDP per Capital

Between 2000 and 2020, the average estimated annual growth rate for total GDP was 3.5% in which the contribution of the sectors was i) Agriculture with 20.30%, ii) Industry including mining 20.90% and iii) Services 58.80%. Given a 2.8% increase in the size of the population, the increase in demand, GDP per capita which is currently 204 USD is expected to change by only 3.5%. Considering short term recession and world crisis, a conservative scenario has been built to portrait the GDP growth until 2035 to remain constant at 3.5% growth rate.

3.3 Energy Sector Mitigation Assessment and Analysis

3.3.1 Business as Usual Scenario

Annual emissions were projected up to 2035 for Business-as-Usual Scenario (BAU) that were used as the baseline against which to demonstrate the expected abatement potential in the energy sector. Key assumptions considered for projecting energy demand and estimating GHG emission for the reference case were the following:

- Population grows by 2.8 annually;
- Household size decrease but total number of households increases;
- Urbanization is assumed to grow to 50 % from present rate of 30 %;
- Share of the economic sector industry to GDP is assumed to grow by 20.9 % to 28 % due to mining sector, share of agriculture is assumed to be 20.3% but production per hectare and mechanization is expected to increase. Service sector is assumed to contribute 58.8%;
- Improvement of life style (fuel shift from traditional biomass to modern commercial fuel, and use of new appliances); and
- Increased access to modern energy sources (e.g. rural access to electricity) is assumed to grow from the current status 3 % to 20 % access by the end of the model year and 7 % increase (from 92 % to 99 %) in urban connection rate.

Based on the above listed assumptions, energy demand projection from end use sectors for the model years is summarised in Table 3.1. From the table, it can be deduced that the total energy demand projection grows by about 1.3 times compared with the base year value 767.6 ktoe. Energy demand projection for the model year in economic and service sectors (Industry, transport and service) respectively grown by 3.0%, 3.2% and 2% compared to the base year levels; whereas, demand of household sector shows decreasing trend. The increase of energy demand in industrial, transport and service sectors were mainly attributed to the demand from mining sector and improvement in services of the service sector, whereas the decrease in energy demand from household sector was attributed to fuel shift to more efficient sources and devices.

Table 3.1: Reference Scenario, Energy demand all fuels in thousand tons of oil equivalents

	Year				
Sector	**2016**	**2020**	**2025**	**2030**	**2035**
Household	602.9	626.4	599.3	571	545.5
Transport	79.3	92.2	127.3	177.9	251.4
Public and Commercial	72.8	77.3	94.1	115.5	142.6
Industry	12.7	14	19.5	27.2	38.3
Total	**767.6**	**809.9**	**840.2**	**891.5**	**977.9**

As shown in Figure 3.12, the projected demand is growing more in the economic sectors which attributes to the close relationship between energy and economic development activities.

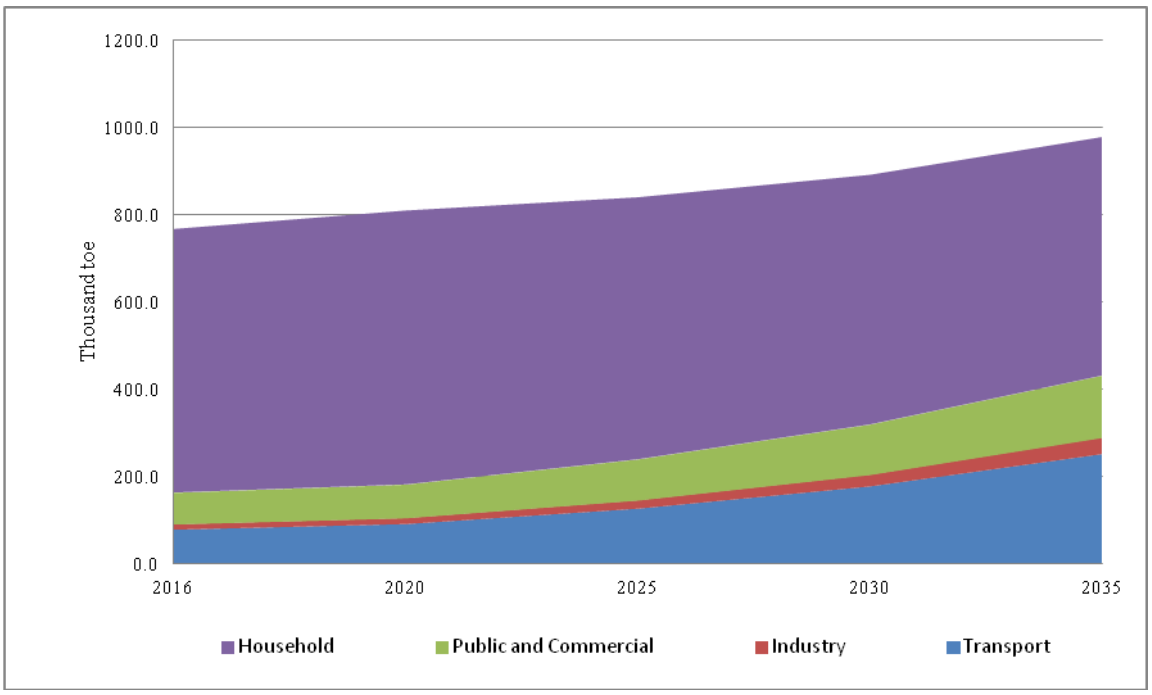


Figure 3.12: Reference Scenario total final fuel demand all fuels (ktoe)

Based on BAU scenario is shown in Table 3.2 in which it is shown during the scenario period emission from transport sector grows faster and the corresponding GHG emission bypasses the level of emission from household sector. These could be due to the fact that the transport sector depends only on oil products (main source for GHGs emissions) while the Industrial, public and commercial sectors use diversified sources. Thus, their corresponding emission is less whereas; in household sector, there is fuel shift to more efficient fuels and devices. Thus, by 2035, the main emission contributors within the energy demand sector are transport (45%), household (30%), and services (20%). Although industry is forecasted to grow; it will only contribute about 5% to the total emission by the same year. Based on the BAU scenario, by 2035 total GHGs emission is expected to rise by 2.32 times (Table 3.2, Figure 3.13).

Table 3.2: Reference Scenario, Global warming Potential in CO2-eq (million kgs)

Year	**2016**	**2020**	**2025**	**2030**	**2035**
Household	302.2	336.8	388.0	449.8	529.1
Transport	241.3	280.4	387.4	541.2	764.8
Public and Commercial	167.2	181.6	221.2	271.4	335.2
Industry	29.1	32.1	44.6	62.4	87.8
Total	**739.8**	**830.9**	**1,041.2**	**1,324.8**	**1,717.0**

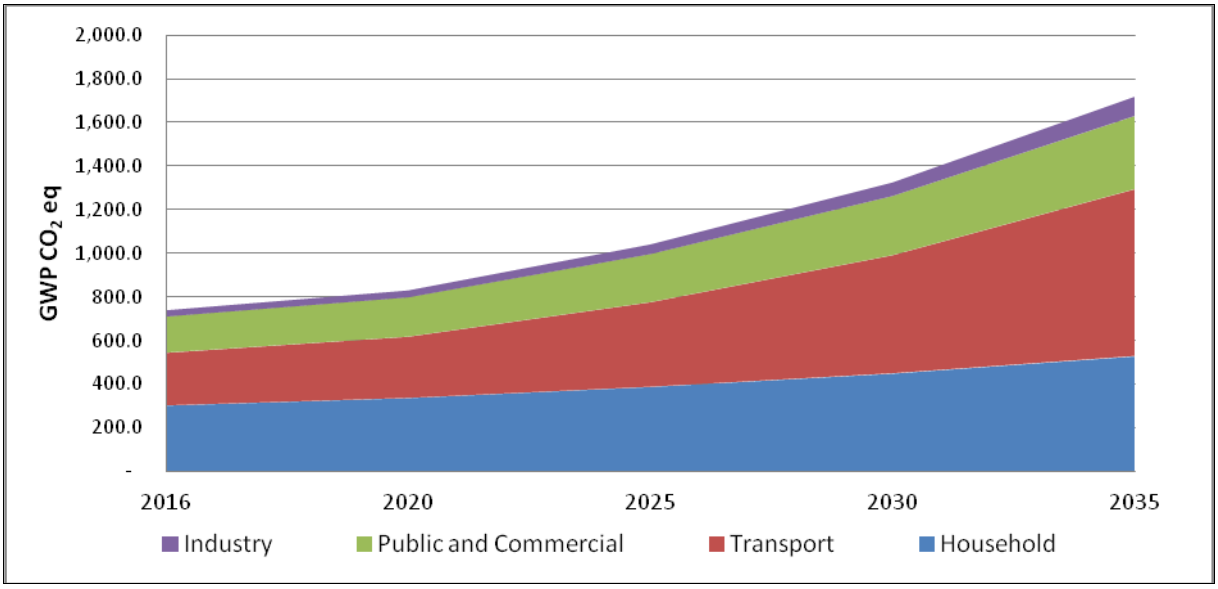


Figure 3.13: Reference Scenario, Global warming Potential in CO2-eq (Gg)

A. Transportation:-Transportation will be the major CO_2 emission contributor in 2035 (Figure 2.13). Share of transport sector GHG emission in GWP CO_2-eq was projected to increase from 32.6% in 2016 to more than 44.5% of which emissions from road transport will account for more than 80% of the sector's emissions. The expected rise in road transport emissions in the reference scenario was attributed to rising motorization and associated traffic congestions. With more than 44% of Eritreans expected to live in urban areas, and steady growth in the economy, the demand for individual car ownership will significantly drive future emissions in the transport category. Similarly, domestic aviation emissions are expected to increase annually considering future growth trends in the aviation industry in Eritrea.

B. Household: In 2016, the household sector, as the main GHGs contributor, accounted for 40.8% in the reference scenario its contribution is expected to be reduced to 30.8%. Within the sector, the 2016 data, the rural households accounted for an average of 60.9% contribution of the total emissions which is mainly from wood, dung and agricultural residue consumption. This is followed by emissions from urban households 35.9% mainly from the use of LPG, kerosene and wood fuel for cooking. The BAU projection shows that the expected emission contribution from household category by 2035 is 529.13 $GgCO_2$ eq. Urbanization and diversification of the energy mix in household sector attribute to fuel shift and efficient end use device. Thus, demand for traditional biomass (dung, agric-residue and wood) will gradually decrease throughout the period. Nonetheless, for charcoal, the household demand will increase with increase in population for instance, it customarily used for preparation of coffee. The demand for LPG, electricity and kerosene is expected to rise as the BAU scenario is based on the assumption that there will be a shift from biomass consumption to those sources of fuel in households (Table 3.3). Therefore, GHGs emission form household sector shows a decreasing trend throughout the scenario years.

Table 3.3: Reference Scenario, Energy demand in Household in kilo tons of oil equivalents

Year	Agric – residue	Charcoal	Dung	Electricity	Kerosene	LPG	Wood	Total
2035	4.346	28.197	34.652	30.981	36.581	35.156	375.61	545.52
2030	5.013	27.807	40.363	26.433	36.396	29.277	405.703	570.99
2025	6.644	27.293	48.165	22.116	36.238	23.777	435.064	599.30
2020	8.146	26.657	56.499	18.212	35.941	19.051	461.935	626.44
2016	8.706	24.291	61.291	13.636	35.807	14.194	444.941	602.8

C. Public and Commercial Services: Based on the BAU scenario analysis, GHGs emission from the services sector are projected to increase from 167 $GgCO_2e$ in 2016 to 335.2 $GgCO_2e$ in 2035; whereas, its share will decrease from 22.6% in 2016 to 20% in 2035 as a result of efficiency improvement and fuel shift.

D. Industries: The BAU scenario analysis of GHGs emission from industrial sector shows increasing trend from 29.09 $GgCO_2$ eq in 2016 to 87.84 $GgCO_2$ eq in 2035. This is attributed to the future demand for energy use in industry (construction, mining and quarry and manufacturing) with an annual average growth rate of 2.35%. Its share in the demand sector also increases from 3.9% in 2016 to 5% in 2035.

3.3.2 Mitigation Scenarios

The mitigation scenario implies a reduction relative to what emissions would otherwise have been in the future in the absence of specific GHG mitigation actions, that is, relative to the reference scenario. This considers a future scenario where the existing renewable energy policies that government is committed to adequately implement; and the emission savings thereof are realized. This scenario is considered as the least ambitious option; and in order to attain greater emission reductions. The key assumptions that form the mitigation scenario are the following.

- Phase - out the existing energy generation plants to enhance their effectiveness and improve their efficiency, improve the grid-connected electrification and distribution.
- Increase in the share of renewable energy sources i.e. energy diversification in all sectors.
- Shift from biomass to electricity and LPG targeting, in both urban and rural households, mainly for cooking and enhanced distribution of efficient smoke less cook stoves and Electric stoves including electric Mogogo.
- Complete replacement of existing lamps with efficient LED lamps, gradual replacement of existing refrigerators with efficient ones
- Use of mass transport and introduction of bus rapid transit and rail ways, as well as non-motorized vehicles.

Based on the above bulleted assumptions, energy demand projection for the model years (Table 3.4), total energy demand will increase by 1.003 times compared with the base year value. Industrial energy demand would be growing by 2.11 times due to potential demand from the mining sector followed by 2 times for transport due to increase in population and 1.5 times grow in service sectors at the end of the model year. However, the model shows a decrease in household sector by 1.3 times due to introduction of new technology and reduction of biomass consumption in households.

Table 3.4: Mitigation Scenario Energy demand in all sectors in kilo-ton of oil equivalent

Year	Household	Transport	Public and Commercial	Industry	Total
2016	602.867	79.3	72.75	12.698	767.615
2020	588.729	89.046	75.71	13.505	766.991
2025	549.296	106.189	84.756	16.703	756.945
2030	508.259	128.883	95.96	20.988	754.089
2035	473.725	159.196	109.874	26.792	769.586

Under the Mitigation Scenario assumption, total energy demand would be reduced by 11.9% compared to the Reference Scenario due to mitigation measures undertaken by the introduction of new environment friendly technologies, fuel shift, and efficient utilization and conservation measures.

3.3.3 GHG Mitigation Analysis

The difference in emissions between the BAU and each individual mitigation scenario provides its abatement potential. The GWP CO_2 eq in Gg trends for the four sectors based on energy demand mitigation scenario is shown in Figure 3.14.

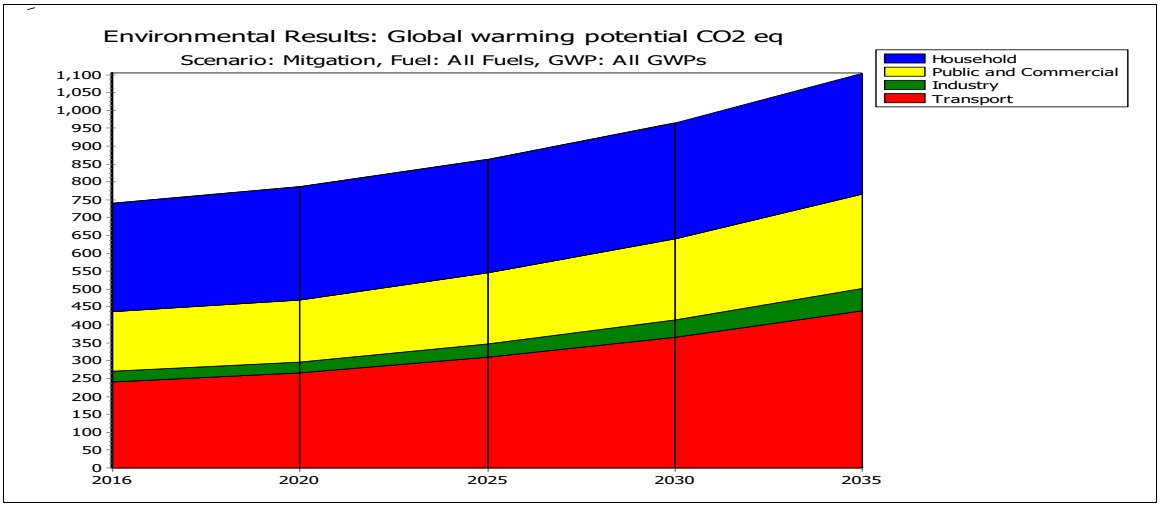


Figure 3.14: Mitigation Scenario, Global warming potential CO2 eq of the different energy subsectors

The Figure 3.14 shows that household sub-sector will remain as the main emitter up to 2025; followed by the transport sub-sector that would outmanoeuvre the household and will be the main emission contributor by 2035 accounting for 440.54 $GgCO_2$ eq. Additionally, while the mitigation scenario of the share of household emission will be reduced from 40.85% to 32.61%; the, transport sector will increase its share in the demand sector from 30.62% to 39.92% GWP CO_2 eq. Based on mitigation measures, the global warming potential in CO_2 equivalent for the GHG Mitigation Potential was 16.8 % less compared to the Reference Scenario as shown in Figure 3.15.

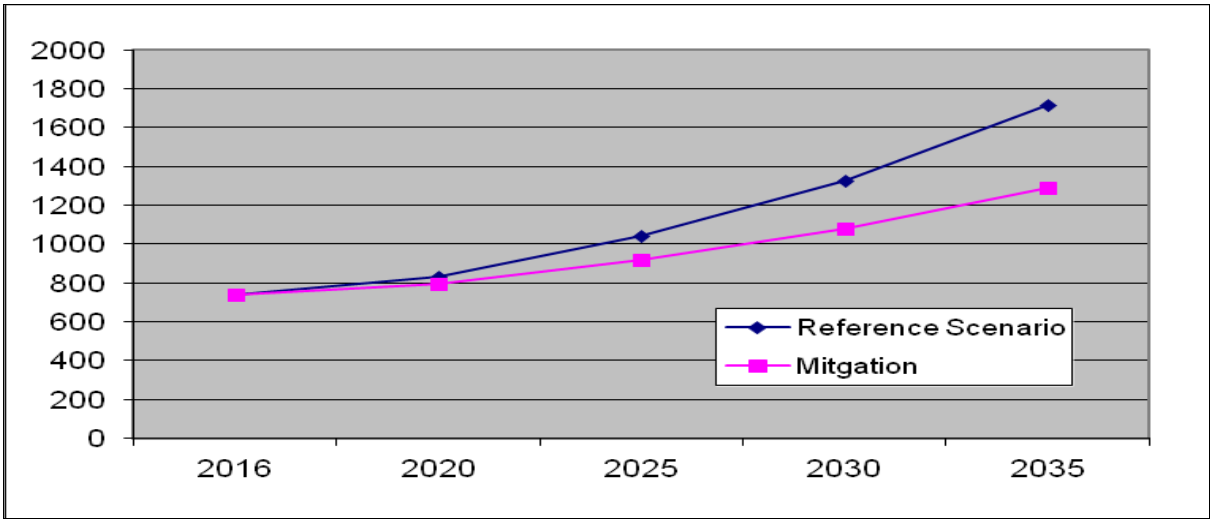


Figure 3.15: Mitigation and Reference Scenario, Global warming potential CO2 eq in millions kgs

By 2035, based on projection model, the CO_2, CH_4 and N_2O emissions will be reduced by 1.4, 1.2 and 1.2 times respectively when mitigation measures are taken (Table 3.5).

Table 3.5: Mitigation and Reference Scenario, GHG emission in thousand Metric tons CO2eq

Scenario	**CO_2 Non Biogenic**	**Methane**	**Nitrous Oxide**
Reference Scenario	1,443.41	220.565	53.053
Mitigation	1,058.53	185.91	44.293

A. Transport Mitigation Assessment and Options

The transport sector consumes more energy than any other productive sector of the Eritrean economy. Liquid petroleum fuels for transport constituted over 50% of Eritrea's total energy demand; which shows that Eritrea uses minimal amount of fossil fuel in electricity production. Hence, the demand of gasoline and diesel are expected to increase cumulatively by 33% in 2035 (Table 3. 6). Road transport will continue to influence the socio-economic development of the country. Within the time frame 2020 - 2035, the mode of transport cannot be changed without impairing the long - term vision of the country irrespective of the type of fuels used. This change is, however, a must, when viewed from an environmental perspective while meeting the requirements of the international agenda with respect to climate change.

Table 3.6: Mitigation Scenario, Transport energy demand kilo ton of oil eq.

	Year				
Scenario	**2016**	**2020**	**2025**	**2030**	**2035**
Reference Scenario	79.30	92.17	127.31	177.88	251.37
Mitigation	79.30	89.05	106.19	128.88	159.20

The urgent mitigation measures to improve the road transport system to meet the latest environmental standards while minimizing the country's heavy reliance on imported liquid fossil fuels using either or combination of the following intervention are the following:

- Improving vehicle fuel use efficiency through improving road infrastructure;
- Shift from light passenger vehicles to buses for passenger transport and railroads or use mass transport; hybrid and electric cars and non-motorized vehicles such as bicycle;
- Introduce mandatory annual vehicle inspection programs that include emission testing in order to identify high-emitting cars, buses and trucks; and

- Additional no cost measures that can easily be implemented include, new legislations to limit speed and new taxation policies on import duties and licenses.

The positive impact of this measure will reduce traffic congestion, improving local air quality, reduction in pollution and improve road safety.

B. Household Mitigation Assessment and Options

Mitigation scenario shows 7.04% (71,790 toe) less energy demand in household sector by 2035 compared to the energy demand in BAU scenario by 2035 Figure 3.16.

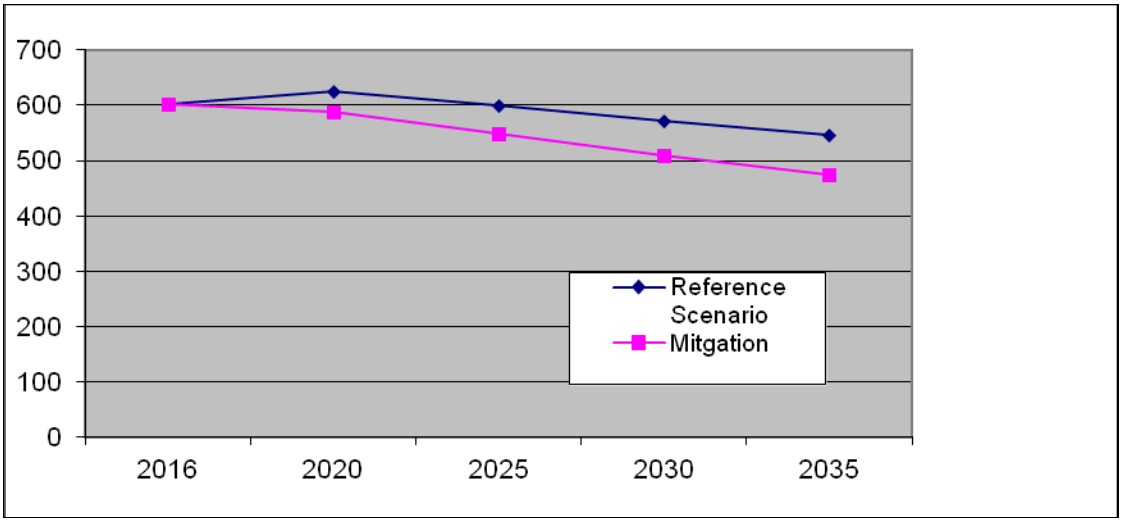


Figure 3.16: Mitigation and Reference Scenario, household energy demand in thousand tones oil eq.

The assessment on household in the entire sub -category shows that the emission from urban will take over the contribution from rural area as population in urban dwellers will surpass the rural by the 2035. The determining factors include introduction of new technologies and shift in consumption of biomass in rural areas. The overall reduction in emission due to mitigation measures taken by 2035 will be 35.5 Gg CO_2 eq. (Figure 3.17).

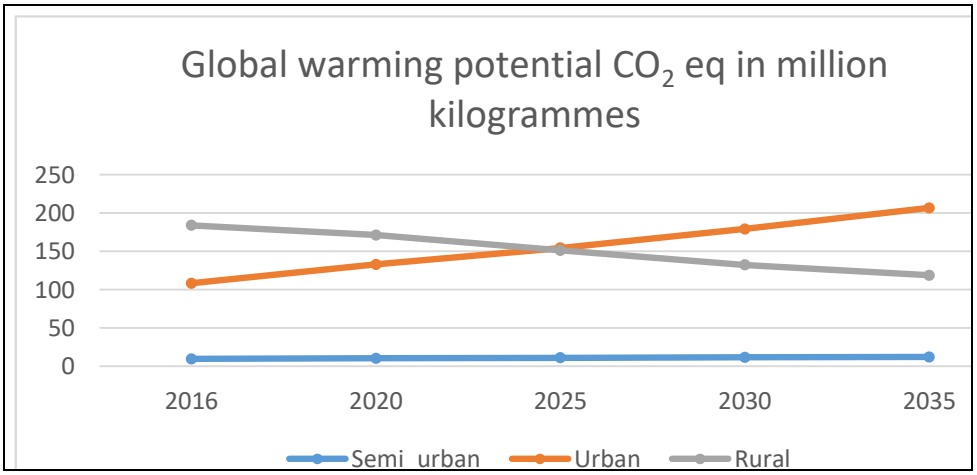


Figure 3.17: Mitigation scenarios, household GWP in million kgCO2 eq.

The vital mitigation measures that can reduce the emission from household are the following.

- Distribution of efficient wood stoves and shift from biomass use to electricity and LPG in residential areas mainly for cooking;

- Introduce new regulations to gradually replace conventional lighting and refrigerators systems by more energy efficient alternatives;
- Reduce cost of LPG cylinders to enable households afford to switch from biomass to LPG stoves, while introducing awareness programs to educate the public of the benefit of using LPG stoves to the environment; and
- Reduce taxation on LPG cooking equipment and other renewable energy sources.

The above measures will have not only positive impacts in reducing indoor air pollution, mainly health benefits for women and children, but also lower fuel wood demand & deforestation and potential cost savings to households (reducing household demand and expenditure on energy).

C. Public and Commercial Services Mitigation Assessment and Options

Energy demand based on the mitigation scenario from the service sector are 75.71, 84.76, 95.96, & 109.87 thousand tonnes of CO_2-eq in the year 2020, 2025, 2030 & 2035 respectively (Figure 3.18). Comparison of mitigation scenario with reference scenario from service sector shows that there will be a reduction in total by 13% in comparison to the BAU scenario.

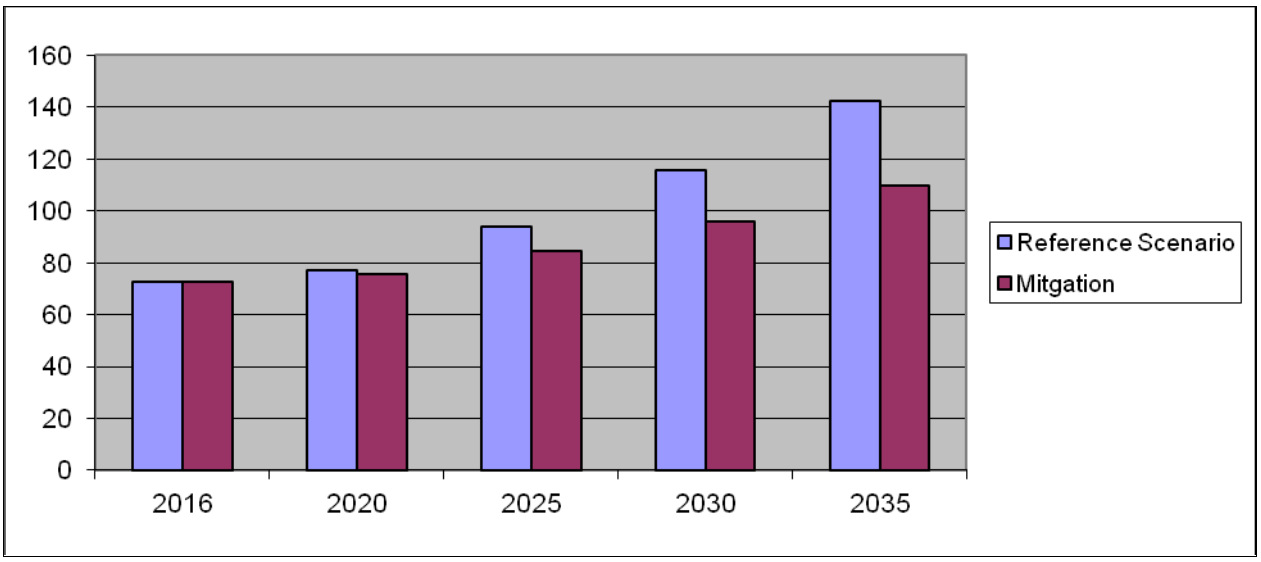


Figure 3.18: Mitigation and Reference, Services Energy demand in 1000 ton of Oil equivalents CO2 eq

The proposed measures focus mainly on the introduction of efficient lighting and other efficient electrical devices, and fuel switching. For lighting and other electrical devices, the mitigation measure involves the gradual introduction of high efficiency equipment such that the average energy intensity improves by 25% of its current value by 2035. For fuel switching, it involves the gradual replacement of diesel, kerosene, and fuel wood by LPG by 2035 in bakeries and restaurants.

D. Industry Mitigation Assessment and Options

The mitigation scenario forecast, mining and cement industries will be the main emitting sectors by 2035. The forecasted emissions based on the energy demand are illustrated in Figure 3.19; which shows a reduction in emission, with mitigation options, of 17.72% in the same year.

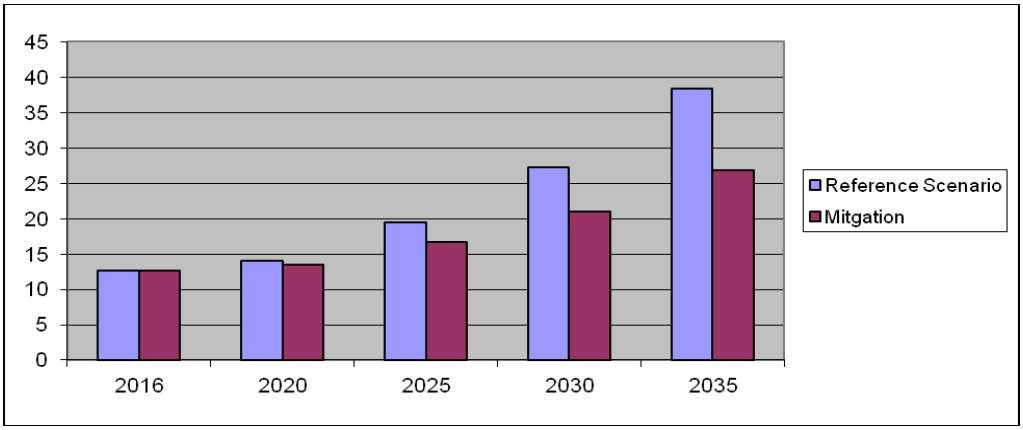


Figure 3.19: Mitigation and Reference, Energy demand in 1000 ton of Oil equivalents CO2 eq

The mitigation scenario projection of GWP CO_2 eq shows a slight increase in emission from 3.93% (29.1 Gg CO_2 eq.) in 2016 to 5.6% (61.4 Gg CO_2 eq.) in 2035. This increase is attributed to the expected increase in demand of the industry sector. Industrial sector mitigation measures focus on clinker replacement, the introduction of efficient lighting and other efficient electrical devices, and fuel switching. For lighting and other electrical devices, it includes the gradual introduction of high efficiency equipment such that average energy intensity improvement by 25% of its current value by 2035 such as in the cement industry. For fuel switching, it involves the complete replacement of charcoal and fuel wood in the lime industry.

E. Electricity supply and Mitigation Options on power generation sub- sector

Power generation and transmission*:* Electricity is produced by a thermal power plants using heavy fuel oil. No power transfers across international boundaries are in place or are projected during the planning period. Current transmission losses are very high, estimated at 20%. A total of 100 MW of new capacity is projected. These measures focus on the complete phased replacement of existing diesel generation by efficient generator, starting in 2025, and a renewable power generation mix in 2035 that consists of 50% solar PV, 20% wind, and 20% Geothermal. The mitigation scenario abatement measures show a decrease importation of primary fuels by 19% in 2035 i.e., when the measures are taken electricity generation from fuels in Gig watt-hour will increase by 70.3% only in 2035 (Table 3.7).

Table 3.7: Transformation; Electricity generation from all fuels in GWh

Year	Mitigation	Reference Scenario	Total
2035	705.523	856.622	1,562.15
2030	627.379	698.763	1,326.14
2025	547.288	552.768	1,100.06
2020	412.125	424.019	836.144
2016	298.64	298.64	597.28

Mitigation analysis on power generation includes the following four options:

- Continue expansion of electrification programs in urban and rural areas.
- Gradually replace existing inefficient diesel- and heavy fuel oil electricity generation with new efficient ones and with renewable energy technologies (solar PVs with large gird, wind turbines, geothermal power and biogas at big farms).
- Reduce distribution losses through rehabilitation of old distribution systems.
- Encourage local and external private investment in the generation of electrical power.

3.4 Non-Energy Sectors Mitigation Options

3.4.1 Forest Management (Afforestation and Reforestation)

Eritrea's land sub-sector is a net sink of CO_2 based on the latest (2015) GHG inventory which accounts for -212.14 Gg of CO_2 and 4.9% contribution to the total emission due to deforestation and agricultural activity. In Eritrea, the land categories include the protected forests, Grass land, Shrub land and sparsely vegetated land, and perennial crops. It should be noted, however, this mitigation has multiple advantages including greater carbon and water storage, reduced soil erosion, increased landscape connectivity and conservation of native biodiversity, provision of food, wood, and shade and income generation for rural communities. Nonetheless, tree planting is not a simple solution to the problem. It must be carefully planned and implemented to achieve desired outcome level of mitigation of GHGs emission. Despite the challenges, the main activities that have a direct impact on Eritrean forests are categorized into the following three major categories.

- Removal of timber (poles) for the construction of houses and fences;
- Removal of fuel wood for charcoal and cooking purpose;
- Minimization of forest degradation through human induced activities (e.g. deforestation, overgrazing) and climate variability (e.g. low, and erratic rainfall), as well as extreme events such as droughts and climate change that lead to loss of vegetation cover.

It is estimated that the younger forest stands and woodlands, that are less than 20 years, are lost quicker than the older, more than 20 years. Annual growth rates of the younger trees are higher and the loss of sink capacity is thus further exacerbated when using the gain loss method for estimating emissions.

Mitigation Options

The BAU scenario emissions include biomass lost on account of deforestation and wood removals for other purposes including charcoal production and fuel wood. The main intervention options and the associated constrains are the following:

The main intervention options	The key barriers and risks associated with implementation of the mitigation options
- Rehabilitate degraded landscapes through reforestation, afforestation, and control run-off and loss of arable land on downstream areas through soil erosion. - Create healthy and well managed forest plantations that withstand the impacts of climate change; - Encourage individual households in communities to plant and own trees and produce sustainable wood, annual crops (fruit and fodder), - Establish new or upgrade existing government and community forest nurseries; - Train communities to integrate tree planting and management in their farming systems through agroforestry systems (crops with trees, trees with livestock, trees, crops and livestock).	• A shortage of skilled human resources, • Conflicting land uses: grazing in competition with tree growing; agriculture versus reforestations etc., • Insufficient coordination between/among different stakeholders with conflicting interests (urban and rural development, agriculture, and other land users/managers), • Financial capacity constraint to support communities (short-term problems versus long-term gains) planting stocks and provision of hand tools, and • Limited enforcement for national and regional action plans and regulatory instruments pertinent to forest conservation and development.

3.5 Solid Waste Management

In the waste sector, management options for solid waste are only considered because it is one of the contributors to the GHG emissions. The rising trend in the emissions is closely linked to population growth, urbanization and changes in lifestyle. With a projected national population of nearly 6.52 million in 2035 and per capita waste generation of 0.5 kg/day, total solid waste is expected to rise by (1.86 thousand tonnes every year). The management of such volumes of waste has major logistical and financial challenges especially to city authorities. Similarly, GHG emissions are likely to be more than triple compared to the 2006 - 2015 average of 125.4 Gg CO_2 eq by 2035. Despite this, however, there are opportunities for avoiding such levels of emissions in the baseline scenario. The challenge is how to convert solid waste threats to opportunity in using as a renewable resource to gain financial gains in recycling and manufacturing durable products.

3.5.1 Mitigation Options for Solid Wastes

Presently, there is no activity of recycling solid waste in general and that of plastic and organic wastes. There exist inadequate incentives for private sector to expand capacity to recycle solid wastes. Hence, the majority of the waste is dumped on unmanaged landfill sites under anaerobic conditions that lead to the production of methane. Other parts are disposed of in low heaps under aerobic conditions, producing mainly carbon dioxide. At the moment, more than half of the scattered waste is openly burnt producing extreme air pollution in settlements.

The GHG Mitigation assessment focused on options for abatement emissions from solid waste including improved recycling of plastics and composting of food waste; eliminate scattering of waste in the landscape; reduce open burning of scattered waste; reduce crude dumping of waste and tap gas from existing landfill including sanitary landfills and production of biogas. The key barriers in the intervention of the solid waste options are:

- inadequate skilled human resources in the operational management of landfills;
- Limited funding arrangements from municipalities and
- Uncertainty about the use of solid waste as raw material for the production of biogas.

3.6 Key Barriers to GHG Mitigation Analysis

3.6.1 Financial Constraints

According to the Eritrea's NDC report of the MoLWE (2018), the implementation of climate resilient economy strategy of the country requires an estimated expenditure of more than USD 3,548 billion by 2030. This suggests that there is a need for key capital investments in the GHG emitting sectors namely energy, IPPU, AFOLU and Waste. Thus, the types of contributions required to implement Eritrea's NDC are categorized into unsupported (unconditional) and supported (conditional) contributions. The details of the specific requirements would have to be determined in collaboration with the key sectors directly involved in mitigation projects. To that end, there is dire need for preparing a detailed programmes and project with clear goals, objectives and activities with budget requirements to execute the mitigation activities in Eritrea.

3.6.2 Capacity Building

To alleviate the constraints related with capacity building are related with training, institutional strengthening, awareness raising (knowledge sharing mechanisms), technology transfer, and management and sharing of experiences across the diverse administrative regions of Eritrea is imperative. The implementation of the capacity, in the time horizon, requires an uninterrupted development and strengthening of Eritrea's capacities in various aspects of GHG mitigation activities. Thus, it is important to establish and strengthen platform for the exchange of information associated with climate mitigation through national, regional and international

networks. Higher Education and Research Institutes, civil societies and professional associations should be involved to expedite implementation process and enhance the sense of belongingness. It is also indispensable to involve the most vulnerable sectors of the society including women headed households and the poor to grantee no one is left behind in the development process.

Geographically, it should also cover the various administrative regions to reduce social and geographical disparity and eventually narrowing the gaps between various social groups. One of the most important requirements for capacity building is the need for a firm internal and external linkage partnership which would not only enable Eritrea to mobilise its internal resources but also expand and strengthen its international cooperation pertinent with the UNFCCC. This linkage partnership would also enable the youth to acquire new skills and knowledge and exchange their experiences with others with same or similar socioeconomic situation. This would enable them to get enlightened about the climatic variability and get acquainted with new tools and approaches that are used to mitigate GHGs.

3.6.3 Lack of Monitoring-Evaluation (M & E) and Reporting Progress

Shortage of quantitative climate change data, and accurate monitoring and evaluation of global environmental benefits is still a bottleneck. Hence, M & E of the mitigation projects should be harmonised. There is a dire need for harmonising dissimilar data and systems collected from various agencies and project management offices. Removing this barrier will allow a holistic perspective of the projects' status and results as well as outputs. In Eritrea, this is possible because, country ownership for any project or program is very strong as demonstrated in the past in explicit effectiveness in enhancing the interest in climate change among various players including rural communities.

In the long run, M & E should involve local communities, researchers and policy makers to triangulate the accuracy consistency of data sets and activities. Various community groups have already shown readiness to make a meaningful contribution in the evaluation of adaption and mitigation technologies. Whatever happens, the Ministry of Land, Water and Environment has the full responsibility to monitor and evaluate through regular stakeholder's consultative engagement. Fine-tuning, and updating the implementation of GHGs mitigation activities.

3.7 Key Opportunities for GHG Mitigation

3.7.1 Community Participation

Local communities' participation is critical to the success of the proposed mitigation projects and programs. The commitment of the local stakeholders is guaranteed as these projects/ideas were generated from the various sectors including energy, agriculture, transport, land water and environment as well as the various municipalities involved in the management of wastes in the six administrative regions of Eritrea. Hence, direct community involvement and participations in the mitigation projects and programs is anticipated through direct including or co-financing in the form of labour inputs in the construction and sustenance as well as management of projects. Local communities are already well acquainted with the risk hazards associated with climate changes; and there are already community demands to solve day in day out societal problems through the introduction of renewable energy sources at various scales.

3.7.2 Integration of Climate Change into Education

Inclusion and mainstreaming climate related topics into the educational system is underway. There is ample opportunity for improving it through extensive and an in-depth curricula review

at the basic, secondary and tertiary education systems. Courses are proposed as standalone courses or part of the syllabus of relevant courses.

There is plenty of space to include climate change topics into the adult education system. The existing topics would expand the awareness of adults regarding the risks related with climate change. This step will enhance school children awareness about the issue at hand. The expansion of environmental education through adult education will have direct bearing while implementing mitigation projects at the local levels.

3.7.3 Contribution of the Mass Media

The radio, press, television broadcasting are already broadcasting climate change documentary films and case studies with tremendous impacts on the public awareness. There are ample opportunities to further expand its scope and in-depth converge of the risks and opportunities for mitigation of GHGs. Expanding the intranet and internet facilities would also enable individuals and communities to tap the wealth of data and information out there on the local, regional and global webs.

3.8 Institutional Capacity-Building

To sustain GHG mitigation works, it is important to strength the National institutions to enable them design and implement projects that are consistent with Eritrea's objectives and operational strategies of UNFCCC focal area. For instance, unnecessary duplication between focal areas namely the UNCBD and UNCCD should be avoided to optimise resources uses and focus on the main issues.

The MoLWE (2018) has already prepared the Eritrean NDC based on sustainable development strategies, plans and objectives aligned with national development plans of the country. Nevertheless, the document should be periodically updated in order to integrate new ideas into the outlined mitigation actions. This is because of the fact that the NDC was developed based on series of consultative process held with the various stakeholders involved in the mitigation activities where the key sectors provided inputs based on their strategic plans and activities contextualised in the short, medium and long-term perspectives. Hence, it is important to capitalise on the confidence built during preparation process.

Against the above mentioned background, it can be confidently stated that there is an institutional set up to enable stakeholder to fully engage themselves and secure their full commitment of the government (e.g. local, regional and national) levels. This lays a firm foundation for further implementation of GHGs mitigation in the country. From now, the implementation of GHGs mitigation activities are well aligned with existing government plans, strategies, policies, legal frameworks. To enhance the implementation of climate related national documents such as the fourth communication (FNC) and Appropriate Mitigation Actions (NAMAs).

3.9 Key Findings

3.9.1 Energy Sub Sector

In 2020, the energy sector will be responsible for large GHG emissions following the AFOLU sector in Eritrea. The energy sector consists of the supply and demands including energy transformation mostly electricity generation and charcoal production, electricity transmission and distribution, fuel storage and distribution and all end-use consumer sub-sectors including transport, industry, mining, commercial, domestic, agricultural/fishery/agriculture sub sectors.

GHGs mitigation options in the energy supply sub-sector should focus on increasing plant efficiency, reducing losses in the transmission and distribution of electricity and fuels. There is also a dire need for increasing the use of renewable energy sources including solar, wind, and geothermal energy sources.

3.9.2 Road Transport

Road transport sub -sector is the highest CO_2 emitter (197 Gg) of all energy demands sub-sectors in (2020). Emission from the road transport is the result of many factors such as the type of fuel used, fuel efficiency, type of mode of transportation used, quality of road infrastructure and efficacy of the type of transport.

In view of the aforementioned fact, the mitigation measures in the transport sub-sector should focus on fuel efficiency improvements. This entails changes in vehicle and engine design (e.g. hybrids). It is also important to expand public transport infrastructure and enforce the regulation on age restriction on the importation of vehicles and encourage the importation of unused vehicles. Further, it would be necessary to raise public awareness about its environmental and public health aspects of using such means of transportation. The need for introducing public transport technologies such as big buses and trains is imperative.

3.9.3 Household

At the household level, biomass is the main sources of domestic source of energy including firewood, charcoal, animal dung and agricultural residue. Biomass provided up to 73.8% of the total energy household demand. Biomass is still used in both urban and rural areas with different proportions. Biomass is used for cooking in traditional stoves for which its energy efficiency is very low (does not exceed 10 %). Further, charcoal is produced in traditional earth kilns using local wood resources having conversion efficiency not exceeding 30 %.

At the national level, 37.2 % of the households in Eritrea have electricity which has increased slightly from EDHS 2002 (32 %) but has substantially increased since EDHS 1995 (23 %). On the other hand, there is a marked increase of households with electricity in rural areas (13 %) which was only three % in 2002. Regarding urban areas, 81 % of households have electricity in 2020 compared to 78 % in 2012. Mitigation options in the household sub-sector include electrification of households, replacement of inefficient incandescent lamps with compact fluorescent lamps (CFLs), lighting emitting diode lamps (LED), upgrading the efficiency of traditional biomass stove, increase supply of modern fuels to allow fuel substitution which have synergistic effects on reducing the pressure on forest resources and hence and reducing CO_2 emissions from AFOLU.

3.9.4 Market-Based Instruments and Regulatory Measures

Market-based instruments to mitigate GHG emissions should focus on social economic and environmental regulatory policies and legal frameworks. Special attention need to be paid in the i) fuel carbon content related taxes and ii) cap-and-trade systems and subsidies for renewable energy. Regulatory measures consist of specifying the use of low carbon fuels, performance and emissions standards. Hybrid measures such as tradable emissions permit and renewable portfolio standards need to be instituted.

3.9.5 Dissemination of Mitigation Technologies

The need for Government funded research, development and demonstration activities emerged as a necessary tool to develop home based technologies and enhances innovation in the sector. In this regard for establishing low-carbon energy system and mitigation costs became

necessary. In conclusion, in this report, assessments of mitigation costs or the reduction potential of the identified measures in term of CO_2 are not quite comprehensive. In this connection, given that this is a very important part of the mitigation analysis, the GHG reductions and costs across all sectors should be done. The AFOLU being the main source of GHG emissions, there is a need for a much more detailed assessment of technology options for the different mitigation options *vis a vis* the land use changes. With time it is increasingly necessary to investigate the various sectors of the economy for reporting in subsequent GHG mitigation assessment and analysis study submissions.

CHAPTER FOUR

4 VULNERABILITY, IMPACTS, AND ADAPTATION ASSESSMENT

4.1 Introduction

As stipulated by the IPCC, climate-change induced hazards are caused mainly by anthropogenic factors occurring at local and global levels. In dry lands, drought is natural hazard that affects the social and economic conditions of a country. Drought could be Hydrological, Meteorological or Agricultural. *In* the Hydrological drought, the important variable is availability of water in rivers, lakes, reservoirs and underground water storage. While meteorological drought refers to the amount of rainfall and its pattern, agricultural drought discusses the soil moisture content to sustain crop growth. Various assessments show that agriculture is the most vulnerable sector as it affects the livelihoods of rural communities; and subsistence farmers and pastoralists are the most vulnerable groups. Vulnerability refers to the degree in which a system is susceptible to and unable to cope with adverse effects of climate change i.e. variability and extremes weather condions.

According to Lingaraj et al. (2014), vulnerability is a function of the character, magnitude, and rate of climate changes and variations to which a system is exposed. Eritrea is vulnerable to climate change because of its least adaptive capacity and geographical location. Increased climatic variability, recurrent droughts, flash flooding and sea level rise are the major threats; and the effects of climate change are evident everywhere. The frequency of prevalence of droughts and dry spells increased and consequently increased runoff and flooding. Though most of the arid and semi-arid parts of the country are affected by drought conditions; the Red Sea coastal areas and the islands of Eritrea are prone to various hazards including sea level rise (MoA and FAO, 2016). Vulnerability of communities across the country varies depending on the social, economic, and institutional conditions of the regions. In view of the above briefed background, this chapter aims to identify the vulnerabilities, impacts and adaptions to climate change. By focusing on selected sectors in Eritrea; it identifies potential options and measures to facilitate adequate adaptation to climate change in the country.

4.2 Methods and Approaches

Various complementary approaches have been used. The policy-based approach has been used to investigate the adaptation strategies, while the adaptive capacity approach was applied to assess actions on increasing capacity and removing barriers to adaptation. The regional climate model used by ASARECA has been thoroughly reviewed for agriculture in which the changes in average precipitation between 2000 and 2050 for the four Global Circulation Models (GCMs) are featured in climate change projection using the A1B scenario. Moreover, the emissions simulation results of the IAMs were made available to the GCM models as inputs that alter atmospheric chemistry.

Open-ended and close-ended questionnaire were prepared; and filled at national and regional levels. Secondary data were reviewed; and discussions were held with key informants and experts involved in climate change adaptation activities. Qualitative and quantitative methods were employed to identify linkages and the directions of climate impacts.

In the V&A assessment, a combination of top-down and bottom up approaches were used. While the readily quantifiable top-down assessments focused on the biophysical effects of climate change, the bottom-up approach assessment was based on the causes of people's

vulnerability to a specific hazard. In situations where simulation models cannot be applied, future projection scenarios from credible regional organizations were included in all sectors (ASARECA) and international organizations (e.g. IPCC, WHO). Finally, adaptation assessment and their options have been compiled using the existing potential adaptation options, based on the existing adaptation projects, and their effectiveness in addressing climate risk and variability. Expert judgment by the V & A Technical Expert Working Groups was used to prioritize adaptation options. In summary, the methodology used to analyse the impact and vulnerability to climate change involves the following major steps.

- current and historic climate trends in rainfall and temperature for the years 1961 to 2018 was generated;
- Assess the extent of the existing vulnerability to climate variability was assessed;
- projections on future climate status using climate model outputs and a range was of scenarios for future rainfall, temperature and other climate variables was made; and
- future impacts of climate change and review appropriate adaptation measures and options were evaluated.

4.3 Climate and Climatic variability: Trends and Projection

4.3.1 Rainfall

About 65% of the Eritrea land surface receives average annual rainfall of less than 350 mm. The eastern lowlands have an average annual rainfall between 50 and 200 mm; which fall within the eastern limit of the Sahelian Africa. The south-western parts experience average annual precipitation of 600 mm; and the central highlands get about 400-500 mm. The eastern escarpment receives a bimodal rainfall of up to 800 -1000mm per annum. The main features of rainfall pattern are extreme variability within and between years, and the spatial variations over a short distance. High rainfall intensity combined with sparse vegetation cover results in excessive runoff, high evaporation rate and reduced recharge of underground aquifers. The current scenario of rainfall accumulated over several years are described in the following paragraphs.

Central highland There was modest decrease in mean annual precipitation by 96.5mm (17%) from 1900 to 2018. Rainfall decreased by 30 % from 1920 to 1967. On the other hand, the rate of decrease of mean annual precipitation decreased during the last 50 years as indicated for Asmara shown in Figure 4.1. It can be concluded that mean annual precipitation in Central highlands has decreased in the range of 20 to 50% at different locations. The rate of decrease of the mean annual precipitation is much higher in the last 20-30 years compared to early years of the century. The variability of rainfall between years and locations is very high

Northern region A significant decrease of mean annual precipitation was observed between 1905 and 1968 and between 1992 and 2009. The trend reveals that the mean annual precipitation has improved in the late segment i.e. 20 years of the record period.

Western region The mean annual precipitation has decreased significantly by 60% (220mm) between 1992 and 2018.

Coastal areas Mean annual precipitation along the country's southern coastline, has decreased significantly by about 47% (27mm) between 1931 and 2017. However, an opposite trend is observed in the central part of the coastal area where the mean annual precipitation has increased by 30mm between 1940 and 1977 and by40mm between 1980 and 2010. Over all, the rate of increase of mean annual precipitation in the coastal areas was much higher in the last 30 years compared with early periods of the century as shown in Figure 4.2).

Long Term Rainfall Trend

Overall, the long term precipitation showed that the rainfall is decreasing in the past 28 years from 1990 to 2018; whereas in other locations an increasing trend is observed in some seasons of the year. The rate of decrease of rainfall in the South Eastern Coastal areas of Eritrea is relatively much smaller compared to the inland rainfall.

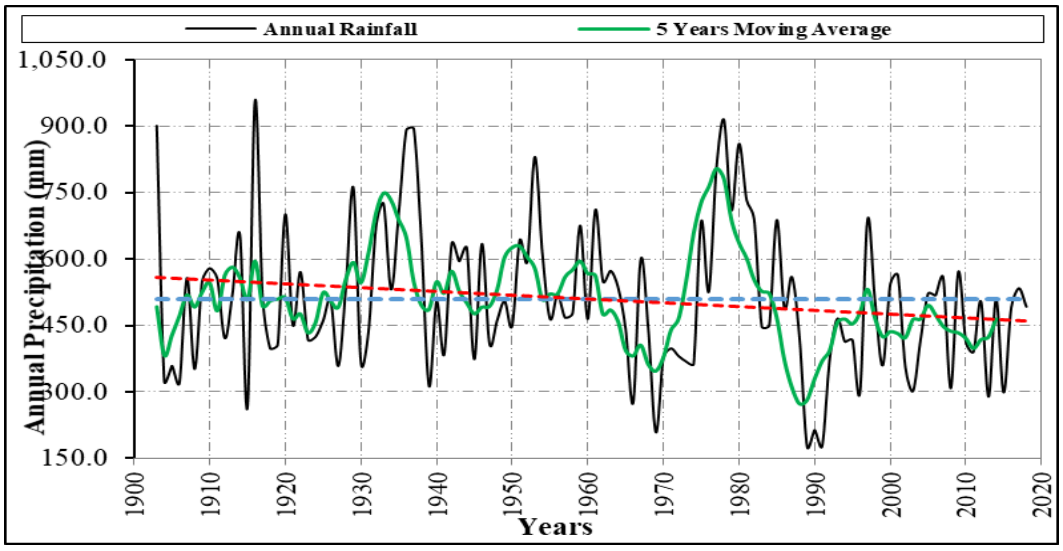


Figure 4.1: Asmara station long -term annual precipitation (1903-2018)

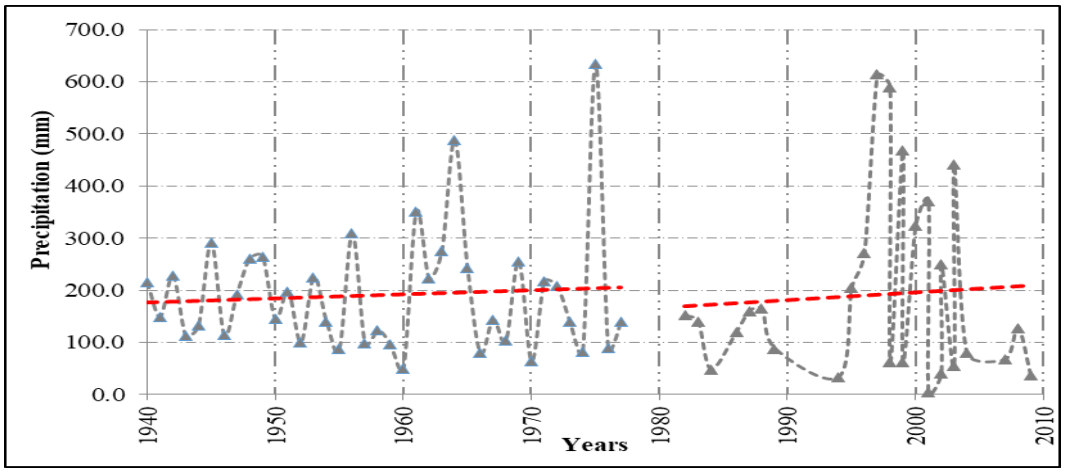


Figure 4.2: Massawa station long term annual precipitations (1940 - 1977 and 1980-2010)

4.3.2 Temperature

The climate of Eritrea ranges from temperate sub -humid in the Eastern escarpment (sub-humid) to hot arid adjacent to the Red Sea (semi-desert). The central highlands has temperate-like climate with lowest temperature occurring during December and January. The Western lowlands are relatively hot especially between April and June with temperatures reaching up to 38^0 C. The coastal areas have the highest temperature of 25-40^0C between June and August.

The temperature peak during drought periods is very high which aggravated the drought situation. In the 1984 drought period, the average air temperature (17.0^0 C) was the hottest year globally (Tollefson, 2016). The monthly minimum daily maximum air temperatures and annual mean daily minimum air temperatures showed a statistically significant increasing pattern. Overall, the extreme warm periods are increasing while cold extreme periods showed a

decreasing trend. Thus, these trends indicated a marked warming pattern over the last 100 years in the central highland of Eritrea (Figure 4.3). Frequency of cold days increased since 1960, despite the significant increases in mean temperature. The frequency of cold nights has, however, decreased significantly for the months of June, July and August, and October, November and December. This rate of decrease is most rapid in September, October and November where the average number of cold nights has decreased by 4.9 nights per month. (McSweeney and Lizcano, 2010).

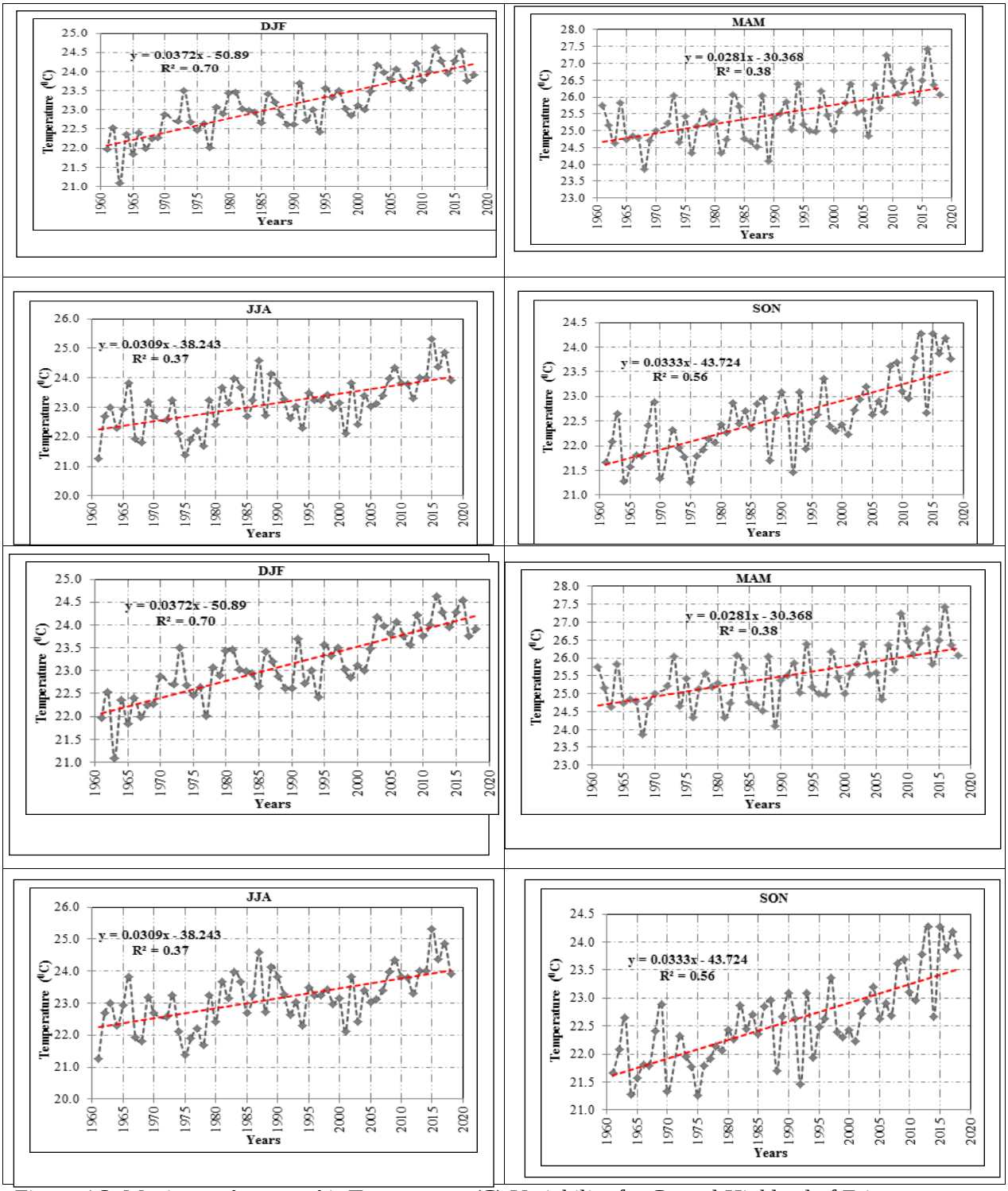


Figure 4.3: Maximum Average Air Temperature (C) Variability for Central Highland of Eritrea

4.4 Projected Future Climate

4.4.1 Rainfall

The model used by ASARECA-IFPRI for Eritrea, for the years 2000-2050 under the four downscaled climate models showed that rainfall will increase by 50 to100mm in the Central, Southern zones and in parts of the Northern Red Sea zone. The model CSIRO Mark 3 showed minimum change in precipitation throughout the country, while the ECHAM 5 Model showed a small increase in precipitation of 50-100 mm in South-western part of the country and parts of the Southern Red Sea zone. Model MIROC 3.2 showed areas of the Red Sea zone gaining 100-200 millimetres in precipitation (Waithaka, *et al.* 2012).

There is no consensus among different models as to the direction of change in the mean annual rainfall. The projected changes range from -13 to +19 mm per month by the year 2090s. The models indicate that there will be an increase of rainfall during the months of October, November and December and a decrease during the months of January February, March, April, and May. The increase in the rainfall for October-December is projected to be the greatest in the South-eastern parts of Eritrea, whilst the decreases of rainfall during the months of January-March and April-June will be greatest in the North-west part of Eritrea. On the other hand, the precipitation showed a decreasing trend of 10 to 20% for the rest of the country (IPCC, 2014). Similarly, precipitation for the period 2046-2065 showed an increasing trend of 0-10% for the South east of the coastal areas and the South western part of the country.

According to IPCC (2014) the projected rainfall for the years 2016-2035, during the months of April-September, showed an increasing trend of 0 to10% for south east coast, South and South west, north and central parts of the country, while a decreasing trend will be observed for the northern part of the country. The projected rainfall for the years 2046-2065 for the same months showed a tendency of 10% decrease in the far North of the coastal areas and an increasing tendency of 10% for the rest of the country. Precipitation has decreased and varied greatly over time and location for the last 30-60 years; and the variability is expected to continue in the near and mid of the century.

4.4.2 Temperature

Most of the General Circulation Models predict increases in the mean annual temperatures, frequency of droughts, and heat waves in Eritrea. However, predictions from these models have not been yet refined to be used as support tool for decision making process due to the coarseness nature of the models. The day to day pattern of temperature change is maintained, but the average monthly temperature becomes higher than 3.6 ^{0}C. Hence, the mean annual temperature is expected to rise. The coastal plains will experience an increase in monthly temperature from 29 to 37^{0}C. The Western lowlands will also experience an increase in temperature with monthly mean between 28 and 37^{0}C. The temperature rise due GHG concentration is expected to be 4.1^{0}C (MoLWE, 2001).

IPCC (2014), in its regional climate change projections , mentioned that there will be increase in surface temperature of 0.5-1.0°C in North, East, Central and South east coast, and an increase of 1.5-2.0°C in the West and South Western part of Eritrea for the period of 2016-2035. The increase in surface temperatures for 2045-2065 will be in the range of 2.0-3.0°C for the whole Eritrea. Regardless of the magnitude of climate change, it can be concluded the surface temperature has increased over the last 50-100 years and this warming trend is very likely to continue towards the mid of the century.

Box 1. Projected Pattern of Climate

The degree of uncertainty in future projections of rainfall patterns is very high in Eritrea. The probability that there will be repeated drought in the country is very high. The variability of rainfall is expected to continue for the future. Similarly, the level of increase is uncertain with variability in projections showing that the mean annual temperature will increase by 1.0 to 1.5^0C by the year 2050 and 1.6 to 5.4^0C by 2090.

4.5 Vulnerability and Impact Assessment

As noted, Eritrea's geographical location in the arid and semiarid region of *Sahelian* Africa makes it vulnerable to the adverse effects of climate change which affect the food security. Food insecurity leads to malnutrition and increased probability of child mortality and reduced life expectancy. The majority of the Eritrean farmers in the highlands practices rain-fed mixed agriculture. The contribution from such traditional farming in meeting the food requirement of the households is limited. Under such condition, only 60 to 70% of annual household food requirements are covered. Hence, agriculture is under pressure to satisfy food demand of the growing population. Hence, assessment of risks posed by climate change and the measures to adapt the impacts of these risks is important to identify the most vulnerable areas, sectors and social groups. In turn, this helps to develop climate change adaptation options targeted at specified contexts for implementation (Lingaraj, et al., 2014). Experiences with various frameworks suggest that vulnerability is a complex subject that has many dimensions, which may often have overlapping effects that make it difficult to pinpoint the precise cause-effect relationship.

4.6 Indicators for the Components of Vulnerability

Vulnerability to climate change is determined by the exposure that results from climate change, sensitivity to the impacts and adaptive capacity (IPCC, 2007). Vulnerability is a theoretical concept which cannot be directly measured or observed. It is based on the systematic process of assigning a number to a phenomenon based on expert judgment. Hence, it is more accurate to speak of making the concept vulnerability operational than measuring vulnerability.

Livelihoods with limited assets are vulnerable to climate-related hazards as they have limited or no capacity to manage the risks. That is why vulnerability is high in marginal areas where the exposure of climatic hazards is severe due to climate change. Thus, vulnerability could be segmented into three components: exposure, sensitivity and adaptive capacity. Table 4.1 shows the indicators for components of vulnerability. Reducing the extent of vulnerability requires i) reduce the exposure to hazards, ii) reduce sensitivity to the effects of hazards and iii) build the capacity for adaptation action (Nelson *et al.*, (2007).

Table 4.1: Indicators used for the Components of Vulnerability

Component	**Indicators**
Exposure	Annual and monthly average rainfall, trend in temperature or annual and monthly average maximum and minimum temperature, trend in temperature from July to September, flood hazards frequency and distribution
Sensitivity	Household assets, building materials for housing; malnutrition and infant mortality rate, malaria incidence, soil organic carbon (crops and livestock)
Adaptive capacity	Irrigation facilities and areas, access to basic health facility, access to safe water, biomass, awareness, breeds of crops, breeds of livestock, soil and water conservation, agroforestry etc.

4.7 Factors Affecting Vulnerability to Climate Change

The main environmental problems in Eritrea which make people vulnerable are soil erosion, deforestation, recurrent drought, desertification, land degradation and loss of biodiversity. Vulnerability to climate change is closely associated with excessive dependence on rain-fed agriculture. Other factors are undeveloped health service coverage, low economic status of the community, poor adaptive capacity, inadequate road infrastructure and lack of awareness. It is considered that marginal or semi-arid areas respond more to increased temperature compared to desert ecosystem subjected to similar change. Thus, the Northern Red Sea and Southern Red Sea parts of Eritrea are much more vulnerable compared to the Central, Southern or Gash Barka regions of Eritrea. The variation related to the causes of hazard/disasters across regions of Eritrea is shown in Table 4.2.

Table 4.2: Factors Affecting Vulnerability to Climate Change in Regions of Eritrea

Region	**Disaster**
Central	Loss of fertile soil due to erosion, higher waste disposal, crop diseases and insects and land degradation, deforestation and loses of biodiversity.
Southern	Loss of fertile soil due to erosion, land degradation, waste disposal, desertification, crop and livestock diseases and insects and drought, deforestation and loses of biodiversity.
Anseba	Loss of fertile soil due to erosion, cause pre-harvest losses in various crops, *tsese fly* in certain villages, livestock movement, dust storms, torrential rains, high temperature, flooding and land degradation, deforestation and loses of biodiversity.
Gash Barka	Human health (malaria), loss of fertile soil due erosion, crop diseases and insects, dust storms, torrential storms, flooding, high temperature, land degradation, deforestation and loses of biodiversity.
Northern Red Sea	flooding, loss of fertile soil, dust storms, high temperature, livestock and human movement to higher elevation, land degradation, desertification, crop insects (locust, army warm), drought.
Southern Red Sea	Human health (Diarrhoea), loss of fertile soil, dust storms, high temperature, seismic activities, land degradation and desertification.

The crop vulnerability exposure to risk hazards is shown in Table 4.3

Table 4.3: Crop Vulnerability Exposure and the Risks according to Experts in the Zobas

Crop	**Risks**	**Sensitivity**
Sorghum	Parasitic weed Striga, loss of soil fertility and soil erosion, *quelea quelea* birds, insects (ants, termites, desert locust, and army warm).	High
Pearl millet	Degradation of land, diseases (downy mildew), insects (termites, ants, desert locus).	Low
Barley	Diseases (rust), loss of soil fertility and soil erosion	Low
Wheat	Rust diseases, erratic rainfall, loss of soil fertility and soil erosion.	High
Maize	Drying during the rainy season and erratic rainfall, stalk borer.	Very High
Banana	Post-harvest losses.	Very High
Potato	Post-harvest losses, blight, shortage of water.	High
Beans/chickpea	Excessive rainfall, water logging, viral and bacterial diseases, pod borer.	High

Sometimes, diseases cause up to 90% losses in horticultural crops, which is equivalent to an estimated financial loss of 497,408,000 USD (Table 4.4). Besides, locust invasion especially in the Northern Red Sea zone prevails every year causing damage to crops and vegetation. However, the size and characterises of the swarm, and the magnitude of losses it inflicted are not properly assessed. Further, hazard from flood is so severe that it not only forms big gulley, but destroys crop fields, livestock and settlements. Incidence of disaster from such natural hazards is enormous especially in parts of Northern Red Sea (MoLHW, 2018a and Southern Red Sea MLHW, 2018b and Gash Barka.

Table 4.4: Vulnerability to Natural Disasters in Zobas during the period 2006 to 2018

Disaster/	**Type of Hazard**	**# of events**	**Estimated # of households affected**	**Estimated damage in US $ ('000)**
Droughts	Rainfall variability	6	1,200,000	495,108
Seismic activity	Earthquake, ground shaking	3	700	1000
Epidemic diseases	Bacterial, parasitic & viral infectious	-	13000-30000	-
Flooding	flooding, flash flooding	5	200-500	700
Wind storm	Violent winds with torrential rainfall		300-500	100
Insect infestation	Locust/crop pests	10-12	-	500
Total				**497,408**

In many parts of the Eritrea, the main causes for crop failure are drought followed by diseases and pests. The results of the survey show that, 72 to 97% of the respondents mentioned drought as a major threat to crop production. Land degradation, poor soil fertility and crop management practices lead to low yield in crop production (Table 4.5).

Table 4.5: Crop Deficits in the Traditional Farming System

	Reasons	**Range (%)**	**Mean (%)**	**Region with highest (%)**
1	Shortage of tools and equipment	11.5.-22.0	19.2	Debub
2	Drought (crops, livestock, natural resources)	72.3-97.8	85.5	All regions
3	Poor seed quality	5.2-34.6	16.2	Maekel
4	Poor soil fertility/Land degradation	4.5-33.3	21.6	Anseba
5	Diseases and pests	6.4-69.8	33.2	North Red Sea
6	Poor crop management practices	14.9-36.0	28.5	North Red Sea

Source: MoA (2017)

Ranking vulnerability across sectors

All sectors are potentially impacted by climate change. Nonetheless, agriculture (crop and livestock production) and water resources are the most affected by the spatial and temporal variability of climate change. Ranking the magnitude of risk shows that while agriculture and water resources are most vulnerable, marine resources and biodiversity are vulnerable with varying degree of severity from high to medium. Comparatively, forests are less risky when compared to the other sectors (Table 4.6).

Table 4.6: Ranking of Vulnerability across Sectors according to Experts in Eritrea

Resource/ ranking	Severity	Importance of Resource
Water Resources	5	5
Agriculture	5	5
Marine, Coastal & Island	3-5	5
Forests	1-5	5
Human Health	3-5	5
Biodiversity	3-5	3-5

Note: High=5, Medium to high= 5-3; Medium to low= 3-1

4.8 Vulnerability and Impacts on Sectors

The projected climate change impacts: increased temperatures and drought conditions will have a detrimental effects on food security and economic development. The current low agricultural productivity will be exacerbate the situation leading to reduced household incomes, increased malnutrition, and associated health impacts. Hence, the number of people at risk from drought events will increase. The most vulnerable groups to climate variability are those who depend mainly on the natural resources including subsistence farmers, rural dwellers, pastoralists, urban poor and fishermen. Adverse impacts of climate change in Eritrea are the following:

- Food insecurity arising from recurrent drought, crop pests and livestock diseases;
- Outbreak of diseases (malaria, dengue fever, etc.)and climate-induced diseases
- Land degradation due to deforestation and high intensity of rainfall; and
- Loss of livestock and
- Loss of biodiversity: agro biodiversity and terrestrial diversity.

4.8.1 Crop and Livestock production

Crop Production: The major crops are cereals, pulses, oil seeds (groundnuts, sesame etc.), vegetables and fruits; crop production is based on subsistence level farming under rain-fed conditions which is dominated by traditional farming techniques Table 4.7 presents comparisons of major crops and vegetables in terms of area, production and productivity.

Among the cereals in Eritrea, sorghum is by far most important, which accounts for 49% of the total cultivated area, and 46.4% of the total production. Sorghum has the greatest genetic diversity; and grows in most parts of the country. This crop is adapted to moisture stress and temperature ranges. Pearl millet which is the second most important crop in the country grows in the lowlands with total cropped area of 13.1% and production of 7.3%. Barley stands third in total area, but second in total production next to sorghum.

Land under sorghum is expected to be reduced in size in some parts of Eritrea as the result of mono-cropping leading to parasitic weed infestation. Striga infestation is compelling farmers to shift to pearl millet which is resistant to Striga. The major pulses grown are chickpeas, Faba beans, field peas, lentils, and grass pea out of which chickpea and grass pea are drought tolerant crops. Among the oil crops, sesame stands first in terms of production and total production followed by groundnuts.

Table 4.7: Production and Yield (t/ha) Cereals, Pulses & Oil Seeds averaged (1992 -2018

Cereals	**Total Area (ha)**	**%**	**Total Production (t)**	**%**	**Value (Nakfa) (000)**	**Yield (t/Ha)**
Sorghum	206,767	49.0	112,854	46.4	2,031,372.0	0.55
Pearl Millet	55,103	13.1	17,806	7.3	267,090.0	0.32
Maize	20,934	5.0	15,296	6.3	275.328.0	0.73
Finger Millet	22,649	5.4	12,330	5.1	221,940.0	0.54
Barley	40,879	9.7	30,757	12.6	768,925.0	0.75
Wheat	26,505	6.3	15,253	6.3	274.554.0	0.58
Taff	3,011	0.7	16,904	6.9	676,160.0	0.56
Hanfetse	6,735	1.6	5,539	2,3	99,720.0	0.82
Sub - Total	**382,583**	**90.7**	**226739**	**93.2**	**2,033,835.0**	**0.54**
Pulses						
Faba Bean	3,910	0.9	1,923	0.8	45,152.0	0.49
Field Pea	3,949	0.9	1,244	0.5	29,856.0	0.32
Chickpea	7,784	1.8	4,380	1.8	166,440.0	0.56
Lentil	734	0.2	259	0.1	6,475.0	0.35
Grass Pea	3,654	0.9	2,024	0.8	36,432.0	0.55
Haricot Bean	188	0.0	17	0.00	306.0	0.09
Sub Total	**20,219**	**4.8**	**9,847**	**4.0**	**284,661.0**	**0.39**
Oil Crops						
Linseed	1,447	0.3	410	0.2	7,380.0	0.09
Sesame	15,381	3.6	4,633	1.9	185,320.0	0.30
Groundnuts	2,189	0.5	1,778	0.7	35,560.0	0.81
Sub - Total	**19,017**	**4.5**	**6,821**	**2.8**	**228,260.00**	**0.40**
Grand Total	**421,819**	**100**	**243,407**	**100**		

Source: MoA (archives)

Rainfall and Production: Figures (4.4) and Figure (4.5) represent the relationships between rainfall, production and productivity for selected cereals. Total production was higher for the years 2007 and 2014, while a fluctuating trend was observed in the central highlands across the years with the lowest productions being in 2008, 2013, 2015 and 2017 due to low rainfall. The productivity of the three crops shows decreasing trend due to moisture stress. The result of household surveys showed fluctuations in crop production and yield from year to year due to drought. The yield loss is estimated to be highest in oil crops (93.8%) followed by pulses (92.8 %) and cereals (77.3 %).

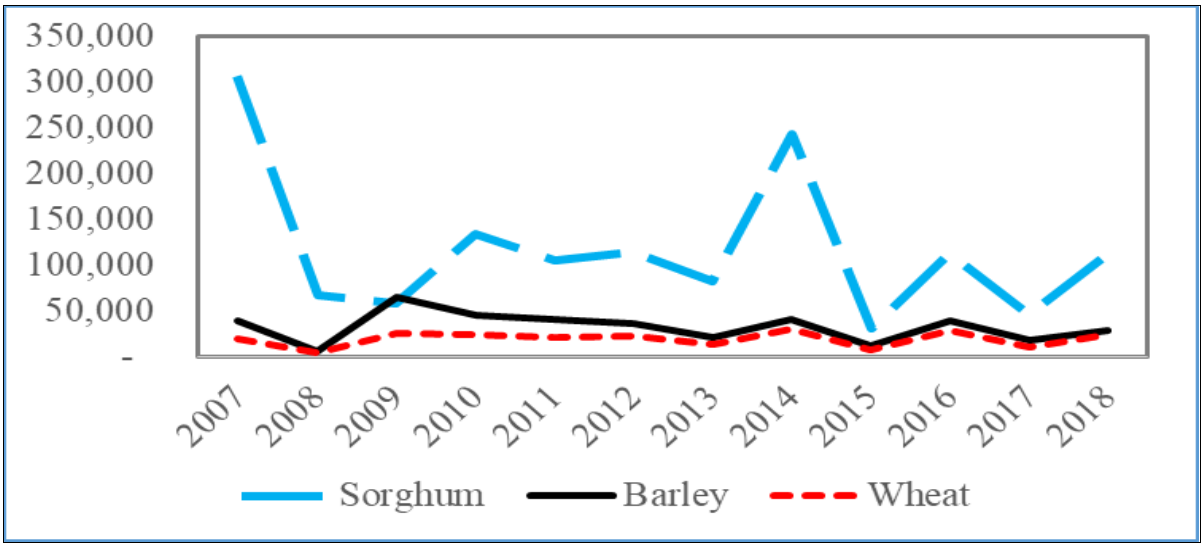


Figure 4.4: Total Production (tons) from 2007 to 2018 for Sorghum, Barley and Wheat

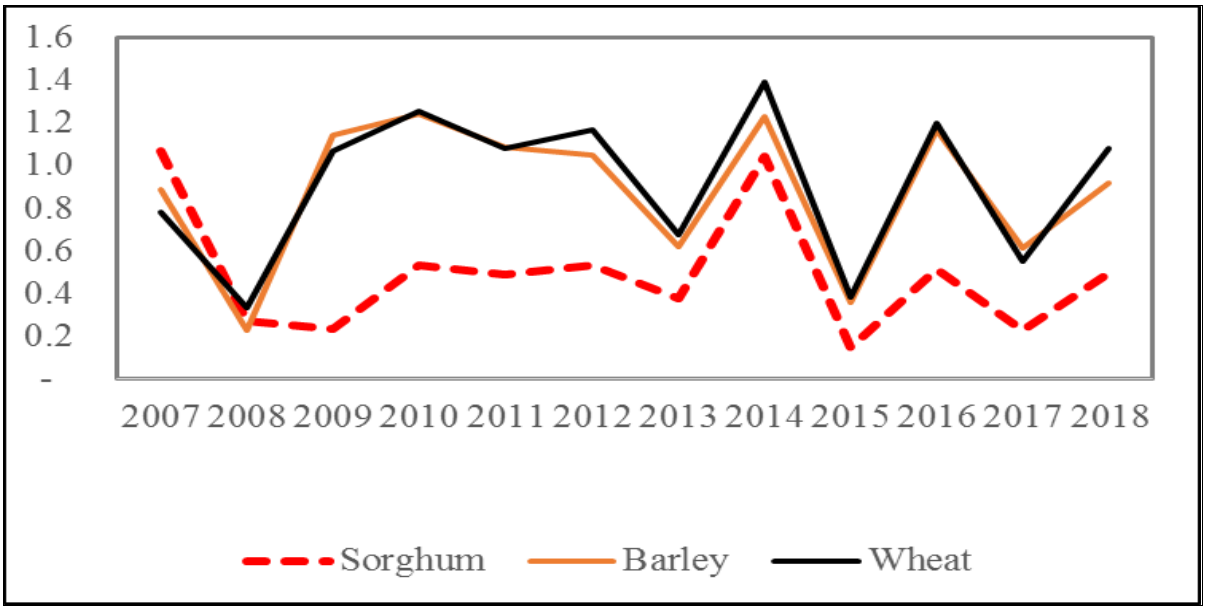


Figure 4.5: Productivity (t/ha) from 2007 to 2018 for Sorghum, Barley and Wheat

Food Consumption: Food production and consumption for the period 2010 -2018 are shown in Table 4.8 in which it can be shown that the lowest food deficit was recorded in 2010 (16 %). The leading crops for human consumption are wheat (40.7%), sorghum (14.3%), and roots and tuber crops (11.0%). As the amount of wheat produced in Eritrea is insufficient; and the country imports considerable amount grain. Efforts are also required to produce sufficient maize and barley. Barley is a staple food crop in the highlands as well used in the brewing industries.

Sorghum is a staple food crop for many people, which is also consumed in various forms. On the other hand, surplus food was recorded in 2014 with an increase of 19 % from the previous production year.

Table 4.8: Food Consumption and Deficit/Surplus in Eritrea 2010 - 2018

Year	Population	Food requirement kg/year					Production (tons)	Deficit/ Surplus (tons)	Coverage (%)
		Cereals	Pulses	Oil seeds	Total				
2010	3,284,966	315,357	39,420	39,420	394,196		329,980	-64,216	16
2011	3,350,666	321,664	40,208	40,208	402,080		305,023	-97,057	24
2012	3,417,679	328,097	41,012	41,012	410,121		312,089	-98,032	24
2013	3,486,033	334,659	41,832	41,832	418,324		209,693	-208,631	50
2014	3,555,753	341,352	42,669	42,669	426,690		509,049	+82,358	19
2015	3,626,868	348,179	43,522	43,522	435,224		128,717	-306,507	70
2016	3,572,706	342,980	42,872	42,872	428,725		313,536	-115,189	27
2017	3,638,873	349,332	43,666	43,666	436,665		139,910	-296,755	68
2018	3,706,265	355,801	44,475	44,475	444,752		275,872	-168,880	38

Food Requirement Person/year: Cereal 96 kg; Pulses 12 kg; Oil seed 12 kg;
Source: National Statistics and Evaluation Office of Eritrea.

Based on average cereal yield under rain-fed and irrigated farming practices and considering different climate change scenarios (2007-2035), there will be consistent changes between mean annual precipitations and mean annual temperatures (Waithaka, 2012). The modelled yield changes for wheat show crop loss as high as 25% with considerable reduction of cultivable land under wheat due to drought. Wheat is highly sensitive to drought and high temperature conditions and unless supported by improved varieties and appropriate technologies, it results in yield loss. Maize will be negatively impacted by climate changes scenario without adaptation because of temperature increase by 2°C.

Result of the simulation for the period 2007-2030 shows that there will be a boost in sorghum production in terms of both yield and amount of cultivable area. The yield is projected to triple, while the area is projected to increase by around 50%, and production expected to quadruple with the application of improved management techniques. The increase in temperature in some areas means that more land will be allocated for sorghum as this crop can survive high temperature conditions. Yield in general increases when the optimum temperature requirement for a crop is met, but if it is above the threshold level, it places a negative influence on yield due to pollen desiccation. In general, crop productivity could increase until around 2030 as a result of climate change, but in some parts of the country there will be a decline in yield. It is expected that increases in temperature and demand for food would pose huge risk of losing of rural livelihoods in the semi-arid regions of Eritrea (IPCC, 2014).

Livestock production: The main livestock in Eritrea are cattle, camel, sheep, and goats. Livestock is based on the traditional techniques of production and it contributes to 20 % of the GDP in agriculture. Goats and sheep are better adapted to the harsh environmental conditions and can survive in situations with feed shortage. In Eritrea, livestock are important sources of milk, meat, manure and draught power. Income from the sale of livestock and poultry is an important means of coping mechanism in times of shortage of food. Livestock are also important means of investment in rural areas where other opportunities for investment are limited. Skins and hides are raw materials for local leather industries; and an important source of foreign currency. The overwhelming majority of livestock and poultry in Eritrea are kept under the traditional systems, kept in limited grazing area, which leads to overgrazing and low

productivity. The livestock population of the country (Table 4.9) had been affected by recurrent droughts resulting in animal feed and lack of water points and massive death. During period 1970 to 1986 period, droughts reduced animal resources has been reduced 50 to705 (MoA 2015). Thermal stress as well exceed the threshold that animals tolerate, which in turn lead to decreased feed intake, interference with animal reproduction functions, and increasing exposure to pathogens.

Table 4.9: Number of Livestock and Products per annum (2006-2018)

Type	**Number (000)**	**Products**	**(millions)**
Cattle	2,239	Milk (litres/year)	341,038
Sheep	2473	Meat (kg/year)	45,998
Goats	5416	Eggs (No/year	71,877.25
Equines	596	Honey (kg/year)	298
Camels	371	-	-
Poultry	1318	-	-
Beehives	23.41	-	-

Diminishing Biological Diversity:
Crop diversity: Land degradation has been the cause of genetic loss in Eritrea where tall, high yielding and late maturing landraces have disappeared as a result of diminished soil fertility. Farmers used to cultivate barley landraces known as *Quunto* over wider geographical areas, but right now, confined to limited areas due to lack of sufficient water. Durum wheat grown vastly, in the past, is nowadays limited to certain pockets areas in Weki - Zager due to spatial and temporal reduction of rainfall. Wheat landraces varieties such as '*Quaderno and '*, '*Demhay*' are extinct (MoLWE, 2008; Woldeamlak *et al*., 1998).

Weeds, Disease and Pest Incidence: Weeds, diseases and pest incidences hamper crop production. While moisture stress increases Striga infestation, grasshopper infestation occurs with onset of the rainy season in spring and damages crops in July and August. Aphids become serious during the drier months in October and November. Shoot fly incidence is higher with low rainfall. Various flies attack potato, tomato, pepper and cabbage under irrigated agriculture in dry season. Crop diseases linked with climate change are wheat rust in cereals, chocolate spot in Faba beans, root rot in chickpea and Faba bean; in vegetables early blight of tomato and late blight of potato cause yield loss when rainfall is higher (Woldeamlak *et al*., 1998). Locust incidence is common almost every year especially in the Red Sea Zone; even though the swarm is bigger during climate fluctuations.

4.8.2 Water Resources

Climate change is projected to reduce surface and groundwater resources in most dry regions resulting in intensified competition for water among different users. The mean annual precipitation has significantly decreased between 20-50%; and the trend changed over the last 30-60 years (IPCC, 2004). Local communities, in the highlands of Eritrea, felt the impact of climate change on water resources (MOLWE, 2005). The following sections describe the impact of climate change on surface, ground water resources in Eritrea.

A. Surface Water Resources
Freshwater resources are highly influenced by inter-and intra-annual rainfall variability, flooding and drought. The demand for water from domestic, livestock and industrial activities is expected to increase with population growth. With increasing temperatures, climate change may further reduce its availability with decrease summer stream flow. To study the trends, the

annual stream flows in different sites were simulated at three gauged basins namely the Gash, Mereb and Anseba. The results showed decreasing stream flow in almost all river basins, though an increasing tendency has been observed for Anseba River at Halib - Mentel site (Figure 4.7). Similar trend is observed for Mereb-Gash (Figure 4.6). The decline of stream flow was consistent with decline in precipitation in the last 30 to 60 years. Nonetheless, trends in stream flow are not always consistent with changes in precipitation owing to data limitations in precipitation and effect of human interventions (e.g. Reservoir impoundment (Lindstrom and Bergstrom, 2004). The annual inflow data from Toker Dam (2001-2019) and Mai - Nefhi Dam (1972-1986) showed a decreasing stream flow ranging from 4.0 - 2.0 MCM (Figure 4.8) at Toker Dam and 9.0-2.0 MCM at Mai - Nefhi Dam (Figure 4.9) in the last 20 years (Figure 10).

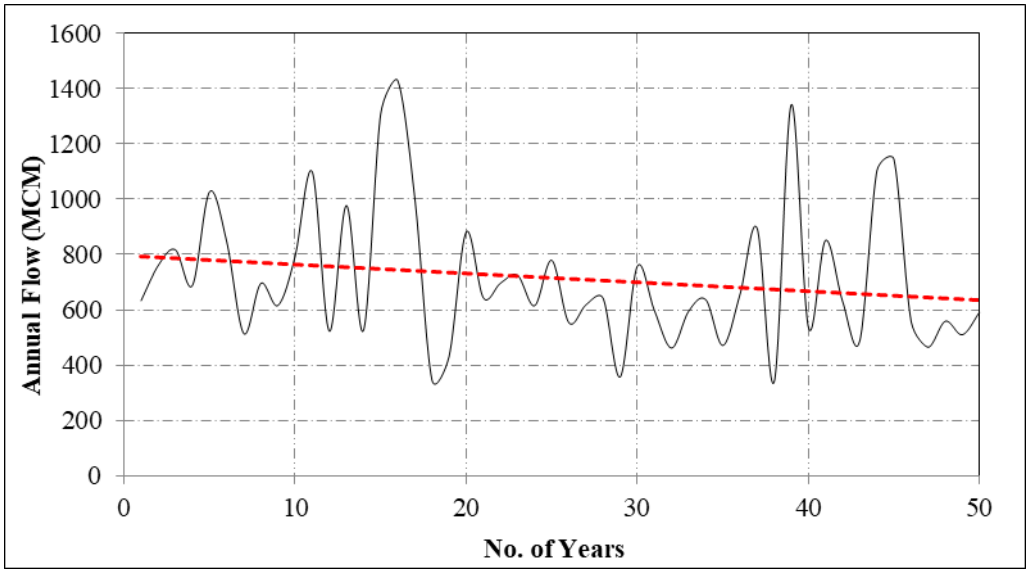


Figure 4.6: Simulated Annual Stream Flow Series of Mereb-Gash Basin at Tesenay (**Source**: Euro consult, 1998)

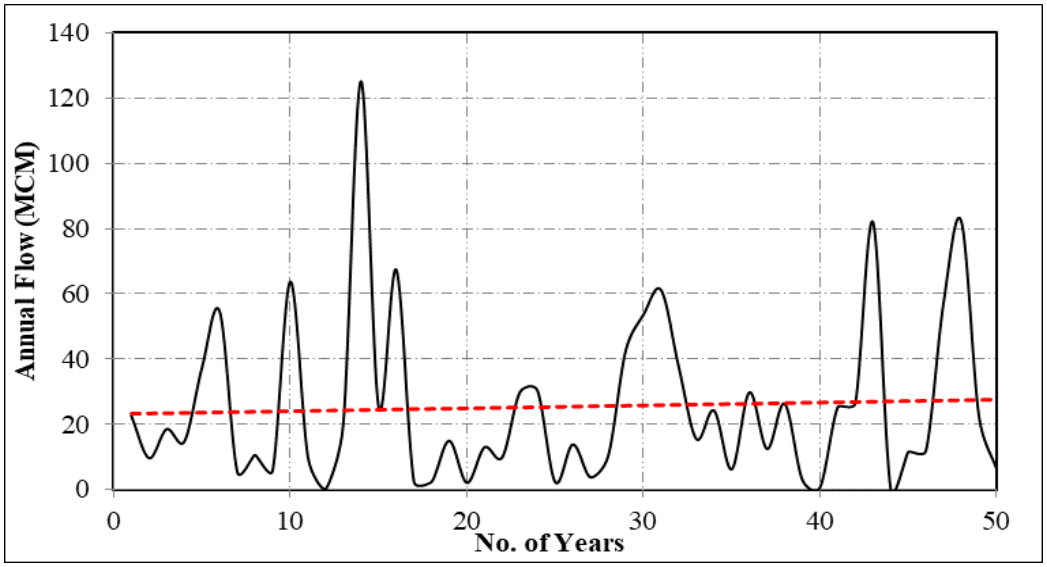


Figure 4.7: Simulated Annual Stream Flow Series of Anseba River System at Halib Mentel (**Source**: Euro consult, 1998)

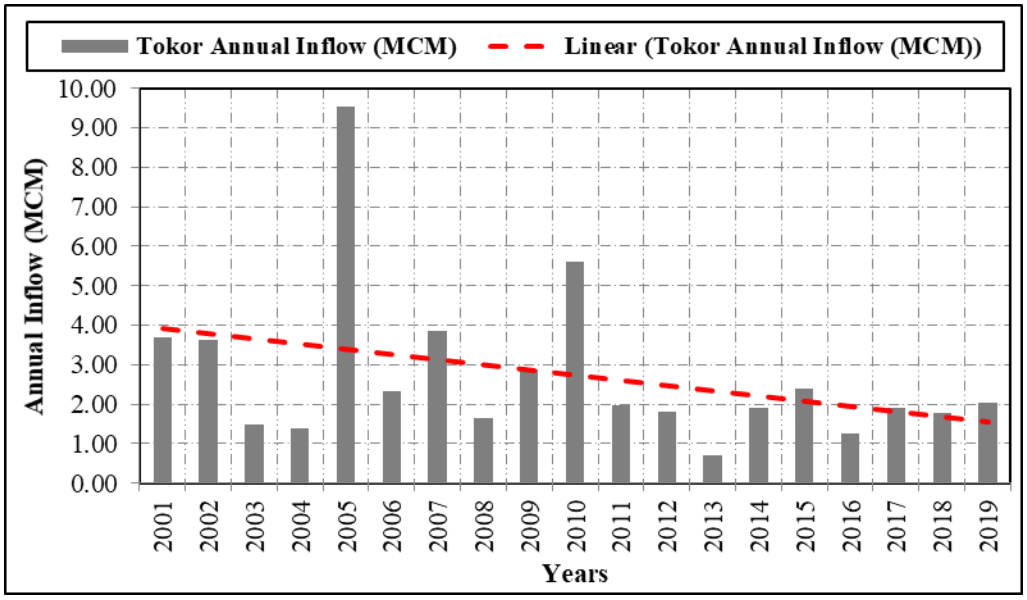


Figure 4.8: Annual inflow of Toker Dam
(**Source**: AWSD, 2019)

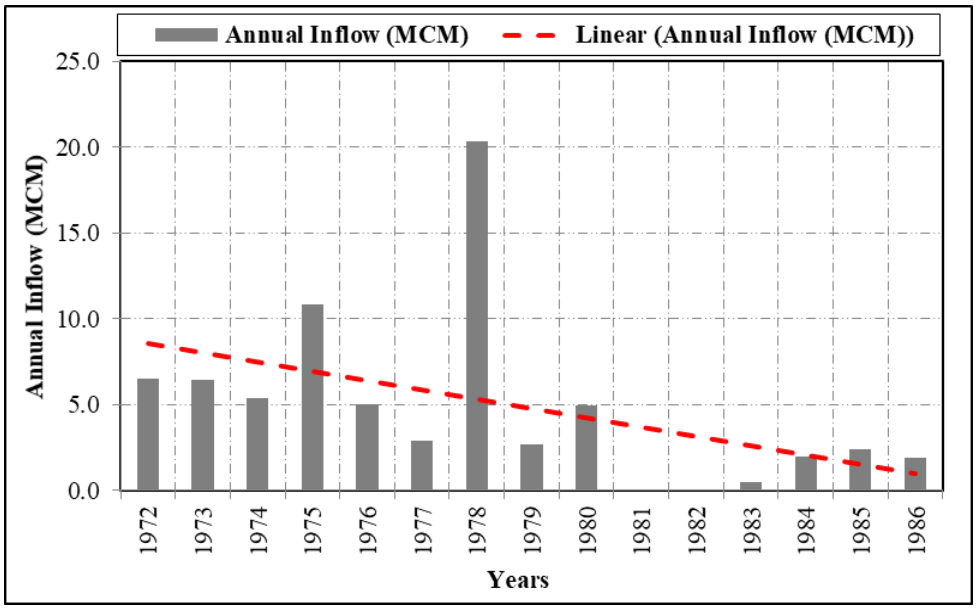


Figure 4.9: Annual inflow of Mai Nefhi Dam (**Source**: AWSD, 2019)

Groundwater Resources: In Eritrea, groundwater is source of water supply for 96% of rural communities. Inhabitants in the Central and Northern highlands, the Eastern and Western escarpments depend on groundwater. Due to over pumping and droughts, ground water table in, many places including, Mogoraeb and Bisha (Figure 4.10) and Adi-Nfas (Figure 4.11) areas declined by about 5m during the last 10 years. Due to high temperature and low precipitation, a similar trend was noted in areas of hard rock aquifers around Dbaruwa area (AMSC, 2018). Such a decline is not only explained by the impact of climate change, equally the level of groundwater could drop significantly due to excessive pumping surpassing the rate of recharging. A large portion of the country is underlain by hard rock, and most frequently the success rate of drilling from such hard rock is very low (Sander, 1996; MOLWE, 2005). Thus, besides climate change and excessive exploitation, ground water availability is constrained by the physical and geological nature of the area which makes the groundwater exploitation expensive and difficult.

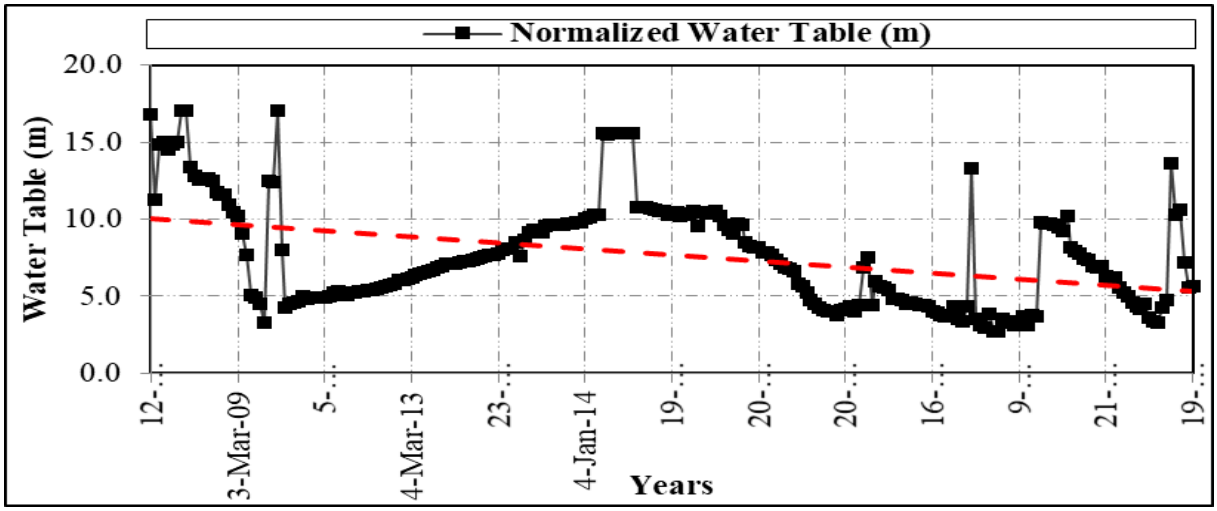


Figure 4.10: Water Table Decline from the Surface in Alluvial Formation of Bisha, Area
(**Source**: BMSC, 2018)

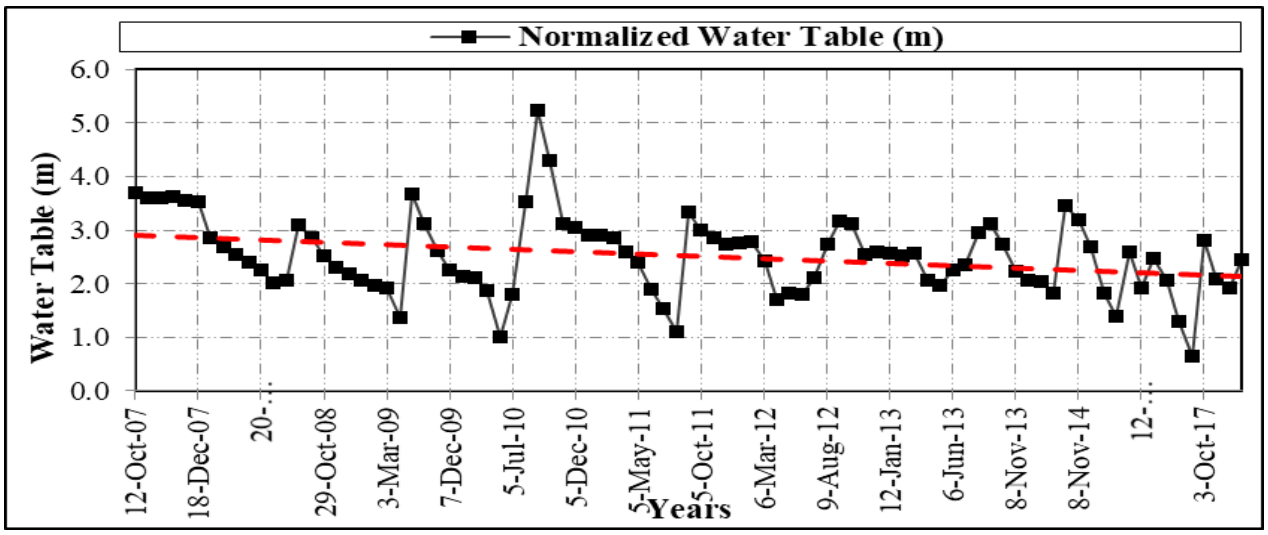


Figure 4.11: Water Table Decline from Surface in the Hard Rock Formation of Adi-Nfas area
Source: AMSC, 2018

Community perception on ground water supply in sub-zoba Dbaruwa: The increase in mean annual temperature and decrease in rainfall in the last 30-60 years has dropped the water levels. The yield of wells has been reduced; and springs dried. This has negatively affected the rural water supply of the sub - zoba which depends on ground water. The village of "Sefea" and "Guhcha" are examples of the sub-regions regions which suffered due to shortage of water supply.

Dam Storage and Structures: In Eritrea, over the past 15 years, 340 dams out of which, twenty five purely for irrigation, eighty three for domestic use and the remaining for both irrigation and domestic use were constructed. The capacity of these dams ranges from 0.02 Mm^3 to over 100Mm^3, most of them in the range of 150,000 - 360,000m^3. The storage capacity of most of the dams is low owing to inadequate investment in water management infrastructure due to the hydrology and hydraulic nature.

Water Quality Status: Water quality assessment, in the Central Highland and the Western lowlands, carried out by the WRD over a ten-year period (1994-2004) showed good quality

with respect to chemical composition. In the Red Sea coastal area, water is generally saline due to increased temperature and intrusion of sea water in the wells. The quality of many shallow hand dug wells and surface water sources is generally acceptable. Drinking water source open hand dug wells springs; dams are prone to bacteriological contamination. Samples taken from 548 water points across the country shows that 59.7percent of the wells are contaminated, 22.7 % are mildly contaminated and 27%are highly contaminated which is aggravated by poor hygiene practices, low sanitation coverage, poor construction and maintenance of water points.

Regarding chemical quality, 30% of water points in the Southern Red Sea region and 40% in the Northern Red Sea region were found to be unsuitable for human consumption due to salinity problem. The high temperature would likely result in water evaporation pushing the salt upward to the surface affecting the chemical quality of the water (IWRM, 2019). Thus, under climate change scenarios associated with drought, flooding and rise in temperature; water quality deteriorates and remains to be one of the major causes of child mortality.

Along the Red Sea coastal areas, the state of water table has been disturbed because of decreased surface water recharge caused by low precipitation. The decline in ground water table could lead to water, which is highly vulnerable to salt water intrusion. The electro conductivity (EC) values in the coastal line have increased from 1400µS/cm-2000µS/cm in the last 25 years (Figure 4.12). This has been described well by the community living around the coast line in Sub Zoba Foro. Furthermore, the water quality (EC values) from inland Eritrea, in Bisha Area showed an increase amount from 800µS/cm-1100µS/cm (Figure 4.13) (MOLWE, 2018).

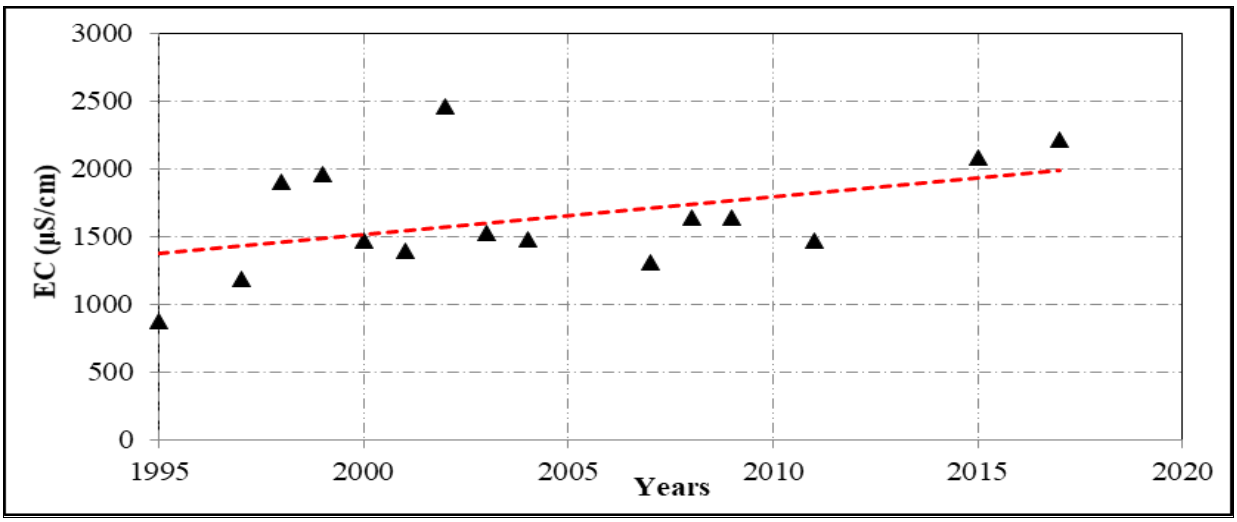


Figure 4.12: EC Values of Asseb water supply, Harsile Area
(**Source**: MoLWE, 2018)

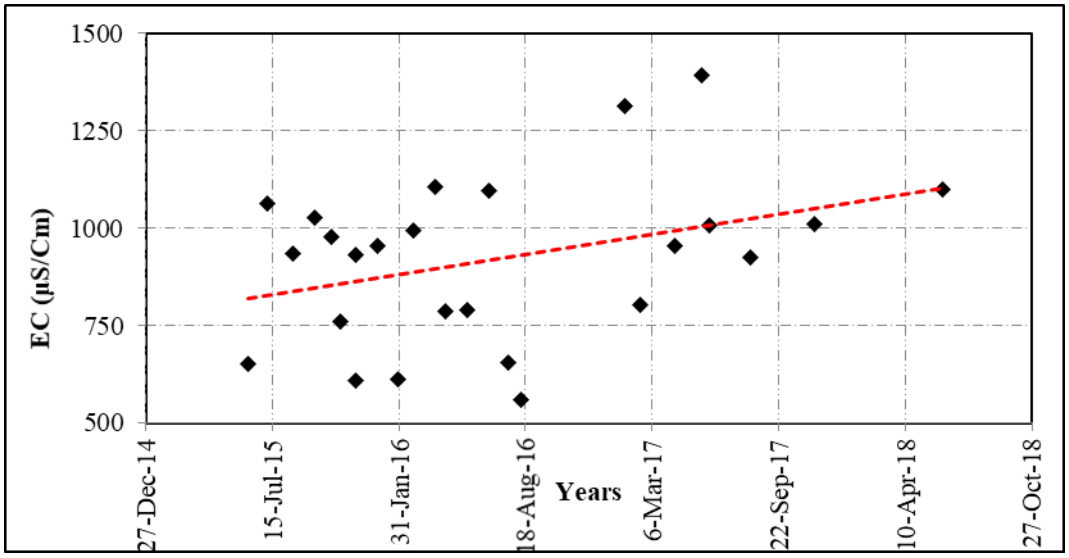


Figure 4.13: EC Values of Bisha Mining Area Monitoring Wells (**Source**: BMSC, 2018)

Community Perception on Groundwater Quality in sub-zoba Foro: The communities in the Northern Red Sea coastal areas are from wells, springs, base flows and shallow dug wells located at foothills of the escarpment. In the last decades, these sources have been declining and some of them are already dried out due to shortage of precipitation. Moreover, the wells located closer to the sea shore become more saline due to high evapotranspiration and intrusion of sea waters into the wells.

4.8.3 Forest Sector

The vegetation cover of Eritrea, which was 30% declined to less than 1% now. Certain plant species having timber and non-wood products uses have disappeared climate change.

Deforestation due to expansion of agriculture, domestic fuel wood consumption, construction of traditional houses, the 'hdmos' agricultural implements and war had negative impacts on forest cover. The overwhelming dependence on biomass (charcoal, firewood) clears forests and woodlands. Thus, deforestation leads land degradation consequently widespread environmental problem. Over-grazing and incidences of bush fire destroy wildlife habitats. Wildlife species such as the Oryx are locally extinct; others such as the Nubian ibex and the African wild ass are critically endangered. It is expected that the trend on biological diversity would diminish for the future unless conservation are in placed to conserve the biodiversity. Studies indicate that the annual rate of soil loss from cropland is estimated at 12-20 tons/ha, while the decline in crop yield is about 0.5 per annum. These unsustainable practices reduced the Eritrea's terrestrial biodiversity. Due to low level of economic activities the coastal and marine biodiversity resources remained relatively stable.

4.8.4 Human Health

Climate changes affect human health through social and environmental determinants of clean air, safe drinking water, food security and shelter. The adverse health impacts of climate change are caused by scarcity of water and disasters such as floods and droughts. Malaria, dengue fever, and yellow fever are the main vector-borne diseases caused due to climate changes in Eritrea (Table 4.10).

Table 4.10: General Climate Change and Impacts on Health in Eritrea

Climate change	**Health Impact**
Extreme weather conditions	Cardiovascular diseases, skin cancer
Lack of hygiene	Diarrheal diseases
Changing rainfall and temperature patterns	Malaria, Dengue fever, Schistosomiasis, Chikungunya
Poor crop yield	Malnutrition and hunger
Sea rise and flooding	Fatal and non-fatal injuries
Air pollution	Deaths and ill health associated with air pollution and allergies

Malaria: In Eritrea, with climate change, the prevalence and distribution of malaria disease gradually diffused from the lowlands to the highlands. Transmission of malaria is seasonal with September to December being the peak transmission season. This places a significant economic burden on the farming populations which coincides with harvesting months for major crops. While *Gash Barka* had the highest prevalence rate of (69%) *Debub* with (9%) is the lowest. The highest mortality rates of 13% and 11% were reported in 2014 and 2016 respectively (Figure 15). Variations in malaria transmission are associated with changes in temperature, rainfall, humidity and the level of immunity (IPCC, 2007). As a case, the country faced serious malaria epidemics following heavy rainfall in 1998 and the El Nino of 1997. Considering the health, social and economic threat of malaria as a public health problem, the MoH launched a Roll Back Malaria Strategy in 1999 (Annual Health Service Report, 2018).

As the result of climate change, temperature, rainfall and humidity are increasingly met by the B2 high 90 percentile 2030s and 2050s scenarios, which will likely increase the prevalence of the disease in the drainage basins (Waithaka et al, 2012). There is a positive association between malaria prevalence and monthly temperatures, and rainfall patterns. Future projections indicate that incidence of malaria, in Eritrea, will increase. However, taking Eritrea's past record, there is higher chance of controlling the disease without causing risk hazards.

Malnutrition: The poor nutritional status of children and women has been a serious problem in Eritrea for many years. Malnourished women during pregnancy often have children with stunted growth during their life time. In rural areas, a considerable proportion of children (50%) are stunted. A similar situation prevails in all other regions of the country except in *Maekel* (Central) where the prevalence of stunting stands at 35%. This is in agreement with the IPCC (20014) assessment where under-nutrition was found to be linked with extreme climatic events. The impact of food insecurity and malnutrition is particularly severe in poor households with limited livelihood assets. Rainfall situation and temperature could partly predict the variations in child stunting and underweight.

Prediction on malnutrition indicates that acute global malnutrition will range from 19.8 -7.8%. Under the A2 and B2 high 10 percentile scenarios, malnutrition increase following incidences drought. Malnutrition increase under the A2 and B2 high 90 percentile scenarios as a result of potential inundations and subsequent decrease in crop yield (Waithaka, 2012). It is important to explore possibilities of conducting model based assessment for the future national communication reports.

Diarrhoea: Diarrhoea is prevalent in areas suffering high under-nutrition and low accessibility to safe drinking water and poor waste disposal systems. It frequently occurs during peak rainy months indicating possible contamination of drinking water by flooding. Children aged below five years are most vulnerable to diarrheal diseases due to poor hygiene, and lack of access to

clean drinking water. The problem is more acute in rural areas where there are no proper excreta disposal systems. The disease is persistently one of the three leading causes of mortality among children under 5 years of age in Eritrea (MoH, 2016). Pathogens that cause water-borne diseases are temperature-dependent where rising temperatures leads to increased bacterial reproduction causing incidence of diarrheal diseases.

Schistosomiasis: Schistosomiasis is prevalent in Gash Barka, Southern Red Sea and the Northern Red Sea administrative zones with the two regions, *Gash Barka* and Southern Red Sea having the highest rate of prevalence (Figure 4.14). The disease diffuses when urine and faeces contaminate drinking water and the intermediate host the snails are present in the ponds. With increasing demands for irrigation, in the arid regions, the snail would easily spread the disease to the population and hence, higher risk of human infection with Schistosomiasis parasite. Under the B2 high 10 percentile 2030s and 2050s scenarios, the disease will likely further prevail and infect more people in the various drainage basins of the country (Waithaka 2012, 2013).

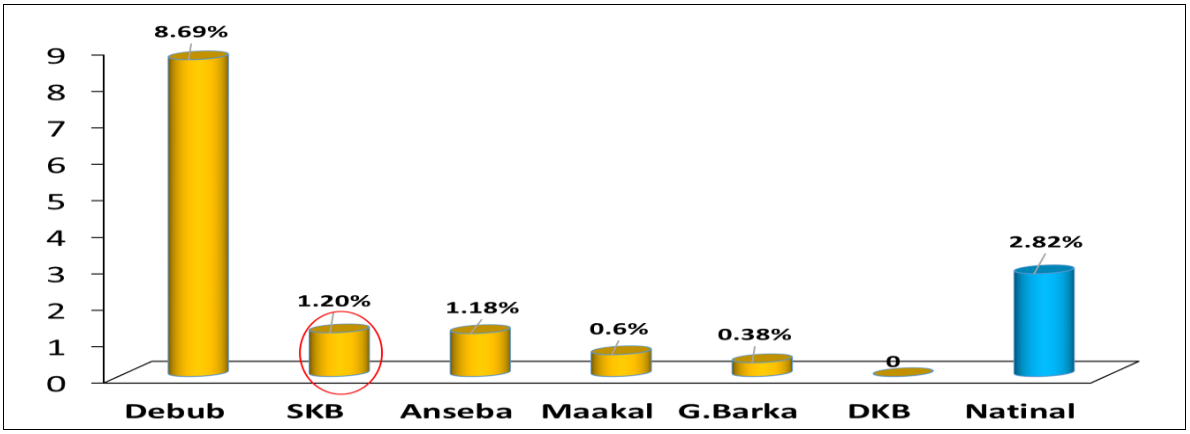


Figure 4.14: Vulnerability and Spread of Schistosomiasis in six regions of Eritrea 2015

Chikungunya: In Eritrea, Chikungunya was first detected in 2018 in the town of Tesenay bordering the Sudan. Later, the disease spread to parts of Gash -Barka, Anseba, Debub, Maekel and Northern Red Sea regions. Today, the largest number of people affected by *Chikungunya* (13,710) was in Gash Barka region followed by Anseba (2,609). In 2018, the MoH (2018) report 16,904 people infected by *Chikungunya*. Till now, there is no report indicating the incidence of the disease in Southern Red Sea.

Dengue Fever: Although Dengue fever is one of the endemic vector-borne diseases in Eritrea; before 2010, the disease was commonly found in the coastal areas. Today, it has spread to all parts of the country following increasing in temperature and consequently widely affecting the population and considered as climate change related disease in Eritrea (MoH, 2018).

Yellow Fever: The distribution of yellow fever shows that the virus (*Flavi virus*) is transmitted through mosquitos' bites. Eritrea is not a high-risk country for yellow fever; but introduction from the neighbouring countries where the diseased is prevalent pose potential risk. In recent years, there has been a global change in the epidemiology of yellow fever with outbreaks occurring in areas not previously assessed as risky. This is due the changes in the pattern of temperature and precipitation. Thus, the disease could be a potential threat for Eritrea unless concerted efforts are made by all countries to tackle the problem (MoH, 2018).

4.8.5 Coastal Areas

The Eritrean Red Sea coastal areas are susceptible to the adverse effects of climate change. The following paragraphs describe the impacts of climate change on various aspects of the ecosystems.

Coral Reefs: Coral reefs are highly vulnerable to climate change as well as human activities. They could be easily killed unless they are protected by environmental law. Excessive salinity and an increase in water temperature of more than 1-2 ℃ (1.8-3.6 ℉) can destroy some species of coral. An increase of 1°C or more above the historical maximum sea surface temperatures (SSTs) results in "coral bleaches," The sea surface temperature (SST) across much of the tropics has increased by 0.4° to 1°C since the mid-1970s. As a result, an increase in the frequency of coral bleaching and mortality has become a concern that pose a major threat to the survival of coral reef ecosystem. Climate model simulations of IPCC predicted that if the current warming trend continues, the coral species could cease growing altogether by 2070 (www.sciencemag.org Science, 2010).

Mangrove: Mangrove patches in the Eritrean coastal areas are, among the most, vulnerable species to climate change. Some mangrove patches along the coast are observed to lose their patchiness periodically and unable regenerate. If the current trend continues the mangrove grown in inter tidal areas could completely submerged and displaced in the future (MOMR, 2019).

Coastal And Island Community: Sea level rise has been observed in many sites along the coastal areas; and adversely affecting the people living in low lying island villages and coastal towns. The coastal villages of *Gelealo*, *Tio*, *Edi* and *Barasole* are located at sea level and vulnerable climate change. During time of extreme tide such as sea water flashes beyond the low lying villages like Barasole (Figure 4.15. If the current situation continues unabated, many islands would be submerged and populations living there would be displaced.

Figure 4.15: High tides inundating the coastal village of Barasole, Southern Red Sea

Observed Sea Level rise in the Red Sea Area at 17° Longitude and 40° Latitude during the 1992-2012 is shown in Figure 4.16.

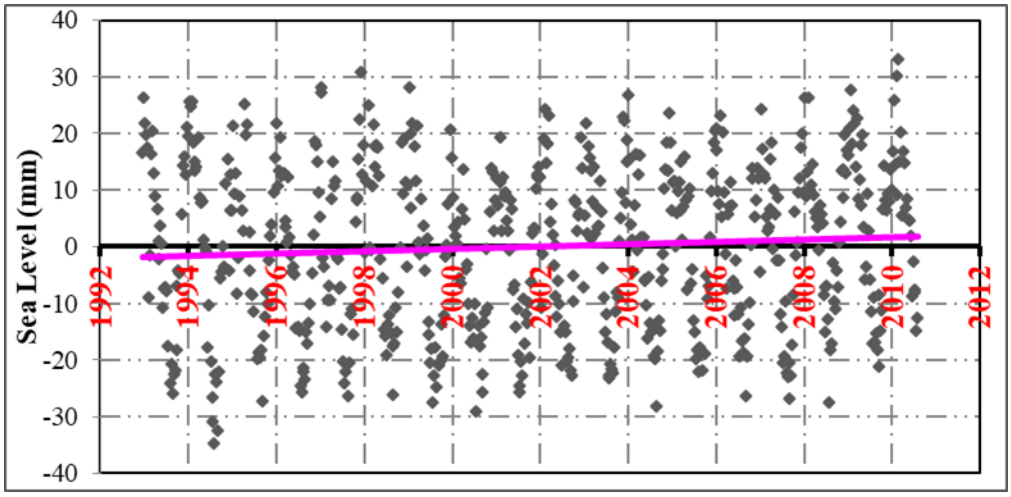


Figure 4.16: Observed Sea Level rise in Red Sea Area at 17° Longitude and 40° Latitude (1992-2012)

4.9 Adaptation Assessment, Strategy and Policies

In this section "adaptive capacity' is taken as system's ability to modify its characteristics or behaviour to better cope with changes in external conditions (Füssel & Klein, 2006). Most often, adaptation does not mean doing new things completely, but rather modifying development interventions. It is not a development objective but a necessary prerequisite for safeguarding beneficial outcomes. Adaptation can contribute to the well-being of people, and to the maintenance of ecosystem goods. It helps to reduce the risks of climate change impacts. However, there are always limitations to its effectiveness, especially when the climate change is extreme. Assessment on adaptation activities is linked with priority sectors such as agriculture and water as both are key issues in achieving food security, economic growth and poverty reduction.

Drought and climatic variability caused reduction in productivity of crops and livestock. These results in economic problems particularly when those affected have no capacity to respond, in any other way. This is particularly evident in the case of extremely poor communities or where the costs of adaptation measures are considered to be high relative to the risk of expected damage.

4.10 Coping Mechanism/Strategies

In Eritrea, assessment on coping mechanism strategies provided information on the measures taken towards formulating and implementing national programs relevant to the UNFCCC Convention. A range of traditional drought coping mechanisms are used at a household level. The most frequently used drought coping mechanism is selling of livestock, while the least mechanism used is food (Menghisteab *et al*, 2019). As a general rule, rich households show less dependency on selling livestock to cope with extreme weather conditions as they have a much more diversified livelihood system. The section below presents adaptation activities related to agriculture in the country.

4.10.1 Crop Production

Use of inputs: As part of adaptive strategy, agricultural inputs such as fertilizers, pesticides, and seeds were distributed to the farming households. In 2015, the amount of inputs distributed were 2208qt of fertilizers, 9662 litres of pesticides and 2199kgs pesticides in the form of powder. A large amount of potato seed (4350qt) was also distributed along with other types of seeds of cereals, vegetables and forage.

The Minimum Integrated Household Agricultural Package (MIHAP): The MoA has introduced a MIHAP in which a given household acquires an improved cross breed of dairy cow or 6 goats, 25 chicken, 2 bee hives, a vegetable plot and 20 trees. The package has improved the living conditions of households and satisfied their food and nutrition requirement. Eggs provide nutritious food for the family and surplus sold to earn money for purchase of items needed by the family. Vegetables and fruits also contribute to the bulk of nutritious food. If up-scaled and implemented properly, the MIHAP would enable farming families become self-sufficient in food and nutrition and financially secured at household and community levels (MoA, 2018).

Choice of Crops and Varieties: Eritrea is a centre of diversity for a number of crops and possess diversified landraces foe given crop species. Farmers use drought resistant varieties such as sorghum, pearl millet and barley in places with shortage of water. These crops mature earlier and thus escaping the impacts of drought. There are a number of landraces grown for generations by adapting the existing climate conditions. By and large, 76% of the households use landraces from their own source.

Inter-tillage cultivation: Inter tillage cultivation is practiced particularly for sorghum and pearl millet at knee height stage. This practice helps to conserve moisture, provides proper aeration in soil; and minimizes weed infestation. About 98% of the farmers in *Gash Barka* and 94%t in *Anseba* practice inter-tillage cultivation for sorghum and pearl millet.

Intercropping/Mixed cropping: This is a method where two or more crops are grown in the same field during the same year. The intercropping/mixed cropping has advantages of making yield stable and ensures farmers with the second crop in case the first crop fails due to drought. It also helps to reduce infestation of insects, diseases and weeds.

Minimum tillage: This is ploughing land only once before planting period (0+1) or ploughing before and after planting (1+1) for covering the seed planted. Minimum tillage creates a coarse seed bed for better moisture conservation, preventing soil erosion/runoff, maintains the soil structure and minimizes the loss of soil fertility.

Improved Varieties for Smart Agriculture: The most serious challenges in crop production are shortage of inputs, lack of high yielding varieties, inadequate multiplication of seeds; and post harvesting losses due to lack of cold storage facilities. Drought will continue to cause shortage of food production in the country unless irrigation and high-yield varieties are introduced in the farming system. An example of improved varieties developed in the face of smart agriculture in Eritrea is Kona in pearl millet, which easily adapts to conditions of drought and high temperature. It is early maturing and disease resistant that gives yield ranging from 12 to 21 qt/ha. The same improvement is reported to sorghum with varieties such as Shambucco, Bushuka and Hamelmalo released recently. Barley varieties such as Shishay and Rahwa have been also developed, which are early maturing and high yielding. Landraces that are relatively drought tolerant and early maturing have survived for generations. Various landraces of pearl millet such as Bariyay and, sorghum- Wedi- Aker and Koden have, for example, survived for long period of time in the face of climate change.

Recommended Adaptation Options in Crop Production

The following are adaptation options for crop production in particularly and agriculture in general is summarised in Table 4.11.

- Choice of crops is important for early maturing, short cycle and heat resistant crops such as barley, sorghum, pearl millet. Land races cultivated for generations adapted to the harsh environmental conditions should be conserved;
- Smart crop management practices should consider crop rotation, mixed cropping/inter-cropping, minimum tillage, water harvesting techniques, inter-tillage cultivation etc. Mixed cropping/intercropping has been used as an insurance against drought and diseases; and the yield which is better than sole cropping.
- Collection of Germplasm and maintaining the genetic resources in situ would be the best strategy for Eritrea as a number of crop species and the genetic wealth are threatened through climatically stressful period;
- Supplementary irrigation and soil water conservation practices improve soil fertility and moisture retention capacity for better productivity;
- Control diseases, pests and weeds through crop management techniques and planting appropriate crops;
- Raise peoples' awareness about the effect of climate change on crop production and create linkages with regional and international networks to generate technologies that would address climate change; and
- Enhance the construction of dams, water reservoirs, water diversion structures, ponds, wells, and introduce efficient irrigation infrastructure such as drip and sprinkler so that crops could be produced 2 to 3 times per year.

Table 4.11: Priority Options in Adaptation Programs in Agriculture

Option	**Remark**
Climate information, research and early warning	Provide information base for decision on adaptation; capacity building and data and technology for adaptation
Institutional strengthening and capacity building	Capacity building in modelling for institutions and stake holders
Meteorological and agro meteorological data	Strengthen meteorological stations, collect adequate data and early warning system
Agricultural research and transfer of technology	Priority to appropriate technology agricultural research for effective adaptation program. and g
Switch to adaptive crops varieties and livestock breeds	Investment on identifying crop varieties and livestock that can be used for the adaptation program
Conservation agriculture	Zero tillage, cover crops and tillage practices
Soil and water conservation structures	The adaptation capacity in terms of bunds, terraces, grass strips, and contour, can provide immediate benefit and others is very high in crop fields in relation to water conservation; it.
Soil management	Has the capacity to provide immediate benefit.
Forests for adaptation	Enhance agroforestry activities
Promoting biodiversity	Germplasm collection to preserve genetic materials in ex situ, but there is a major gap in situ conservation;

Expansion of Irrigation systems: A number of dams and diversion structures had been constructed to boost agricultural productivity in Eritrea. In Gash Barka, for example, 35 diversion structures were constructed most of which are not functional at present due to lack of

proper design and maintenance. There are 10 dams in Gash Barka and 7in Anseba with a total capacity exceeding 300,000 m^3. However, much remains to be done to fully operationalize their usage and increase the number of beneficiaries. There are a total of 121 ponds out of which 93% are functional, while the remaining is non-functional due to sedimentation. In Anseba, there are 34 dams whose water holding capacity varying greatly. The dam in **Habero** have a capacity of 90,000 m^3 is the smallest and the one **Mesa-Shebah (Hamelmalo)** the largest with a capacity of 600,000 m^3. At present these dams are either fully or partially filled with sedimentation. At a national level, an estimated 35,500 ha of land is under perennial irrigation using water from dams and wells. Although the spate irrigation potential in Gash Barka is 13,535 hectares, only 12,773 ha of land have been irrigated as some of the structures are dysfunctional.

The use of modern and affordable irrigation system is a viable option to crop production. In this respect, installation of drip system is highly recommended as it has very high water efficiency and could cover up to 25percent more land. Drip system reduces the incidence of fungal diseases and saves labour, and reduces salinity problems. Initially, properly designed drip irrigation is more expensive than sprinkler irrigation system. However, the lower operating cost and higher efficiency of the drip system quickly offsets the extra expenses incurred in sprinkler irrigation in many horticultural production systems. Although furrow irrigation is very popular in most regions of the country, salt accumulation, rough field surface with poor levelling, soil erosion hazards and high labour requirement limits its use on sustainable basis. With regular maintenance of the infrastructure spate irrigations a viable adaptation option in Eritrea (Figure 4.17).The total land area occupied by various types of irrigation systems is shown in Table 4.12.

Table 4.12: Total Land areas Occupied by Various Types of Irrigation Systems

Irrigation system	**Hectare**	**%**
Spate irrigation	63,000	60.6
Dams	8,600	8.3
Pressurized irrigation	5,400	5.2
Well irrigation	26,900	25.9
Total	103,900	100

Source: MoA-annual reports

Figure 4.17: Spate Irrigation Dams that need Periodic Maintenance in Gash Barka

Livestock Production: Livestock production suffers from various types of constraints and as a result yield is extremely low. Shortages of animal feed and lack of capital and skills are among the challenges that hinder sufficient production from the sector.

Recommended Adaptation Options in Livestock Production: The following are adaptation activities are recommended for livestock production to address difficulties of use of appropriate breeds, feeds and feeding, water supply and livestock diseases.

- Selection and use of local breeds of livestock that are resistant to water and feed shortages, and extreme weather conditions;
- Production of feeds and formulation of appropriate feeding ration
- Construction of water ponds, area closures including promotion of permanent and temporary enclosures for cut and carry system;
- Enriching the natural pasture by over-sowing grasses and other drought resistant legumes; and
- Improve management of livestock, pasture and health for higher productivity.

4.10.2 Adaptation Options in Natural Resource Management

A key concept linked to maintaining a healthy and productive ecosystem is to look for options that would enable communities use natural resources on a sustainable manner. In view of environmental conservation, it is important to identify tree species that survive under adverse environmental. Selecting species that are capable of acclimatization and possessing a wide genetic diversity could act as adaptation option to climate change. There are fast growing tree species adapted to a wide -range of climatic conditions is grown in Eritrea. Species such as *Acacia etbaica* and *Eucalyptus cladocalyx* are well adaptable to a wide range of ecological conditions in the highlands. Similarly, Acacia *polyacantha* and other *Eucalyptus* in the midlands and *E. camaldulensis*, *Acacia Senegal* and *Acacia tortilis* in the lowlands have demonstrated wide adaptability.

Soil and water conservation structures using stone and earth bunds are best adaptation practises in Eritrea. Though measures and achievements in soil and water conservation fluctuate from year to year; Table 4.13 presents adaptation activities carried out as part of the natural resource management in the country.

Table 4.13: Adaptation Activities in Natural Resources Management

Type	Activities
Soil and water conservation (SWC	-Off farm SWC measures: hill side terrace, half moon, micro basin, loose rock check dam, tree planting -On farm SWC activities: terraces, check dams and agronomic measures; -Along rivers and streams: loose rock check dams, gabion check dam, masonry check dam, micro dams and dams
Afforestation	More than 43,257,747 seedlings have been planted in the last 12 years to rehabilitate the degraded lands; different exotic and indigenous species have been used for reforestation degraded landscapes.
Nurseries	About 37 nurseries with a total capacity of producing 12.5 million seedlings are established; some regions having 2 to 10 nurseries.
Area closure development and catchment rehabilitation	A total of 371,390 ha (18%) of land have been closed 1991 in order to promote natural vegetation; the plan is to enclose about 18% of the total surface area of the country.
Demarcation and draft mapping	A total of 308,294 ha of the enclosures are demarcated and mapped. A total of 157,866 has of land is protected or put under enclosures. The extent of degraded community catchments that needs rehabilitation is about 2,007,400 ha.
Afforestation and green clubs	Since 2006, the number of green clubs for afforestation programs have increased by 43.8%; a total of 46,396,360 trees are planted through Green campaign in religious sites, schools, institutions, community, and private people,
Distribution of energy saving stoves	Improved stove reduces firewood consumption by over 50%; energy saving stoves that far, saved an estimated 28,000 ha of land from deforestation; a total of 12,000 energy saving stoves have been distributed to households and the number is expected to increase.

The following adaptation options for management of natural resources are recommended.

- Integration of multipurpose tree and shrubs in cropping systems (agroforestry) with the aim of providing fuel wood, improvement of soil fertility and land stabilization. Effort should be also extended to stabilize farmland through biological or physical measures of reducing soil erosion;
- Re-establishment of habitats in selected areas such as *Buri* Peninsula and *Hawakil* Bay for the conservation of terrestrial wild life.
- Introduce comprehensive rehabilitation and protection plans in forested areas to meet the demand for fuel wood and fodder for rural communities as well as sequester carbon dioxide and hence reduce the impacts of climate change;
- Provide incentives to promote community involvement in forestry conservation programs. Encourage private reforestation schemes and ensure that trees planted belong to those individuals who planted and cared them. Plant a mix of drought resistant indigenous and fast growing exotic species through community forestry initiatives;
- Complete demarcation and designation of forest areas that has already started; introduce proper resource management plan and overall land use map of the country;
- Introduce a national reforestation scheme and encourage school wood-lot programs and traditional energy saving stoves; delineate certain forest areas for the conservation of forest genetic resources, encouraging natural regeneration through closure etc. It is important to maintain the diversity of forest species in situ.
- Promote energy diversification to substitute wood fuel such as solar, wind, kerosene, gas, electricity etc. while improving wood consumption efficiently using improved stoves.

Table 4.14: Type of Vegetation of Eritrea

Type	Area (Km2)	% Coverage
Forest	591	0.48
Trees And Shrubs	410	0.33
Scattered Trees	14094	11.34
Grassland And Bushes	25577	20.57
Bushes	53824	43.29
Riverine Vegetation	1865	1.50
Mangrove	64	0.05
Others	27915	22.45

Source: FAO, 1997

4.10.3 Adaptation Activities of Water Resources

In Eritrea, recurrent droughts, rising temperature and high rate of evaporation have resulted in reduced water flow, lowered ground water level and deterioration of water quality. In order to alleviate the problem, development in the water sector should concentrate on climate smart water resources. To alleviate the problems, dams and check-dams been constructed; and so far, 450 concrete earthen dams and 2000 km long check-dams have been constructed to protect the dams from siltation. The dams vary in water holding capacities from 0.1 million m^3 to 350 million m^3. Many of these dams are being used for small-scale vegetable production. The SWC structures constructed from 2012 up to 2018 is shown in Table 4.15.

Table 4.15: Soil and Water Conservation Structures

Year	Hillside Terracing (ha)	Check Dam (m^3)	Stone Bund Terrace (km)	Soil Bund Terrace (km)
2012	3,554	203,681	573	432
2013	1,709	377,276	143	18
2014	3570	44,561	143	18
2015	1914	33,234	2,570	9336
2016	884	76,573	1,209	4,849
2017	762	6,644	7,287	17,076
2018	2441	5120	1,643	15,402

Source: MoA, 2018

Over the past decade, the State of Eritrea has shown interest to incorporate adaptation strategies to climate change in its comprehensive development plans. However, implementation and integration of these adaptation strategies and programs remained highly limited, though it is steadily growing. A major setback was the development plans were not streamlined to reflect the reality of future climate conditions. Thus, it is recommended to develop and implement adaptation strategies by focusing on the following intervention areas:

Water Resources Management: This includes water resource assessment, water supply augmentation and water demand management.

a) Water Resource Assessment

- Strengthen studies on the underground water and river basin potential of Eritrea for water resources development.
- Improve the assessment of current and future water needs across sectors
- Use climate models to assess the impact of current and future climate change impact

b) Water Supply Augmentation

- Prioritize options to increase the availability of surface and ground water (e.g. construction of small and large water harvesting structures, and water treatment plants).

c) Water Demand Management:

- Outline strategies to address anticipated water shortfalls.
- Outline strategies of frequent and intense droughts to reduce demand.
- Allocate water to more economically, ecologically sound and more efficient uses (within the water sector and across sectors); and
- Improve and prioritize water pollution reducing strategies.

Management of Extreme Events

- Outline and improve strategies aimed at increasing water resources development to cope up with frequent and intense floods arising from climate change.
- Categorize and incorporate drought and flood management strategies into short and long term strategies for prioritization purposes.

Supporting Environment

- Review and streamline the existing adaptation strategies and programs outlined by different sectors towards Climate Change Response strategies.
- Develop National Climate Change Response Strategy. In addition, the following options are recommended for the water resources:
    - Establish, upgrade and strengthen a national meteorological and hydrological information system. and upgrade the hydrological information system and network;
    - Increase storage capacity of water by building water harvesting structures;
    - Rehabilitate catchment areas through planting trees, soil water conservation and rain water harvesting measures to reduce runoff and to enhance recharge the ground water;
    - Improve urban water and sanitation infrastructure and utilize and plant crops with high water use efficiency;
    - flood protection through construction infrastructure to create barriers against flooding and water rise; and
    - Water quality through surveillance of ground water and surface water resources; improve forecasting of water resources and promulgate national water law.

Some of the climate-change induced hazards of water could be alleviated using the following adaptive measures

- Reducing exposure to flooding by restoring the function of flood plains in combination with a comprehensive land use planning;
- Introducing sustainable use of river basins to expand livelihood assets and to enhance economic development through use of new technologies such as drip irrigation, diversification of crops and agroforestry practices; and
- Dissemination of knowledge in the protection of water resources to empower the community in planning and decision making related to adaptation.

4.10.4 Health Sector

Climate variability negatively affects health status of population; and malnutrition reduces work force capacity. Parasitic and microorganisms caused disease are influenced by climate change. Thus, in the context of the Eritrean health system, adaptation strategies focus on the

provision of integrated health services. According to the Millennium Health Development Goal Report (MHDG, 2014), the Eritrean health system is based on the following strategies:

- Primary level of health services, with coverage of an estimated 2,000 to 3,000 people, provide basic health care package by empowering communities and mobilizing resources;
- Health Stations offering facility-based primary health care services to a catchment population of approximately 5,000-10,000; and
- Community Hospital is the referral facility for the primary health care level of service delivery, serving a community of approximately 50,000-100,000 people.

The indicators of the success in the health sector are the provision of clean water and sanitation, improved housing, ecological sustainability, building of roads and waterways, and enhanced roles for women. The MoH works in collaboration with various governmental agencies to improve the health system of the country to address malnutrition, feeding supply of ORs, and improving stool disposal. These are detailed in the following paragraphs.

Malnutrition: The MoH address malnutrition in different parts of the country including improving maternal nutrition; early breastfeeding, community based therapeutic feeding and supplementary feeding program. These approaches are effective in preventing diseases; and consequently the death rate. In 2018, the death rate was reported to be 0.8% with no case of deaths in the centres that run supplementary feeding programs.

Feeding and supply of ORS: Mothers are encouraged to supply their children Oral Dehydration Solution (ORS) as supplement to the normal feeding habit. Moreover, increased fluid intake of their children to reduce dehydration is promoted. These interventions minimize the adverse consequences of diarrhoea.

Stool Disposal: The proper disposal of children's faeces is important in preventing the spread of diseases; and is of particular importance as faeces are causes for the contamination in the household environment.

Adaptation Activities in the Health Sector

The following are important measures to control climate related diseases:

- Improved sanitation and adequate and safe water supply would reduce the prevalence of diseases. Adoption of Integrated Management of Child Illness (IMCI), allows a child visiting a clinic for one particular type of disease to be treated for other possible diseases.
- Use of ORS to avoid dehydration and reduce mortality rate in children less than 5 years.
- Increase community awareness on the impacts of climate change on health using leaflets and brochures in languages easily understood by the community.
- Equip the health research centres with adequate laboratory facilities and strengthen the research capacity and the national research collaborations related to climate change and health.
- Update the existing health policies and develop new strategies to meet national and international standards. There is also an urgent need to mainstream climate change and health units at various organizations and academic/research institutes.
- A multidisciplinary approach among professionals in the fields of health, agriculture, climate, and water resources need to be strengthened.
- Climate change cannot be addressed in a fragmented manner; hence it is important to create partnership among institutions to address climate change hazards.

Figure 4.18: Drug Administration for Schistosomiasis to community Members and School Children

4.10.5 Coastal Areas

Several adaptation activities have been carried out along the Eritrean coastal areas. These packages include the distribution of fishing gears, strengthening inland fisheries, mangrove reforestation and aquaculture. Fishery management measures are emplaced to avoid over-exploitation of marine resources and strengthen conservation and management efforts. Adaptation activities for the coastal areas of the country are described as follows.

Distribution of fishing gears and tools: The MoMR in collaboration with its partners such as IFAD has distributed different fishing gears to fishermen in the Northern and Southern Red Sea Regions. This is project is intended to enhance productivity among the fishing communities. So far, 5,722 fishing nets, 10,872 Poly ethylene rope, 61, 8750 floats, 2,628 Nylon multifilament twine and 1,344 Long line and its accessories were distributed.

Mangrove Reforestation Program: About 380 km of the Eritrean mainland and island coastlines is covered by mangrove forests. Of the seven mangrove species in the Red Sea area, *Avicennia marina*, *Rhizophora mucronata* and *Ceriops tagal* are found in Eritrea. The mangrove forest cover 70 km² (7000ha) mainly found in patches along the Eritrean coast and islands (State of the Coast of Eritrea, 2007). Since mid-1996, 'Manzanar Project' took mangrove reforestation initiative along the Eritrean coast. The project planted inter-tidal zones with mangrove plants to enhance inshore fisheries and restore the coastal environment. The project was also involved in an innovative method of growing mangrove trees in places where they never grew before. To date, the project has piloted a 20 hectare inter-tidal area in **Hirgigo**, planting half a million trees to rehabilitate severely overgrazed mangrove forests (State of the Coast Eritrea, 2006-2007).

Strengthening inland fisheries: To support fish consumption at a national level, the MoMR is extending its effort toward inland fisheries by stocking dams with species of fishes that mostly contain tilapia, cat fish and carp. The inland fishery potential is estimated to produce 100-150 tonnes per year. A total of 15 dams with higher potential for fisheries are selected for the programme to produce at least 74 tons of fish per year (GoE, 2016).

Coastal setback: A coastal setback is a horizontal distance along the coastline defined on the basis of coastal morphology, exposure and stability of the coastline, and nature of coastal resources. In Eritrea, the setback distance is meant to protect development investments such as roads, industries or tourism facilities by absorbing the impact of severe storms, the global sea level rise and the fluctuation of natural coastal processes. The proposed 100m setback will be applied from a defined line known as the horizontal setback datum (HSD).

Fishery Management

There are measures in place to avoid over-exploitation of marine resources, and habitat destruction. In this respect, the MoMR has outlined regulations for the proper management of fisheries such as closed seasons and closed areas, prohibited fishing methods and gear specification. The characteristics of fish and its size are addressed as part of the scheme for fisheries management. There are certain type fish species where people are not allowed to catch. In case these species are caught accidentally, they must be released immediately with the least injury to the water.

Recommended adaptation options for the coastal areas

In coastal areas, the following adaptation options are recommended to address the adverse effects of climate change.

- Integrated Coastal Zone Management Plan (ICZMP) should be considered taking into account short- and long-term concerns of climate change. Accommodation and protection methods should be implemented to protect coastal areas from hurricanes and sea level rise. The plan must address erosion in coastal areas, pollution, and habitat destruction.
- Coastal area afforestation and reforestation, particularly mangroves, could stabilize shorelines and prevents wave erosion. Mangroves provide habitat for wildlife and nursery for many marine species. It is therefore, extremely important that mapping and evaluation of mangroves and other coastal vegetation is considered in the ICZMP.
- The discharge of heated water from the cooling systems of power generation plants along urban settlements should be properly managed. The water should be cooled before reaching the marine environment.
- The development of appropriate institutional and technical capacities for the establishment of a comprehensive ecological, oceanographic and metrological information system is essential for developing an adaptive strategy of coastal areas.

CHAPTER FIVE

5 INFORMATION RELEVANT TO ACHIEVEMENT OF UNFCCC

5.1 Introduction

Subsequent to the realisation of its *d'jure* independence in 1993, Eritrea has been actively engaged in ratifying and signing global conventions and protocols to contribute its part to the global challenges facing our globe in general and climate change in particular. In this regards, between 1995 and 2005, it signed and ratified the following global conventions that have direct bearing on climate change. These are the i) the UNFCCC, ii) UNCBD and iii) UNCCD, iii) Kyoto Protocol and Doha Amendments, iv) Cartagena Protocol on Biosafety v) Nagoya Protocol on access and benefit sharing of Biologic Resources iv) Vienna Convention on the Preservation of the Ozone Layer vi) Stockholm convention on pesticides and organic pollutants and vii) Montreal Protocol on Substances that Deplete the Ozone Layer.

Its participation implementation of these global endeavours reflects the extent to which Eritrea views itself vulnerable to the impacts of climate change, and biodiversity depletion, and land degradation in at the local level and global environmental problems facing the globe. Further, the international conventions and protocols create a platform for the country to express its specific climate change challenges at the national level and enable it access to technical, scientific, and financial resources to support the implementation of climate change mitigation and adaption programmes and projects. In view of the abovementioned background, this chapter provides additional information that is relevant to the achievement of the UNFCCC objectives in Eritrea. It specifically describes

- steps taken to integrate climate change into the national polices,
- activities related to technology transfer,
- climate change research and systematic observations,
- information on research programmes,
- Information on education training, and public awareness,
- Capacity building, and
- Information and networking.

To facilitate the formulation and implementation of sustainable development programmes, non-Annex I Parties are encouraged to provide information on any step untaken to integrate climate change considerations into relevant social, economic and environmental policies and actions in accordance with Article 4, paragraph 1 (f), of the Convention. Cognizant those National reports are continuous; this section referred back to the INC and SNC and other relevant enabling activities to identify relevant information for the preparation of report.

5.2 Steps Taken to Integrate Climate Change into Social, Economic and Environmental Policies

In order to describe and analyse the steps taken to integrate climate change into the social and economic policies, the plan and strategy for the implementation of activities relating to integration of climate change considerations into social, economic and environmental policies and action***s*** based on previous and on-going interventions were thoroughly analysed. Based on the activities described below; information on activities relating to integration of climate change considerations into social, economic and environmental policies and action*s* are described. For that, the following activities were carried out or will have to be carried out

- Reviewed the National Rules of Procedure (Regulations)/mandates/acts/policies/road maps, in view of effective implementation of the Convention and its Kyoto protocol in Eritrea;
- Identified institutional arrangement/units to deal with climate change issues in key selected ministries and institutions, as a first step, along with the respective ToRs;
- Identified capacity-building needs for the new institutional arrangements/units in key selected pilot ministries mentioned below, and plans to organize and conduct targeted training;
- Proposes to establish an innovative national climate change fund in consultation with relevant institutions (Ministry of Finance);
- Proposes to Participate in the preparation of the first biennial climate change sectoral report by key ministries and organizations as input to BURs;
- The NCCWG will encourage and coordinate the planning, development and implementation of climate proofing of on-going and planned development projects and programmes in Eritrea;
- Encourage and coordinate the planning, development and implementation of new projects/programs for mitigation and adaptation of climate change through initiatives such as NAP, CDM, NAMAs and CTCN;
- Encourage and coordinate plan, the and adoption of national and sectoral policies supporting effective implementation of NAMAs, CDM, NAPs, GCF and CTCN in Eritrea;
- Encourage and coordinate mainstreaming of international climate policies into national, regional, sectoral and local polices, as appropriate;
- Review regularly the appropriateness and the adequacy of Eritrea's Nationally Determined Contributions (NDCs) for full and effective participation of Eritrea in the global climate change regime; and
- Prepared of the chapter on Integration of Climate Change Concerns into Sustainable Development Plans and Programmes to be included in the communication

5.2.1 Economic Policies

In 1994, the GoE prepared the Macro-Policy document (GoE, 1994) which outlines the background for Eritrea's national economic growth strategy. It includes the establishment of an efficient outward-looking market economy in which the government playing a proactive role to stimulate private initiatives. Being one of the major economic sectors, irrigation-based agriculture was identified key sectors targeted for development. In view of potential negative effects of some of the development activities, it specified the need for environmental impact assessment (EIA); Land use plan while implementation agricultural projects to avoid land degradation and conserve biodiversity. The policy underlines the importance of early warning systems in general drought preparedness in particular.

The National Economic Policy Framework and Program (1998 - 2000) provides a framework, for climate change adaptation strategy including the restoration, enhancement and preservation of Eritrea's ecology; prudent utilization of land, air and water resources; establishment of sound environmental standards; and introduction of sustainable land management practices; all of which form part of the project design and implementation activities.

Developed by the MoND, the Interim Poverty Reduction Strategy (IPRS) outlines the actions to be taken to improve crops' productivity, promotion of high value crops, expanding land under cultivation, increasing water availability by harnessing seasonal water flows and improving storage capacity. It list activities such as improving water conservation techniques at farm level,

improved pest control, reducing post-harvest losses, developing and disseminating of drought resistant, faster-maturing varieties, soil conservation measures (terracing, construction of check dams, planting/afforestation, and closure of areas to allow natural regeneration), improve soil fertility; protecting and restoring the rural environment and reorienting agricultural extension and research to respond effectively to farmers' priority needs and demands; assisting in markets and marketing, livestock production, developing and rehabilitating hatching centres (poultry) milk collection centres, technical advice and training, strengthening dairy associations and bee keeping (IPRSP, 2004).

National Food Security Strategy of Eritrea (FSSP, 2006) focuses on the following key issues. i) increase the agricultural production and productivity, ii) improving marketing of agricultural output; iii) improving national capacity to import food, iv) keeping adequate strategic reserve of food. It emphasises on using international food assistance more efficiently and effectively as a measure of last resort during emergency. The Household Food Security strategy encompasses increasing domestic production and farm income, nutrition, ensuring access to food or enhancing household purchasing power and promoting public assistance program including food for vulnerable and the poor (FSSP, 2006).

Although social, economic and environmental policies and measures constituted, thus far, in Eritrea may not have specifically targeted climate change as such, these policies, in one way or the other, touch upon climate change issues. In this respect, steps taken by the government to integrate climate change informally into social, economic and environmental policies have been summarized in the SNC under two headings including the sections of Integrated Social Services; and Economic and Environmental Policies. Now, Eritrea has realized that it is almost impossible to prepare the NCs on a continuous basis and to integrate climate change adaptation and mitigation into national development plans and policies in a formal, planned and coordinated manner without an official regulation/mandate/act/policy/road map, as appropriate, approved and implemented by the government. Therefore, there is an urgent need to establish a *"National Climate Change Working Group (NCCWG)"*comprised of high-level representatives from all relevant ministries and organizations. The primary task of the NCCWG should be to develop the National Rules of Procedure (Regulations) /mandates/acts/policies/road maps, as appropriate, for effective implementation of the Convention, its Kyoto Protocol, the implementation of the intended nationally determined contributions for full and effective implementation. Accordingly, the NCCWG should comprise of high-level representatives from the following ministries and organizations. Once the NCCWG with detailed ToRs on permanent basis is established; there is a need for identification of capacity-building needs for the NCCWG and conduct targeted training. The proposed members of the NCCWG are listed below.

Ministry of Land, Water & Environment;	Ministry of Transport & Communication
Ministry of National Development	Ministry of Agriculture
Ministry of Finance	Ministry of Foreign Affairs
Ministry of Trade & Industry;	Ministry of Energy & Mines
Ministry of Public Works	Ministry of Marine Resources
Ministry of Tourism	Ministry of Labour& Human Welfare
Representatives of NARI	NHERI

The NCCWG can be Co-chaired by the Ministry of Land, Water & Environment and the Ministry of National Development to harmonize national development and environmental issues by maintaining their specific roles and responsibilities in policy formulation.

5.2.2 Environmental Polices

The National Environmental Management Plan for Eritrea (NEMP-E, 1995) is the most relevant to the UNFCCC. The document which was prepared using participatory approach provides policy framework for action in environment. The plan laid out strategies for conservation and protection of natural resources which are of the strategic importance of the country. As part of national economic growth and development process, it intends to conserve the natural resources as well as maintaining the environmental quality.

As follow - up to the NEMP-E, the MoLWE in 2007 developed the NAPA; which is the most specific plan of action to climate change. In this document, agriculture, water resources, forestry, coastal environments, and human health were identified as the most vulnerable sectors. Small-scale farmers, agro-pastoralists and rural women living in the particularly drought-prone areas were the most vulnerable segments of the society. It identified several direct and indirect climate hazards driving climate change. In the agricultural sector, recurrent droughts increased temperature; decreased rainfall, increased hot night and days, change in rainfall pattern both spatially and temporally, torrential rainfall with heavy runoff and flooding, increased evapotranspiration due to increased aridity index, desertification and increased aridity, increased heat stress were the most important hazards for immediate action. Accordingly, the highest five priority adaptation programmes were the following:

- breeding drought and disease resistant crops,
- community-based afforestation and agroforestry,
- groundwater recharge for irrigation and wells,
- improved community-based rangeland management and
- Selecting livestock breeds such as sheep and goat adaptable to climate change.

Drought and unsustainable resource exploitation have negative impacts on Forest resources of Eritrea. To expedite the rehabilitation effort on degraded forest resources of the country, in 2006, the MoA issued the 'Forestry and Wildlife Conservation and Development Proclamation (GoE, 2006). Other relevant specific policies, strategies, and legal frameworks that have been integrated into the national environmental policies are i) the Ozone Depleting Substances (ODS), ii) Persistent Organic Pollutants, iii) Eritrean Environmental Protection, Management & Rehabilitation Framework (Proclamation N^{o} 179/2017), and iv) Environmental Protection and Management Regulations (Legal Notice N^{o}. 127/2017).

In view of its sensitivity to climate change the MoMR integrated the coastal area policy and fisheries legislation in the sector. The coastal policy for instance, defines the coastal area as 100 meters setback from a fixed geological feature near the coastal line. Multiple Use Managed Areas' is supposed in to favour many of the endangered species, the marine turtle. In addition, a core of national Marine Protected Areas (MPAs) networks and species conservation programme has been established with all technical and legal documents to declare two MPAs for the species and educational purposes (State of the Coast Eritrea, 2006 - 2007). The Fisheries legislation is promulgated to safeguard the sustainability of marine resource and protects the country's marine and coastal biodiversity. Two proclamations and thirteen legal notices are already adopted. The laws provide comprehensive coverage about the development and management of the marine sector in Eritrea; and cover a numbers of articles that are relevant to the protection and conservation of marine resources in the country. It refers to the establishment of marine protected areas. The Fisheries proclamations provide comprehensive coverage about the development and management of the marine sector include a number of articles relevant to the protection and conservation of marine resources, and the need for the establishment of marine protected areas.

Eritrea's coastal marine are vulnerable to climate change; and the MoMR in collaboration with GEF), carried out an Integrated Coastal Area Management (ICAM) project from 2004 to 2007 (ICAM, 2007). Accordingly the outcome of the project are as follows i) the establishment of the Eritrean Coastal Authority, ii) Integrated Coastal Area Management and iii) Mainstreaming Environmental Protection in the marine sector plan. Today, the MoMR requires appropriate environmental impact assessments; and effective enforcement mechanisms in compliance with the national standards.

Climate change has direct bearing on the health and wellbeing of the population in Eritrea. Accordingly the ministry issued policy guidelines for training, monitoring and management policy guidelines and environmental health document related to specific climate related diseases including malaria and Persistent Organic Pollutants (Tekie, 2019). In the health sector, the MoH issued the Health Policy (HP) (MoH, 2010). The policy, the course of action, is driven towards strengthening the community - based health services. It targets at gradually restructuring facility-based health services to make it much more responsive to people closest to their homes especially in the rural areas through upgrading the health centres to community hospitals. It strengthens decentralised health governance structures and improves the efficiency and the quality of care provided by hospitals. Simultaneously, it looks at restructuring of the existing health financing framework into an acceptable and appropriate financing structure that minimises catastrophic health-care expenditure; and impoverishment of care-seeking individuals. The policy provides ample space to strengthen health sector coordination at all levels to enable better participation of public or private sectors.

The WRD of the MoLWE has developed an Integrated Water Resources Management (IWRM) policy. The policy elaborates strategies, actions and activities to support an IWRM for sustainable economic development of the country (WRD, 2009). It recognizes water resource as a social and economic good; its allocation gives first priority to domestic use. The policy highlights the key role played by stakeholders in water management and development specific activities. Water Resources Proclamation emphasise on the need for water resource development as a base to achieve sustainable socio economic development and ecosystem stability (MoLWE, 2007).

Land degradation contributes to climate change; and it is one of the major problems affecting land resources in Eritrea. In response to the UNCCD, the MoA prepared NAP (MOA, 2002) to addresses environmental problems affecting the agricultural sector in country. The priority actions include cautionary expansion of agriculture into dry woodlands and pasturelands. It encourages community forestry with the aim of securing fuel wood and fodder plantations. It proposes adopting moisture retention, groundwater conservation and water recycling measures as core activities. Furthermore, its demands expanding fuel substitution programs using energy saving stoves, creating a national database to monitor, assess and evaluate land degradation and to use such information as input to early warning system and predict climate anomalies. Land rehabilitation and restoration of degraded areas is a daunting task and calls upon communities to participate in the processes. Hence, the action plans specified sensitisation of communities and hence increase awareness.

In Eritrea, different Land tenure systems co-existed in the past. These systems had varying degree of negative effects that hamper sustainable land management. In response to the fundamental effects of these tenure systems, the GoE issued the 'Land proclamation 58/94' which states that land is exclusively owned by the state in which all citizens and other legal body, regardless of their gender, religion or ethnicity have the right to use a piece of land

allotted to them for life. This proclamation was intended to develop sense of ownership from the part of users; and at the same time integration of sustainable land management (SLM) practices on farm land; and hence increase land productivity. This land law encourages long-term investment including the establishment of perennial crops, forest plantation, agro-forestry and building major soil and water conservation structures. The user is required to take good care of land allotted to him/her; and have the right of having in only one place in his village. As part of SLM project, it was implemented, as a model, in 5 villages of Zoba Maekel administrative zone in 2015. Right now, the 6 administrative regions of Eritrea are in the process of implementing the proclamation but found at varying extent.

In response to the UNCBD convention, the DoE of the MoLWE prepared the NBSAP. The plan is highly relevant to climate change. It recognizes three core areas on biodiversity: terrestrial, marine and agricultural biodiversity. In the strategy, Pollution management, Public awareness & education, sustainable use of natural resource; in-situ conservation (protected areas, information acquisition & storage, lien invasive species; ex-situ conservation, taxonomic knowledge and legal & institutional structure and capacity building are identified thematic areas deserving attention.

In 1999, the MoLWE prepared the National Environmental Assessment Procedures and Guidelines (NEAPG). The NEAPG requires adequate level of environmental assessment prior to the development and implementing projects to avoid negative environmental consequences. All proposed projects must pass through a screening process by relevant government agencies. The EIA guidelines have proved to be effective mechanism for ensuring an integrated approach for development. Specific and relevant policies, strategies, and legal frameworks are the following:

- The Ozone Depleting Substances (ODS),
- The national Biodiversity Strategy Action Plan (NBSAP),
- Persistent Organic Pollutants,
- Environmental impact assessment guideline (NEPAGA, 2009) to regulate the environmental impacts of development projects,
- The Water Law promulgated (WRD, 2012),
- Eritrean Environmental Protection, Management & Rehabilitation Framework (Proclamation Nº. 179/2017), and
- Environmental Protection and Management Regulations (Legal Notice Nº. 127/2017).

Drought and unsustainable resource exploitation negative impacts on Forest resources of Eritrea. To expedite the rehabilitation effort on degraded forest resources of the country, in 2006, the MoA issued the 'Forestry and Wildlife Conservation and Development Proclamation (GoE, 2006). This proclamation is effectively used by the forestry and wildlife authority.

Climate change has direct bearing on health and wellbeing of population in Eritrea. As policy, the MoH adopted policy of 'prevention is better than cure'. Accordingly, the ministry issued policy guidelines for training, monitoring and management policy guidelines and environmental health document related to specific climate related diseases including malaria and Persistent Organic Pollutants (Tekie, 2019).

Eritrea's coastal marine are prone to climate change. The MoMR in collaboration with the GEF), carried out projects during the period 2004 – 2007 (ICAM, 2007). As an outcome of the project, an 'Integrated Coastal Area Management (ICAM)' was drafted. As an outcome, the following were achieved: i) the establishment of the Eritrean Coastal Authority, ii) Integrated

Coastal Area Management and iii) Mainstreaming Environmental Protection in the sector plan. The effort from the Ministry also required appropriate environmental impact assessments and effective enforcement mechanisms for compliance with the national standards. The marine Proclamation also ensures that exploitation marine aquatic resource is consistent with sustainable economic, environmental and social conditions.

5.3 Development and Transfer of Environmentally Sound Technologies (ESTS)

Pursuant to decision 4/CP 7, its annex, and the implementation of Article 4, paragraph 5 of the Convention, non-Annex I; Parties are encouraged to provide information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies. In this context, Eritrea conducted preliminary GHG mitigation and adaptation technology needs and needs assessment. This aspect was reported as part of the SNC focusing on energy and agriculture sectors. The outcomes of the TNA were prioritized technologies for energy sector mitigation actions; and for agricultural sector adaptation actions. However, there are constraints for implementing the identified mitigation and adaptation technologies. There lack of understanding about the enabling frameworks and Technology Action Plan (TAP) including development of project ideas. Therefore, full-fledged TNA and transfer process needs to be initiated by initiating phases I, II and III of the TNC as well as elements of implementation. In this context, Eritrea needs to benefit from Convention's technology initiatives such as the Poznan Strategic and Long-Term Programme on Technology Transfer, CTCN mechanisms, GEF Programming (GEF Trust Fund), GCF, SCCF-B and LDCF. A plan and strategy for the implementation of activities relating to technology development, acquisition and transfer based on previous and on-going interventions should be revised and prepared.

5.3.1 Technology Needs Assessment

The negotiations under the UNFCCC create a framework to promote transfer of technologies. Technology transfer comprising i) technology needs assessment, ii) technology generation, iii) creating enabling environment iv) capacity building and v) mechanisms for technology transfer should be implemented. As a follow- up activity, a project profile has been prepared for implementation by establishing an institutional framework within the DoE, as central coordinating body. This institutional arrangement enables key actors and stakeholders to prepare awareness materials in local languages; and organize periodic sensitization and training workshops for targeted audiences through the mass media.

Eritrea has conducted GHG mitigation and adaptation technology needs and needs assessment for priority socio-economic sectors namely energy and agriculture. The objective of Eritrea's Technology Needs Assessment

5.3.2 Priority Technologies Needs of Eritrea

Pursuant to the implementation of article 6 of the UNFCCC, the National Capacity Self - Assessment (NCSA, 1999) identified education, training and public awareness as priority areas for interventions. According to the NDCs report to the UNFCCC, following technologies were identified (MoLWE, 2018). The Mitigation technologies and the level of implementation are enlisted in Figure

A. GHGs mitigation technologies

Table 5.1: GHG mitigation technologies and level of implementation

No	GHG mitigation technologies	Level of implementation
1	Geothermal Power	Not yet implemented
2	Combined Heat and Power	Not yet implemented
3	Use of CFL for Lighting	At household level
4	LED lumps	At household, Private and Public institutions
5	Industrial Energy Efficiency Improvement	Not yet implemented
6	None Motorised Transport (NMT)	In the plan
7	Increase Vehicle Load Factor Bus Rapid Transfer (BRT)	The NDC has paved a way for its implementation
8	Efficiency Improvement in Power Transmission and Distribution	In the plan
9	Use of Compressed Natural Gas (CNG) Retrofitted in Combustion Engine	Not yet implemented
10	Solar PVC and wind power	Under implementation in rural areas, Private and Public institutions
11	Dissemination of Improved Traditional Biomass Cooking Stoves	Adopted in rural areas about 360,000 household in the rural areas use *Adhanet*
12	Shift from Inefficient Traditional Biomass to Modern Fuel	In progress
13	Bio Fuels: Biogas and Ethanol	Biogas technologies have been piloted through SGP-small grant projects in Anseba, Debub and Maekel regions of Eritrea
14	Natural Gas Combined Cycle	Needs further assessment
15	Production fuel oil from Asmara Landfill Waste through Fractional Distillation	One plant installed in the landfill site in Asmara, but the outcome will have to be evaluated
16	Integrated Domestic and Commercial Hot Water Technology	Needs further study
17	Waste Composting Technologies	Composting technologies used/ not yet

Source: MoLWE 2018

The climate change adaption technologies and the level of implementation since the SNC are shown in Figure 5.2.

B. Climate Change Adaptation Technologies

Table 5.2: Climate change adaption technologies and the level of implementation since the SNC

no	Climate Change Adaption Technologies	Level of implementation since the second national communication
1	Climate Resilient Crop and Livestock Production	Climate and agriculture project in Zoba Anseba, Tslema in Zoba Debub (Project endorsed)
2	Crop & Animal Technologies	Crop improvement projects have been piloted. Pearl millet (Kona), sorghum (Bushuka) has been successful in Anseba, Gash Barka and Anseba.
3	Modern Irrigation Technologies e.g. drip systems	Water saving technologies: drip and sprinklers irrigation are introduced in the large - scale farms and to some extent at small and medium farms.
4	Soil and Water Conservation: Soil Bunds, Stone Bunds, and Check Dams Construction	Adopted throughout the country with the aim of conserving soils and improving land productivity, this technology has proven to be effective in doubling the yield of crops, recharge of underground water.
5	Improved Traditional Farming Practices	Pilot projects on climate and agriculture, sustainable land Management have been implemented in Zoba Maekel.
6	Research and Development	The NARI of the MoA undertakes research on Agriculture and natural resources management. To supplement undergraduate and postgraduate studies, the institutions of Higher education carry out adaptive and applied research on climate smart agriculture, crop and livestock production and soil organic carbon assessment. The research wing of the MoMR carried out a comprehensive study on 'integrated coastal areas management. The MoEM undertakes adaptive research on renewable energy and checking the efficiency of the improved stoves.
7	Drought Resistant and Early Maturing Crop Varieties & Improved Seeds/alternative Crop and hybrid varieties	Some research was carried out addressing these issues. For instance, HAC release three sorghum varieties
8	Modern Water Conservation Technologies (WCT)	The GoE undertook several effective WCT in which construction of water storage structures was encouraged. The approximate overall water holding capacity of the structures reaches 446, 000,000 M^3)
9	Conservation Tillage	With increase sensitization of the farming communities, the frequency of tilling the land has been reduced to three. Although this is inadequate, it in the right tracks.

This section provides information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how; the development and enhancement of endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies. The report specifically contain information on the technology needs assessment conducted, technology action plan, the data base on prioritized technologies, project ideas and programme for strengthening the human and institutional capacities of Eritrea to adopt and develop relevant technologies. This section

goes further to develop a project/proposal to develop and integrate environmental technologies effectively, efficiently and on a suitable manner. To that end, the following priority activities are proposed to achieve proposed projects.

- Establish National Technology Development and Transfer Technical Expert Group (NTDTTEG) with detailed ToR on permanent basis;
- Organize and conduct targeted training for NTDTTEG on how effectively and efficiently address all areas of technology transfer for adaptation and mitigation actions;
- Establish appropriate institutional arrangement for CTCN building on the NTDTTEG for effective participation of Eritrea in the CTCN process;
- Develop a project proposal to conduct full-fledged TNA and transfer process for adaptation and mitigation as part of the TNC to benefit from existing funding windows including the GEF Programming (GEF Trust Fund), the CTCN, the GCF and other GEF funds such as the SCCF-B and the LDCF;
- Enhance the capacity of the DNE for the CTCN in consultation with the CTCN and the TEC mechanisms to coordinate effectively the tasks of technology development and transfer in Eritrea; and
- Prepare report on development and transfer of environmentally sound technologies (ESTs) for inclusion in national reports.

5.4 Climate Change Research and Systematic Observation

5.4.1 Climate Change Research

Annex I Parties are encouraged to provide information on climate change research and systematic observation, including their participation in and contribution to activities and programmes, as appropriate, of national, regional and global research networks and observing systems such as the Global Climate Observing System (GCOS), Global Terrestrial Observing System (GTOS) and Global Ocean Observing System (GOOS).

Climate change research has not yet been well developed in Eritrea. To date climate change research is not fully integrated in the research and academic systems of the country. For instance, the Division of Renewable Energy Centre of the MoEM works on the development of renewable energy and technologies, energy efficiency improvement and conservation; The NARI MoA focuses on plant genetic resources (e.g. high yielding and drought tolerant crops) and livestock, animal breeding, soil and water conservation and post-harvest loss assessment; As part of the undergraduate and postgraduates programmes HAC conducts various research activities on various aspects of crop and livestock production, natural resources management including land degradation, biodiversity conservation and climate change; Colleges of Engineering and Sciences focus on various engineering aspects, biodiversity and oceanographic and earth related researches.

In view of the aforementioned background, much remains to be done in climate change research and systematic observation that could provide adequate and quality climate data and information for planning of climate change response measures. Although a number of research activities were carried out using limited resources and capacity; the research outputs are not organized in a way that responds to climate change. They are haphazardly found in different institution representing only very limited information about what is being done in the respective organizations. Despite the importance of scientific research and innovation, as tools, to address societal problems, there still exist scientific knowledge gaps in climate change. Thus, human and institutional capacity of higher education and the various research institutions should be strengthened to bring about effective, efficient and sustainable responses to climate change.

To a certain extent, there exists knowledge and technology, in the country, that can be used to mitigate climate change and reduce the vulnerability of communities to the impacts of climate changes. These technologies need to be adapted to local circumstances. For that to happen, there is a need for continuous innovation to find and test the suitability of technologies that best fit into Eritrea' environment and socioeconomic circumstance. Scientific research should meet certain qualities; and be relevant to the local needs. Quality could be achieved through engagement of experts as well as the use of valid data to generate the desired level of outcomes. Besides, research should explore possibilities for integrating exogenous knowledge with the modern knowledge system. Further, it is important for research and innovation system to be instituted to ensure that local need and land users are well linked. With regard to instrumentation, it is necessary to acquire up-to-date equipment and continuously upgrade them to move along with global or regional systems. Installation and calibration of the instruments used in the data collection and analyses should be seriously considered. While some calibrations are done at the local level; there might be cases regional or international assistance are required.

The limited research activities focusing on agriculture (e.g. climate adaptation related to crop and livestock), energy (e.g. energy saving stoves), marine resources (e.g. integrated coastal and island ecosystems) and natural resources management (e.g. soil organic carbon assessment and impact of smart agriculture) carried out by various institutions should be systematized in a manner that contributes toward the mitigation and adaptations of climate change.

Eritrea's involvement in research activities with bilateral and multilateral institutions is inadequate. Thus, there is a need for a comprehensive action addressing the gaps that need to be filled within given timeframe. Specific and relevant aspects of climate change related information is lacking. In GHG inventory, identification of mitigation activities, sector specific emission factors and activity data particularly for key source categories were lacking. Thus, research needs to be carried out to generate such information. Funding sources including the CDM should be explored to gather data, generate information and knowledge on the extent of greenhouse emission and reduction of deforestation and desertification.

5.4.2 Systematic Observation

There is no systematic climate observation system in Eritrea. Climate data collection and documentation is carried out by different institutions for their own purposes. In Eritrea, Systematic observation is shared among different institutions including MoA, the WRD of the MoLWE, Asmara International Air Port, etc. The roles and responsibilities of these institutions are not clearly defined; and a number of overlapping activities exist. Each of them established meteorological stations at selected sites to generate data needed for the respective institutions. The attributes such as the location, distribution, and type of instruments used, in each of these stations, do not satisfy the WMO standards. Hence, the coverage and quality of data is not complete. There is no adequate upper-air and oceanographic observations and other existing data need to be improved in terms of standardization and exchange of data. More importantly, there has been little downscaling of climate change projections for Eritrea and considerable uncertainties exist.

Besides the above mentioned facts, there is no upper-atmosphere and oceanographic observations instruments in Eritrea. Most of the climate prediction models are derived from remote sensing lack ground trothing and they are downscaled to reflect the situation on the ground. For that reasons, Eritrea's seasonal forecasts for agriculture is done with support from the IGAD Climate Prediction and Applications Centre (ICPAC) which is based in Nairobi.

ICPAC in collaboration with international organizations has undertaken human resources development targeting the climate prediction in the region including Eritrea. Participation in the global research and observation systems such WMO and Global Climate Observation System (GCOS) should be strengthened.

Irrespective of the institutional set - up, it is necessary to ensure that relevant climate data is gathered, processed stored/used on timely bases. There should be smooth flow of data from the various regions to a centrally managed system. Investment needed to upgrade the communication and information technology to satisfactory to support systematic observations.

The above mentioned facts clearly demonstrate that extensive data gaps exist with respect to assessing impacts, and developing adaptation strategies. The Eritrean capacity to analyse climate change trends is underfunded. Downscaling exercises have only been conducted in the broadest terms. Asmara International Air Port which is currently considered to be providing meteorological services does not yet have an adequate database. Observations are not always systematically conducted and information received from the regions is not computerized, and may be unreliable. This means that climate risk information, in terms of climate observations and projections, is scanty and poorly understood by policy makers and civil society. An in-depth assessment of the potential changes in climate from national to local scale has yet to be undertaken.

Climate services are increasingly necessary because of the rapidly growing climatic impacts. Therefore, there is a need to improve systematic observation and the sharing in a coordinated manner by establishing a National Meteorological, Hydrological and Oceanographic Agency (NMHOA) to enhance adaptation responses. The relevant activities would include increasing the number and standard of atmospheric and hydrological observing stations and installing new oceanographic observing stations, developing downscaled projections for the region and establishing a National Climate Change Research and Systematic Observation Technical Expert Group (NCCRSOTEG) for facilitating activities including National Communications.

Besides, Eritrea's participation in and contribution to activities and programmes of national, regional and global research networks and observing systems is inexistent. Thus, there is a need to enhance Eritrea's participation to benefit from their activities and programmes. Matters emerging from the 2010 updated Global Climate Observing System (GCOS) implementation plan and related activities can be consulted for identifying priority areas of participation.

To solve the problem, it is important to undertake a thorough assessment of the status of the implementation of research and systematic observations in Eritrea. This can be done based on previous and on-going programmes including action plan for development of national hydro meteorological and oceanographic services. It is equally important to develop a strategy for improving climate services in the country. In this regard, it is anticipated to produce a study report containing information on climate change research and systematic observation, research relating to programmes containing measures to mitigate climate change and programmes containing measures to facilitate adequate adaptation to climate change. To that end, the following are plausible activities.

- Establish a National Climate Change Research and Systematic Observation Technical Expert Group (NCCRSOTEG) with detailed ToR on permanent basis;
- Organize and conduct training for the expert group specifically on research methodology including quantitative approaches;

- Establish a National Meteorological, Hydrological and Oceanographic Agency (NMHOA) with clear mandate and responsibility;
- Develop the capacity of meteorological, hydrological and oceanographic observations through iterative training, equipment and institutional development;
- Develop National Climate Service Action Plan (NCSAP) by participating in the Global Framework for Climate Services (GFCS);
- Enhance partnership with UN agencies and other international organizations which have comparative advantage in climate services;
- Develop the capacity for regional climate downscaling by partnership with Regional Climate Centres; and
- Write report on Climate Change Research and Systematic Observation as part of the fourth national communication.

5.5 Education, Training and Public Awareness

Human resource is the main asset of Eritrea; and the country needs to promote education, training and awareness to address climate change and variability at different levels. Today, there is increased public awareness about climate variability. Many people sense natural hazards such as droughts and torrential floods; and the damages inflicted on agriculture and physical infrastructures in many parts of the country. On the other hand, there are people who do not have a clear distinction between climate change and seasonal climatic variability.

5.5.1 Education

The running school curricula which have been into effect, during the last three decade, require period revision not only to update its contents but also integrate global issues such as climate change. The Department of General Education and School Curriculum, MoE works in collaboration with DoE to prepare environmental topics and integrate them into new school curriculum. The DoE has assigned the tasks to the Climate Change Unit (CCU) to take the lead and prepare relevant environment materials into the school curricula. The CCU unit has already taken concrete steps to introduce relevant climate change topics at various levels of the educational system in all relevant subjects including geography, biology and agriculture. In this context, 15 student hand books, at all levels of school have, been prepared.

The MoLWE was actively engaged in reviewing school curriculum to ensure that climate and environmental issues are mainstreamed in the country's educational system. This endeavour is sought to appropriately integrate climate change issues in the training programmes at various levels of the educational system in the country. Such step encourages training institutions to integrate climate change topics into their training programmes; and eventually strengthen the human resources of those institutions involved in the implementation of climate change.

Restructuring of higher education took place in 2004. The higher education facility which was confined to one University expanded to seven autonomous higher education institutions. The Colleges of Agriculture, Marine Science and Technology, Eritrean Institute of Technology, Business and Economics, Medicine, Heath Sciences and Arts and Social Sciences were strategically located in different administrative regions of the country. Over the last 10 years, more than 31,000 students graduated at diploma and B.Sc. /BA Degree levels. Some of the colleges offered postgraduate programs, while more than 584 were sent abroad to pursue their studies at Masters and PhD levels.

Vulnerable farmers and pastoralist in Eritrea lack systematic advance warning about climate risks such as dry spells which hampers their ability to build adaptive capacity. Although much

has been done in education, training and public awareness, nothing is known about the extent of implementation of article 6 of the UNFCCC convention that deals with this aspect. Hence, there is a need for an assessment of the status of the implementation of Article 6 (education, training and public awareness) based on previous and on-going interventions and development of a plan and strategy for improving the situation. This would clarify, in a measurable manner the information on activities relating to climate change education, training and public awareness conducted or envisaged. Such report would help in availing concrete information for the national communication. In this connection, the following activities are proposed for achievement of the desired output and outcome.

- Establish National Education, Training and Public Awareness, Information Networking and Capacity Building Technical Expert Group (NETPAINCBTEG) with clear ToR on a permanent basis;
- Organize and conduct training for the NETPAINCBTEG;
- DoE, coordinate, MoE, NHERI and mass media to promote periodic CC awareness and training in local languages and revise the curricula at elementary, secondary and tertiary levels;
- Promote and facilitate public access to information on CC, and its effects though various means;
- Revitalize and implement a national early warning system to accelerate the provision of user-orientated climate services: seasonal outlooks, drought and flood advisories to allow for a more proactive approach to reducing risks; and
- Prepare user manuals/ on climate change education, training and public awareness.

5.5.2 Capacity Building

The major synergistic constraints and opportunities for capacity building have been identified in 1999, during the NCSA process. Specific needs and priorities in the climate change thematic areas were included. The following are broad categories:

- Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessments into sustainable development programmes and implement climate response activities;
- Strengthening existing national research and training institutions;
- Instituting and strengthening the capacity of meteorological, hydrological and oceanographic services; and
- Enhancing public awareness, training and education.

Although these capacity needs were identified years back, the status report on the implementation of capacity building decisions of the COP under the Convention and its Kyoto Protocol in Eritrea based on previous and on-going interventions and to develop a plan and strategy for improving on the situation needs to be revisited. Thus, a comprehensive report containing information on steps taken to implement capacity building activities at national, sub-regional and regional levels as contained in the capacity building framework for Non-Annex I Parties (Decision 2/CP. 7) should be prepared to have up-to-date information. In this regards, the following priority activities are proposed:

- Review all activities conducted on capacity building and assess information contained in previous national communications, NEMP-E, NAPA, NCSA and the Stocktaking and Stakeholder Consultations conducted in preparation of the previous NC;
- Determine all capacity building gaps and data and information requirements of Eritrea not only to prepare its national communication on continuous basis but also enable the country implement other Climate Change Convention and its Kyoto Protocol issues;

- Develop a programme and strategy for the implementation of capacity building needs for the implementation of the Convention and its Kyoto protocol in Eritrea;
- Develop and strengthen the institutional and human capacity of the Climate Change Focal Point and Climate Change Unit under the DoE of the MoLWE;
- Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessments into sustainable development programmes and implement climate response activities;
- Strengthening existing national research and training institutions by providing funds to carry out research on climate change;
- Instituting and strengthening the capacity of meteorological, hydrological and oceanographic services;
- Enhancing CC public awareness (press and TVs), training and education; and
- Prepare a report on the status of capacity-building to mitigate and adapt to climate change which would be integrated into the national communication reports.

Capacity building is one of the key strategic elements to build, develop and strengthen the economic development of Eritrea. Its contribution to the achievement of the objective of the Convention through preparation and implementation of the provisions of the Kyoto Protocol is significant.

A. **Short-term training**: The MoLWE, in collaboration with national and international stakeholders, carried out short-term training sessions to build human capacity to respond to the challenges of climate change. On-job training modules focussed on upgrading competencies and specific tasks related to climate change were offered. Table 5.1 presents opportunities for in-country and out of country training programs (Table 5.1).

Table 5.3: In-Country and out- Country Training Opportunity

Country	**Themes/Topic of training**
Eritrea	Earth Observation Receiving Stations: System Administration and Earth data Observation Data Application'
Eritrea	Environmental Monitoring and Hazards Assessment Using Earth Observation & GIS"
Eritrea	GHGs inventory and mitigation modelling using GCMO models. This short term training activities helped the technical expert group to successfully prepare the NDC.
Eritrea	Short-term Training carried out on the application models (e.g. WEAP, LEAP)
Algeria	Consultative group of Experts (CGE) hands on training workshop for Africa region on institutionalisation of data management for GHGI held in Algeria;
Tanzania	East Africa Regional MRC network first training and peer review held in Tanzania
Kenya	Africa Regional Training Workshop on the Building of Sustainable National GHGI Management system; and the 2006 IPCC guidelines for national GHGI
Morocco	Central and North and west Africa workshop on national CC report, project management and regional MRV network development'

B. **Specific Needs Options and Priorities for Capacity Building:** Based on Annex VIII of the convention, which refers to the specific needs to strengthen climate change, mitigation and adaption measures; the constraints and opportunities for capacity building have been identified. The NCSA process (MoLWE, 1999) identified education and capacity needs as a major setback. Although the level of environmental awareness has improved, over the past

years, in all of the administrative regions of the country, their capacities for environmental management, in general, and climate change response in particular, still remains limited at various local levels. Hence, the regional governance structures needs institutional capacity building to address environmental and climate change concern and prevent the impacts of climate change at the grass root levels.

C. **South - South Cooperation:** Though the potential for South-South cooperation to enhance capacity building is essential, its opportunity has not been fully exploited. In view of the recent positive development between the neighbouring countries in the Horn of Africa, setting a strategy to enhance cooperation is the first step in the right direction. The cooperation would guarantee and ensures that climate change matters are well grasped and understood. It would not only maintain the current north -south partnership but also initiate and promote south-south partnership among countries in the region.
D. **Building of Stakeholders' Involvement:** In the Second national Communication (MoLWE, 2012), Eritrea has developed guidelines that allow stakeholders to, effectively, engage in the various climate related activities and projects. The stakeholders participate in critical climate change issues focussing on measures for mitigation and adaptation. Thus, the level of involvement of stakeholders is in recognition of the fact that climate change is a cross-cutting issue across all activities covered in the various sectors. Thus, all stakeholders involved in climate change mitigation and climate adaptation projects and programmes are involved; and their involvement is critical to effectively, efficiently respond to the impact of climate change on a sustainable manner.

The MoLWE invited various stakeholders to participate climate change consultative process. The initiative was taken to establish Technical Expert Working Group (TEWG) in the preparation of the TNC and BUR1. Members of the task force forward their strategic plans and assessed how these plans fit within the framework of UNFCCC. Reprehensive of the key stakeholders participated in climate change public dialogue. In 2015, the INDC which later formulated as the NDC were prepared in consultation with taskforce representing the ministries of agriculture, marine resources, forestry and wildlife authority, energy and mines, trade and industry and, health and local. The on-going dialogue and negotiation and policy dialogue is expected to assess the viability of adaptive and mitigation measures. Together, the research community and stakeholders can develop adaptive and mitigation strategies by combining scientific or factual information with local knowledge and experience of change and responses over time too.

Traditional community based climate change adaptation strategies are widely used in Eritrea. However, the gap between research, extension and communities should be narrowed down to facilitate smooth flow, and exchange of information between the various stakeholders. There is an on-going discussion among researchers and stakeholders to generate and develop adaptive mitigation strategies. This step explores possibilities for integrating indigenous practices with modern scientific knowledge; as there are increased tendencies to assess and accept merits of traditional coping mechanisms in the country. Hence, there is a need for increased dialogue to enhance the involvement of stakeholders.

E. **Status of Activities Related to Coordination and Sustainability:** Focal points and national coordinating entities lack capacity to ensure effective coordination at the country and regional levels of capacity-building activities which compromise the development and sustainability of capacity-building activities. Hence, capacity-building for national focal points is imperative. To that end, a number of workshops and seminars were carried out on climate change and gender main streaming.

F. **Workshops and Seminars:** Ssince Eritrea submitted its SNC in 2012, a number of workshops were held, varying in duration. These workshops were carried in and outside of the country to offer training on specific aspects of climate mitigation and adaptation. These trainings were part of the capacity-building activities conducted under the implementation of NAPA, the INC and SNC. A number of capacity building activities to implement projects across all components by engaging relevant stakeholders to enhance national capacity were held. The GoE in collaboration with international partners prepared a number of short-term (e.g. full size) projects aimed at tackling challenges of climate change. Among these include the Water and Agriculture in Anseba, the SLM in Maekel region. Mainstreaming climate change consideration in Tslema in Debub, and the Rora-Habab and Nakfa in the Northern Red Sea region are in progress.
G. **Gender Mainstreaming:** Climate change affects the most vulnerable segment of the population including women headed households, children and the elderly. The National Union of Eritrean Woman is engaged in sensitising women on how to cope - up with the adverse effects of climate variability. In this direction, there are community-based activities aimed at empowering women. A good example is the distribution of energy saving stoves to women which reduces the time spent in the collection of fuel wood for domestic of energy saving stoves to households and reduces the GHG emission improves the energy consumption.

5.5.3 Public Awareness

Despite progress in general awareness, much remains to be done for improvement in public education and awareness. Public awareness communication strategies should be prepared to avail climate change issues accessible to the general public. This would enhance public awareness and enhance understanding about climate change and reduce vulnerability to the adverse effects of Climate Change. Adult education, training and public awareness facilitates capacity building to participate and implement effectively the commitments to the UNFCCC. It is a means used to drive support for actions about climate change issues nationally, and eventually encourage support for government policies. It is critical measures that influences change in habits that have adverse effects on climate change.

Although climate change is a reality, still there exist scepticism about its impacts on the economic, social and environment. There remains insufficient awareness among people and key stakeholders concerning the impact of climate change and adaptation options. Hence, besides awareness building, at the local level, it is equally important to involve high-level policy makers that will not only open policy dialogues among stakeholders but also facilitate integration of climate change issues into national development policies. Within the local administration, *ad-hoc* environment committees are established to organize and participate in environmental awareness raising and training of zone and local actors on climate change. Some of the related issues include Multilateral Environmental Agreements (MEAs), UNCCD and UNCBD implementation at that level. Specific issues addressed are described in the following paragraphs.

Greening Day: Since 2006, the Forestry and wildlife authority organises a national greening day in which all stakeholders including government officials are invited. The aim of such occasion is to appraise the activities carried out on i) afforestation/reforestation activities, protected areas establishment to expand forest area and wildlife, iii) establishment of green clubs, iv) introduction and promotion of energy saving stoves in the country.

International Water Day: The MoLWE launches a number of environmental public awareness campaigns using various means including interviews with experts and reportages. The packages include video shots on environmental challenges and possible solutions. Information on global and local climate, in general and information on mitigation and adaption to climate change in particular, are broadcasted in TV and radio programmes. Besides Climate change specific documentaries are shared from international platform enhances public awareness.

Production of Environmental Booklets and Posters: The Biodiversity Report (2019) indicated that 750 booklets, 25 newsletters, 170 posters, 5 documentary films, 20 TV spots, and 25 radio programs were produced and disseminated in local languages. The national News letter "Haddas Eritrea", publishes article entitled 'The Environment' on regular basis in which the threat posed by climate change are covered.

5.6 Information and Networking

Nowadays, information and networking should not be taken too lightly for a number of reasons. Consequently, Eritrea's participation in and contribution to global and regional information and networking should be enhanced. As thisis is a cross cutting issue requires multilateral dialogue among stakeholders at national, regional and global levels. By and large, information and networking in Eritrea could be improved. This might be understatement of the situation on the ground; and there is a need for a comprehensive identification, inventory and prioritization of regional and global centres for information and networking in line with the national needs. In all cases, access to, and use of, information technologies for information exchange needs reliable intranet and internet access; and availability of Clearing House Mechanism (CHM). Thus, the issue at hand is how to provide, as complete as possible, information on Networking, Knowledge and Information sharing for implementation of the UNFCC Convention. Preparing a report containing information on the efforts of Eritrea to promote networking and information sharing with other countries and regions, and how it utilizes and contributes to global and regional knowledge networks, as input for the national communication is required. To that end, the following priority activities are proposed for achievement of the desired output.

- Assess the information technology needs of the country in the area of climate change and other environmental areas;
- Develop and use a Climate Change Clearing House Mechanism (CHM);
- Promote networking with NCSP, UNEP, UNDP, FAO, GCOS, GTOS, GOOS, GFCS, CTCN, etc.
- Conduct comprehensive inventory and prioritization of regional and global CC information centres; and
- Write a report on activities on information and networking as part of the TNC.

While some of these activities have been already done, others require long term and through investigation on a continuous basis.

5.6.1 Efforts to Promote Sharing Among Within Countries and Regions

The need for information sharing within the country and among other countries has been emphasised during the SNC. Since then, not much has been achieved in this respect. The secretariat needs to establish a regional mechanism to share information on a continuous basis. The strategy must focus on creating a regional platform for countries to share information created by themselves instead of organizing and conducting business as usual trainings and workshops. Countries might be invited to present their works in different areas such NAPA, NCs, FNR -Rio, AF concrete projects and programmes, SCCF project activities, and NCSA as

appropriate to the respective countries. Each participating country might be required to present, at least, one area of work representing country including; how to prepare project documents as per the eligibility criteria of a particular fund. At national level, focal points should organize platforms to link regional and sub-regional officers and policy makers at regular interval. In this area, the secretariat needs to establish regional mechanisms to share information on a continuous basis.

5.6.2 Participation In and Contribution to Information Networks

Despite the efforts of the UNFCCC secretariat's effort to establish regional hubs for sharing of experience and information; such effort is still at its infancy stage. So far, the country participated in a number of international fora; and contributed to information networks of regional and international initiatives. These are i) Africa Adapt knowledge sharing platform, ii) Global Climate Change Adaptation Network. Thus, the regional cooperation should be strengthened to create regional platforms where countries share timely information on regular basis. This would enhance south – south cooperation. In as much as possible, workshops and trainings should be arranged in Africa to create regional hubs to put developing countries on equal/comparable footing with the developed countries. This would not only enable developing countries such as Eritrea to present their programs and action plans that facilitates sharing of information and resource in a more appropriate manner. The DoE, as a national focal point, is ready to organize platforms linking regional and sub-regional experts and policy makers to present specific area of activity pertinent to climate change.

5.6.3 Access and Use of Information Technologies

Nowadays, fast, affordable and reliable communication systems are critical for sustainable economic development. This is because of the fact that technological advancement and human needs are changing faster than ever before. Hence there is need for updating old knowledge systems and acquiring new knowledge and skills to respond appropriately to the problems climate change challenges. Despite Eritrea's investment in Information technologies, much remains to be done in this field. Indeed, it has substantially invested in the development of its telecommunications and postal services. The country is now connected domestically and internationally by both telecommunications and postal services. All of the major cities can be accessed through postal and telephone services; and efforts are underway to provide access to telephone services throughout the country.

Internet services and the installation of GSM - 900 with the capacity of 400,000 users have improved the access to telecommunication services. Since 2009, the CDMA-WLL fixed network is operational; and enhanced access and reliability of the telecommunication system in Eritrea. In spite of these accomplishments, the transmission of large volume text, voice and video data is still limited by the absence of inadequacy of broadband fibre optic infrastructure system.

CHAPTER SIX

6 CONSTRAINTS AND GAPS, AND RELATED, TECHNICAL AND CAPACITY NEEDS

6.1 General Background

As non-Non-Annex I Parties member, Eritrea is required to describe any constraints and gaps, and related financial, technical and capacity needs, as well as proposed and/or implemented activities for overcoming the gaps and constraints, associated with the implementation of activities, measures and programmes envisaged under the Convention. Eritrea has undertaken a number of climate change adaptation projects and strengthened policy frameworks in favour of climate change mitigation and adaptation works. However, there are still gaps; and constraints that hinder effective implementation of mitigation and adaption projects and programmes.

The preparation of the TNC of Eritrea builds on the INC and SNC. Since the SNC in 2012, much has been gained during the pasts eight years. The past reports facilitated in described important climate change problems that deserve immediate attention in various sectors. On the other hand, there are still a lot of challenges that Eritrea is facing with regards to sustaining the capacity that has already been built and ensuring sustainable preparation of the national communications for the future. This section is intended to present the major constraints, gaps and related financial, technical and capacity needs. It also reviews the support received from international partners for climate change adaption and mitigation; and the way such support programmes have met the specific needs and concerns of Eritrea.

6.2 Financial Constraints

6.2.1 Financial Constraints to Report National Communications

Eritrea has faced a number of financial difficulties in the course of implementing its reporting commitment under the Convention. In this regards, one of the difficulties was the inadequacy of fund to cover priority areas identified under the components of the INC and SNC national communication. Therefore, there is a need to enhance the funds if meaningful preparation and improvement of national communications is to be achieved on a continuous basis.

Preparation of the national communications, in Eritrea, is done on an ad-hoc basis; and most of the work is contract out to consultants. Yet, the enhancement of the reporting requirements demands for advanced reporting standards. For that, permanent institutional arrangements need to be emplaced to enable sustainable reporting while guaranteeing quality. Consequently, there is a need for Eritrea to establish permanent institutional framework which would be responsible for the preparation of the future national communications. The national climate change policy highlights the need for a sustainable institutional framework for the national reporting under the UNFCCC; and the DoE, the focal point, takes the responsibility to ensure the recruitment of adequate and skilled personnel with the aim of sustainable reporting. Undoubtedly, such arrangement will facilitate the capacity building of public institution in general and those working in the DoE to ensure timely and continuous improvement of the national reports. To that end, the main challenges of the present set-up are the following:

- Inadequate capacity of the coordinating institution ,
- Lack of institutional and technical capacity for the different thematic areas of the national communication i.e. GHG inventory, GHGs inventory, Mitigation assessment and Vulnerability and adaption.

- Shortage of national expertise, particularly in GHGs mitigation assessment, vulnerability and adaptation assessment and GHG inventory;
- Unavailability of personnel from collaborating/ stakeholders institutions; and even lack of technical capacity due to over schedule workloads;
- Lack of motivations and derisory incentives to maintain permanent team members to work continuously to improve reporting of the national communication.

A. Financial Constraints to Implement NAPA

Eritrea has prepared and submitted its NAPA to the COP in 2007. However, most of the urgent and immediate adaptation needs identified therein have not yet been implemented, partly, due to financial constraint from the Least Developed Countries Fund (LDCF). Eritrea's various expectations from the climate change negotiation have not yet been materialized hindering the country's progress in complying with its commitment under the Convention. Eritrea has favourable environmental policy and legal framework at the national level. It has prepared the National Environment Management Programme- NEMP-E (GoE, 1996), which serves as a blue-print for a holistic environmental management embracing climate change, land degradation and dwindling biodiversity. It addresses the major environmental and development issues confronting Eritrea (Annex IX). These issues are grouped into those with direct bearing and indirect bearing on human health and wellbeing. Other environmental and development issues are categorized into natural resources, socioeconomic, institutional and environmental affairs. Although many of the projects listed in the plan are partially or fully implemented; some remain pending due to financial constraints or capacity gaps.

In 2007, the NAPA identified six coping strategies and potential adaptation projects through a consultative work with the stakeholders (MoLWE, 2007). These strategies cover agriculture, livestock, forestry, water resources, marine and coastal zone; and public health sectors. NAPA is a platform of action, in this regard, which represented the highest priority interventions as determined through a structured Multi-Criteria Analysis (MCA) process involving a broad range of stakeholders.

B. Pilot Project

The 'Climate Change Adaptation Programme in Water and Agriculture' was implemented in Eritrea as a pilot project between 2013 and 2018 with a grant from GEF to the amount of US$ 6.5 million (UNDP, 2019). The project aims to promote food security in Eritrea through ecologically sustainable and climate-resilient improvements in the agricultural sector. It also aims at increasing community resilience and adaptive capacity to climate change through integrated water management and agricultural development approaches in various regions of the country. The main beneficiaries of the programme were small-scale farmers, pastoralists, agro-pastoralists and rural women, who are vulnerable to the impacts of climate change. The implementation of the programme, being part of a bigger process under the National Adaptation Programmes of Action (NAPAs) of the country, represents one of the five prioritized course of actions in the agriculture, forestry and water sectors. While this programme is funded under the Adaptation Fund (AF), two other projects will be funded by the Least Developed Country Fund (LDCF). The pilot project has showed the following satisfactory results.

- Increased water availability through groundwater recharge & rainwater harvesting, irrigation, and soil and water conservation measures;
- Enhancement of climate-resilient agricultural and livestock production;
- Improvement of climate risk information used to raise awareness of and enhance community preparedness to climate hazards; and

- Establishment of knowledge management system; and knowledge management activities.

The above outcomes came into effect as a result of a successful implementation of the planned activities including the construction of diversion structures, irrigation technologies, structures related to micro-dams and soil and water conservation works. Climate-resilient agricultural technologies, methods and trainings were provided to the farmers in what is now called the Minimum Integrated Household Agricultural Package (MIHAP). Traditional improved fuel-efficient stoves and solar panels are part of MIHAP that provided diversified livelihood options and opportunities to many farming households in the project area. Many farmers have appreciated the adaptive capacity and production systems that resulted in increased crop and livestock productivity. As a result, there are possibilities for up scaling lessons learned as a viable adaption strategy to climate change.

A) Financial Support: Eritrea, in collaboration with the global partners, has exerted tremendous efforts to tackle climate change impacts by mobilizing its own human and material resources. The outcome in general is commendable particularly in areas related to soil and water conservation, area closure and expansion of the renewable energy sources such as the traditional energy saving stove (*Adhanet*). Nevertheless, financial constraints still hinder climate change mitigation and adaptation measures at a national, zoba and sub-zoba levels. In this connection, fiscal management reforms might be required to improve the overall budget formulation and reporting mechanisms.

B) Climate Funds: Eritrea made significant strides toward implementing a number of climate change mitigation and adaptation projects. GEF funded a number of these projects including the INC, SNCs and now the TNC. It also benefited from the Least Developed Countries Fund (LDCF) provided USD 200,000 for the preparation of NAPA; the Adaptation Fund (AF) USD 4,000,000.00 for the implementation of an adaptation programme. Although various sources of funds are allocated from Clean Development mechanism (CDM), Special Climate Change Fund (SCCF), and Strategic Priority on Adaptation Fund (SPA), they will have to be materialised in the course of time when and if the requisite capacity are built. Although the contributions of GEF funds have been evaluated positively, they were inadequate because most community-based projects required additional follow-up funds to up-scale the technologies to other areas.

6.2.2 Identification and Utilization of Support Programmes

The level of financial support from annex II parties, the Global Climate Fund (GCF) and the Global Environment Facility (GEF) was inadequate to bring about a significant result in reversing the impacts of climate change. The shortage of financial support can be analysed from the perspectives that the number of climate change projects in the country is small because climate change is viewed as a global issue linked with the emission of GHG from the industrial countries. In the developing countries, the immediate environmental problems are related with land degradation that attracts less financial resources. Land degradation like that of climate changes deserves sufficient attention while preparing projects and allocating funds. Total budget allocated to the amount of 64,183,600 USD came to Eritrea from two sources. These are contributions from local communities and from the Global Environment Facility (GEF). Various agencies including the United Nations Development Program (UNDP), United Nations Environment Program (UNEP), and International Fund for Agricultural Development (IFAD) are also involved in these projects. The following list presents projects relevant to climate in Eritrea:

- National Biodiversity Strategy, Action Plan and National Reports,
- Conservation Management of Eritrea's Coastal, Marine and Island Biodiversity,
- Assessment of Capacity Building Needs for Biodiversity, Participation in Clearing House Mechanism and Preparation of Second National Report,
- National Capacity Self - Assessment (NCSA) for Global Environmental Management
- Enabling Activities to Facilitate Early Action on the Implementation of the Stockholm Convention on POPs,
- SIP-Sustainable Land Management Pilot Project,
- Eritrea: Prevention and Disposal of POPs and Obsolete Pesticides and Operationalization of Protected Areas Management Systems of Eritrea
- Wind Energy Applications,
- Development of a National Adaptation Program of Action (NAPA), and
- Climate Change Adaptation Programme in Water and Agriculture.

6.2.3 Level of Financial Investment in Climate Change

A total of 22 projects were executed in Eritrea with the support from GEF to the amount US$ 433,883 and in-kind contribution from local resources equivalent to US$ 1,522,323. Since 2010, the GEF Small Grants Programme (SGP) received a financial support of US$ 1,034,998 for various projects. A large share of SGP fund was allocated to support Land Degradation projects (US$ 607,316), while climate specific projects accounted for a small share only suggesting the need for preparing climate specific projects in the future. Beside Land Degradation projects, other programs including Climate Change Mitigation (US$ 197,017), Multifocal Area (US$171,186) and Biodiversity (US$59,479) were also supported. In addition to the above full-scale projects implemented by government institutions, community based activities were also carried out during the period 2009-2019. Out of the 28 small-scale projects, seven were climate-specific implemented in *Anseba, Maekel, Keih - Bahri,* and *Debub* regions.

6.2.4 General Needs

Generally, Eritrea‘s capacity needs are related to its specific needs and concerns arising from the adverse effects of climate change (Article 4. 8). At present, even though the heightened environmental awareness and the efforts made to adopt better natural resources management and to protect the environment, Eritrea’s overall environment remains fragile and a matter of great concern. Nevertheless, specifically what are the general needs of the country that require immediate attention? To respond to the question posed, this section provide, as complete as possible, information on constraints and gaps, and related financial, technical and capacity needs of Eritrea in the implementation of the Convention and its Kyoto protocol. The technical working group assessed and analysed the status of the following priority activities.

- Develop comprehensive national baseline data on the environment (land, water & atmospheric components) to prepare periodic State of Environment Reports (SoERs) to monitor environmental sustainability;
- Establishing and strengthening the capacity of meteorological, oceanographic and hydrological services;
- Strengthening existing national research and training institutions considering climate change at the centre;
- Develop a project proposal to conduct a full-fledged Technology Needs Assessment (TNA) and transfer of technology process for adaptation and mitigation included as part of the TNC to benefit from existing funding windows including the GEF Programming (GEF Trust Fund), the CTCN, the GCF and other GEF funds such as the SCCF-B and the LDCF.

- Provide information on specific barriers and opportunities in implementing the on-going pilot adaptation projects or programmes (pilot or demonstration) that are being undertaken through existing and upcoming UNFCCC funding windows;
- Identification and utilization of support programmes which provide financial and technical resources for adaptation and how such support programmes are meeting the specific adaptation needs and concerns of Eritrea;
- Provide information on the level of financial support from Annex II Parties, the GCF and the GEF; Eritrea's participation in the CTC and CTN; development and enhancement of endogenous capacities, technologies and know-how.

6.3 Technical Needs

Technical needs cut across all activities spanning from scientific knowledge of climate change to skills of climate and impact modelling to formulation of GHG mitigation and adaptation strategies to preparation of project and programme documents, monitoring and evaluation of concrete projects and programmes to climate change negotiation skills. These technical needs are hindering Eritrea from maximizing and optimizing the Convention resources. While preparing the TNC, a number national experts working in various ministries were involved as members of the different technical working groups and contributed substantially. Nevertheless, it was also become clear that these experts needed capacity building to fully understand and contribute to the various thematic areas of the communication. Thus, Eritrea's commitment to implement the ToR under UNFCCC partly depends on the extent that developed country Parties' willingness not only to extend financial support but also transfer of appropriate technologies.

6.3.1 Technical Assistance

There are a number of technical needs that constrain climate change projects and programs. These needs should be properly addressed on a timely basis putting into consideration the specific needs of a target area. The difficulties related with transfer of technology are related with inadequacy of fund to cover priority areas identified under the components of the national communication.

International and/or regional experts were invited to provide assistance to national team responsible for the preparation of the TNC in specific approaches, tools and methods to be used for the planned activities under the GHG Inventories, vulnerability and adaptation assessment and mitigation assessment. However, the Technical assistance from UNEP did not materialise. In view of that, past NC experiences and lessons learnt from other on-going climate change enabling activity programs in the region technical assistance were used to train local experts in the process. Training materials from the past and the on-going activities were partly obtained from various regional and international sources, such as IPCC, UNFCCC and UNITAR. To assess the technical assistance provided, the team reviewed the project document and realised that Due to COVID-19, international/regional technical assistance was not obtained. Instead, the following activities were carried out.

- National expertise who had prior training (consultants) provided technical Assistance) and trained to the technical working groups involved in GHG Inventory Training;
- National expertise (consultants) provided Technical Assistance on the V & A training; and
- National expertise (consultants Technical Assistance) was engaged with Mitigation Assessment).

6.3.2 Inadequate Human Capacity

At present, there is lack of adequate capacity to sustain climate change data collection and analysis that ultimately generates information and knowledge. Consequently, it is indispensable to develop and upgrade human resources at various levels and move together with the changing circumstances. In connection with climate change and mitigation and adaptation activities, climate and hydrological sciences are dynamic that change at the fastest rate. Emphasis should be focussed on human capacity that is needed for data collection, data analytical tools and methodologies. Capacity could get improved either on continuous basis i.e. on the job training or on a long - term training in higher education institution within country or abroad.

A. Greenhouse Gas Inventory

Even though much progress has been achieved since the submission of the INC to UNFCCC in 2001, Eritrea still faces challenges in undertaking detailed GHG inventories. These processes are crucial components that inform the development of effective policies, strategies, and mitigation measures. The following challenges were encountered during the preparation of the national GHG inventory. First and foremost, there was no continuity in the estimation of the inventory as there was no data or any information available from the last inventory calculation. This is mainly because the following reasons:

- There is no archiving system put in place; or any inventory manual that was produced in the last inventory.
- Some of the activity data was not available for the past years in some sectors, especially IPPU and wastes hence, a lot of interpolation and extrapolation was done.
- Solid waste generated and characterization data was collected for selected town. Besides, the waste water generated was not measured in all towns; and it had to be derived in the future;
- The national experts lack technical capacity to estimate the inventory; for this reason training of national experts on the IPCC 2006 guidelines and inventory software should be a priority before the next inventory is prepared.
- There no climates change institutional arrangement regarding data collection and provision.
- The inventory is done on an ad-hoc manner through consultants; hence there is a need to put in place sustainable GHG inventory system to help improve inventory estimation and quality.

B. Mitigation and Adaptation

The effectiveness of mitigation measures and adaptation options is dependent on strong institutions with technical, financial, and managerial capabilities. Any institutional weakness in these areas undermines the attempt to implement adaptation and mitigation measures effectively. Implementation and monitoring of mitigation and adaptation actions since the second national communication pose some challenge. This is mainly because of other national urgent priorities and the absence of a national climate change policy to guide the implementation of this action. Hence, there is a need for mainstream mitigation and adaptation to national development objectives and enhance the capacity of the MoLWE, a focal institution for climate change.

Eritrea's action are further constrained by the fact that climate change concerns are yet to fully mainstream into national development programmes and integrated into national planning and budgeting. Therefore, they are not yet reflected significantly in the sectoral development plans or the overall development agenda for the country at present. In the preparation of national communication, Eritrea faces the following challenges:

- Lack of national experts for mitigation assessment and estimation of abatement cost for mitigation action.
- Lack of capacity in doing GHG inventory projections and use of the LEAP/WEAP model.
- Lack of national experts to do climate change scenarios and projections.
- Lack of capacity to do socio-economic scenarios for the vulnerability and adaptation component,
- Inadequate climate research experts for vulnerability and adaptation assessments.

Based on this background, the main constraints and corresponding needs are summarised in table 6.1

Table 6.1: Main Constraints and description of the needed capacity

Activity	**Description of The Needed Capacity**
Sustainable GHGs inventory management system	• Setting of an institutional arrangements; and GHGs data management, • Development of national GHGs manual, and • Establishment of a national GHGs management system.
GHGs estimation	• training on the use of IPCCC, 2006 guidelines and software • Agriculture, Forestry, and Other Land Uses (AFOLU) land classification • use of satellite remote sensing data and Geographical Information System (GIS)
Mitigation	Training on Developing Mitigation Baseline
	Training on use of LEAP/WEAP
	Training on marginal abatement cost curve
Adaptation	**Climate scenario**: training in downscaling of global/regional meteorological data climate modelling
	Climate impacts assessments: training on uses of statistical packages and dynamic crop and hydrological modelling
	Adaptation tools and methods: training on the uses of different adaptation tools and methods applicable to different sectors including economic models, biophysical models and cost benefits analyses
	Scenario development in different sectors (AFOLU, Energy, Waste, IPPU)
General	Climate Change Programmes and project development
	Policy analyses

6.3.3 Inadequate Institutional Capacity

In the short-term, there are institutional gaps including inadequate expertise in climate change science, analysis of vulnerability and adaptations, and impacts of climate change for key social and economic sectors. Moreover, there is lack of sufficient knowledge, skills and tools for integrating climate change into development planning, budgeting, implementation and monitoring. Further, there are capacity limitations in designing and preparing climate change projects and programme documents, monitoring progress and impacts, and budgeting and economic appraisal also hampers timely design of projects. Recent consultations with stakeholders on the National Adaption Plan (NAP) highlighted the need for specific human development requirements in the following areas:

- meteorological sciences, including modelling to plan future climate change and impact assessments on key geographical areas and economic sectors;
- hydrological and water resource assessment and management;
- coastal zone and fishery management;
- Smart agriculture and
- Integrated landscape and ecosystem-based management for climate change adaptation.

Looking at the magnitude of the gaps, it can be concluded that there is a limited pool of climate change experts in the government, academia and civil societies. There remains a low level of awareness about climate change and its potential impacts on the economy and livelihoods across all levels of Eritrea's society including key decision-makers. In addition, there is dire shortage of human resource capacity to effectively plan and execute the economic, social and environmental pillars of sustainable development as called for in Agenda 2030 and the SDGs.

6.3.4 Insufficient Climate Data

Meteorological stations which are established by different organisation in selected sites generate climate/weather data to meet specific institutional needs. These stations don't satisfy the requirements of the World Meteorological Organization (WMO). Consequently, there are gaps in area coverage and data quality. Recent documentation from the Climate Prediction and Application Centre for IGAD indicates that the number of climate data collection points in Eritrea compared to other countries in eastern Africa. The inadequacies in climate data covering the main geographical areas is a significant barrier for national and sub-national based modelling of climate change projections over time. Thus, inadequate climate data is an overriding factor hindering experts to undertake thorough analyses and climate change projections.

In view of the above background, local experts largely depend on downscaled climate projections and scenario analysis to undertake risk and vulnerability assessments to simulate effective climate adaptation activities. Result from the questionnaire survey revealed that there are weather stations in all administrative regions. However, only those located in Asmara, Asseb, Massawa, Sawa, Halhale, Hamelmalo and Afdeyu are in good working conditions. Hence, it can be concluded that Eritrea is far behind the countries in the region with regards to the availability of climate data (e.g. rainfall, temperature and wind) which poses a major challenge for long-term climate predictions. This being the case, experts are obliged to use Global Circulation Models (GCM). The GCM can't only capture the local atmospheric dynamics but also has poor grid resolution of data. Hence, this can't disclose local effects such as mountains and bays and certain unique coastal landscapes. Further, while down – scaling, the global data to local levels, there are losses in sight in the course of the analytical process.

Historical trends and recent level of changes in climate become complicated. This is mainly due to the inadequacy of climate data covering a given project area. Under such circumstances, the issue of climate data has to be handled with sufficient care and build climate data bases from reprehensive stations.

Installation of weather stations in strategic locations throughout the country has to meet certain scientific requirements. Calibration of instruments, which in most cases is underestimated, needs to be addressed properly. In parallel, curriculum development in meteorology and atmospheric sciences need to be properly designed and integrated into higher educational systems of Eritrea to ensure training of young scientists on a sustainable basis. Further, the existing national research and training institutions should be strengthened to enhance the

research and development. This domain entails knowledge management systems right from data collection up to knowledge generation. Procurement of vital equipment such as Remote Sensing and Geographic Information Systems (GIS) tools, biomass and carbon stock assessment for carrying out forest inventory and soil organic carbon are vital for data collection tasks. Further, research on adaptive technologies especially alternative renewable energy sources (e.g. wind and solar) should be promoted at various scales. The major issues identified to strengthen climate change science and adaptation planning re the following:

- Investing in meteorological and hydrological data collection stations;
- introducing standardized methods for climate and hydrological data collection and analysis;
- Investing in meteorological and climate modelling;
- strengthen national institutions' capacity including academic and research institutes to better anticipate the country's range of climate change scenarios and risks;
- Researching indigenous adaptation tools and initiatives to identify best practice and lessons learnt to inform capacity building, assessment and planning processes; and
- Consolidating national and sub-national information exchange platforms to more readily making climate change science and adaptation information available at all levels of society and government.

Climate database should integrate traditional knowledge in a way that allows for the management system of adaptation and mitigation efforts. Knowledge management system should be instituted to allow predictable flow of information targeted towards the above goal. This type of management also necessitates a comprehensive analyses on the manner in which data is collected, analysed and knowledge is generated and disseminated. In this regards, much needs to be done to encourage local communities to be vigilant on climatic variability at the local level and noticeable climate change should be reported accordingly.

6.3.5 Scientific Research and Innovation needs

Despite the importance of scientific research and innovation to address specific societal problems; there still exist scientific knowledge gaps in climate change. Higher education and research institutes in the country need to be strengthened in terms of institutional and human capacities to contribute to the knowledge and skills of climate change and bring about attitude changes among people in Eritrea. To date, a number of research activities were carried out using available resources and capacity, which paved way for further mitigation and adaptation activities. Nonetheless, the research outputs are not organized in a proper manner; and haphazardly found in different institution. These topics represent very limited information about what is being done in specific institutions. Thus, long-term investment in research and development is required to enhance capacity in research, development and innovation to address the challenges of climate change across all key vulnerable sectors. A financing strategy for research and development should be created in partnership with all stakeholders. Continuous research on vulnerability and adaptation in agriculture, water resources, forestry, human health, and biodiversity including wildlife is needed in order to establish the level of vulnerability to climate change and identify the best adaptation options and policies.

To certain extent, there exists knowledge and technology, in the country, that can be used to mitigate and reduce the vulnerability of communities to the impacts of climate changes. These technologies invariably should be adapted to local circumstances; and there is a need for continuous innovation to test suitability of technologies that fit into a given environment and socioeconomic circumstance of the country. Scientific research should meet certain qualities and should be relevant to the local needs. Quality could be achieved through engagement of

experts as well as the use of valid data to generate the desired level of outcomes. Besides, the research should also explore possibilities for integrating exogenous knowledge with the modern knowledge system. Further, it research and innovation system should be instituted to ensure that local need assessment and land users are well linked. There are also events where the qualities of outputs generated become questionable with regard to instrumentation. It is necessary to acquire up-to-date equipment and continuously upgrade to move along with global or regional systems. Installation and calibration of the instruments used in the data collection and analyses should be seriously considered. While some calibrations are done at the national level; there might be cases where regional or international assistance might be required.

6.3.6 Incoherent Climate Change Regulatory Framework

National and sector policies, and associated legal frameworks are required for successful adaptation to climate change across all climate vulnerable sectors. The link between national, sub-national and local levels should be mutually supportive and coherent to guarantee smooth flow of information. It is important to avoid consequences arising from unforeseen policies that may result in undermining the objectives of other relevant policies. Sector policies needs to have sufficient consideration about a long-term climate change scenarios and possible impacts on the sectors (e.g. agriculture, forestry) and that climate change and adaptation should be directly referenced. In this respect, there is a need for undertaking a stocktaking of existing sector policies to identify the extent of incorporating climate change information in the determination of priorities, objectives and main programmes to be implemented.

National development plans, policies, strategies are not static; instead they vary within a certain period of time such as medium to long-term. Normally, a given plan that covers a period of 5 to 10-year cyclic time should be periodically revised. Nonetheless, revision should be carried out based on progress and achievements, knowledge gained; and local, regional and global changing circumstances. There is increasing justification for forthcoming national development plans and sector plans (e.g. 2019 -2029) to draw on the analysis and recommendations from climate change scenarios and vulnerability assessments. The technical inputs provided by MoLWE and key Environment Units in sector ministries needs to be duly incorporated in the framework.

6.4 Monitoring and Evaluation (M&E) Plan

At present, monitoring and reporting activities is inadequate. The progress of adaptation activities, both the amount of funds and lessons learned by sector ministries and *zoba* administrations are not satisfactory. The need for M & R is important as it focus on concrete climate change projects and programmes. It also develops certain level of negotiation skills as to how to acquire project funds from the international sources. Further, it is important to focus on sustainability issues and impacts assessments on the livelihoods with the potential for up-scaling of specific technologies. For some sectors, such as health, there is a working monitoring and reporting system in place to track key health sector indicators involving the support of UNICEF. Besides limitations in human capacity and inadequate training and access to resources for regular monitoring, there is insufficient policy framework in place to advance time and resource investments into national adaptation monitoring and reporting.

Irrespective of the circumstance, a detailed schedule of project reviews meetings need to developed by the project management, in consultation with project implementation partners and stakeholder representatives and incorporated in the Project Inception Report need to be worked out including (i) tentative time frames for project oversight meetings and (ii) project related M & E activities. For that UNEP should provide periodic funding as per the request of the Project

Executing Agency (EA), which is the DoE; and in as much as possible UNEP should be in a position to provide technical assistance.

Day to day monitoring of implementation progress will be the responsibility of the National Project Coordinator (PC) based on the Annual Work Plan. The PC will inform the UNEP of any delays or difficulties faced during project execution so that appropriate support or corrective measures can be adopted in a timely manner.

Periodic monitoring of implementation progress should be undertaken in collaboration with UNEP using appropriate means of communication including quarterly tele-conferences with the project proponent, or more frequently as deemed necessary. This will allow parties to take stock and to troubleshoot any problems pertaining to the project in a timely fashion to ensure smooth implementation of project activities. The PC will be responsible for the preparation and submission of the following reports that form part of the monitoring process including inception report, quarterly progress report, technical report and other.

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Annexes-A: TNC Preparation and Coordinating System

Annex-A1: List of Experts responsible for Quality Assurance and Quality Control

S. no	Full Name	Contact information	Role	Organisation
1	Mr. Kibrom Asmarom	kibromaw@gmail.com Tele:002917154731	Project Supervisor	MoLWE
2	Dr. Woldeselassie Ogbazghi	wogbazghi@gmail.com	Lead Consultant	Hamelmalo Agricultural College, department of Land Resources and Environment, HAC
3	Prof. Woldeamlak Araia	woldearaiahac@gmail.com Tele: 002917154593	Consultant	Hamelmalo Agricultural College, department of Agronomy, NHERI
4	Dr. Woldetnsae Tewolde	wolde1956@gmail.com Tel:002917195457	Consultant	Adi Keih College of Business and Social Science, department of geography NHERI
5	Mr. Haben Haile	hbnhabte@gmail.com Tele:002917131730	consultant	College of Science, Department of Chemistry
6	Mr. Teame Tekleab	Teametek2016@gmail.com Tele: 002917266389	Quality Assurance	MoLWE
7	Mr. Robel Kibrom	Roki0404@gmail.com Tele:002917338151	Quality Assurance	MoLWE

Annex-A2: List of Experts and Consultants participated in TNC preparation

Full Name	Contact information	Role	Organisation
Mr. Michael Berhane	asmike06@gmail.com	Provide activity data and information used to assess the vulnerability of the Agricultural sector to climate change and related to the sector have been appropriately integrated, to the document GHG emission data, efforts that have been undertaken to adapt to climate change; validate data and information	Ministry of Agriculture, Department of Agricultural Extension
Mr. Solomon Sium	ssng73@gmail.com Tele: 002917131511	Gather information and data related to Industrial greenhouse gases emissions and emitting and all efforts that have been undertaken in the sector to minimize GHGs emissions. Ensure all information related to the sector appropriately captured in the document	Ministry of trade and Industry
Mr. Haile Selassie Tsegai	Tele: 002917463219 haileman@gmail.com	Gather/Provide data on water resources and relevant information that are used to assess the vulnerability of water resources to climate change and ensure that the issues related to the sector have been addresses appropriately.	MoLWE, Department of Water resources
Mr. Tesfamariam Woldegebriel	Tele: 002917126006	Provide (gather) data and information related to the transport sector that is used in determining the GHGs emissions; and mitigations efforts of the sector. Fuel consumption by sector, number of vehicles by types, models, year of productions and related regulations that contribute to the reduction of GHgs emission. Information related to efforts that have been undertaken in the reduction of greenhouse gases.	Ministry of Transport and Communication
Mr. Tesfai Gebrehiwet	gtesfai@gmail.com	National fuel consumption of the sector, efforts that has been undertaken to improve electricity generation, consumption. On top of this, he was responsible to determine the GHGs emission from the inventory and perform the mitigation assessment and analyses; gave general training on the application of the different models for GHGs inventory and mitigation assessment and analyses. Participated in the preparation of draft reports on these components.	MoEM
Mr. Teklezghi Tekie		Provide information on land use and vulnerability of land resources to climate change. Provided activity data that contribute to GHGs emission and efforts used and efforts undertaken to reduce the vulnerability and GHGs emissions (AFOLU); and ensured that issues related to the sector are appropriately integrated.	Department of Land MoLWE

Mr. Tekie Abraha	Wediabraha06@gmail.com Tele: 002917454641	Provided information related to the vulnerability of the health sector and efforts that have been under the sector to mitigate and adapt to climate change. Prevalence of climate change induced human health problems such as Malaria, Dengue and Chikungunya)	Department of Public health, Ministry of Health
Mr. Petros Araia	petraraya@gmail.com Tele: 002917433460	Provide data related to Forestry and wildlife that is used the vulnerability of the sector (AFOLU); and the sub-sectors contributing in carbon sequestration (sinks) and the efforts, so far, carried out to combat climate change (mitigation and adaption) i.e. forest cover by type, reforested and afforested areas in ha, tree number, deforestation rate and other relevant data pertaining to climate change.	Forestry and Wildlife Authority
Mr. Andemicahel Hidru	@gmail.com	Provide data and information on marine resources that is used to assess the vulnerability of the sector to climate change and ensure that the issues related to this sector have been addressed appropriately. He also availed activity data that is used foe estimating GHGs emissions and efforts that have been carried out so far to reduce vulnerability and emissions.	MoMR
Mr. Mulubrhan Gebreyohannes	mulexgb61@gamil.com	Provided /collected data and information on the waste sector that is used to assess the GHG emission from the sector; and availed feedback on the efforts that have been carried out to reduce greenhouse gases emissions. Prepared a concise report on national waste management i.e. (solid waste, liquid, etc.).	Ministry of Local Government
Mr. Dawit Berhane	danaasemahs@gmail.com Tele: 002917140670	Having prior training during the second national communication, he undertook training on the vulnerability of the water resources to climate change. He also assisted in identifying relevant water resources data and information; and prepared concise report on the water sector.	Segen Construction pt. Lt.
Mr. Michael Haile	Tel: 002917122406	Provided social, economic, data and formation relevant to assessment of climate change vulnerability, adaption, and mitigation components. Previous efforts and future plans of the sector and other relevant sectors that would contribute to the adaption and mitigation to climate change.	Ministry of Local Government
Mr. Mebrahtu Zewde	mebriez@gmail.com Tel: 002917176393	Logistical arrangements i.e. meetings seminars, and taking care of the management issues.	National Bureau of Standards and Evaluation, NHERI

Annex-B: Implemented Adaption projects

Annex B1: Smart Agriculture Practiced by Farming Community

Aspects of smart agriculture	Description
Choice of Crops And KYR Varieties	Eritrea is a centre of diversity for a number of crop species and land races. Farmers use drought resistant crops such as sorghum, pearl millet and barley in locations that have drought problems. These crops mature earlier which is a drought escape mechanism. There are also a number of landraces that have grown for generations and adapting the existing climate situations. A total of 76percent of the households use landraces from their own source.
Inter Tillage Cultivation	Inter tillage cultivation is practiced for sorghum and pearl millet when the crop reaches knee height stage. Inter tillage cultivation helps for better moisture conservation or water harvesting in the crop field, provides proper aeration in the soil; minimizes weed infestation and provides better nutrient supply. About 98 % of the farmers in Gash Barka and 94percent in Anseba practice inter-tillage cultivation for sorghum and pearl millet.
Intercropping/ Mixed Cropping	Two or more crops are grown in the same land and in the same year with or without raw arrangements. The intercropping/mixed cropping has advantages such as yield stability, insurance for the farmers during periods of drought because if one crop fails then farmers could get the harvest of the second crop and reduce the infestation of insects, diseases and weeds.
Minimum Tillage:	This is ploughing the land only once during planting (0+1) for covering the seed or it is 1 + 1 ploughing which is one time ploughing before planting and additional ploughing for covering the seed during planting. Minimum tillage creates a coarse seed bed for better moisture conservation, preventing soil erosion/runoff, maintains the soil structure and minimizes the loss of soil fertility.
Improved Varieties for Smart Agriculture	Examples of improved varieties developed in the face of smart agriculture are Kona in pearl millet which is adaptable to drought and hot areas. The variety is early maturing and disease resistant that gives a yield range from 12 to 21 qt/ha. The same thing can be noted in sorghum with improved varieties released such as Shambucco, Bushuka and Hamelmalo. The varieties are early maturing and drought resistant and relatively high yielding types adapted in the western lowlands and mid altitude areas. There are also barley varieties developed such as Shishay and Rahwa that are early maturing and high yielding.
Land Races for Smart Agriculture	Eritrea is a centre of diversity for a number of crops such as barley, sorghum and pearl millet. The landraces that needs high water requirement and late maturing that were grown by farmers have disappeared. The landraces that are relatively drought tolerant and early maturing have survived for generations. For example the landraces of barley grown includes Tsada-sgem and in wheat-Italy. There are various landraces of pearl millet such as Bariyay and sorghum- Wedi Aker, Koden etc. that have survived for generations in the face of climate change.

Annex B2: Specific Needs, Options & Priorities in Climate Change and Related Thematic Areas

S. no	Activities	Objectives
1	Establish national climate change secretariat	To enable the effective identification of sector- specific climate change related challenges and proposed approaches to tackle them to appropriately responds to the requirements of the UNFCC Convention,
2	Develop an integrated implementation programme	to take into account the roles of research and training in capacity building
3	Develop and enhance technical capacities and skills	Carry out and effectively integrate vulnerability and adaptation assessments into sustainable development programmes; and implement national adaptation programmes of action
4	Development of National Climate change strategy and National Mitigation Action Plan	To enable the country appropriately address climate change adaptation and mitigation programmes at various levels.
5	Strengthen existing national research and development programmes	equip research centres e.g. the National Agricultural Research Institutes (NARI), Hamelmalo Agricultural College (HAC), National Energy Research & Training Centre; (Renewable energy training centre) and Marine resources research centre To strength institutional and human capacity to ensure sustainability of climate mitigation and adaption projects and programmes.
6	Strengthen the capacity of meteorological and & hydrological services	Enhance the human and institutional capacity; Equip the regions with the necessary tools and equipment to collect, analyse, interpret; and disseminate weather and climate information to support implementation of national adaptation programmes of action, mitigation and adaptation strategies formulated in the national communications
7	Enhance public awareness	Increase the level of understanding and human capacity development through various means: media and press, booklets and brochures.
8	Enhance effective participation in the Kyoto protocol meetings to move in tandem with the on-going processes	Tap opportunities in the CDM to enable Eritrea effectively mobilise its resources; Strengthen the technical, institutional and managerial capacity of stakeholders to effectively prepare CDM project Enhance/build capacity CDM project and formulation including monitoring and evaluation
9	Strengthen institutional capacity to integrate traditional knowledge into modern systems to address climate change	Support/enable existing national institutions to incorporate traditional skills, knowledge and practices; Provide appropriate services and facilitate information sharing to the required level mobilize existing national, sub-regional and regional institutions on existing processes and endogenous capacities;

S. no	Activities	Objectives
10	Establish an early warning systems for climate related natural disaster management e.g. drought	Reduce the disaster risk; enhance the coping range of the country as a whole and individuals/communities in the face of climate hazards. Disseminate information on the magnitude of eminent disaster risks such as drought.
11	Rehabilitate degraded lands and combat desertification	Implement the proposed 23 Project Profiles in 2002 indicated in the National Action Plan (NAP) of UNCCD. Enhance the awareness on land degradation as key environmental concerns that compromise Eritrea' adaptive capacity.
12	Mobilizing financial resources and political will s	Mobilise financial resources to implement projects that have been identified in the NAPA, NBSAP, INC, SNC Create enabling environment to fully implement the proposed projects.

Annex-B3: Climate Change- Specific Projects Implemented Under GEF-SGP, 2009-2019

Administrative Region	Focal area	Name of projects	Year	Budgets (USD)
Anseba	Climate specific	Mahabesh Watershed Management	2018	49,990
		Adi Berbere Watershed Management		50,000
		Gabgabo Watershed Management		50,000
Semenawi Keih Bahri		Harena Community Based Fish Development for improved Livelihood using Fish Aggregating Devices (FAD)	2019	39,020
Debub		Demonstration of low carbon solar home systems and afforestation in Qnafna in Zoba Debub	2013	149,998
		Bio-Gas as alternative source of energy for Environmental protection and improving livelihood at household level	2010	31,128
		Solar powered IT system for the schools of Adibeza and Adi-Gulti in sub- region Areza		47,019
Semenawi Keih Bahri	Biodiversity	Traps in Maedir village to conserve Biodiversity and improve community livelihood	2019	84,528.00
		Introduction of Fish Traps in Gelealo village to conserve Biodiversity and improve community livelihood,	2019	248,264
		Rehabilitation of Hirgigo Mangrove Forests and Improving Communities' Livelihood	2009	50,000
Maekel	Land Degradation	Azien - Quazien Community Based Afforestation Programme Maekel	2013	50,000
		Community -based Gulie micro watershed Management in Gala Nefhi Sub region	2013	50,000
		Community - based Rehabilitation of Degraded Land through fruit trees	2013	50,000
		Rehabilitation of Land Degradation through Afforestation and Introduction of Compost in Serejeka Sub region	2013	50,000;
		Weki - Zager Community Based Afforestation Programme	2013	50,000
		Rehabilitation of Degraded Catchments in Elaberd sub - region	2012	50,000;
		Rehabilitation of Degraded Sub catchments in Gala-Nefhi sub region	2012	50,000
Debub		Community based Watershed Management in Dbaruwa Sub region	2013	50,000
Gash-Barka		Community Based Watershed Management in Laelai Gash sub region	2013	50,000
Anseba		Gerger Integrated Watershed Management in Gelb, Sub region,	2013	50,000
		Promotion of Community Based Afforestation and Soil & Water Conservation at Sub Zoba Adi -Tekelezan	2010	33,018;
		Promotion of community afforestation and land reclamation in Sub zoba Adi-Tekelezan Anseba	2010;	25,568;

Administrative Region	Focal area	Name of projects	Year	Budgets (USD)
		Optimizing tillage and rain water conservation in the soils of Hamelmalo region of Eritrea for arresting soil degradation and achieving sustainable high crop yields,	2012;	40,000;
Semenawi - Keih Bahri		Community based Soil and Water Conservation practices in Sub region of Ghindae	2012	45,000
		Improved Traditional Stove in three villages of Adi-Tekelezan sub region MFA Anseba	2009	49,260
		Community Based turtle conservation at Dissie Island	2010	33,101
		Training of Trainers to communities on Forest management, Improved Traditional Stove and Nutrition	2010	13,730.
	Multifocal areas	Improvement of livelihood in rural community through provision of solar lanterns and environmental rehabilitation, Debub 2009 40,798.		

Annex-B4: National Policies, rules, regulations and guidelines

No	National policies, legal Documents	References
1	Macro Policy, 1994	GoE, 1994
2	National Economic Policy Framework and programme (NEPFP), 1998	GoE, 1998-2000
3	Interim-Poverty Reduction Strategy Paper (I-PRSP), 2003	GoE, 2003
4	Five Year Indicative Development Plan (FYIDP), 2009	GoE, 2009
	Agriculture	
5	National Agricultural Development Strategy and Policy	MoA, 2005
6	Plant Quarantine Proclamation, N^{o}.156/2006	MOA, 2006
7	Agricultural Sector Policy and Strategy framework	MOA, 2006
8	Forest and Wildlife Policy	MoA, 2005
9	Agriculture Sector Policy	MoA, 2006
10	Forest and Wildlife Conservation & Development Proclamation N^{o}. 155	MoA, 2006
11	National Action Program (NAP) for the UNCCD,	MoA, 2002
12	ODS Terminal Phase-out Management plan 2008	MoA, 2008
13	Registration for Importation, Handling, Use, Storage and Handling of Pesticides	MoA, 2006
	Energy	
14	Renewable Energy Sub-Sector policy	MoEM, 1997
	Health	
15	Guidelines for indoor residual spraying, 2017	MOH 2017
16	Training manual for indoor residual spraying, 2017	MOH, 2017
17	Insecticide Resistance Monitoring and Management plan, 2015	MOH, 2015
18	Policy and Guidelines For Malaria Control in Eritrea, 2003	MOH, 2003
19	Environmental Health Policy and Guidelines, 1998	MOH, 1998
	Land, Water and Environment	
20	The Eritrean Environmental Protection, Management & Rehabilitation Framework Proclamation No. 179/2017, 2017	MLWE, 2017
21	Environmental Protection and Management Regulations- Legal Notice No. 127/2017	MLWE, 2017
22	Eritrean National Code of Conduct for Environmental Security	MLWE, 1995
23	National Environnemental Management Plan (NEMP), 1995	MoLWE, 1995

No	National policies, legal Documents	References
24	National Environmental Assessment Procedures & Guidelines (NEAPG), 1999	MoLWE, 1999
25	Land Use Policy, 2007	MoLWE, 2007
26	Water Policy , 2010	MoLWE, 2010
27	National Biodiversity Strategy and Action Plan, 1996, 1999, 2015	MoLWE, 1996, 1999, 2015
28	Proclamation on Conservation of Biodiversity, 1998	MoLWE, 1998
29	Bio safety Policy Framework, 2007	MoLWE, 2007
30	National Adaptation Program of Action (NAPA), 2007	MoLWE, 2007
31	Land law Proclamation No.58/1994, 1998	MoLWE, 1994
32	Legal Notice No. 31, 1997	MoLWE, 1997
33	Land Use Planning Regulatory Framework, 1999	MoLWE, 1999
34	Integrated Water Resource Management, 2003	MoLWE, 2009
35	Water Law, Proclamation No. 162 /2010, 2010	MoLWE, 2010
36	Five Year Action Plan for The Great green wall initiative, 2015	MoLWE, 2011-2015
37	Hydro-Chloro-Floro-carbon Phase-out Management Plan (HPMP), 2010	MoLWE, 2010
38	Regulations for the Issuance of Permit for the Importation or exportation of Ozone Depleting Substances (ODS) and ODS Based Equipment or Products, 2010	MoLWE, 2010
39	Initial National Implementation plan (NIP) for the Management of POPs-chemical, 2012	MoLWE,2012
40	Updated NIP for the Management of POPs, 2018	MLWE, 2012
	Marine resources	
41	Eritrea Integrated Coastal Area Management (ICAM), 2007	MoMR, 2007
42	National Coastal Policy (draft) , 2006	MoMR, 2006
43	Proclamation No. 176/2014 the Fisheries Proclamation:	MoMR, 2014

Annex-C: National Emissions and Removals

Annex-C1: Key Summary of GHG Emission (2015)

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	565.411	150.233	0.462	14.234	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 - Energy	607.161	6.898	0.104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A - Fuel Combustion Activities	607.161	6.898	0.104						0.0	0.0	0.0	0.0
1.B - Fugitive emissions from fuels	0.0	0.0	0.0						0.0	0.0	0.0	0.0
1.C - Carbon dioxide Transport and Storage	0.0								0.0	0.0	0.0	0.0
2 - Industrial Processes and Product Use	169.556	0.0	0.0	14.234	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.A - Mineral Industry	169.556	0.0	0.0						0.0	0.0	0.0	0.0
2.B - Chemical Industry	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.C - Metal Industry	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.D - Non-Energy Products from Fuels and Solvent Use	0.0	0.0	0.0						0.0	0.0	0.0	0.0
2.E - Electronics Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.F - Product Uses as Substitutes for Ozone Depleting Substances				14.234	0.0			0.0	0.0	0.0	0.0	0.0
2.G - Other Product Manufacture and Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.H - Other	0.0	0.0	0.0						0.0	0.0	0.0	0.0
3 - Agriculture, Forestry, and Other Land Use	-212.319	142.037	0.359	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.A - Livestock		142.037	0.359						0.0	0.0	0.0	0.0
3.B - Land	-209.183		0.0						0.0	0.0	0.0	0.0
3.C - Aggregate sources and non-CO2 emissions sources on land	0.000	0.0	0.0						0.0	0.0	0.0	0.0
3.D - Other	-3.136	0.0	0.0						0.0	0.0	0.0	0.0
4 - Waste	1.013	1.297	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.A - Solid Waste Disposal		1.297							0.0	0.0	0.0	0.0
4.B - Biological Treatment of Solid Waste		0.0	0.0						0.0	0.0	0.0	0.0

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
4.C - Incineration and Open Burning of Waste	1.013	0.0	0.0						0.0	0.0	0.0	0.0
4.D - Wastewater Treatment and Discharge		0.0	0.0						0.0	0.0	0.0	0.0
4.E - Other (please specify)	0.0	0.0	0.0						0.0	0.0	0.0	0.0
5 - Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3			0.0						0.0	0.0	0.0	0.0
5.B - Other (please specify)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Memo Items (5)												
International Bunkers	4.358	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.a.i - International Aviation (International Bunkers) (1)	4.358	0.0	0.0						0.0	0.0	0.0	0.0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	0.0	0.0	0.0						0.0	0.0	0.0	0.0
1.A.5.c - Multilateral Operations (1)(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Annex-C2: GHG Emission from Energy Sector (2015)

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	607.161	6.898	0.104	0.0	0.0	0.0	0.0
1.A - Fuel Combustion Activities	607.161	6.898	0.104	0.0	0.0	0.0	0.0
1.A.1 - Energy Industries	259.290	0.007	0.003	0.0	0.0	0.0	0.0
1.A.1.a - Main Activity Electricity and Heat Production	259.290	0.007	0.003	0.0	0.0	0.0	0.0
1.A.1.a.i - Electricity Generation	158.213	0.006	0.001	0.0	0.0	0.0	0.0
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				0.0	0.0	0.0	0.0
1.A.1.a.iii - Heat Plants	101.077	0.001	0.002	0.0	0.0	0.0	0.0
1.A.1.b - Petroleum Refining				0.0	0.0	0.0	0.0
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.1.c.i - Manufacture of Solid Fuels				0.0	0.0	0.0	0.0
1.A.1.c.ii - Other Energy Industries	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.2 - Manufacturing Industries and Construction	21.505	0.001	0.0	0.0	0.0	0.0	0.0
1.A.2.a - Iron and Steel				0.0	0.0	0.0	0.0
1.A.2.b - Non-Ferrous Metals	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.2.c - Chemicals				0.0	0.0	0.0	0.0
1.A.2.d - Pulp, Paper and Print				0.0	0.0	0.0	0.0
1.A.2.e - Food Processing, Beverages and Tobacco				0.0	0.0	0.0	0.0
1.A.2.f - Non-Metallic Minerals				0.0	0.0	0.0	0.0
1.A.2.g - Transport Equipment				0.0	0.0	0.0	0.0
1.A.2.h - Machinery				0.0	0.0	0.0	0.0
1.A.2.i - Mining (excluding fuels) and Quarrying				0.0	0.0	0.0	0.0
1.A.2.j - Wood and wood products				0.0	0.0	0.0	0.0
1.A.2.k - Construction				0.0	0.0	0.0	0.0
1.A.2.l - Textile and Leather				0.0	0.0	0.0	0.0
1.A.2.m - Non-specified Industry	21.505	0.001	0.0	0.0	0.0	0.0	0.0
1.A.3 - Transport	196.529	0.023	0.010	0.0	0.0	0.0	0.0
1.A.3.a - Civil Aviation	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1.A.3.b - Road Transportation	196.529	0.023	0.010	0.0	0.0	0.0	0.0
1.A.3.b.i - Cars				0.0	0.0	0.0	0.0
1.A.3.b.i.1 - Passenger cars with 3-way catalysts				0.0	0.0	0.0	0.0
1.A.3.b.i.2 - Passenger cars without 3-way catalysts				0.0	0.0	0.0	0.0
1.A.3.b.ii - Light-duty trucks				0.0	0.0	0.0	0.0
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts				0.0	0.0	0.0	0.0
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts				0.0	0.0	0.0	0.0
1.A.3.b.iii - Heavy-duty trucks and buses				0.0	0.0	0.0	0.0
1.A.3.b.iv - Motorcycles				0.0	0.0	0.0	0.0
1.A.3.b.v - Evaporative emissions from vehicles				0.0	0.0	0.0	0.0
1.A.3.b.vi - Urea-based catalysts	0.0			0.0	0.0	0.0	0.0
1.A.3.c - Railways				0.0	0.0	0.0	0.0
1.A.3.d - Water-borne Navigation				0.0	0.0	0.0	0.0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation				0.0	0.0	0.0	0.0
1.A.3.e - Other Transportation				0.0	0.0	0.0	0.0
1.A.3.e.i - Pipeline Transport				0.0	0.0	0.0	0.0
1.A.3.e.ii - Off-road				0.0	0.0	0.0	0.0
1.A.4 - Other Sectors	129.838	6.867	0.091	0.0	0.0	0.0	0.0
1.A.4.a - Commercial/Institutional	56.210	0.232	0.003	0.0	0.0	0.0	0.0
1.A.4.b - Residential	48.160	6.631	0.087	0.0	0.0	0.0	0.0
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	25.467	0.003	0.0	0.0	0.0	0.0	0.0
1.A.4.c.i - Stationary	25.467	0.003	0.0	0.0	0.0	0.0	0.0
1.A.4.c.ii - Off-road Vehicles and Other Machinery				0.0	0.0	0.0	0.0
1.A.4.c.iii - Fishing (mobile combustion)				0.0	0.0	0.0	0.0
1.A.5 - Non-Specified				0.0	0.0	0.0	0.0
1.A.5.a - Stationary				0.0	0.0	0.0	0.0
1.A.5.b - Mobile				0.0	0.0	0.0	0.0
1.A.5.b.i - Mobile (aviation component)				0.0	0.0	0.0	0.0
1.A.5.b.ii - Mobile (water-borne component)				0.0	0.0	0.0	0.0

Categories	Emissions (Gg)						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1.A.5.b.iii - Mobile (Other)				0.0	0.0	0.0	0.0
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.B.1 - Solid Fuels	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a - Coal mining and handling	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.i - Underground mines	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.i.1 - Mining	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.i.2 - Post-mining seam gas emissions	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.i.3 - Abandoned underground mines				0.0	0.0	0.0	0.0
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.ii - Surface mines	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.ii.1 - Mining	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.a.ii.2 - Post-mining seam gas emissions	0.0	0.0		0.0	0.0	0.0	0.0
1.B.1.b - Uncontrolled combustion and burning coal dumps				0.0	0.0	0.0	0.0
1.B.1.c - Solid fuel transformation				0.0	0.0	0.0	0.0
1.B.2 - Oil and Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.B.2.a - Oil				0.0	0.0	0.0	0.0
1.B.2.a.i - Venting				0.0	0.0	0.0	0.0
1.B.2.a.ii - Flaring				0.0	0.0	0.0	0.0
1.B.2.a.iii - All Other				0.0	0.0	0.0	0.0
1.B.2.a.iii.1 - Exploration				0.0	0.0	0.0	0.0
1.B.2.a.iii.2 - Production and Upgrading				0.0	0.0	0.0	0.0
1.B.2.a.iii.3 - Transport				0.0	0.0	0.0	0.0
1.B.2.a.iii.4 - Refining				0.0	0.0	0.0	0.0
1.B.2.a.iii.5 - Distribution of oil products				0.0	0.0	0.0	0.0
1.B.2.a.iii.6 - Other				0.0	0.0	0.0	0.0
1.B.2.b - Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.B.2.b.i - Venting	0.0	0.0		0.0	0.0	0.0	0.0
1.B.2.b.ii - Flaring				0.0	0.0	0.0	0.0
1.B.2.b.iii - All Other				0.0	0.0	0.0	0.0

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1.B.2.b.iii.1 - Exploration				0.0	0.0	0.0	0.0
1.B.2.b.iii.2 - Production				0.0	0.0	0.0	0.0
1.B.2.b.iii.3 - Processing				0.0	0.0	0.0	0.0
1.B.2.b.iii.4 - Transmission and Storage				0.0	0.0	0.0	0.0
1.B.2.b.iii.5 - Distribution				0.0	0.0	0.0	0.0
1.B.2.b.iii.6 - Other				0.0	0.0	0.0	0.0
1.B.3 - Other emissions from Energy Production				0.0	0.0	0.0	0.0
1.C - Carbon dioxide Transport and Storage	0.0			0.0	0.0	0.0	0.0
1.C.1 - Transport of CO2	0.0			0.0	0.0	0.0	0.0
1.C.1.a - Pipelines	0.0			0.0	0.0	0.0	0.0
1.C.1.b - Ships	0.0			0.0	0.0	0.0	0.0
1.C.1.c - Other (please specify)	0.0			0.0	0.0	0.0	0.0
1.C.2 - Injection and Storage	0.0			0.0	0.0	0.0	0.0
1.C.2.a - Injection	0.0			0.0	0.0	0.0	0.0
1.C.2.b - Storage	0.0			0.0	0.0	0.0	0.0
1.C.3 - Other	0.0			0.0	0.0	0.0	0.0
Memo Items (3)							
International Bunkers	4.358	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.a.i - International Aviation (International Bunkers) (1)	4.358	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)				0.0	0.0	0.0	0.0
1.A.5.c - Multilateral Operations (1)(2)				0.0	0.0	0.0	0.0
Information Items							
CO2 from Biomass Combustion for Energy Production	2553.663						

Annex-C3: GHG Emission from IPPU sector (2015)

Categories	(Gg)			CO2 Equivalents(Gg)				(Gg)				
	CO2	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	NOx	CO	NMVOCs	SO2
2 - Industrial Processes and Product Use	169.556	0	0	14.234	0	0	0	0	0	0	0	0
2.A - Mineral Industry	169.556	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	163.02								0	0	0	0
2.A.2 - Lime production	6.536								0	0	0	0
2.A.3 - Glass Production	0								0	0	0	0
2.A.4 - Other Process Uses of Carbonates	0	0	0	0	0	0	0	0	0	0	0	0
2.A.4.a - Ceramics	0								0	0	0	0
2.A.4.b - Other Uses of Soda Ash	0								0	0	0	0
2.A.4.c - Non Metallurgical Magnesia Production	0								0	0	0	0
2.A.4.d - Other (please specify) (3)	0								0	0	0	0
2.A.5 - Other (please specify) (3)									0	0	0	0
2.B - Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.B.1 - Ammonia Production	0								0	0	0	0
2.B.2 - Nitric Acid Production			0						0	0	0	0
2.B.3 - Adipic Acid Production			0						0	0	0	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0						0	0	0	0
2.B.5 - Carbide Production	0	0							0	0	0	0
2.B.6 - Titanium Dioxide Production	0								0	0	0	0
2.B.7 - Soda Ash Production	0								0	0	0	0
2.B.8 - Petrochemical and Carbon Black Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.8.a - Methanol	0	0							0	0	0	0
2.B.8.b - Ethylene	0	0							0	0	0	0
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	0	0							0	0	0	0
2.B.8.d - Ethylene Oxide	0	0							0	0	0	0
2.B.8.e - Acrylonitrile	0	0							0	0	0	0

Categories	(Gg)			CO2 Equivalents(Gg)				(Gg)				
	CO2	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	NOx	CO	NMVOCs	SO2
2.B.8.f - Carbon Black	0	0							0	0	0	0
2.B.9 - Fluorochemical Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.9.a - By-product emissions (4)				0					0	0	0	0
2.B.9.b - Fugitive Emissions (4)									0	0	0	0
2.B.10 - Other (Please specify) (3)									0	0	0	0
2.C - Metal Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.C.1 - Iron and Steel Production	0	0							0	0	0	0
2.C.2 - Ferroalloys Production	0	0							0	0	0	0
2.C.3 - Aluminium production	0				0				0	0	0	0
2.C.4 - Magnesium production (5)	0					0			0	0	0	0
2.C.5 - Lead Production	0								0	0	0	0
2.C.6 - Zinc Production	0								0	0	0	0
2.C.7 - Other (please specify) (3)									0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use (6)	0	0	0	0	0	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	0								0	0	0	0
2.D.2 - Paraffin Wax Use	0								0	0	0	0
2.D.3 - Solvent Use (7)									0	0	0	0
2.D.4 - Other (please specify) (3), (8)									0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor (9)				0	0	0		0	0	0	0	0
2.E.2 - TFT Flat Panel Display (9)					0	0		0	0	0	0	0
2.E.3 - Photovoltaics (9)					0				0	0	0	0
2.E.4 - Heat Transfer Fluid (10)					0				0	0	0	0
2.E.5 - Other (please specify) (3)									0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	14.234	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning	0	0	0	14.234	0	0	0	0	0	0	0	0

Categories	(Gg)			CO2 Equivalents(Gg)				(Gg)				
	CO2	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	NOx	CO	NMVOCs	SO2
2.F.1.a - Refrigeration and Stationary Air Conditioning				13.528					0	0	0	0
2.F.1.b - Mobile Air Conditioning				0.706					0	0	0	0
2.F.2 - Foam Blowing Agents				0				0	0	0	0	0
2.F.3 - Fire Protection				0	0				0	0	0	0
2.F.4 - Aerosols				0				0	0	0	0	0
2.F.5 - Solvents				0	0			0	0	0	0	0
2.F.6 - Other Applications (please specify) (3)				0	0			0	0	0	0	0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1 - Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1.a - Manufacture of Electrical Equipment					0	0			0	0	0	0
2.G.1.b - Use of Electrical Equipment					0	0			0	0	0	0
2.G.1.c - Disposal of Electrical Equipment					0	0			0	0	0	0
2.G.2 - SF6 and PFCs from Other Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.2.a - Military Applications					0	0			0	0	0	0
2.G.2.b - Accelerators					0	0			0	0	0	0
2.G.2.c - Other (please specify) (3)					0	0			0	0	0	0
2.G.3 - N2O from Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.3.a - Medical Applications			0						0	0	0	0
2.G.3.b - Propellant for pressure and aerosol products			0						0	0	0	0
2.G.3.c - Other (Please specify) (3)			0						0	0	0	0
2.G.4 - Other (Please specify) (3)									0	0	0	0
2.H - Other	0	0	0	0	0	0	0	0	0	0	0	0
2.H.1 - Pulp and Paper Industry									0	0	0	0
2.H.2 - Food and Beverages Industry									0	0	0	0
2.H.3 - Other (please specify) (3)									0	0	0	0

Annex-C4: GHG Emission from AFOLU Sector (2015)

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	-209.183	142.037	0.359	0.0	0.0	0.0
3.A - Livestock	0.0	142.037	0.359	0.0	0.0	0.0
3.A.1 - Enteric Fermentation	0.0	136.236	0.0	0.0	0.0	0.0
3.A.1.a - Cattle	0.0	71.816	0.0	0.0	0.0	0.0
3.A.1.a.i - Dairy Cows		1.061		0.0	0.0	0.0
3.A.1.a.ii - Other Cattle		70.756		0.0	0.0	0.0
3.A.1.b - Buffalo		0.002		0.0	0.0	0.0
3.A.1.c - Sheep		12.733		0.0	0.0	0.0
3.A.1.d - Goats		27.881		0.0	0.0	0.0
3.A.1.e - Camels		17.549		0.0	0.0	0.0
3.A.1.f - Horses		0.110		0.0	0.0	0.0
3.A.1.g - Mules and Asses		6.141		0.0	0.0	0.0
3.A.1.h - Swine		0.005		0.0	0.0	0.0
3.A.1.j - Other (please specify)		0.0		0.0	0.0	0.0
3.A.2 - Manure Management (1)	0.0	5.801	0.359	0.0	0.0	0.0
3.A.2.a - Cattle	0.0	2.306	0.0	0.0	0.0	0.0
3.A.2.a.i - Dairy cows		0.023	0.0	0.0	0.0	0.0
3.A.2.a.ii - Other cattle		2.282	0.0	0.0	0.0	0.0
3.A.2.b - Buffalo		0.000	0.0	0.0	0.0	0.0
3.A.2.c - Sheep		0.509	0.096	0.0	0.0	0.0
3.A.2.d - Goats		1.227	0.263	0.0	0.0	0.0
3.A.2.e - Camels		0.977	0.0	0.0	0.0	0.0
3.A.2.f - Horses		0.013	0.0	0.0	0.0	0.0
3.A.2.g - Mules and Asses		0.737	0.0	0.0	0.0	0.0
3.A.2.h - Swine		0.005	0.0	0.0	0.0	0.0
3.A.2.i - Poultry		0.027	0.0	0.0	0.0	0.0
3.A.2.j - Other (please specify)		0.0	0.0	0.0	0.0	0.0

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3.B - Land	-209.183	0.0	0.0	0.0	0.0	0.0
3.B.1 - Forest land	-212.139	0.0	0.0	0.0	0.0	0.0
3.B.1.a - Forest land Remaining Forest land	-212.139			0.0	0.0	0.0
3.B.1.b - Land Converted to Forest land	0.0	0.0	0.0	0.0	0.0	0.0
3.B.1.b.i - Cropland converted to Forest Land	0.0			0.0	0.0	0.0
3.B.1.b.ii - Grassland converted to Forest Land	0.0			0.0	0.0	0.0
3.B.1.b.iii - Wetlands converted to Forest Land	0.0			0.0	0.0	0.0
3.B.1.b.iv - Settlements converted to Forest Land	0.0			0.0	0.0	0.0
3.B.1.b.v - Other Land converted to Forest Land	0.0			0.0	0.0	0.0
3.B.2 - Cropland	2.576	0.0	0.0	0.0	0.0	0.0
3.B.2.a - Cropland Remaining Cropland	0.026			0.0	0.0	0.0
3.B.2.b - Land Converted to Cropland	2.549	0.0	0.0	0.0	0.0	0.0
3.B.2.b.i - Forest Land converted to Cropland	0.0			0.0	0.0	0.0
3.B.2.b.ii - Grassland converted to Cropland	0.0			0.0	0.0	0.0
3.B.2.b.iii - Wetlands converted to Cropland	0.0			0.0	0.0	0.0
3.B.2.b.iv - Settlements converted to Cropland	0.0			0.0	0.0	0.0
3.B.2.b.v - Other Land converted to Cropland	2.549			0.0	0.0	0.0
3.B.3 - Grassland	0.0	0.0	0.0	0.0	0.0	0.0
3.B.3.a - Grassland Remaining Grassland	0.0			0.000	0.000	0.000
3.B.3.b - Land Converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0
3.B.3.b.i - Forest Land converted to Grassland	0.0			0.0	0.0	0.0
3.B.3.b.ii - Cropland converted to Grassland	0.0			0.0	0.0	0.0
3.B.3.b.iii - Wetlands converted to Grassland	0.0			0.0	0.0	0.0
3.B.3.b.iv - Settlements converted to Grassland	0.0			0.0	0.0	0.0
3.B.3.b.v - Other Land converted to Grassland	0.0			0.0	0.0	0.0
3.B.4 - Wetlands	-0.017	0.0	0.0	0.0	0.0	0.0
3.B.4.a - Wetlands Remaining Wetlands	-0.017	0.0	0.0	0.0	0.0	0.0
3.B.4.a.i - Peatlands remaining peatlands	-0.017		0.0	0.0	0.0	0.0

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3.B.4.a.ii - Flooded land remaining flooded land				0.0	0.0	0.0
3.B.4.b - Land Converted to Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
3.B.4.b.i - Land converted for peat extraction			0.000	0.0	0.0	0.0
3.B.4.b.ii - Land converted to flooded land	0.000			0.0	0.0	0.0
3.B.4.b.iii - Land converted to other wetlands				0.0	0.0	0.0
3.B.5 - Settlements	0.398	0.0	0.0	0.0	0.0	0.0
3.B.5.a - Settlements Remaining Settlements	0.0			0.0	0.0	0.0
3.B.5.b - Land Converted to Settlements	0.398	0.0	0.0	0.0	0.0	0.0
3.B.5.b.i - Forest Land converted to Settlements	0.0			0.0	0.0	0.0
3.B.5.b.ii - Cropland converted to Settlements	0.0			0.0	0.0	0.0
3.B.5.b.iii - Grassland converted to Settlements	0.0			0.0	0.0	0.0
3.B.5.b.iv - Wetlands converted to Settlements	0.0			0.0	0.0	0.0
3.B.5.b.v - Other Land converted to Settlements	0.398			0.0	0.0	0.0
3.B.6 - Other Land	0.0	0.0	0.0	0.0	0.0	0.0
3.B.6.a - Other land Remaining Other land				0.0	0.0	0.0
3.B.6.b - Land Converted to Other land	0.0	0.0	0.0	0.0	0.0	0.0
3.B.6.b.i - Forest Land converted to Other Land	0.0			0.0	0.0	0.0
3.B.6.b.ii - Cropland converted to Other Land	0.0			0.0	0.0	0.0
3.B.6.b.iii - Grassland converted to Other Land	0.0			0.0	0.0	0.0
3.B.6.b.iv - Wetlands converted to Other Land	0.0			0.0	0.0	0.0
3.B.6.b.v - Settlements converted to Other Land	0.0			0.0	0.0	0.0
3.C - Aggregate sources and non-CO2 emissions sources on land (2)	0.0	0.0	0.0	0.0	0.0	0.0
3.C.1 - Emissions from biomass burning	0.0	0.0	0.0	0.0	0.0	0.0
3.C.1.a - Biomass burning in forest lands		0.0	0.0	0.0	0.0	0.0
3.C.1.b - Biomass burning in croplands		0.0	0.0	0.0	0.0	0.0
3.C.1.c - Biomass burning in grasslands		0.0	0.0	0.0	0.0	0.0
3.C.1.d - Biomass burning in all other land		0.0	0.0	0.0	0.0	0.0
3.C.2 - Liming	0.0			0.0	0.0	0.0

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3.C.3 - Urea application	0.0			0.0	0.0	0.0
3.C.4 - Direct N2O Emissions from managed soils (3)			0.0	0.0	0.0	0.0
3.C.5 - Indirect N2O Emissions from managed soils			0.0	0.0	0.0	0.0
3.C.6 - Indirect N2O Emissions from manure management			0.0	0.0	0.0	0.0
3.C.7 - Rice cultivation		0.0		0.0	0.0	0.0
3.C.8 - Other (please specify)				0.0	0.0	0.0
3.D - Other	0.0	0.0	0.0	0.0	0.0	0.0
3.D.1 - Harvested Wood Products	0.0			0.0	0.0	0.0
3.D.2 - Other (please specify)				0.0	0.0	0.0

Annex-C5: GHG emission from Waste Sector (2015)

Categories	Emissions [Gg]						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	1.013	1.297	0	0	0	0	0
4.A - Solid Waste Disposal	0.000	1.297	0	0	0	0	0
4.A.1 - Managed Waste Disposal Sites				0	0	0	0
4.A.2 - Unmanaged Waste Disposal Sites				0	0	0	0
4.A.3 - Uncategorised Waste Disposal Sites				0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	1.013	0	0	0	0	0	0
4.C.1 - Waste Incineration	0	0	0	0	0	0	0
4.C.2 - Open Burning of Waste	1.013	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge	0	0	0	0	0	0	0
4.D.1 - Domestic Wastewaster Treatment and Discharge		0	0	0	0	0	0
4.D.2 - Industrial Wastewater Treatment and Discharge		0		0	0	0	0
4.E - Other (please specify)				0	0	0	0

Annex-C6: Level and Trend Uncertainty (2015)

A	B	C	D	E	F	G	H	I	J	K	L	M
2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1.A - Fuel Combustion Activities												
1.A.1.a.i - Electricity Generation - Liquid Fuels	CO2	148.37	158.21	5.00	5.00	7.07	0.03	0.00	0.03	0.02	0.21	0.04
1.A.1.a.i - Electricity Generation - Liquid Fuels	CH4	0.12	0.13	5.00	228.79	228.84	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1.a.i - Electricity Generation - Liquid Fuels	N2O	0.36	0.38	5.00	228.79	228.84	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1.a.iii - Heat Plants - Solid Fuels	CO2	0.00	101.08	5.00	12.41	13.38	0.04	0.02	0.02	0.23	0.13	0.07
1.A.1.a.iii - Heat Plants - Solid Fuels	CH4	0.00	0.02	5.00	200.00	200.06	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1.a.iii - Heat Plants - Solid Fuels	N2O	0.00	0.50	5.00	222.22	222.28	0.00	0.00	0.00	0.02	0.00	0.00
1.A.1.c.ii - Other Energy Industries - Solid Fuels	CO2	0.00	0.00	5.00	12.41	13.38	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1.c.ii - Other Energy Industries - Solid Fuels	CH4	0.00	0.00	5.00	200.00	200.06	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1.c.ii - Other Energy Industries - Solid Fuels	N2O	0.00	0.00	5.00	222.22	222.28	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.b - Non-Ferrous Metals - Liquid Fuels	CO2	0.00	0.00	5.00	6.14	7.92	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.b - Non-Ferrous Metals - Liquid Fuels	CH4	0.00	0.00	5.00	228.79	228.84	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.b - Non-Ferrous Metals - Liquid Fuels	N2O	0.00	0.00	5.00	228.79	228.84	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.j - Wood and wood products - Solid Fuels	CO2	0.00	0.00	5.00	12.46	13.43	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.j - Wood and wood products - Solid Fuels	CH4	0.00	0.00	5.00	200.00	200.06	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.j - Wood and wood products - Solid Fuels	N2O	0.00	0.00	5.00	222.22	222.28	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.m - Non-specified Industry - Liquid Fuels	CO2	82.13	21.50	15.00	6.14	16.21	0.00	0.01	0.00	0.09	0.09	0.02
1.A.2.m - Non-specified Industry - Liquid Fuels	CH4	0.07	0.02	15.00	228.79	229.28	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.m - Non-specified Industry - Liquid Fuels	N2O	0.20	0.05	15.00	228.79	229.28	0.00	0.00	0.00	0.01	0.00	0.00
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CO2	29.10	4.36	10.00	4.17	10.83	0.00	0.01	0.00	0.02	0.01	0.00
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CH4	0.00	0.00	10.00	100.00	100.50	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	N2O	0.25	0.04	10.00	150.00	150.33	0.00	0.00	0.00	0.01	0.00	0.00
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO2	0.00	0.00	5.00	4.17	6.51	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CH4	0.00	0.00	5.00	100.00	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N2O	0.00	0.00	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.b - Road Transportation - Liquid Fuels	CO2	201.41	196.53	20.00	3.07	20.23	0.38	0.01	0.04	0.03	1.04	1.08
1.A.3.b - Road Transportation - Liquid Fuels	CH4	0.56	0.49	20.00	244.69	245.51	0.00	0.00	0.00	0.01	0.00	0.00
1.A.3.b - Road Transportation - Liquid Fuels	N2O	3.16	3.08	20.00	209.94	210.89	0.01	0.00	0.00	0.03	0.02	0.00
1.A.4.a - Commercial/Institutional - Liquid Fuels	CO2	106.51	56.21	25.00	6.14	25.74	0.05	0.01	0.01	0.08	0.37	0.14
1.A.4.a - Commercial/Institutional - Liquid Fuels	CH4	0.30	0.16	25.00	200.00	201.56	0.00	0.00	0.00	0.01	0.00	0.00
1.A.4.a - Commercial/Institutional - Liquid Fuels	N2O	0.26	0.14	25.00	228.79	230.15	0.00	0.00	0.00	0.01	0.00	0.00
1.A.4.a - Commercial/Institutional - Biomass	CO2	74.20	87.69	5.00	18.69	19.35	0.07	0.00	0.02	0.01	0.12	0.01
1.A.4.a - Commercial/Institutional - Biomass	CH4	4.06	4.73	5.00	227.27	227.33	0.03	0.00	0.00	0.01	0.01	0.00
1.A.4.a - Commercial/Institutional - Biomass	N2O	0.76	0.88	5.00	297.73	297.77	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b - Residential - Liquid Fuels	CO2	66.48	48.16	25.00	6.14	25.74	0.04	0.01	0.01	0.04	0.32	0.10
1.A.4.b - Residential - Liquid Fuels	CH4	0.19	0.12	25.00	200.00	201.56	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b - Residential - Liquid Fuels	N2O	0.16	0.10	25.00	236.36	237.68	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b - Residential - Biomass	CO2	1964.91	2465.97	5.00	18.69	19.35	54.98	0.02	0.46	0.36	3.26	10.74
1.A.4.b - Residential - Biomass	CH4	112.46	139.13	5.00	227.27	227.33	24.15	0.00	0.03	0.17	0.18	0.06
1.A.4.b - Residential - Biomass	N2O	21.90	26.93	5.00	297.73	297.77	1.55	0.00	0.01	0.03	0.04	0.00
1.A.4.c.i - Stationary - Liquid Fuels	CO2	8.19	25.47	25.00	6.14	25.74	0.01	0.00	0.00	0.02	0.17	0.03
1.A.4.c.i - Stationary - Liquid Fuels	CH4	0.02	0.07	25.00	200.00	201.56	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.c.i - Stationary - Liquid Fuels	N2O	0.02	0.06	25.00	236.36	237.68	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.b.i - Mobile (aviation component) - Liquid Fuels	CO2	0.00	0.00	5.00	4.17	6.51	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.b.i - Mobile (aviation component) - Liquid Fuels	CH4	0.00	0.00	5.00	100.00	100.12	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.b.i - Mobile (aviation component) - Liquid Fuels	N2O	0.00	0.00	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.b.vi - Urea-based catalysts	CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A - Mineral Industry												

A	B	C	D	E	F	G	H	I	J	K	L	M
2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
2.A.1 - Cement production	CO2	14.92	163.02	10.00	6.14	11.73	0.09	0.03	0.03	0.17	0.43	0.21
2.A.2 - Lime production	CO2	3.45	6.54	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.04	0.00
2.D - Non-Energy Products from Fuels and Solvent Use												
2.D.1 - Lubricant Use	CO2	0.00	0.00	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.2 - Paraffin Wax Use	CO2	0.00	0.00	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F - Product Uses as Substitutes for Ozone Depleting Substances												
2.F.1.a - Refrigeration and Stationary Air Conditioning	CH2FCF3	0.09	13.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.1.b - Mobile Air Conditioning	CH2FCF3	0.00	0.71	5.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A - Livestock												
3.A.1.a.i - Dairy Cows	CH4	15.46	22.27	25.00	6.14	25.74	0.01	0.00	0.00	0.00	0.15	0.02
3.A.1.a.ii - Other Cattle	CH4	1322.36	1485.87	25.00	6.14	25.74	35.32	0.02	0.28	0.12	9.81	96.32
3.A.1.b - Buffalo	CH4	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.1.c - Sheep	CH4	237.77	267.38	25.00	6.14	25.74	1.14	0.00	0.05	0.02	1.77	3.12
3.A.1.d - Goats	CH4	524.64	585.50	25.00	6.14	25.74	5.48	0.01	0.11	0.05	3.87	14.96
3.A.1.e - Camels	CH4	317.99	368.53	25.00	6.14	25.74	2.17	0.00	0.07	0.02	2.43	5.92
3.A.1.f - Horses	CH4	1.85	2.31	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.02	0.00
3.A.1.g - Mules and Asses	CH4	113.74	128.96	25.00	6.14	25.74	0.27	0.00	0.02	0.01	0.85	0.73
3.A.1.h - Swine	CH4	0.00	0.11	10.00	6.14	11.73	0.00	0.00	0.00	0.00	0.00	0.00
3.A.1.j - Other (please specify)	CH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	CH4	0.34	0.48	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	N2O	0.02	0.03	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.a.ii - Other cattle	CH4	42.66	47.93	25.00	6.14	25.74	0.04	0.00	0.01	0.00	0.32	0.10
3.A.2.a.ii - Other cattle	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.b - Buffalo	CH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
3.A.2.b - Buffalo	N2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.c - Sheep	CH4	9.51	10.70	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.07	0.00
3.A.2.c - Sheep	N2O	26.38	29.67	25.00	0.00	25.00	0.01	0.00	0.01	0.00	0.20	0.04
3.A.2.d - Goats	CH4	23.08	25.76	25.00	6.14	25.74	0.01	0.00	0.00	0.00	0.17	0.03
3.A.2.d - Goats	N2O	73.03	81.50	25.00	0.00	25.00	0.10	0.00	0.02	0.00	0.54	0.29
3.A.2.e - Camels	CH4	17.70	20.51	25.00	6.14	25.74	0.01	0.00	0.00	0.00	0.14	0.02
3.A.2.e - Camels	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.f - Horses	CH4	0.23	0.28	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.f - Horses	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.g - Mules and Asses	CH4	13.65	15.48	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.10	0.01
3.A.2.g - Mules and Asses	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.h - Swine	CH4	0.00	0.11	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.h - Swine	N2O	0.00	0.00	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.i - Poultry	CH4	0.51	0.57	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.00	0.00
3.A.2.i - Poultry	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B - Land												
3.B.1.a - Forest land Remaining Forest land	CO2	-230.89	-212.14	35.00	6.14	35.53	1.37	0.01	0.04	0.08	1.96	3.85
3.B.1.b.v - Other Land converted to Forest Land	CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.2.a - Cropland Remaining Cropland	CO2	0.03	0.03	35.00	6.14	35.53	0.00	0.00	0.00	0.00	0.00	0.00
3.B.2.b.v - Other Land converted to Cropland	CO2	0.00	2.55	35.00	6.14	35.53	0.00	0.00	0.00	0.00	0.02	0.00
3.B.3.a - Grassland Remaining Grassland	CO2	0.00	0.00	35.00	6.14	35.53	0.00	0.00	0.00	0.00	0.00	0.00
3.B.4.a.i - Peatlands remaining peatlands	CO2	-0.02	-0.02	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.00	0.00
3.B.4.a.i - Peatlands remaining peatlands	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.5.a - Settlements Remaining Settlements	CO2	0.00	0.00	35.00	6.14	35.53	0.00	0.00	0.00	0.00	0.00	0.00
3.B.5.b.v - Other Land converted to Settlements	CO2	0.00	0.40	35.00	6.14	35.53	0.00	0.00	0.00	0.00	0.00	0.00
3.D.1 - Harvested Wood Products	CO2	-2.04	-3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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4.A - Solid Waste Disposal												
4.A - Solid Waste Disposal	CH4	0.00	27.25	25.00	6.14	25.74	0.01	0.01	0.01	0.03	0.18	0.03
4.C - Incineration and Open Burning of Waste												
4.C.1 - Waste Incineration	CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.1 - Waste Incineration	CH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.1 - Waste Incineration	N2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CO2	0.66	1.01	25.00	6.14	25.74	0.00	0.00	0.00	0.00	0.01	0.00
4.C.2 - Open Burning of Waste	CH4	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	N2O	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
Total												
	Sum(C): 5353.291		Sum(D): 6435.920			Sum(H): 127.390					Sum(M): 137.961	
						Uncertainty in total inventory: 11.287					Trend uncertainty: 11.746	