THE STATE OF ERITREA
MINISTRY OF LAND, WATER AND ENVIRONMENT

ERITREA'S SECOND NATIONAL COMMUNICATION

Under the United Nations Framework Convention on Climate Change (UNFCCC)

February 2012
Asmara, Eritrea

FOREWORD

There are a number of reasons that Eritrea had ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. Given its past land use practices as well as its location, physical features, and arid climate, Eritrea has an area liable to drought and desertification, fragile eco-system including mountainous ecosystem and low-lying coastal area and the country is dependent on consumption of fossil fuels and associated energy-intensive products.

Increased climate variability has already been evidenced in Eritrea. Mean annual temperature has increased by 1.7 ^{0}C since 1960, an average rate of 0.37^{0}C per decade. The increase is most rapid in July, August and September at a rate of 0.55^{0}C per decade which is the most important season in Eritrea for agricultural production. Increases in the frequency of hot nights are larger and statistically significant in June, July and August as well as October, November and December and in the annual data. The average number of 'cold' nights per year has decreased by 34 (9.3% of days). The 1912-2005 data suggest that rainfall has been declining for central and southern highlands on average by circa 0.4 mm/year. Eritrea has experienced frequent and recurrent droughts since the early 1920s which has aggravated food insecurity and poverty. The spread of malaria in the upland, which has never experienced before, desertification and decline in biodiversity have also been witnessed. A number of recent assessments have revealed that observed climate change has already serious impacts on socio-economic systems and livelihoods of the country.

It could be noted from Eritrea's Initial and Second National Communications that Eritrea's GHG emissions are negligible small. Nevertheless, Eritrea has recognized that climate change is a global challenge and should be approached by collective actions of developed and developing nations. As a Party to the Convention, Eritrea is willing to fulfill its commitment to the achievement of the ultimate objective of the Convention. Besides the preparation of Eritrean NAPA, in both national communications that Eritrea has thus far prepared, the country has identified a number of potential GHG mitigation and adaptation options. They can contribute to the national sustainable development objectives and protection of the global climate system only if they are translated into short and long-term strategies and implemented effectively.

Eritrean Second National Communication (SNC) contains information required by the UNFCCC from Non-Annex I Parties and specifically it provides comprehensive description of the climate and climate change background of the country since the reporting of its Initial National Communication (INC) in 2001. Nonetheless, the preparation of Eritrea's Second National Communication (SNC) has been motivated not only to comply with the reporting commitment of Eritrea to the COP of UNFCCC but also to serve as a clear roadmap to support the rapidly evolving process of mitigation and adaptation policy making. The SNC being a policy tool seeks to offer a flexible approach to implement responsive mitigation and adaptation strategies, polices and measures.

It is an honour and a great pleasure for the Ministry of Land, Water & Environment to submit, on behalf of the Government and People of Eritrea, the Eritrean Second National Communication to the Conference of Parties through the secretariat of the UNFCCC.

December 2011

Mogos Wolde-Yohannes
Director General
Department of Environment
Ministry of Land, Water and Environment

ACKNOWLEDGEMENT

The Second National Communication (SNC) of Eritrea to the UNFCCC is the result of the Climate Change Enabling Activities supported by the Global Environmental Facility (GEF). The objective of preparation of SNC is to promote sustainable development of the country while contributing to the achievement of the ultimate objective of the Convention. On the other hand, preparation of SNC has provided Eritrea great experience that can be used to undertake similar work in the future.

The SNC Project office would like to take this opportunity to express its thanks to the GEF for its financial and technical support in preparing National Communications on a continuous basis. It would also like to acknowledge the UNFCCC Secretariat particularly the staffs of Non-Annex I Implementation Programme, the various Subsidiary Bodies (SBI & SBSTA), the National Communications Support Program (NCSP) for coordinating the review of Eritrean SNC and arranging workshops, providing and distributing technical materials, information and analytical tools.

Special thanks go to the members of the Steering Committee who oversee and give guidance for the preparation of National Communications on a continuous basis. We would also like to thank the various Thematic Working Groups, namely, the GHG Inventory, the GHG Mitigation Assessment and Analysis, the V&A Assessment, the Technology Transfer, and Research and Systematic Observation, and Education, Training and Public Awareness, Information and Networking and Capacity-Building Thematic Working Groups. This report is the result of a collaborative work among experts from Government, Non-government, Education and Research Institutions.

The SNC Project office takes this opportunity to thank various individuals and consultants, namely, Dr. Devaraji de Condappa-associate professor of the SEI, US Center, Dr. Wei Ye from CLIMSystems Ltd-New Zealand, Dr. Audace Ndayizeye from Burundi, Dr. Gilbert O Oume from Kenya, Dr. Mark Tadross and Dr. Oliver Crespo both from CSAG-South Africa, Dr. Carlos Lopez from Cuba, Yamil Bonduki ,Gabriela Walker and Allison Towel from UNDP-GEF, New York, United States, CTMREH from Asmara and others who have contributed or facilitated inputs related to capacity-building of the country team.

Finally, the project office would like to express its deepest gratitude to the Project Support Team who directly contributed to the preparation of this National Communication. Had it not been for them, this exercise would not have been realized.

Seid Abdu Salih
SNC, National Project Coordinator
Department of Environment
Ministry of Land, Water & Environment

TABLE OF CONTENTS

LIST OF ACRONYMS

ACMAD:	African Center of Meteorological Applications for Development
AF:	Adaptation Fund
AFOLU:	Agriculture, Forestry & Other Land Use
AGRHYMET:	Regional Center for Training and Application in Agrometeorology and Operational Hydrology
ALM:	Adaptation Learning Mechanism
AOGCMs:	Atmospheric Oceanic Global Circulation Models
APF:	Adaptation Policy Framework
AR4:	Fourth Assessment Report of the Intergovernmental Panel on Climate Change
ARI:	Acute Respiratory Infections
ASCII:	American Standard Code for Information Interchange
BRT:	Bus Rapid Transit
CSAG:	Climate Systems Analysis Group
CBOs:	Community Based Organizations
CC:	Climate Change
CFL:	Compact Flourcent Lamp
CDM:	Clean Development Mechanism
CERs:	Certified Emission Reductions
CHP:	Combined Heat and Power
CLIMSystems:	Decision Making in a climate changed world
COMESA:	Common Market for Eastern and Southern Africa
CSO:	Civil Society Organization
COP:	Conference of the Parties of UNFCCC
CRF:	Common Reporting Framework
CSV:	Comma Separated Variable
DANIDA:	Danish International Development Agency
DMC:	Drought Monitoring Center
DOE:	Department of Environment
ECD:	Early Childhood Development Program
ENDA:	Environment Development Action
ENPEP:	Energy and Power Evaluation Programme
ENSO	El Nino Southern Oscillation
ET:	Evapotranspiration
FAO:	Food Agricultural Organization of the United Nations
FNR_Rio:	Facilitating National Reporting for the three Rio Conventions
FSS:	Food Security Strategy
GAN:	Global Climate Change Adaptation Network
GAW:	Global Atmospheric Watch
GCOS:	Global Climate Observation System
GDI:	Gender Development Index
GDP:	Gross Domestic Product
GEF:	Global Environmental Facility
GER:	Gross Enrolment Rate
Gg:	Giga gram
GHG:	Greenhouse Gas
GIS:	Geographical Information System
GPG:	Good Practice Guidance
GSE:	Government of the State of Eritrea
GUAN:	Global Upper Air Network
GWP:	Global Water Partnership
GWP:	Global Warming Potential
HCS:	High Climate Sensitivity
HDI:	Human Development Index
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
IGAD: Inter Governmental Agency for Development
IHEs: Institutions of Higher Education
INC: Initial National Communication
IPCC: Intergovernmental Panel on Climate Change
I-PRSP: Interim Poverty Reduction Strategy Paper
ITCZ: Inter Tropical Convergence Zone
IWRM: Integrated Water Resources Management
Kc: Crop Coefficient
Ke: Crop Coefficient for Evaporation
Kcb: Basal Crop Coefficient for Transpiration
KP: Kyoto Protocol
LAI: Leaf Area Index
LCS: Low Climate Sensitivity
LDCs: Least Developed Countries
LDCF: Least Developed Countries Fund
LEAP: Long range Energy Alternative Planning
LPG: Liquefied Petroleum Gas
LUCF: Land Use Change & Forestry
LULUCF: Land Use Land Use Change & Forestry
MAED: Model for Analysis of Energy Demand
MAR: Mean Annual Rainfall
MAT: Mean Annual Temperature
MEAs: Multilateral Environmental Agreements
MDGs Millennium Development Goals
M&E: Monitoring & Evaluation
MOA: Ministry of Agriculture
MOEM: Ministry of Energy and Mines
MOH: Ministry of Health
MOLWE: Ministry of Land, Water & Environment
MOND: Ministry of National Development
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
NAMAs: National Appropriate Mitigation Actions (NAMAs)
NAP: National Action Plan for Drought & Desertification
NAPA: National Adaptation Programmes of Action
NARI: National Agricultural Research Institute
NBSAP National Biodiversity Strategy & Action Plan
NC: National Communication
NCSP: National Communication Support Programme
NCSA: National Capacity Needs Self Assessment
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 Center
NGAP: National Gender Action Plan
NGHGITWG National Greenhouse Gas Inventory Thematic Working Group
NGHGMTWG National Greenhouse Gas Mitigation Assessment and Analysis Thematic Working Group
NHCP: National Healthcare Policy
NICE: National Insurance Corporation of Eritrea
NMVOC: Non-Methane Volatile Organic Compounds
NUEW: National Union of Eritrean Women
NUEYS: National Union of Eritrean Youth and Students

NVATWG	National Vulnerability and Adaptation Assessment Thematic Working Group
NWP:	Nairobi Work Programme
OND	October, November, December
PEM:	Protein-Energy Malnutrition
PFDJ:	People Front for Democracy and Justice
PIF:	Project Identification Form
PRECIS:	Providing Regional Climate for Impacts Studies
PPs:	Project Profiles
QA/QC:	Quality Assurance and Quality Control
RAF+:	Resource Allocation Framework Plus
RCM:	Regional Climate Model
RD:	Research and Development
RET:	Renewable Energy Technology
RMS:	Root Mean Square
SCC:	Social Cost of Carbon
SCCF:	Special Climate Change Fund
SD:	Standard Deviation
SEI:	Stockholm Environment Institute
SGP:	Small Grant Programme
SimCLIM:	Simulation of Climate
SEI:	Stockholm Environment Institution
SLR:	Sea Level Rise
SNC:	Second National Communication
SoER:	State of Environment Report
SPA:	Strategic Priority on Adaptation Fund
SPM:	Summary for Policy Makers
SRES:	Special Report on Emission Scenarios
SSA:	Sub-Sahara Africa
START:	Global Change SysTem for Analysis, Research and Training
SWC:	Soil and Water Conservation
SWDS:	Solid Waste Disposal Site
TAR:	Third Assessment Report of the IPCC
TED:	Technological and Environmental Data
TNA:	Technology Needs Assessment
ToRs:	Terms of References
TVET:	Technical and Vocational Education Training
UNCCD:	United Nations Convention on Combating Desertification
UNCBD:	United Nations Convention on Biodiversity
UNDP:	United Nations Development Programme
UNEP:	United Nations Environmental Programme
UNFCCC:	United Nations Framework on Climate Change
UNITAR	United Nations Institute for Training and Research
USD:	United States Dollar
V&A:	Vulnerability and Adaptation
VATWG:	In-Country Vulnerability and Adaptation Thematic Working Group
WEAP:	Water Evaluation and Planning
WG:	Working Group of the IPCC
WRD:	Water Resources Department
WMO:	World Meteorological Organization

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

MEASUREMENT UNITS

Unit Abbreviation	Measurement Unit Name	Measurement Equivalent
Ha	Hectare	1 Hectare = 0.01 Square Kilometer
Km^2	Square Kilometer	1 Square Kilometer = 1,000,000 Square Meter
Tj	Tetra Joule	1 Tetra Joule = 10^{12} Joules
Tc	Tetra Calorie	1 Tetra Calorie = 10^{12} Calories
C	Calorie	1 Calorie = 4.12 Joules
MJ/Kg	Mega Joule per Kilogram	1 Mega Joule per Kilogram = 10^6 Joules per Kilogram
MJ/Litre	Mega Joule per Litre	1 Mega Joule per Litre = 10^9 Joules per Cubic Meter
Kg/Litre	Kilogram per Litre	1 Kilogram per Litre = 1,000 Kilogram per Cubic Meter
Gg	Gigagram	1 Gigagram = 10^9 Grams
Kg ha^{-1}	Kilogram per Hectare	1 Kilogram per Hectare = 1 Kilogram per 10^4 per Square Meter
T/h	Tone per Hectare	1 Tone per Hectare = 10^2 Tone per Square Kilometer or 10^3 Kilogram per Square Kilometer

EXECUTIVE SUMMARY

1. Introduction

Eritrea's Second National Communication (SNC) to the COP of the UNFCCC is an endeavor to report on climate change related activities carried out in the country since the reporting of its Initial National Communication (INC) in 2001. This report includes, among others, national inventory of anthropogenic GHG emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol, GHG mitigation assessment and analysis, impact, adaptation and vulnerability assessment, technology needs assessment, education, training and public awareness and systematic observation components of the SNC.

2. National Circumstances

Eritrea is located in the Horn of Africa, lying between 12º 22′, and 18º 02′ north and between 36º 26′ and 43º 13′ east. Sudan borders it in the west, Ethiopia in the south, Djibouti in the southeast, and the Red Sea in the east. The country has a total land area of 124, 300 km^2, and a coastline of 1900 km. Eritrea's territorial waters in the Red Sea zone are about 120,000 km^2.

The population of Eritrea is approximately 3.66 million[1], with population growth rate at 2.74%[2] and an average density of about 28 persons per km^2. Despite the fact that Eritrea is small country, it has diverse ethnic groups. These ethnic groups are Afar, Bilen, Hedarb, Kunama, Nara, Rashaida, Saho, Tigre and Tigrinya. Eritrea is a young country that is heavily engaged in the reconstruction and development of its economy. Its aspiration is to become a developed and democratic nation where the potentials of its people are fully realized.

The country could roughly be divided into three physio-graphic regions, namely, the central highlands, the midlands and the lowlands. The months from June-September are characterized by relatively high pressures in Southern and western Africa and very low pressure in Asia creating prevailing southwesterly winds. The resulting southwest monsoon characterized by moist airflows from the South brings rains in the highlands. During the months of October-March, a reverse pressure gradient created by the high pressure areas advancing from Asia toward the low pressure area of southern Africa creates northeasterly winds. These northeasterly monsoons results in a continuing dry continental air mass, which is responsible for the driest season of the year. Portion of northeasterly winds, that pass over the Red Sea, pick up moisture and deliver very little amount of rainfall along the coastal plain. However, when facing the steep escarpment, abundant rainfall is produced there by orographic effects, especially during the period November through March.

The mean annual temperature in Eritrea ranges from temperate comfortable 16^0C in the highlands around Asmara to extreme high temperature along the Red Sea coastal area to over 31^0C around Assab. As precipitation, temperature also fluctuates with altitude.

Approximately 66% of the population was living below the poverty line in 2003. Eritrea's per capita GDP is US$ 626[3]. Eritrea's economy is based primarily on agriculture, followed by mining, fisheries, industry, tourism and service sector. Over 80 per cent of the population relies on traditional subsistence crop cultivation

---

[1] National Demographic Health Survey, 2002. A further million Eritreans live abroad, mostly in Sudan with lesser numbers in Saudi Arabia, Germany, USA and elsewhere.

[2] Eritrea Interim-Poverty Reduction Strategy Paper, April 2004

[3] 2007 Africa Report of the World Bank

and livestock husbandry[4]. Despite this, agriculture, which is primarily rain fed, accounts for just one-fifth of the gross domestic product (GDP). Less than 10% of arable land is irrigated. Key socio-economic indicators of the country for 2003 are shown in Table ES.1.

Table ES.1: Important Physical, Social and Economic Indicators (2003)

Indicator	**Value**
Population (millions)	3.66
Population Growth Rate (%)	2.74
Average Population Density (Persons per Km 2)	28
Land surface area (‘000 km2)	124.3
Territorial water area (‘000 km2)	120
GDP (US $)	626
Share of Agriculture in GDP (%)	19
Arable land (‘000 ha)	2100
Land under cultivation (‘000 ha)	417
Urban population (% of total population)	20
Access to safe-water supply- urban (% of total population)	70
Access to safe-water supply- rural (% of total population)	50
Irrigated land (% of total land)	< 10
Gross Enrolment Rate (GER)	42
Forest area (% of the total area)	0.5
Biomass energy consumption (% Total Final Energy Supply)	77.3
Incidence of poverty (% of population)	66
Human Development Index (HDI)	0.472
Gender Development Index (GDI)	0.459
Level of malnutrition children under five (%)	40

Source: (NSEO, 2003)

There are five major river basins in Eritrea namely: Mereb-Gash, Barka-Anseba, Setit, Red Sea and Dankil Depression. The Mereb-Gash basin has a total area of 23,200 km^2, of which about 21,000 km^2 is within Eritrea. The Barka-Anseba is the largest basin that rises within Eritrea (41,300 km^2). The Setit basin lies south of the Mereb-Gash and rises in central Ethiopia and flows northwards, forming the border between Ethiopia and Eritrea in the far south-western corner of Eritrea. It is also the only perennial river in Eritrea. The Red Sea and the Danakil Depression are each formed of numerous small separate basins, with a total area of about 54,500 km^2.

3. National Greenhouse Gas (GHG) Inventory

The second national GHG inventory has addressed potential key GHG emitting and removal sectors including the Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste Sectors. The inventory has addressed three major direct greenhouse gases including Carbon Dioxide (CO_2), Methane (CH_4)

[4] Ministry of Land, Water and Environment. (2007*). National Adaptation Programme of Action*.(NAPA) . Asmara, Eritrea.

and Nitrous Oxide (N_2O) and other ozone precursors and indirect greenhouse gases including Carbon Monoxide (CO), Nitrogen Oxides (NOx), Non-Methane Volatile Organic Compounds (NMVOCs) and sulphur dioxide.

The Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories was used for estimating and reporting Eritrea's second national greenhouse gas inventory. The methodology used to estimate carbon emissions from Land Use and Land Use Change and Forestry (LULUCF) was based on IPCC guidelines of 2006 Volume 4 and Good Practice Guidance (GPG) 2003.

Emissions of Main Greenhouse Gases- 2000

Carbon dioxide (CO_2)

The total national CO_2 emission in 2000 was 8,826 Gg. Key GHG Source Categories, which contributed to the total emission, were the Energy Sector 586 Gg, Industrial Processes 35 Gg and the Land Use Change and Forestry (LUCF) Sector 8,205 Gg. In percentages, the CO_2 emissions from the energy, industrial processes and the LUCF source categories were 6.6%, 0.4% and 93 %, respectively.

Thus, biomass uptake was not sustainable in Eritrea in 2000. The highest CO_2 emission came from Changes in Forest and Other Woody Biomass Stocks sub-sector which was 4,722 Gg followed by the Forest and Grassland Conversion sub-sector which was 3,608 Gg. The whole of CO_2 emission in the Industrial Processes was contributed from mineral products of cement and lime production as well as limestone use which was estimated to be 35 Gg nearly 0.4% of the total CO_2 emission in 2000.

Methane (CH_4)

The total national methane emission in 2000 was 147 Gg of which the Agricultural sector emitted the highest level which was 133 Gg (90.5%) followed by Energy 8.3 Gg (5.4%), Land-Use Change and Forestry 4 Gg (2.7%) and Waste sector 2 Gg (1.4%).

Nitrous Oxide (N_2O)

Nitrous Oxide emission was estimated at 1 Gg coming exclusively from the agricultural sector of Agricultural Soil source sub-category.

Aggregated Emissions of Trends

The key share of GHG, primarily CO_2 was from LUCF, accounting for about 93% of the total absolute CO_2 emissions. This was followed by energy use from fuel combustion which accounted for 7 % of the total absolute emission of CO_2. Key share of CH_4 was from Agriculture, accounting for about 90 % of the total absolute CH_4 emissions. This was followed by energy use from Fuel Combustion which accounted for 5.4 %, LUCF 2.7% and waste 1.4 %. The resultant GHG emissions in Eritrea therefore amounted to 12,223 Gg CO_2 equivalent in 2000. In this context, the country's source of GHG emissions, by sector, mainly came from LUCF, Agriculture and Fossil Fuel Combustion accounting for about 67.8 %, 25.4 %, and 6.2% respectively of total CO_2 equivalents. When viewed by gases, CO_2, CH_4 and N_2O were the main pollutants, accounting for 72.2 %, 25.3 %, and 2.5 %, respectively.

Key Source Analysis

The LUCF, Energy and Agriculture Sectors were key sources while in terms of greenhouse gases, CO_2 and CH_4 were key greenhouse gases in terms of absolute level of emissions and trends of emissions. The key categories LUCF, Energy and Agriculture Sectors and the key greenhouse gases CO_2 and CH_4 were therefore flagged for consideration in the GHG Mitigation Assessment and Analysis.

Uncertainty Assessment

Although the ***LUCF*** was a key category, default factors were used to estimate emissions as there was lack of detailed and regularly updated, checked and published activity data or experimentally measured parameters that assisted in the determination of country specific emission factors. Emission factor and Default Value Sources were obtained from 2006 IPCC - NGGI Guidelines, Vol 4 and GPG 2003.These values were regional values that did not take national circumstances in to consideration. The statistics of traditional wood that was gathered and used directly for household firewood purposes and the coverage of forest area burnt were of very high uncertainty as such activities were not reported. Also there was high uncertainty in the annual forest clearing rates and the amounts of biomass and therefore carbon removed from the given forest. These values were lacking in Eritrea, and hence the IPCC default values were adopted to serve a purpose. Lack of time series data was another obstacle to the national inventory of GHG. Relatively speaking the lack of data was more limiting in the LUCF sector as compared to the other sectors. In light of this situation the uncertainties in the LUCF sector could be quite high.

4. GHG Mitigation Assessment and Analysis

In order to conduct GHG mitigation assessment and analysis in the Energy sector, a bottom-up and integrated system approach was utilized using the Long range Energy Alternatives Planning (LEAP) modeling tool. Besides LEAP and for verification purpose, another bottom-up energy demand model known as Model for Analysis of Energy Demand (MAED) was also used to project Eritrea's Energy Demand.

The scope of the study was to conduct 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. The time frame 2000-2030 was selected for the study. In estimating the demand projections two scenarios, namely, Reference (business as usual) and Mitigation Scenarios were considered.

Major identified mitigation options in the energy supply sub sector includes, among others, increasing plant and end-use efficiencies, reducing losses in the transmission and distribution of electricity and fuels, and increasing the use of renewable energy forms including solar, wind, and geothermal energy.

Mitigation measures in the transport sub-sector hence includes fuel efficiency improvements, such as changes in vehicle and engine design (e.g. hybrids), expansion of public transport infrastructure, raising public awareness and introducing public transport technologies such as buses and trains.

Mitigation options in the household sub-sector includes electrification of households, replacement of inefficient incandescent lamps with more efficient compact fluorescent lamps (CFLs), improvement of efficiency of traditional biomass stoves, increase supply of modern fuels to allow fuel substitution. These options are also synergistic in reducing the pressure on forest degradation and reducing CO_2 emissions from LUCF sector.

Identified ***market-based instruments*** include GHG emissions and fuel carbon content related taxes, 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 include tradable emissions permits and renewable portfolio standards. Government funded research, development and demonstration activities are also vital in establishing a low-carbon energy system.

5. Impact, Adaptation and Vulnerability Assessments

System Studied and Project Boundary

The study boundary was the Mereb-Gash Basin which was identified to be socially and economically significant. The vulnerability and adaptation assessments focused on water resources and agricultural sectors. Nonetheless, integration of indirect effects of climate change in other sectors including human health, settlement, ecosystem, crop and livestock was addressed and potential adaptation options were identified. To undertake the assessment, primary and secondary stakeholders were identified. They have been engaged intensively based on comprehensive stakeholder analysis that includes role analysis, responsibilities, mandates and contribution towards the preparation of Eritrean SNC. The follow-up to the assessment will be the formulation of a comprehensive adaptation strategy for inclusion in national development plan and policies and preparation of fundable concrete projects and programmes for implementation.

Framework, Approach and Method for Assessment

The Adaptation Policy Framework (APF) was used, mainly, as a Vulnerability and Adaptation Framework. The *Intergovernmental Panel on Climate Change (IPCC) seven steps*, the *UNEP Handbook* (Feenstra et al., 1998) and the *NAPA guidance* were also used as additional frameworks, as appropriate. Within the APF, the vulnerability-based approach was used to assess current climate risks while the natural hazards-based approach was used to assess future climate risks. The adaptive capacity and policy-based approaches were also used to evaluate current and ongoing adaptation strategies, policies and measures.

An integrated climate model known as SimCLIM was used to develop future climate and climate change scenarios. The sectoral impact models which were applied included the CropWater 4 Windows 4.3 agricultural model, FAO crop coefficient model, Rainfall-runoff hydrological model developed for Eritrea and Water Evaluation and Planning (WEAP) model. One baseline socio economic scenario and two alternative future socio-economic scenarios based on the B2 and the A2 SRES emission scenarios, the best case and the worst case scenarios, were developed and linked with the climate change scenarios and impact models.

Current Climate Variability

Mean annual temperature has increased by 1.7 ^{0}C since 1960, an average rate of 0.37^{0}C per decade[5]. The increase is most rapid in JAS[6] at a rate of 0.55^{0}C per decade. While increases in the frequency of 'hot' days have been small, increases in the frequency of hot nights are larger, and statistically significant in JJA, OND, and in the annual data. The 1912-2005 data suggest that rainfall has been declining for central and southern highlands on average by circa 0.4 mm/year.

Projected Climate Changes

The 1961-1990 climate has been taken as the baseline climate of the country. The scenario period is 30 years (2007-2035). An ensemble method of developing annual and seasonal future climate and climate change scenarios has been used. In this method, 21 transient AOGCMs were run for different time slices (2020s, 2030s and 2050s) with A2 and B2 emission scenarios and selected climate sensitivity (low (1.5^{0}C) ,mid (2.5^{0}C) and high (4.5^{0}C)) to generate the 10 and 90 percentiles and median projections. In the model time

[5] UNDP country-level climate profile
[6] July, August, September

slices, 2030s and 2050s, the lowest projected mean annual precipitation change is -33% while the projected highest precipitation change is 44%. The lowest projected mean annual temperature change is 0.4 ^{0}C while the projected highest temperature change is 3.2^{0}C.

A. Impact, Adaptation and Vulnerability Assessment of Water Resources Sector

Efficacy of Current Adaptation Policies and Measures in Water Resources

After full treatment of the components of vulnerability, it has been concluded that the ongoing adaptation polices and measures are not effective in coping with ***current climate variability and change*** because the level of burden due to exposure and sensitivity is already too much and the adaptive capacity is too weak. The greater the exposure or sensitivity, the greater the vulnerability while the higher the adaptive capacity, the lower the vulnerability. Therefore, autonomous and planned, reactive and anticipatory adjustment and additional types of adaptation options, polices and measures, which are effective, feasible and acceptable, have to be identified, prioritized and implemented so that current vulnerability is reduced and coping range is enhanced in so doing prepare for future to minimize the worst and maximize the benefit of future climate change and variability.

Simulation of Potential Impacts of Climate Change

After calibration and verification of the impact model (WEAP), the simulations of streamflow, groundwater and catchment processes during climate change were conducted. For this purpose, the Mereb-Gash Catchment was divided into three sub-catchments including the Mereb Headflow, Mereb Catchment and Gash Catchment. The most likely climate change scenarios were used for the simulation. The results of simulations could be summarized as follows.

Potential Impacts on Streamflow

Under the B2 high climate sensitivity 10 percentile scenario, the streamflow of the Mereb-Gash River will likely to decrease by 50 % in 2030s. Under this scenario, the Basin will likely to face negative adverse effects by increased drought hazards with potential harm on biophysical and socio-economic systems.

On the other end, under the B2 high climate sensitivity 90 percentile scenario in 2030s, the streamflow will likely to increase by 244% for Mereb and by 223% for Gash Catchment in 2030s. Thus, with increasing climate change, the Basin will likely to be impacted positively and/or negatively depending on the nature of the outcomes and the magnitude of impacts. Hence, both the upstream and the downstream will likely be impacted but the impact in the upper catchment will likely be more noticeable. Generally, heavy precipitation events with increased frequency and flash floods will likely to prevail with potential biophysical and socio-economic impacts.

Under the B2 high climate sensitivity 10 percentile scenario in 2030s with high population growth rate of 5%, the streamflow will likely to decrease by 50 % and 68 % for Mereb and Gash Catchments, respectively, in 2030s. Thus, the compounded effect of climate change and increased population growth rate will likely to have more pronounced impact on the Basin than that projected exclusively by the B2 high climate sensitivity 10 percentile scenario in 2030s.

Potential Climate Change Impacts on Groundwater

Under all likely climate change scenarios, the groundwater storage of Mereb-Gash Basin will likely to decrease in the scenario period. The groundwater storage under different future climate change scenarios is summarized in Table ES.2.

Table ES.2: Groundwater Storage in Mereb-Gash Basin (Mm^3) under Different climate Scenarios

Scenarios	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Reference	477	460	451	450	442	435	485	595	544	510	513	507
Expansion of Irrigation (5%)	155	72	31	1.7	0.9	0	43	173	261	266	212	214
B2 90% 2030s	471	478	458	458	459	459	510	593	527	482	484	485
B2 10% 2050s	427	426	390	390	366	325	375	501	503	498	476	476
B2 10 % 2030s & population growth (5%)	432	413	400	389	370	344	394	520	578	480	481	459
B2 10% 2030s	448	430	418	407	388	362	412	539	589	496	497	476
A2 10% 2030s	459	441	428	418	400	374	424	551	590	506	506	485

Source: NVATWG, 2011

Simulation of Potential Climate Change Impacts on Evapotranspiration

Evapotranspiration change from the headflow will likely be negligibly small under all climate change scenarios as the area of the headflow is small. Mereb catchment will likely to experience the highest evapotranspiration under all climate change scenarios; and the highest evapotranspiration will likely be under the B2 high 90 percentile scenario in 2030s when much available precipitation is accompanied by intense heating.

Potential Climate Change Impacts on Soil Moisture

The highest soil moisture loss will likely to occur in both major catchments from the Browsing and Grazing Land Use. Gash catchment will likely to lose the highest soil moisture under expansion of irrigation followed by the B2 high 90 percentile scenario in 2030s. Mereb Catchment will likely to lose the highest soil moisture under the B2 high 90 percentile scenario in 2030s when the temperature change is projected about 3^{0}C. This will likely to have negative impact on livestock as a result of potential drought. The pastoralists and agro-pastoralists will likely be the most vulnerable.

Potential Climate Change Impacts on Water Demand

The B2 high climate sensitivity 10 percentile scenario in 2030s projects an additional 1.1 Billion m^3 supply of water required with respect to the reference. This scenario if compounded with population growth rate of 5% will likely to require an additional supply of 2.2 Billion m^3 of water as compared to the reference. Thus, the compounded impact of climate change and population growth would be severe on the Mereb-Gash Basin. The projected water demand for the scenario period under different climate change scenarios is summarized in Table ES.3.

Table ES.3: Mereb-Gash Water Demand under Different Climate Change Scenarios (2007-2035) (Billion m^3)

Scenario	Gash Catchment	Gash Domestic	Gash Livestock	Mereb Catchment	Mereb Domestic	Mereb Livestock	Others Gash	Others Mereb	Sum
Reference	3.2	0.2	0.4	2.2	0.2	0.3	0	0.1	6.6
High Population Growth (5%)	3.2	0.3	0.4	2.2	0.3	0.3	0	0.1	6.8
B2 90, 2030s	3.1	0.2	0.4	1.9	0.2	0.3	0	0.1	6.2
Exp.Irrigation	24.0	0.2	0.4	5.0	0.2	0.3	0	0.1	30
B2 10, 2050s	3.7	0.2	0.4	3.4	0.2	0.3	0	0.1	8.3
B2 10, 2030 & Population Growth (5%)	3.7	0.4	0.4	3.4	0.5	0.3	0	0.1	8.8
B2 10, 2030s	3.5	0.2	0.4	3.0	0.2	0.3	0	0.1	7.7
A2 10, 2030s	3.5	0.2	0.4	3.0	0.2	0.3	0	0.1	7.7

Source: NVATWG, 2011

Integration of Potential Climate Change Impacts

Cross-sectoral integration, involves examining sectors that are interrelated as climate change impacts do not happen in isolation from each other. For example, what happens in water resources affect other sectors, inter alia, crop, settlements, livestock, ecosystem and human health. Details of indirect effects are found in the relevant chapter of this report.

Effectiveness of Existing and Potential Adaptations in Light of Current Climate

The ongoing measures and polices need to be improved in such a way that both the direct and indirect effects of current climate variability and change are considered. The strategy should take water as an integrator to deal with today's climate hazards occurring across sectors in that the impacts of climate variability and change on water resources propagate naturally to other human and natural systems. Cross-sectoral strategy has to be pursued by identifying those sectors which have logical linkages with water resources, identifying the indirect effects of climate variability and change on them and designing additional integrated adaptation options, polices and measures.

When these additional adjustments or adaptive capacities are integrated to the ongoing planned and autonomous adaptations, as appropriate, and fully realized, the coping range of all systems including human and natural, managed and unmanaged will expand. This in turn displaces critical vulnerability thresholds, enhances resilience while reducing vulnerability. Details of the additional strategies are found in the relevant section of this report.

Effectiveness of Existing and Additional Adaptations in Light of Future Climate Change

The ongoing and additional adaptation options, policies and measures could be improved to deal with future climate and variability by developing a dynamic and process-oriented approach to adaptations referencing established indicators. Careful monitoring and evaluation (M&E) of implemented adaptation measures can enable to assess what is working, what is not working, and why. Learning by doing is also another approach to be pursed. This approach will enable to undertake midcourse corrections in implemented adaptations, so that they meet their objectives more efficiently; and improve the understanding of the determinants of adaptive capacity so that capacity development activities can be more successful from the outset.

Adaptation options, policies and measures could reduce vulnerability in the future by pursuing strategies and actions which could reduce uncertainty in climate change impact projections, by enhancing adaptive capacity inherent in the system representing the set of resources available for adaptations, as well as the ability of the people to use these resources effectively in the pursuit of adaptation. Such resources are natural, financial, institutional or human, and include access to ecosystems, information, expertise, and social networks. However, the realization of this capacity (i.e., actual adaptation) may be frustrated by outside factors; these external barriers, therefore, should be addressed. At the local level, such barriers may take the form of national regulations or economic policies that make certain adaptation strategies unviable.

B. Impact, Adaptation and Vulnerability Assessment of Agriculture Sector

Mereb-Gash Basin is the major sorghum, wheat and barley producing region in the country. Most barley is also produced in this zone. The leading commodities as far as consumption is concerned are wheat (41 percent), sorghum (14 percent) and other roots and tuber crops (11 percent) in the country. Sorghum is a staple food crop consumed in different forms. Hence, modeling of the impact of climate change on these three cereals in the Mereb-Gash Basin has a paramount importance and priority.

Efficacy of Current Adaptation Policies and Measures in Agriculture Sector

After full treatment of the components of vulnerability, it has been concluded that the ongoing adaptation polices and measures in agriculture sector are not effective in coping with ***current climate variability and change*** because the level of the burden due to exposure and sensitivity of agricultural sector is already too much and the adaptive capacity is too weak. Therefore, autonomous and planned, reactive and anticipatory adjustment and additional types of adaptation options, polices and measures, which are effective, feasible and acceptable, have to be identified, prioritized and implemented so that current vulnerability is reduced and coping range is enhanced in so doing prepare for future to minimize the worst and maximize the benefit of future climate change and variability.

Potential Climate Change Impacts on Total Yield

Under future climate change scenarios of moderate to medium climate warming and all farming conditions, major cereals will continue to be heat and drought resilient and water efficient crop in Eritrea. But with increased climate change this characteristic will likely be compromised as the critical thresholds would be exceeded resulting in vulnerability of the crop sub-sector. Under water harvesting, supplementary and improved full irrigation practices and other technologies, it could possible to minimize the impact of climate change on cereal yield. However, it could not be possible to avoid fully the potential adverse impacts of climate change to bring about what is known as a “sustainable agricultural production” under uncertain changing climate and demographic factors.

Potential Climate Change Impacts on Cereal Market Value

For all climate change scenarios, the total market value has been projected based on the discount rate of 4%. Under all scenarios except the B2 SRES emission scenario, the total market value, for both the rainfed and irrigated cereals, would be near the present value. That means there would be a decrease in cereal yield but an increase in cereal price. This may have some influence on food security and food cost in the country. This analysis is consistent with that projected by the IPCC AR4 in that crop production in low latitude developing countries would suffer more, and earlier than in mid-to-high latitude developed countries due to a combination of adverse agro-climatic, socio-economic and technological conditions (Alexandratos, 2005).

Under the B2 SRES emission scenario, the total market value for both rainfed and irrigated cereals in the scenario period would decrease between 16 and near zero percent in 2030s and between 10 and 2 percent in

2050s. Nonetheless, the impact could be significantly minimized in the near term by supplementary and improved irrigation practices, improved crop management practices, land and water management and the use of land races that are adapted to local agro-climatic and environmental conditions.

6. Other Information

This section provides for the provision of other information considered relevant to the achievement of the objectives of the Convention.

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

Adaptive capacity depends on the availability of national resources including economic, social capital, access to ecosystem, information, technology, education, wealth. Nonetheless, the availability of these resources by itself cannot address climate change vulnerability. The resources have to be used effectively so as to realize adaptive capacity or enhance coping range to deal with current variability and change. In this backdrop, Eritrea has been devoting substantial amount of resources to promote development of its social, economic and environmental sectors along with supporting enabling environment and has made significant progress in all walks of life. Details of these actions are found in the relevant section of this report.

Activities Related to Technology Transfer

The negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have created a framework to promote the transfer of technologies. Technology transfer comprises five steps including technology needs and needs assessment, technology, enabling environments, capacity-building and mechanisms for technology transfer. In Eritrea, the first three steps including implementation plan have been completed while capacity-building and mechanisms for technology transfer are ongoing processes. The details of Eritrea's technology needs are found in the relevant section of this report.

Climate Change Research and Systematic Observation

A number of national research institutions in Eritrea are currently promoting climate and climate change related research on integrated climate-resilient crop and livestock production in a wide range of disciplines, including SWC, integrated crop-livestock production systems, conservation agriculture, agroforestry, rangeland management, sustainable irrigation technologies, environmental regeneration and natural resource management.

Ministry of Land, Water and Environment, Ministry of Fisheries and Ministry of Agriculture, among others, have conducted a number of climate change related researches which could provide data, information and tools for various activities relating to the preparation of national communication.

Systematic Observation

Systematic climate data collection and documentation activities are shared among different institutions such as MOLWE, MOTC (Asmara International Air Port), MOA, MOEM, MOH, MOPW and the Local Government. The roles and responsibilities of these ministries are not clearly identified. There are a number of overlapping activities. Each established many of meteorological stations at selected sites. These stations were put in place to generate data needed for the respective institutions. Most of the attributes such as the location, distribution, and type of instruments used in each of these stations do not satisfy the requirements for a national observation network and WMO. The coverage and quality of data are not complete.

Information on Research Programme

Research programme, on specific aspects of climate change such as mitigation, development of country specific emission factors and activity data particularly for key source categories, and Clean Development Mechanisms (CDM) for funding are far from satisfactory. The country's involvement in such research activities with other bilateral and multilateral institutions is not adequate. There is a need for an action plan in this area to address the gap.

Information on Education, Training and Public Awareness

The implementation of Article 6 of the convention has been identified by the NCSA as one of the priority area. In this backdrop, a project profile has been prepared for implementation. The detail is found in the relevant section of this report.

Specific Needs, Options and Priorities for Capacity-Building

The major synergistic constraints and opportunities for capacity building have been identified during the preparation process of National Capacity Self Assessment (NCSA). Overall, the capacities for environmental management in general and climate change response in particular at local and regional levels have been identified to be weaker than at national level, although the level of environmental awareness is relatively high.

South-South Cooperation

This area of capacity-building has not been exploited and / or targeted the right people to the required level to date mainly due to lack of commitment, negligence and low awareness as to the impact of such intervention.

Promotion and Level of Involvement of Stakeholders

Eritrea has developed country specific guidelines for effective engagement of stakeholders in various climate change activities and projects. The level of involvement of stakeholders is to the extent that stakeholder participation is a cross-cutting issue across all components and activities of climate change.

Status of Activities Related to Coordination and Sustainability

Focal points and national coordinating entities lack capacity to ensure 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 urgent.

Dissemination and Sharing of Information on Capacity-Building

Both at the secretariat and national focal point levels, improved decision-making, including effective and efficient assistance for participation in regional and international negotiations and capacity-building training workshops targeting those directly working in climate change issues is critical. Participation should be driven more by technical relevancy not exclusively by political criteria and/or financial benefit which have long been proved to be inefficient, particularly in LDCs, as a sequel to this several negotiations and capacity-building outcomes are not effectively disseminated, shared and translated into action at national, sub-regional and regional levels.

Capacity-Building Activities

Capacity-building activities aimed at integrating adaptation to climate change into medium- and long-term planning are mainly those enabling capacity-building activities conducted under the implementation of NAPA and National Communication. NAPA has immediate-term objective of integrating adaptation while NCs and NCSA have medium to long term objectives. Eritrea has conducted a number of capacity building activities to implement these projects and follow ups across all components.

Information and Networking

In this area, the secretariat needs to establish regional mechanisms to share information on a continuous basis. The strategy is to create platforms for countries to share information created by themselves in stead of organizing and conducting business as usual trainings and workshops.

Eritrea has been participating in and contributed to information networks of regional and international initiatives such as FNR_Rio, NCSP, WEAP, SimCLIM, etc. Fast, accessible, affordable and reliable communications system is critical for development. In recognition of this, Eritrea has invested substantially in the development of its telecommunications and postal services. However, in spite of these accomplishments, the transmission of large volume text, voice and video data is limited by the absence or inadequacy of broadband fiber optic infrastructure system.

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

Eritrea has encountered a number of financial difficulties in the course of implementing its commitment under the Convention. The main difficulty was the inadequacy of the national communications fund to cover priority areas identified under all components.

Eritrea has also prepared and submitted its NAPA to the COP of the Convention in 2007. However, most of the urgent and immediate adaptation needs identified by NAPA have not yet been implemented to date due to financial constraint faced by the LDCF. Eritrea's various expectations from the climate change negotiation have not been yet materialized obstructing the country's progress in complying with its commitment under the Convention.

Technical needs cut across all activities of the country's commitment under the Convention. Technical needs span from scientific knowledge of climate change to skills of climate and impact modeling to formulation of GHG mitigation and adaptation strategies to preparation of project and programme documents and from monitoring and evaluation of concrete projects and programmes to climate change negotiation skills. In general, these technical needs are impeding the country from maximizing the benefits of the Convention's resources and hence country's contribution to the achievement of the objective of the Convention.

Capacity Needs

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, notwithstanding 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. Given its past land use practices as well as its location, physical features, and arid climate, Eritrea has an area liable to drought and desertification, fragile eco-system including mountainous ecosystem and low-lying coastal area and the country is dependent on consumption of fossil fuels and associated energy-intensive products. In this backdrop, Eritrea needs capacity development in key priority areas that can enhance the realization of its adaptive capacity to cope with the current and potential future climate risks and at the same time to contribute to the achievement of the objective of the Convention. These key priority areas for capacity development are found in the relevant section of this report.

The GEF, Annex II Parties, Multilateral/Bilateral Contributions

Eritrea has made significant support to the implementation of a number of projects funded by the GEF to comply with its commitment under the Convention both in kind and in cash. In cash, it has been estimated at USD 10,000.00, mainly, costs for telephone and internet.

The majority of the fund was obtained from the GEF trust fund, LDCF and AF fund for implementation of enabling activities such as INC, SNC, NAPA and formulation of concrete project and programmes as follow-up actions. In this context, the GEF contributed to data about USD 8,980,000.00. UNDP CO also contributed some co-financing. Despite it has not been captured, the UNFCCC secretariat has been supporting full costs for participation of three delegates of the focal point in climate change negotiation processes each year. Funds which have not been utilized so far include CDM, SCCF, and SPA. Eritrea has not received yet any financial and technical assistance from bilateral programmes and activities.

Information on Implementation of Adaptation Measures

In the implementation of adaptation measures both barriers and opportunities exist. Operationally, the formulation of an adaptation strategy can pose a big challenge. It means situating the climate change issue in a policy world that is full of competing priorities, interest groups, short attention spans and a host of potential unpredictable events. On the other end, the various national developments plans and polices open up the possibility for effective mainstreaming of adaptation / appropriate GHG mitigation concerns. Besides, significant momentum has also occurred through international participation in multilateral environmental agreements (MEAs) that could be effectively leveraged. Although these efforts, both national and international, were not directly motivated by climate change adaptation, their objectives overlap. The adaptation strategy development process should build on such experience.

In this context, Eritrea has been implementing a number of pilot adaptation projects which are considered as opportunities to learn by doing. However, developed parties are required to enhance their support to Eritrea to meet its specific needs and concerns relating to vulnerability and adaptation to climate change in line with their obligation under the Convention. The priority intervention areas for support would include development and enhancement of capacities, technology transfer and know-how.

Uncertainties

The GCMs have been used to capture large scale dynamical response of atmosphere and grid resolution data is not robust and too coarse to capture local effects of mountains and lakes. Moreover, historical trends or recent changes in climate are complicated by data availability, gaps and quality. Specifically, time series data availability and climate variability data at all temporal scales is limiting the quality of the V&A Assessment.

CHAPTER 1

INTRODUCTION

Eritrea acceded to the UNFCCC on 24 April 1995, and entry into force for Eritrea was in 23 July 1995. Since then Eritrea has been actively participating in the UNFCCC process. Eritrea is one of the most vulnerable countries to the adverse effects of climate change, mainly because of its low adaptive capacities. It has therefore taken a number of steps to fight back the effects of climate change and hence guides its sustainable development planning process. In this connection, Eritrea's second national communication to the UNFCCC, which has been prepared in accordance with the guidelines on national communications from non-Annex I Parties, is an endeavor to report on the over all climate change situations of the country since the reporting of its Initial National Communication in 2001.

Climate change impacts can affect all sectors and levels of society in the country. In the past few years, reducing vulnerability to climate change has become an urgent issue for Eritrea. Not only Eritrea lacks the means to cope with climate hazards, but its economy also tends to have greater dependence on climate-sensitive sectors, such as agriculture, water, and coastal zone. Climate change adaptation remains at the forefront of any sustainable development policy agenda in the country. However, the process of adaptation is not new as farmers have been adapting to changing conditions, including natural long-term changes in climate. What is innovative is the idea of incorporating future climate risk into policy-making. Although our understanding of climate change and its potential impacts has become clearer, the availability of practical guidance, such as SNC, on adaptation to climate change has not kept pace in the country.

Thus, the preparation of Eritrea's Second National Communication (SNC) has been motivated not only to comply with the reporting commitment of Eritrea to the COP of UNFCCC but also to support the rapidly evolving process of adaptation policy making which has lacked a clear roadmap. The SNC being a policy tool seeks to address this gap by offering a flexible approach through which the established adaptation stakeholders and communities can clarify their own priority issues and implement responsive adaptation strategies, polices and measures. In this backdrop, the organization of the SNC report is outlined as follows.

Chapter one presents background of the SNC reporting. Chapter two deals with information on national circumstances which provides opportunities for dealing with national and regional development priorities and objectives that serve as the basis for addressing issues relating to climate change. Chapter three deals with national greenhouse gas inventory which is a key element of the SNC. Chapter four elaborates GHG mitigation assessment and analysis which provides information relevant for sustainable development and activities contributing directly to GHG emissions abatement and GHG atmospheric concentration reduction. Chapter five deals with impact, adaptation and vulnerability assessments in priority sectors, which describes activities, measures and programmes that are being undertaken and planned in the country to adapt to climate change. Chapter six deals with other information which deals with activities considered relevant to the achievement of the objectives of the Convention. Finally, chapter seven deals with constraints and gaps, and related financial, technical and capacity needs.

CHAPTER 2

NATIONAL CIRCUMSTANCES

2.1. Geography

Eritrea is located in the Horn of Africa, lying between 12º 22′, and 18º 02′ north and between 36º 26′ and 43º 13′ east. Sudan borders it in the west, Ethiopia in the south, Djibouti in the southeast, and the Red Sea in the east. The country has a total land area of 124, 300 km^2, and a coastline of 1900 km. Eritrea's territorial waters in the Red Sea zone are about 120,000 km^2, stretching out to the Red Sea Central Rift, where the maximum depth is several hundred meters. The territorial waters may be divided into a continental shelf region of around 56,000 km^2, and the rest divided into shallow water region (<30 m depth) and deep-water region (>30 m depth).

2.2. Climatic and Agro-ecological Zones

In simplistic terms the country could roughly be divided into three physio-graphic regions, namely, the central highlands, the midlands and the lowlands. The months from June-September are characterized by relatively high pressures in Southern and western Africa and very low pressure in Asia creating prevailing southwesterly winds. The resulting southwest monsoon characterized by moist airflows from the South brings rains in the highlands. During the months of October-March, a reverse pressure gradient created by the high pressure areas advancing from Asia toward the low pressure area of southern Africa creates northeasterly winds. These northeasterly monsoons results in a continuing dry continental air mass, which is responsible for the driest season of the year. Portion of northeasterly winds, that pass over the Red Sea, pick up moisture and deliver very little amount of rainfall along the coastal plain. However, when facing the steep escarpment, abundant rainfall is produced there by orographic effects, especially during the period November through March.

Hence, there are two major periods of precipitation in Eritrea whose pattern is affected by these pressure gradients and physiographic regions. The first, from June to September, covers both the western lowlands and highlands. The second occurs between October and March and covers the eastern lowlands. In the highlands and western lowlands, the rainfall ranges from 400-700 mm and from 300-400 mm in the northern part of the country. Most of the runoff produced from the rains on the plateau flows westerly and northerly towards the Sudan. Rainfall over the highlands is relatively uniform, slightly decreasing as one moves north towards to lower elevation around Nacfa. The northern part of the western lowlands is quite arid, whereas the south and southeast parts of the western lowlands receive relatively higher rainfall during June-September. There are also small rains during March- May in small parts of the highlands. In the Eastern region of Eritrea, the rainfall ranges from 200 mm in the coastal area to about 1000 mm along the escarpment. Most of the runoff originating in this part of the country drains to the Red Sea. Despite of the occurrence of the two major rainy seasons in Eritrea, it is uncommon for large areas of the country to enjoy two rainy seasons in any year, with the exception of a narrow strip between the highlands and the eastern escarpment called the Greenbelt. Rainfall pattern in Eritrea is extremely variable within and between years and also spatial variation over very short distances. Amounts and patterns of rainfall distribution is presented in Fig. 2.1

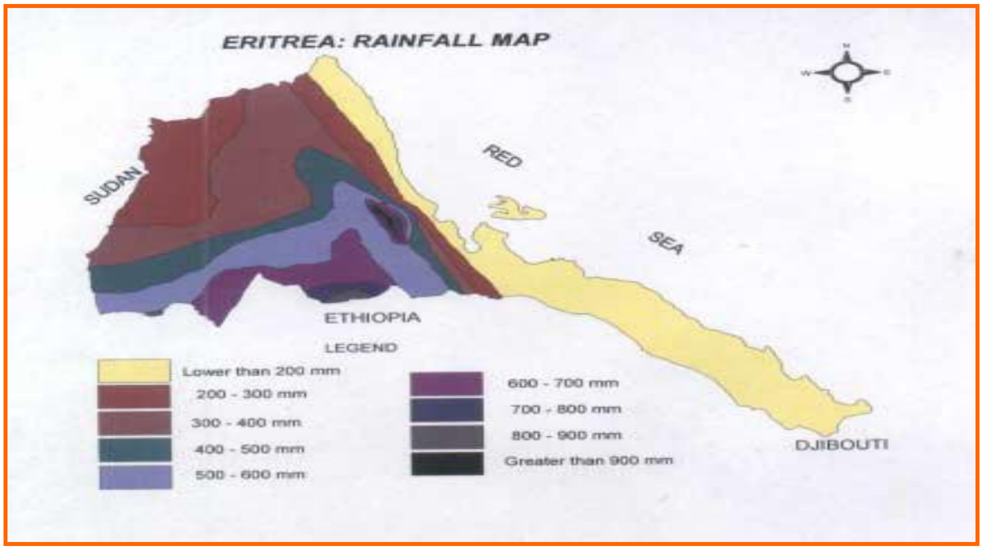


Figure 2.1: Variations in Mean Annual Rainfall of Eritrea (Source: MOLWE, 1998)

The mean annual temperature in Eritrea ranges from temperate comfortable 16^0C in the highlands around Asmara to extreme high temperature along the Red Sea coastal area to over 31^0C around Assab. As precipitation, temperature also fluctuates with altitude. Moving westward from the Red Sea towards Asmara, temperature reduces around 1.8^0C every 200 m of elevation increase.

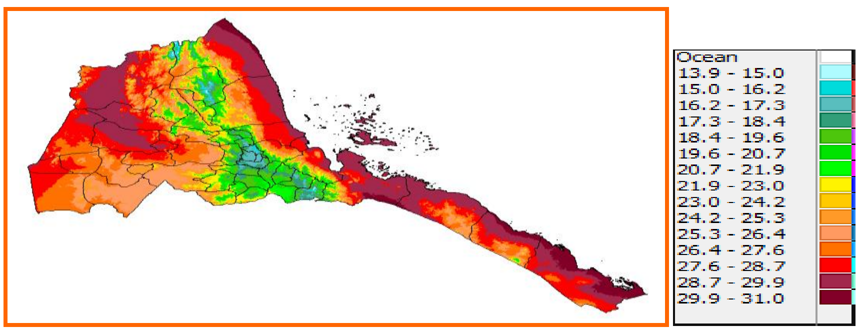


Figure 2.2: Mean Annual Temperature of Eritrea (Source: WORLDCLIM)

The country has diverse climatic situation ranging from 120 m.b.s.l in Danakil depression to above 2400 m.a.s.l in the central highlands to temperate sub-humid in isolated micro-catchments within the eastern escarpment. Based on climate and soil parameters six agro-ecological zones exist in the country (Fig.2.3). A summary of these agro-ecological zones is provided in Table 2.1.

Table 2.1 Summary of Information on Agro-Ecological Zones of Eritrea

Agro-ecological Zone	% of Total Land	Elevation (m)	Mean Annual Rainfall (mm)	Mean Annual Temperature (^{0}C)	Dominant Land Uses
Moist Highland	7	1600-3018	500-700	15-21	Rain-fed Agriculture
Arid Highland	3	1600-2820	200-500	15-21	Rainfed & Pastoralism
Sub-Humid	0.8	600-2625	700-1100	16-27	Forest
Moist Lowland	16.2	500-1600	500-700	21-28	Rainfed, Irrigated & Pastoralism
Arid Lowland	34	400-1600	200-500	21-29	Nomadic Pastoralism
Semi-Desert	39	-120-1355	< 200	24-32	Flood Irrigation & Nomadic Pastoralism

Source: Ministry of Land, Water & Environment (MOLWE), 1995

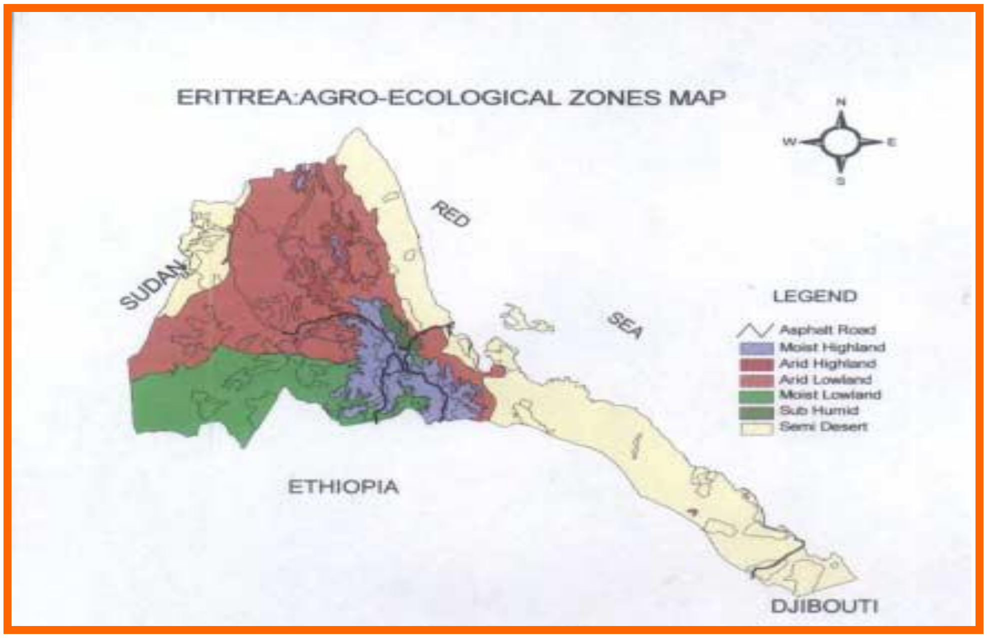


Figure 2.3: Agro-Ecological Zones of Eritrea (Source, MOLWE, 1995)

2.3. Land Use /Land Cover

According to Ministry of Agriculture and FAO agricultural sector review of 1994, the total land area of the country is 12.2 million ha. Major land uses include browsing and grazing land, barren land, wood land and scrub land, disturbed forest plantations, and the smallest one is cultivated land. At the present the greatest cultivated area is 0.53 million ha (4.3%) of which 28,000 ha is irrigated. However, potential cultivated land is estimated to be 2.1 million ha (17.2%), with 1.5 million ha (12.3%) under rain-fed and 0.60 million ha (4.9%) are under irrigation.

Table 2.2: Land Classification Categories of Eritrea

Description	Land Type	Area (ha)	Percentage of total
Current	Cultivated (rain fed)	417,000	3.42
	Irrigated land	22,000	0.18
	Disturbed forest	53,000	0,43
	Plantations	10,000	0.08
	Woodland and Scrubland	673,000	5.52
	Browsing and Grazing	6,767,000	57.16
	Barren Land	4,047,000	33.21
Potential	Total rain-fed land	1,500,000	8.61
	Total irrigable land	600,000	4.92

Source: MoA and FAO Agricultural Review Sector, 1994

2.4. Socio-Economic and Development Context

The population of Eritrea is approximately 3.66 million[7], with population growth rate of 2.74%[8] and an average density of about 28 persons per km^2. Despite the fact that Eritrea is small country, it has diverse ethnic groups. These ethnic groups are Afar, Bilen, Hedarb, Kunama, Nara, Rashaida, Saho, Tigre and Tigrinya. Eritrea has not yet adopted an official language but it has working languages mainly Tigrinya, Arabic and English. Much of the population is clustered in the cooler climates of the central highlands; more than 80% of the population live in rural areas[9].

When Eritrea achieved independence from Ethiopia in 1993 after 30 years of war, the country's economy was in ruins, and public infrastructure and institutions were seriously damaged or destroyed. The new government embarked on a lengthy process to establish public sector organizations to stimulate economic growth and provide basic services. However, political tensions related to subsequent border conflicts with Ethiopia have had a significant impact on the socio-economic development of the country, with financial and human resources diverted to defense.

Eritrea's status can be characterized by an integrated indicator of Human Development Index (HDI) of 0.472[10]. Development in Eritrea has further been seriously affected by the recurrent drought experienced in the Horn of Africa region. As a result of these and other causes, food production has fallen, and also the investment in development, leading to increasing poverty and vulnerability. Poor communication and transportation infrastructure in the outlying areas further exacerbate development challenges. Nonetheless, the government is currently working actively to readdress these development barriers.

According to the National Statistics and Evaluation Office (NSEO), approximately 66% of the population was living below the poverty line in 2003. Eritrea's per capita GDP is US$ 626[11]. Levels of malnutrition are extremely high, and 40% of children under five are underweight for their age. Life expectancy at birth is 59.2 years.[12] According to the 2009 Human Development report, 40% of Eritreans do not have access to improved water sources[13]. The adult literacy rate is 36.8%, with the literacy rate for women being 69.6% of that of males. Eritrea's gender-related development index (GDI) is 0.459, which should be compared to its HDI value

[7] National Demographic Health Survey, 2002. A further million Eritreans live abroad, mostly in Sudan with lesser numbers in Saudi Arabia, Germany, USA and elsewhere.
[8] Eritrea Interim-Poverty Reduction Strategy Paper, April 2004
[9] Eritrea National Adaptation Programme of Action, 2007
[10] 2009 Human Development Report. The HDI goes beyond GDP to encompass a broader definition of well-being, and provides a composite measure of three dimensions of human development: living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and enrolment at the primary, secondary and tertiary level) and having a decent standard of living (measured by purchasing power parity, PPP, income). The index is not a comprehensive measure of human development, and does not, for example, include important indicators such as gender or income inequality and more difficult to measure indicators like respect for human rights and political freedoms.
[11] 2007 Africa Report of the World Bank
[12] 2009 Human Development Report
[13] 2009 Human Development Report

of 0.472. Its GDI value is 97.2% of its HDI value[14] indicating that additional efforts are required to achieve national goals of gender equality. About 30% of households in Eritrea are headed by women, of which 18% are widowed. On average, female employees earn less than half the amount that males earn and a majority of poor women in the rural areas are engaged in low-paying manual labour in construction and agriculture. Furthermore, female-headed households have fewer household assets including livestock than male-headed households. Rural women are less likely to be literate and numerate - about 40% leave school at an early stage due to marriage. Rural women often do not receive pre-natal care and suffer from poor nutrition (undernourishment).

On a positive note, Eritrea is on track to achieve the Millennium Development Goal (MDG) dealing with gender equality at the primary school level by 2015. According to current trends, the country will also achieve the MDG targets regarding child health, maternal mortality, HIV/AIDS, malaria and other major diseases, and access to safe water. However, the goals of eradication of extreme poverty and achievement of universal primary education remain elusive.

Eritrea's economy is based primarily on agriculture, followed by mining, industry, fisheries, tourism, and the services. Over 80 per cent of the population relies on traditional subsistence crop cultivation and livestock husbandry[15]. Despite this, agriculture, which is primarily rain fed, accounts for just one-fifth of the gross domestic product (GDP). Less than 10% of arable land is irrigated.

Food security is a pressing issue in Eritrea, where, even in years with adequate rainfall, approximately half of the food that the country requires has to be imported. Poverty is closely linked to food security in Eritrea: rural households are the most severely affected by poverty because of the low productivity of their crops and livestock enterprises, with almost two thirds of all households are vulnerable to food security.[16] Many rural Eritreans lack access to safe drinking water. At present, 50% of the rural population has access to safe-water supply. Inadequate communications infrastructure provides a further barrier to development: for example, in 2008, there were three fixed line and mobile phone subscribers per 100 people, and three internet users per 100 people, with an even lower number of personal computers (0.8 per 100 people in 2007)[17]. While progress has been made in power generation, 77.3% of total energy consumption is derived from biomass.[18]

Despite their tough situation, rural communities across Eritrea have displayed remarkable resilience through traditional ways of protecting the poor. During times of extreme stress, wealthier households dispose of assets, mainly livestock, and then make loans to poorer relatives and neighbours. Labour-sharing is also common at various times during the agricultural cycle, a community's wealthier adults will assist households that are unable to cultivate their land.[19]

2.5. Environmental Context

A century ago, 30% of Eritrea was covered by forest, but less than 1% of this remained by 1995. Deforestation has resulted from expansion of agriculture, cutting of trees for fuel-wood, the long war of liberation during which military forces cut trees for the construction of fortifications, and the construction of materials-intensive traditional houses. Widespread land degradation is the most serious environmental concern of Eritrea, caused to a large extent by inappropriate land management, unsustainable agricultural practices, and overgrazing and deforestation resulting in clearing of vegetation cover and increased soil erosion. The annual rate of soil loss from cropland is estimated at 12–17 tons/ha and crop yield is declining at the rate of 0.5% per annum owing to soil erosion[20]. The overwhelming dependence on biomass (charcoal, firewood, agro-residues and cow dung) for domestic energy contributes significantly to clearing of forests and woodlands. A number of these unsustainable practices have resulted in a reduction in Eritrea's terrestrial biodiversity, although it appears that

[14] The gender-related development index (GDI), introduced in Human Development Report 1995, measures achievements in the same dimensions using the same indicators as the HDI but captures inequalities in achievement between women and men. It is simply the HDI adjusted downward for gender inequality. The greater the gender disparity in basic human development, the lower is a country's GDI relative to its HDI.
[15] Ministry of Land, Water and Environment. (2007). *National Adaptation Programme of Action*.(NAPA) . Asmara, Eritrea.
[16] IFAD Rural Poverty Profile of Eritrea, http://www.ruralpovertyportal.org/web/guest/country/home/tags/eritrea accessed 01/10/2010
[17] http://www.ruralpovertyportal.org/web/guest/country/statistics/tags/eritrea accessed 01/10/2010
[18] Ministry of Energy and Mines, 1996
[19] IFAD Rural Poverty Profile of Eritrea, http://www.ruralpovertyportal.org/web/guest/country/home/tags/eritrea accessed 01/10/2010
[20] Source: Ministry of Agriculture, quoted in UNDP Small Grants Programme Mobilisation Strategy

coastal and marine biodiversity resources have remained relatively stable.

Despite the country has ratified a number of Multilateral Environmental Agreements (MEAs) and fulfills its reporting commitments under the respective Conventions , the country has not yet compiled a State of Environment Report (SoER) and monitoring and reporting on natural resources is largely absent. Lack of adequate data on environmental sustainability has prevented a clear assessment of progress in this area.

2.6. Economic Sectors

Eritrea is a young country that is heavily engaged in the reconstruction and development of its economy. Its aspiration is to become a developed and democratic nation where the potentials of its people are fully realized. As can be inferred from the Charter of the PFDJ (1994) and the National Constitution (1997), Eritrea's vision is to become a nation that is economically, politically, socially, spiritually, culturally and psychologically well developed. In other words, its goal is to become a prosperous and resilient nation characterized by strong national unity and social cohesion.

The Eritrean economy is currently characterized by macroeconomic imbalances. These imbalances limit the available choices of action that can be taken to stimulate economic growth with stability. Under these circumstances, the preferred approach is focusing on prudently selected and quick impacting measures that promote rapid economic recovery and growth while restoring macroeconomic balances.

Agriculture, fisheries, tourism, mining, manufacturing, construction, transport and communication, domestic and external trade, and banking and related services are expected to be the main drivers of economic growth. These sectors are expected to make significant contributions to growth by attracting new quick-impacting investments and by improving the rate of utilization of existing assets and production capacities. Expanding output of existing production capacities would be a priority. This may require providing basic inputs (such as spare parts, energy and raw materials) as well as shifting from an input-intensive to productivity driven mode of production. The main trust of the existing sector development programs/projects shall, therefore, be creating wealth by improving efficiency of existing production capacities in each of these sectors and exploiting new sources of growth.

Agriculture

Agriculture is considered an important source of economic growth, food security, employment, and foreign exchange generation. Its growth will be derived from significant planned increases in supplementary and full service irrigation, application of modern farm inputs (machinery services, improved seeds, fertilizer, etc.), and improvements in farming and animal husbandry practices. Bringing in more areas under cultivation and increasing productivity through improvements in farming methods, soil and water conservation, reforestation, and livestock rearing are given great attention. Provision of additional critical support services, such as market outlets, access to credit, and extension service and training of farmers are the priorities of the country.

Fisheries

The marine and coastal resources, particularly fisheries can become a significant source of protein-rich food and foreign exchange earnings. To exploit this sector's potential, measures have been taken. They include establishing modern fishing fleets; improve fish landing and preservation infrastructure, and establishing value-adding fish processing facilities. Steps have also been taken to enhance income-generating opportunities for the coastal communities by improving artisan fishing. To ensure sustainable exploitation of marine resources and to preserve the integrity of the Red Sea and Coastal Environment, sound regulations have been adopted and are being improved upon. In this connection, formal approval of the Draft Coastal Policy and Management Strategy already submitted to government would go a long way in ensuring sustainable development of the national coastal assets.

Mining

Mining development is a priority in Eritrea. Eritrea is well endowed with significant untapped precious minerals, base metals and industrial and construction materials that augur well for the development of a viable mining industry. The known precious and base minerals of Eritrea include economic deposits of gold, silver, zinc and copper. Similarly, the known industrial and construction minerals include substantial endowments of manganese, potash, gypsum, silica sand, marble, granite, and coral limestone. Given these endowments, the mining sector is expected to become an important driver of economic growth. Toward realizing the potential of the sector, the Government has adopted sound mining laws and regulations that lay a solid foundation for developing upstream and downstream mining activities.

Tourism

Eritrea‘s pristine waters, beautiful coastline and islands, diverse marine-life and colorful coral reefs, numerous historical sites, ancient and fascinating religious heritage, spectacular-mountain scenery, and pleasant and varied climatic zones augur well for the development of a dynamic tourism industry. Tourism has, therefore, a potential to become one of the most important contributors to GDP growth, foreign exchange earnings, and gainful employment. Under the current tourism development plan, establishing tourism-related infrastructure and hospitality facilities is a priority. The plan also focuses on preservation, conservation and development of the country‘s historical sites and religious heritage, and improvements in the quality of tourism products and services.

Industry

Manufacturing has a potential to become an important contributor to growth and development. Eritrea‘s strategic location offers opportunities to access export markets. The potential for import substitution is also significant. The main manufacturing sub-sectors in which Eritrea can become an efficient producer are agro-processing, textiles and garment making, leather and leather products, metal fabrication, plastic processing, glass and glass products, and construction materials—including cement, marble and granite. As a member of COMESA, Eritrea will benefit from economies of scale derived from enlarged input-output markets.

Eritrea has a long tradition of manufacturing and promoting regional integration through the elimination of trade barriers. At liberation, Eritrea inherited many state owned manufacturing enterprises that were suffering from technological obsolescence, overstaffing, inefficient and corrupt management, and low capacity utilization. Most of them were operating without taking commercial or economic efficiency into account. While most of them have been privatized since then, many continue to suffer from low capacity utilization and cash-flow problems. To remedy this problem and improve the growth of the sector, substantial investment will be needed for the rehabilitation, modernization, and expansion of existing capacities. Eritrea‘s industrial development strategy is, therefore, to create a policy environment conducive to utilization of existing manufacturing capacities. It is also to promote investments for the modernization, expansion and creation of new capacities in sub-sectors where Eritrea has comparative advantages to competitively supply domestic and export markets.

Table 2.3: Capacity Utilization by Manufacturing Sub-Sector in 2006

No.	Sub-sector	No. of establishments	Capacity Utilization (%)	Gross output in _000 Nakfa (weight)
1	Food and beverage	41	41	584,006
2	Textile, leather and garments	30	42	294,634
3	Paper, printing and publications	9	29	87,390
4	Chemicals, paints and pharmaceuticals	15	27	134,322
5	Rubber and plastic	9	39	45,768
6	Construction materials	21	48	191,021
7	Metal	13	26	71,682
8	Furniture	19	41	82,659
Total		157	-	1,491,483
Weighted average			39	

Source: National Indicative Development Plan (2009-2013)

Trade

Cognizant of the benefits that can be derived from trade expansion, Eritrea has been, since liberation, promoting trade as a critical component of its overall development strategy. Given its rather high import to GDP ratio, Eritrea could be considered an open economy. However, more recently, given the acute shortages in foreign exchange, administrative restrictions in trade have become necessary to ensure that basic needs of the population are not priced out and long-term strategic investments are not undermined. Concurrently, foreign exchange restrictions have been imposed allowing the Nacfa to be substantially overvalued. In combination, these restrictions have created a policy bias in favor of imports and against exports. This regime is intended to promote inter-sectoral and inter-generational efficiency and equity.

Transport and Communication

The land transport sector has played a major role in meeting the demand for transport services and contributed significantly to the development of the nation. This has been made possible through the construction and rehabilitation of road networks and the continued expansion of passenger transport and freight services across the country. Land transport services have been enhanced further by the opening up of new routes and terminals, establishment of several bus transport companies, and the acquisition and deployment of light and heavy trucks. To ensure smoother traffic mobility and safety, as well as to improve overall public transport services, several proclamations, including Proclamation 119/2002 on compulsory motor vehicle third party insurance and Proclamation 154/2006 on road traffic safety and Legal Notice 61/2002 regulating technical specifications and standards of vehicles, have been issued and enforced.

Eritrea has the potential and the aspiration to become a major regional maritime nation. Historically too, the ports of Adulis, Massawa and Assab have been important enterpôt ports to the African continent. Since liberation, Port rehabilitation and modernization has been at the forefront of the maritime transport investment program. The Massawa and Assab ports and related enterprises have been reorganized, reconstituted and reinstituted by various Proclamations to ensure their operational autonomy and commercialization. Accordingly, both ports are well positioned to provide adequate services to the country and the region. A master plan for the development of a new port in the vicinity of Massawa has also been completed.

In an interconnected and fast moving world economy, effective air transport services are of paramount importance. In view of this, Eritrea has adopted an open-sky policy that has enabled various airlines to transport passengers and goods across space more competitively. Currently, Eritrea has four international airports, (Asmara, Massawa, Assab and Sawa) and several small airports and landing strips that facilitate domestic and international air transport. However, to support full fledged and more efficient air transport services, these airports need to be further upgraded through the installation of modern communication and safety control equipment, appropriate staffing, and management.

2.7. National Communication Preparation Arrangements

Preparation of National communications in Eritrea has been carried out regularly. Its preparation on a continuous basis assumes a defined institutional arrangement. The implementing entity (IE) may be one of the agencies of the Global Environment Facility (GEF), including UNEP, UNDP, etc, as appropriate. The executing entity and UNFCCC focal point is the Department of Environment of the Ministry of Land, Water and Environment.

The National Steering Committee (NSC) will guide and oversee the preparation process and will facilitate access to additional technical assistance when required. It has composed of representatives of the line ministries, namely, the Ministry of Land, Water and Environment, Ministry of Agriculture (MoA), Ministry of Energy and Mines, Ministry of Fisheries, Ministry of Trade and Industry, Ministry of Transport and Communication, Ministry of Health, Ministry of Finance, Ministry of Tourism, Ministry of Public Works, and representatives from Regional Administrations. The NSC Secretariat, which convenes meetings of the NSC, composed of the UNFCCC Focal Point and the National Climate Change Coordinator (NCCC).

The National Communication Technical Committee (NCTC) has been guiding the technical issues of preparation of National Communications. The NCTC composes sub-technical committees for each component of the National Communication including sub-technical committees for the preparation of National Circumstances, National Greenhouse Gas Inventories, National Greenhouse Gas Mitigation and Analysis, Vulnerability and Adaptation Assessment, Climate Change Research, Systematic Observation and Technology Transfer, Awareness, Education and Training and Compilation of National Communication. The NCTC has been chaired by the National Climate Change Coordinator (NCCC), and has included representatives of the line ministries, representatives from Regional Administrations and research institutions.

Each of the elements of the institutional arrangement has clear roles and responsibilities as described in the respective Terms of References (ToRs) to deal with the preparation of national communications on continuous basis. Nonetheless, these roles and responsibilities are not separate but overlap across components and activities that will enable the various sub-technical committees to work together to bring integrated and consistent results

CHAPTER 3

NATIONAL GREENHOUSE GAS INVENTORY

3.1. Introduction

National Greenhouse Gas Inventory addresses estimates of national anthropogenic emissions of Greenhouse Gases not controlled by the Montreal Protocol by sources and removals by sinks. Eritrea prepared its first national greenhouse gas (GHG) inventory for the year 1994 as part of its initial national communication which was completed and submitted to the COP in 2001. As a follow up to this process, the current national greenhouse gas inventory has been prepared for the year 2000 as part of the preparation of Eritrea's Second National Communication (SNC). The second national GHG inventory has addressed potential key GHG emitting and removal sectors including the Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste Sectors. The inventory addressed three major direct greenhouse gases including Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) and other ozone precursors and indirect greenhouse gases including Carbon Monoxide (CO), Nitrogen Oxides (NOx), Non-Methane Volatile Organic Compounds (NMVOCs) and Sulphur Dioxide (SO_2).

In order to facilitate and institutionalize the national GHG inventory process, Department of Environment of the Ministry of Land, Water and Environment, as the focal point of UNFCCC and the executing agency of the preparation of National Communications in Eritrea, has established a National Greenhouse Gas Inventory Thematic Working Group (NGHGITWG) whose members have been drawn from key Government ministries and institutions including, inter alia, the Ministry of Energy and Mines, Ministry of Agriculture , Ministry of Land, Water and Environment, Ministry of Trade and Industry, Ministry of Transport and Communication, Ministry of Fisheries and National Statistics and Evaluation Office. Each ministry and institution involved in the NGHGITWG has been entrusted to compile GHG emissions and removals relevant to its respective operational mandates as well as actively participate in planning and subsequent preparation of documentation, reporting, quality control and other key activities necessary for the completion of national GHG inventory. This institutional arrangement for NGHGI is part of the national effort to help make inventory preparation a continuous process.

3.2. Methodologies

The NGHGITWG has used, mainly, the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines to carry out the National Greenhouse Gas Inventories for estimating and reporting Eritrea's second national greenhouse gas inventory for the Energy, Industrial Processes, Agriculture and Waste Sectors.

However, the methodologies used to estimate carbon emissions from Land Use and Land Use Change and Forestry (LULUCF) have been based on the IPCC Guidelines of 2006 Volume 4 and Good Practice Guidance (GPG), 2003. The software includes both worksheets for the LULUCF and the LUCF categories, module5b and module5, respectively. First, the amount of carbon dioxide, including indirect GHGs associated with emission of carbon dioxide, emitted or sequestered from different land uses, land use changes, soil types and land management practices (e.g. ., application of liming and management of soils) has been estimated using the IPCC Guidelines of 2006 Volume 4 and GPG, 2003 . Subsequently, a mapping back procedure has been conducted to estimate the categories of Land-Use Change and Forestry in line with the Common Reporting Framework (CRF) of the Revised 1996 IPCC Guidelines. The detailed data and calculations used to estimate these emissions are available within the IPCC software employed in the inventory. Eritrea acknowledges that the use of the 2006 IPCC Guidelines even is not mandatory. However, the IPCC Guidelines are flexible and encourage the use of any other method if better appropriate as long as this is properly documented and explained, so this does not prevent the use of the 2006 version of the IPCC Guidelines.

For all source categories, due to lack of availability of sufficient source-category and technology-based inventory activity and emission factors data, the Tier 1 methods included in the IPCC default Guidelines have been applied to facilitate and estimate GHG emissions and removals in the country. Thus, in order to come up with accurate national GHG emission estimates, there is a need to formulate cost-effective national or regional programmes aiming at the development of country-specific or regional emission factors along with the consideration of capacity building and taking account of the use of the most updated and final version of the IPCC Guidelines for all source and sink categories. Eritrea will also explore the possibility to use the IPCC GPG, 2000 for the sectors Energy, Industrial Processes, Agriculture and Waste in future inventory submissions. In this connection, it should be considered to undertake recalculation of earlier inventory results.

3.3. Data Sources

3.3.1 Activity Data

National data sources have been used for activity data for most cases for the energy, industrial processes, agricultural and waste sectors whereas international data sources have been used to some extent for the agricultural and for most part for land use, land-use change and forestry sectors. Ministry of Energy and Mines and National Statistics and Evaluation Office were the activity data sources for accounting of GHG emissions from the energy sector. Ministry of Trade and Industry was the activity data source for accounting of GHG emissions from the industrial processes. Ministry of Agriculture was the activity data source for accounting of GHG emissions from the agricultural sector while Municipality of Asmara was the sole activity data source for accounting of GHG emissions from the waste sector. The same sources were also utilized to supply data for the calculation of previous national GHG inventory except for LULUCF sector. The most recent available data on Eritrean LULUCF has been obtained from State of the World's Forests 2005 FAO publication and Forestry and wildlife Pre-Investment Study Report (TCP/ERI/6712(F) volume 2, 1997 compiled by the FAO Investment Centre Division.

3.3.2. Emission Factors

Since there are no country specific emission factors, energy content values and parameters, the IPCC default values available in the Reference Manual (Volume 1) of the Revised 1996 IPCC Guidelines have been used for the respective energy, industrial processes, agriculture and waste sectors. For LULUCF, emission factors have been obtained from 2006 IPCC - NGGI Guidelines, Vol 4 and GPG, 2003.

When using the IPCC default emission factors, the NGHGITWG assessed the applicability of these factors to national circumstances as per requirements of the IPCC GPG, 2003. This assessment included an evaluation of national conditions compared to the context of the studies upon which the IPCC default emission factors were based. When there was insufficient information on the context of the IPCC default emission factors, the NGHGITWG took account of this in assessing the uncertainty of the national emissions estimates based on the IPCC default emission factors.

3.4. Emissions of Direct Greenhouse Gases by Sources and Removals by Sinks

The NGHGITWG has made every effort to report on the three direct greenhouse gases including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) on gas-by-gas basis in units of gigagramme (Gg).

3.4.1. Emissions of Carbon Dioxide (CO_2)

The total national CO_2 emission in 2000 was 8,826 Gg. Key GHG Source Categories, which contributed to the total emission, were the Energy Sector 586 Gg, Industrial Processes 35 Gg and the Land Use Change and Forestry (LUCF) Sector 8,205 Gg. In percentages, the CO_2 emissions from the energy, industrial processes and the LUCF source categories were 6.6%, 0.4% and 93 %, respectively.

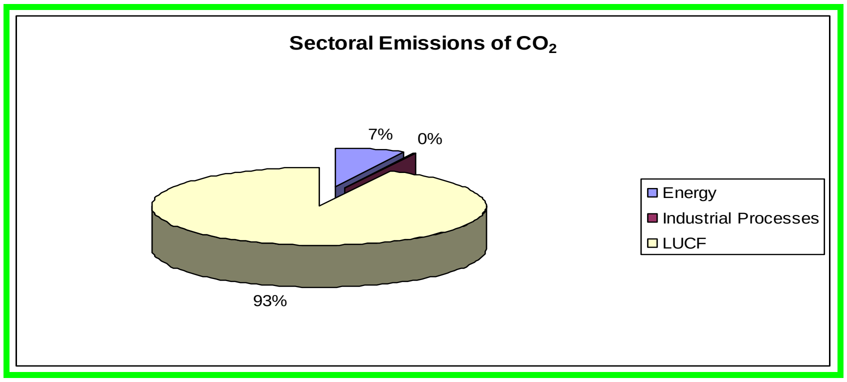


Figure 3.1 Sectoral Distribution of CO_2 in 2000 (Source: NGHGITWG, 2009)

CO_2 emission from fuel combustion which was estimated using the sectoral approach for the year 2000 was 586 Gg (see Table 3.1). The Land-Use Change and Forestry Sector was the highest net-emitter of CO_2 in 2000 which was estimated to be 8,205 Gg. Thus, biomass uptake was not sustainable in Eritrea in 2000. The highest CO_2 emission came from Changes in Forest and Other Woody Biomass Stocks sub-sector which was 4,722 Gg followed by the Forest and Grassland Conversion sub-sector which was 3,608 Gg.

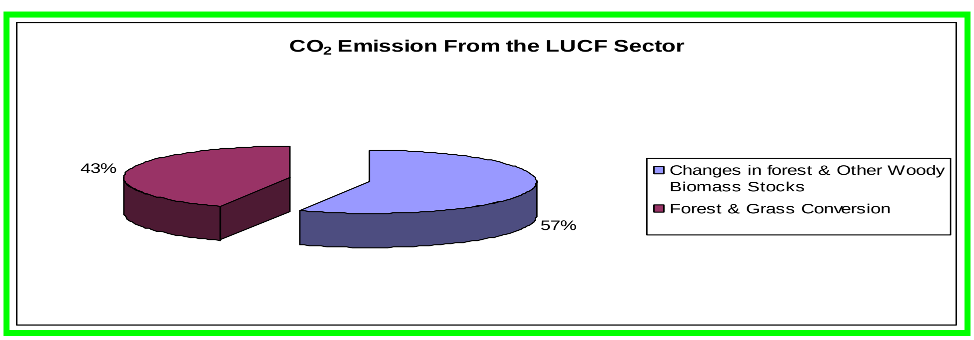


Figure 3.2 Distribution of CO_2 Emission in the LUCF sector in 2000 (Source: NGHGITWG, 2009)

The whole of CO_2 emissions in the Industrial Processes was contributed from mineral products of cement and lime production as well as limestone use which was estimated to be 35 Gg amounting 0.4% of the total CO_2 emission in 2000.

3.4.2. Methane (CH_4)

The total national methane emission in 2000 was 147 Gg of which the agricultural sector emitted the highest level which was 133 Gg (90.5%) followed by energy 8.3 Gg (5.4%), land-use change and forestry 4 Gg (2.7%) and waste sector 2 Gg (1.4%).

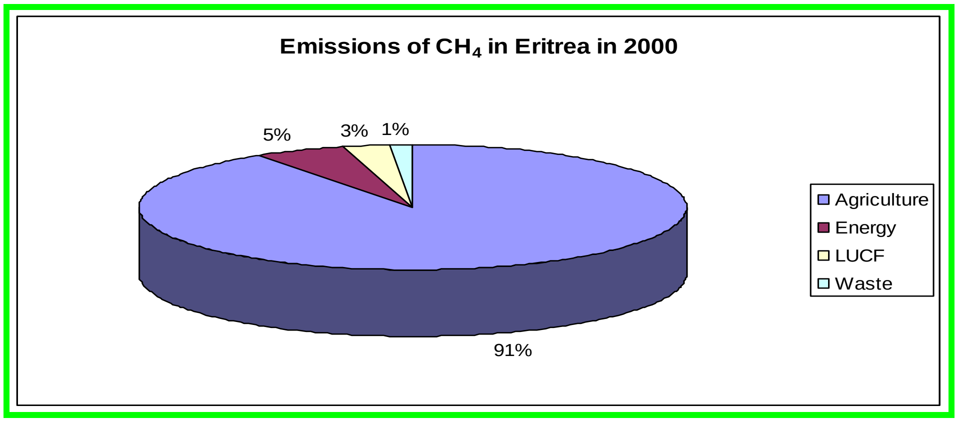


Figure 3.3 Sectoral Distributions of Methane Emissions in 2000 (Source: NGHGITWG, 2009)

With respect to the total agricultural methane emission, enteric fermentation from ruminant animals contributed 128 Gg (96.2%) followed by manure management 5 Gg (3.8%). Under the energy source category, the residential source sub category emitted 7.9 Gg (95 %) followed by the commercial/institutional 0.4 Gg (4.8 %) and road transport 0.02 Gg (0.2%). Changes in forest and other woody biomass stock sub category contributed all methane emission under the LUCF sector while solid waste disposal on land from waste disposal sites emitted all the waste source category CH_4 emission.

3.4.3. Nitrous Oxide (N_2O)

Nitrous Oxide emission was estimated at 1 Gg coming exclusively from the agricultural sector of agricultural soils source sub category.

3.4.4. Emissions of HFCs, PFCs and SF_6

HFCs, PFCs and SF_6 are direct GHGs. Anthropogenic emissions by sources of hydroflourocarbons (HFCs), perflourocarbons (PFCs) and sulphur hexafluoride (SF_6) from *production* activities did not occur in the country in 2000. Nonetheless, the *consumption* of some of these direct GHGs was occurred but emissions were not estimated.

3.5. Emissions of Indirect Greenhouse Gases by Sources

Although they are not included in global warming potential-weighted greenhouse gas emission totals, emissions of carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2) are reported in greenhouse gas inventories. 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, NOx emission plays an important role in the earth’s nitrogen cycle. Sulphur Dioxide emissions lead 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 are the basis used for the estimation of emission from CO, NOx, NMVOCs and SO_2.

The total CO emission in 2000 was 220 Gg. It was mainly emitted by the Energy and LUCF source categories which contributed 147 and 73 Gg CO, respectively. With respect to energy source category, the residential, road transport, commercial/institutional and agriculture/forestry/fishery source sub-categories contributed 133 Gg (90.5%), 6.6 Gg (4.5%), 6.6 Gg (4.5%) and 0.5 Gg (0.5%), respectively. The Changes in Forest and Other Woody Biomass Stock was the sole contributor of CO emission for the LUCF sector. The total NO_x emission was 6 Gg. It was emitted mainly by transport (road, 2 Gg), other sectors (including commercial/institutional and residential, 3 Gg) and LUCF (Changes in Forest and Other Woody Biomass Stock, 1 Gg). Energy industries and manufacturing industries and construction contributed very little NO_x emissions. The total NMVOCs emission was 3 Gg, mainly, from road transport (1 Gg), mineral products from road paving with asphalt (1 Gg) and other production which was from meat and bread production (1 Gg). The total national emissions for sulphur oxides (SO_x) was negligibly small (zero) in 2000.

3.6. Sectoral GHG Emissions

3.6.1. Energy Sector

3.6.1.1. Carbon Dioxide (CO_2) Emissions from Fuel Combustion- Sectoral Approach

In order to estimate Carbon Dioxide emissions from fuel combustion, two approaches are recommended by the IPCC manual: (i) the reference approach and (ii) the sectoral approach. CO_2 emission from fuel combustion which was estimated using the sectoral approach for the year 2000 was 586 Gg (see Table 3.1). With respect to this emission, the transport, other sectors, energy industries and manufacturing industries and construction contributed 199, 169, 147 and 71 Gg CO_2, respectively. In percentages, the transport source category emitted the highest (34%) followed by other sectors (29%), energy industries (25%) and manufacturing industries and construction (12 %) in that order. Nonetheless, the only emission estimated for the transport sub-sector was the road transport. Carbon dioxide emissions from domestic aviation, railways and national navigation were not estimated due to low level domestic activities in these respect and lack of activity data. The future submission of GHG inventory will explore of reporting these subcategories. There is also a need to use the higher Tiers methodologies for, at least, the road transport sub-sector. Eritrea will create conditions to apply inventory submissions for the road transport with more disaggregated calculation considering the different vehicle categories. The other sectors source category comprises the commercial/institutional, residential, and agricultural/forestry/fishing sub-sectors which emitted 95, 64 and 10 Gg, in decreasing order, respectively. Stationary sources emitted a total of 387 Gg (66%) while mobile sources 199 Gg (34 %) of CO_2.

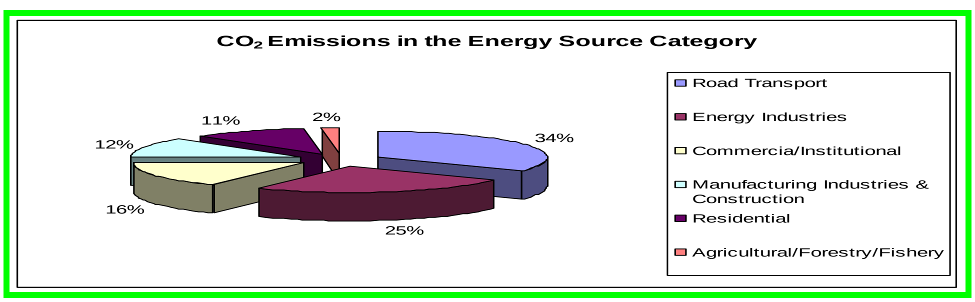


Figure 3.4 Distribution of CO_2 Emission in the Energy Sector in 2000 (Source: NGHGITWG, 2009)

Table 3.1: CO_2 Emission (Gg) from Fuel Combustion by Source Categories- Sectoral Approach for 2000

Sector	**CO_2 emission (Gg)**
Energy Industries	147
Manufacturing Industries & Construction	71
Transport	199
Public & Commercial	95
Residential	64
Agriculture/Forestry/ Fisheries	10
Total	**586**

Source: NGHGITWG, 2009

3.6.1.2. Carbon Dioxide (CO_2) Emissions from Fuel Combustion-Reference Approach

The Reference Approach is designed to calculate the emissions of CO_2 from the fuel combustion, starting from high level energy supply data. It can be used as a means of verification of the CO_2 emission estimate from fuel combustion using the Sectoral Approach. The assumption is that carbon is conserved so that, for example, carbon in crude oil is equal to the total carbon content of all the derived products. The Reference Approach does not distinguish between different source categories within the energy sector and only estimates total CO_2 emissions from Source category 1A, Fuel Combustion.

National total Carbon Dioxide emission from fuel combustion using the Revised 1996 IPCC Guidelines Reference Approach was estimated at 595 Gg which was the upper limit of CO_2 emission from fuel combustion. This emission was disaggregated by fuel types delivered as shown in Table 3.2.

Table 3.2: CO_2 Emission (Gg) from Fuel Combustion by Type of Fuel- Reference Approach for 2000

Fuel type	**Estimated CO_2 Emissions (Gg CO_2)**
Fossil fuel total	**595**
Gasoline	44.32
Jet Kerosene	0.00
Other Kerosene	67.66
Gas/ Diesel Oil	348.47
Light Fuel Oil	132.21
LPG	0.98
Bitumen	0.00
Lubricants	1.27

Source: NGHGITWG, 2009

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. As can be seen from Table 3.1 and Table 3.2, the gap between the two approaches is relatively small (1.5%) when compared to the total flows involved. Thus, the Reference Approach and the Sectoral Approach lead to similar evaluations of the CO_2 emissions trends because stock changes in final consumer level are not significant and statistical differences in the energy data are limited, among others.

Under the Reference Approach, CO_2 emission from the use of Biomass for fuelwood was 1,902 Gg which came from wood (1,395 Gg), charcoal (53 Gg), dung (315 Gg) and agricultural-residue (139 Gg). Nonetheless, this emission was not accounted in the energy source category in order to avoid double counting as it was accounted in the Land-Use Change and Forestry Sector since there was net-deforestation in the country in 2000. Under the Sectoral approach, it was shown that the Residential sub-sector was the highest user of fuelwood which emitted 1,704 Gg CO_2 followed by the commercial/institutional sector 69 Gg for process heat.

3.6.1.3. Bunker Fuels

These 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 1996 IPCC Guidelines. CO_2 emission from International Aviation Bunker in 2000 came from the use of Jet Kerosene which produced 72 Gg. Emissions of non-CO_2 gases from International Aviation Bunker Fuels were calculated but the emissions were negligibly small in 2000.

Emission from International Marine Bunker was not estimated as there was not sufficient supporting data in the country for this purpose. Thus, in order to improve the completeness of the inventory, Eritrea will create conditions to estimate those emissions in future inventory submissions. Eritrea will also create conditions, in future inventory submissions, to apply the Tier 2 method based on the number of landing/take-off cycles (LTOs) and fuel consumption. The advice on this subcategory included in the IPCC GPG, 2000 will be followed.

3.6.1.4. Fugitive Emissions from Fuels

According to the Revised 1996 IPCC Guidelines, in Fugitive Emissions should be considered the following categories: 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 occurring in Eritrea in 2000.

3.6.2. Industrial Processes and Product Use Sector

The Industrial Processes and Product Use Sector includes seven main categories: 2A Mineral Products, 2B Chemical Industry, 2C Metal Production, 2D Other Production, 2E Production of Halocarbons and Sulfur Hexafluoride, 2F Consumption of Halocarbons and Sulfur Hexafluoride, and 2G Other, with corresponding subcategories.

The whole of CO_2 emission (35 Gg) was contributed from the category 2A Mineral Products (subcategories 2A1 Cement Production, 2A2 lime Production and 2 A3 Limestone Use). In percentage, the CO_2 emissions from this sector in 2000 accounted for 0.4% of the national total. This low percentage is considered due to the fact that activities in the industrial sector were dawdling during 2000, as a result of the boarder war with Ethiopia. The total NMVOC emission was 2 Gg, mainly from 2A6 Road paving with asphalt (1 Gg) and 2D Other Production (Bread and Meat production, 1 Gg).

Production of halocarbons and sulphur hexafluoride was not occurring while *Consumption* of halocarbons and sulphur hexafluoride was not estimated in 2000. Nonetheless, there is a comprehensive assessment on the *consumption* of ODS and use of ODS-related equipment in the country which has been conducted by the Climate Change Unit. It requires some formatting and refinement to be used as an input to the National GHG Inventory. Eritrea will explore the possibility of reporting these emissions from consumption activities, mainly, from the use of refrigerator and air-conditioning units in future inventory submissions.

3.6.3. Solvent and Other Product Use Sector

This sector covers mainly NMVOC emissions resulting from the use of solvents and other product containing volatile compounds. Also includes evaporative emissions of GHG arising from other types of product use for example, N_2O emissions from medical use. When the solvents and other products are, or are produced from petroleum products, the carbon in the NMVOC emissions will be included in the CO_2 inventory if the Reference Approach for CO_2 emissions from energy is used. The emissions from this sector were reported as NE (Not-estimated). Nonetheless, in order to improve the completeness of the inventory, Eritrea will explore the possibility of reporting those emissions in future inventory submissions.

3.6.4. Agriculture Sector

The Agriculture Sector looks at GHG emissions from six categories: 4A Enteric Fermentation, 4B Manure Management, 4C Rice Cultivation, 4D Agricultural Soils, 4E Prescribed Burning of Savannas and 4F Field Burning of Agricultural Residues.

Emissions in this sector were determined for the categories 4A (Enteric Fermentation), 4B (Manure Management) and 4D (Agricultural Soils). The categories 4C (Rice Cultivation) and 4E (Prescribed Burning of Savannas) were not occurring in 2000 in Eritrea. The emission from the category 4F (Field Burning of Agricultural Residues) was zero. The total CH_4 emission in the agriculture sector was 133 Gg contributed mainly from livestock (enteric fermentation and manure management). The sole source of N_2O emission was agricultural soils which emitted 1Gg in 2000.

3.6.4.1. Enteric Fermentation- CH_4

Methane emissions from enteric fermentation accounted for 128 Gg in 2000. The emissions were calculated using the Tier 1 approach from the IPCC 1996 Guidelines with default regional IPCC emission factors according to the type of livestock and the population of each category of livestock. Activity data on animal population according to livestock types were provided from the Ministry of Agriculture of Eritrea. The livestock population data for 2000 were extrapolated from a survey done in 1997 by National Agricultural Statistics Office (NASO) assuming 5% annual increment rate. The information used to support the calculation is provided in Table 3.3. Taking into account the importance of enteric fermentation for aggregate emissions of the country, Eritrea will explore the possibility of applying Tier 2 approach in future GHG inventory submissions.

Table 3.3: Methane Emissions from Domestic Livestock Enteric Fermentation and Manure Management, 2000

Livestock Type	**A** **Number of Animals**	**B** **Emissions Factor for Enteric Fermentation**	**C** **Emissions From Enteric Fermentation**	**D** **Emissions Factor For Manure Mang't**	**E** **Emissions From Manure Mang't**	**F** **Total Emissions From Domestic Livestock**
		(kg/head/yr)	t/yr	(kg/head/yr)	t/yr	(Gg)
			C= (A*B)/1000		E=(A*B)/1000	F= (C+E)/1000
Dairy cattle	16000	36.0	576.00	1.00	16.00	0.59
Non-Dairy Cattle	2231272	32.0	71401.00	1.00	2231.30	74.00
Buffalo	0.00	0.00	0.00	0.00	0.00	0.00
Sheep	2464519	5.0	12322.00	0.20	493.00	13.00
Goats	5396599	5.0	26983.00	0.22	1187.00	28.00
Camels	369183	46.0	16982.00	2.56	945.00	18.00
Horses	5873	18.0	106.00	2.19	13.00	0.12
Mules & Asses	10794	10.0	108,00	1.20	13.00	0.12
Swine	2601	1.0	2.60	1.0	2.60	0.01
Poultry	1313054	0.0	0.00	0.02	26.30	0.03
Totals			128,481.00		4,927.00	133.00

Source: NGHGITWG, 2009

3.6.4.2. Manure Management-CH_4

Methane emissions from manure management accounted for 5 Gg in 2000. The emissions were also estimated using the Tier 1 approach from the IPCC 1996 Guidelines with regional default emission factors provided in the IPCC Guidelines. Activity data on animal population according to livestock types are country specific and the source of data was mentioned in the section above.

3.6.4.3. Emissions from Animal Waste Management Systems (AWMSs) - N_2O

The AWMS categories considered were the Anaerobic Lagoons, Liquid Systems, Daily Spread, Solid Storage and Drylot and Pasture Range and Paddock. Nonetheless, the two categories, namely, the Solid Storage and Drylot and Pasture Range and Paddock were only practiced in the country in 2000. All other AWMSs were not occurring. The Pasture Range and Paddock category was considered under Agricultural Soils under N_2O soil emissions from Grazing animals. N_2O emissions for Solid Storage and Drylot were estimated here. However, the estimate was negligibly small, close to zero.

3.6.4.4. 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 NOx and V) Indirect Nitrous Oxide Emissions from Leaching.

The total N_2O emitted from all these sources was approximately 1 Gg in 2000. Emissions from the use of synthetic fertilizer (0.06 Gg), animal waste (0.0 Gg), N-fixing crops (0.01 Gg) and crop residue (0.02 Gg) made up the Direct N_2O Emissions from Agricultural Fields, Excluding Cultivation of Histosols which was totaled at 0.09 Gg. Direct N_2O Emissions from Cultivation of Histosols contributed 0.13 Gg while Nitrous Oxide Soil Emissions from Grazing Animals or Pasture Range and Paddock contributed 0.15 Gg. Indirect N_2O Emissions from Atmospheric Deposition of NH_3 and NOx and Indirect N_2O Emissions from Leaching contributed 0.02 Gg and 0.35 Gg, respectively.

3.6.4.5. Prescribed Burning of Savannas- Non-CO_2 Gases

Prescribed burning of savannas releases net anthropogenic emissions of CH_4, CO, N_2O and NOx. In earlier time, Pastoralists in the rangelands used to burn grassland to get better juvenile grass for next growing season. Nonetheless, since this purposeful practice has been banned in the country, these non-CO_2 gases were reported as not occurring.

3.6.4.6. Field Burning of Agricultural Residues- Non-CO_2 Gases

Field burning of agricultural residues releases net anthropogenic emissions of CH_4, CO, N_2O and NOx. Despite annual production data for 20 crops was gathered from the MoA for this purpose, these emissions were not occurring in 2000 as the total biomass burned and, hence, the total carbon and nitrogen released were zero.

3.6.5. Land Use Land-Use Change and Forestry (LULUCF) Sector

In this sector were used the 2006 IPCC Guidelines and the IPCC GPG-LULUCF, 2003. Subsequently, a mapping back procedure was conducted to estimate the categories of Land-Use Change and Forestry (LUCF) according to the Common Reporting Framework (CRF) of the IPCC 1996 Guidelines. The IPCC GPG

LULUCF, 2003 are organized following six broad land-use categories (forest land: cropland; grassland; wetlands; settlements; and other land). Land may remain in any of these categories or its use may change to another category. The guidance provides advice on the estimation of emissions and removals of CO_2 and non-CO_2 GHG for the LULUCF sector for both situations. The key greenhouse gases of concern are CO_2, CH_4, N_2O, NOx and CO.

The emissions and removals were determined using the default methods and emission parameters included for this sector in the IPCC GPG LULUCF, 2003 and the 2006 IPCC Guidelines. Activity data were obtained from FAO reports (State of the World's Forests, 2005).

The LUCF sector was the highest net-emitter of CO_2 in 2000 in Eritrea (8,205 Gg CO_2). Emissions from the category 5A Changes in Forest and Other Woody Biomass Stocks accounted for 4,722 Gg CO_2 and the category 5B Forest and Grassland Conversion 3,608 Gg CO_2. Also were emitted 4 Gg CH_4, 73 Gg CO, and 1 Gg NOx from Changes in Forest and Other Woody Biomass Stocks. These emissions correspond to the immediate release of non-carbon dioxide trace gases from the burning associated with gradual Changes in Forest and Other Woody Biomass, mainly, used in military camps in wood lands for the purpose of fuelwood.
Nonetheless, the forestland remains forestland after 2000. These non- CO_2 emissions were calculated from non-CO_2 emissions from vegetation fires sub-category.

Emissions of non-CO_2 gases from forest and grassland conversion were zero in 2000 as the forest and grassland conversion which took place in 2000 was not associated with fire. The IPCC Guidelines and the IPCC GPG for LULUCF provide methodology to estimate CH_4, NMVOC, NOx and CO emissions for emissions from fire only. In 2000, because of the war with Ethiopia a forest land was converted to settlements for returnees (spontaneous, organized and deportees). Most of the trees cut were either taken offsite or used for house construction.

CO_2 removal from the category 5D CO_2 emissions and removal from soil was -125 Gg CO_2 in 2000. All Land Use Remaining the Same Land Use and All Land Use Converted to Other Land Use were assessed for annual change in carbon stock in mineral and organic soils, carbon emissions from agricultural lime application and annual soil carbon stock change in croplands. The total soil carbon stocks were calculated for each category and summed to come up with the grand total. *Annual change in carbon stock in mineral soils was the largest contributor to CO_2 remova*l. Carbon emission from agricultural lime application and annual change in carbon stocks in organic soil were not occurring in 2000.

Table 3.4: Some Activity Data and Parameters used for calculation of Land Use and Land Use Changes Emissions-2000

Type of Land Use	**Activity Data/ Carbon Stock Change**	**Value**
Forestland Remaining Forestland	Area (ha)	1585000
	Annual Carbon loss due to commercial felling (tonnes C/yr)	426.00
	Annual volume of fuelwood gathering (m^3/yr)	2323000
	Annual carbon loss due to fuelwood gathering (tonnes C/yr)	1650345
	Forest area affected by disturbances (ha/yr)	5000
	Annual change in carbon stocks in living biomass (tonnes/yr)	-1287693
	Annual change in carbon stocks in dead organic matter (tonnes/yr)	0.00
	Area burnt in 2000 (ha)	68013
	Annual soil carbon stock change in mineral soils (tonnes C /yr)	34100
	CO_2 Emissions from drained organic soils (tonnes C/yr)	NO
Land Converted to Forestland	Area of land converted to forest land through natural regeneration (ha)	0.00
	Area of land converted into forest land through establishment of Plantations (ha)	0.00
	Total afforested land derived from former cropland or grassland (ha)	22000

Cropland Remaining Cropland	Annual growth rate of perennial woody biomass (ha/yr)	1.80
	Actual carbon stock in biomass removed (ha/yr)	1.80
Land Converted to Cropland	Annual area of forestland converted to cropland (ha/yr)	2820.00
	Annual carbon stock change in mineral soils (tonnes C/yr)	255.00
Land Converted to Settlements	Area of land converted annually from forestland to settlements (ha/yr)	21,115.00

Source: NGHGITWG, 2009

3.6.6. Waste Sector

In the IPCC 1996 Guidelines the Waste Sector looks at greenhouse gas emissions from three main categories: 6A Solid Waste Disposal; 6B Wastewater Handling; 6C Waste Incineration (optional). Emissions in this sector were determined for the category 6A. From this sector were reported 2 Gg CH_4 in 2000 derived from solid waste disposal.

3.6.6.1. Solid Waste Disposal on Land-CH_4

Methane emissions from solid waste disposal on land accounted for 2 Gg in 2000. Due to data gaps, only methane emission from the solid waste disposal site (SWDS) of Asmara was estimated. The method used in the estimation could be summarized in six steps shown below followed chronologically:

- Identify solid waste by Composition and Quantity. The solid waste was categorized into Nine Types as shown in Table 3.5 below;
- Potential Methane Generation Rate per Unit of Waste, which was categorized in step one, was calculated by multiplying Fraction of Degradable Organic Carbon (DOC) in MSW, Fraction of DOC which Actually Degrades, Fraction of Carbon Released as Methane and Conversion Factor;
- Realized (Country-specific) Methane Generation Rate per Unit of Waste was calculated by multiplying Methane Conversion Factor (MCF) with Potential Methane Generation Rate per Unit of Waste which was calculated in step two;
- Gross Annual Methane Generation was calculated by multiplying total Annual MSW Disposed to SWDs with Realized Methane Generation Rate per Unit of Waste which was calculated in step three;
- Net Annual Methane Generation was calculated by the difference between Gross Annual Methane Generation, which was calculated in step four, and Recovered Methane per Year; and
- Net Annual Methane Emission (Gg CH_4) was calculated by multiplying Net Annual Methane Generation, which was calculated in step five, with One Minus Methane Oxidation Correction Factor

The common figures which were used among all types of solid wastes for emission estimates were as follows: MCF=1, Fraction of DOC which actually degrades= 0.5, Fraction of Carbon Released as Methane= 0.5, Conversion Factor= 16/12, Recovered Methane per Year (Gg CH_4) = 0, One minus Methane Oxidation Correction Factor= 1, Oxidation Correction Factor= 0 (anaerobic system was considered). The other calculated figures for parameters and emissions are shown in Table 3.5 below. Solid Waste per Capita Generation was considered 0.79 kg/capita/day which is the value for African Region. This value for Solid Waste per Capita was acceptable or justified for Asmara City from expert judgment.

Table 3.5: Parameters used for Estimation of Methane Emissions at Asmara SWD Site:

Types of Solid waste	Annual Disposal of MSW (Gg MSW)	Fraction of DOC in MSW	Potential CH_4 Generation (Gg CH_4 Per Gg MSW)	Realized CH_4 Generation (Gg CH_4 Per Gg MSW)	Gross Annual CH_4 Generation (Gg CH_4)	Net Annual CH_4 Generation (Gg CH_4)	Net Annual CH_4 Emissions (Gg CH_4)
Food Waste	20.80	0.15	0.05	0.05	1.04	1.04	1.04
Paper & Board	5.10	0.40	0.10	0.10	0.69	0.69	0.69
Plastic	2.50	0.00	0.00	0.00	0.00	0.00	0.00
Textiles	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Metal	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Glass	0.60	0.39	0.13	0.13	0.07	0.07	0.07
Leather & Rubber	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Ceramic & Stone	9.0	0.43	0.14	0.14	0.05	0.05	0.05
Others	10	0.20	0.07	0.07	0.59	0.59	0.59

Source, NGHGITWG, 2009

The quantity of Annual MSW Disposed of in Solid Waste Disposal Sites using country data was estimated at 79.58 Gg MSW where urban population for Asmara whose waste went to SWDS was assumed to be 400,000 persons. MSW Production Rate was taken 0.79 kg/capita/day, annual amount of MSW generated was 115.34 Gg MSW, and Fraction of MSW Disposed in SWD (urban total) was also taken 0.69. For in-depth information, the readers are referred to the inventory worksheets for Waste Sector which has been submitted with this report.

To improve the completeness of the inventory, Eritrea will explore the possibility of considering in the estimation of Other Cities SWDS that operate in the country in future GHG inventory submissions.

3.6.6.2. Industrial Wastewater- CH_4

Industrial wastewater management releases anthropogenic emissions of CH_4. Emissions from this category were not estimated in 2000 due to lack of activity data for this purpose. However, to improve the completeness of the inventory, Eritrea will explore the possibility of estimating and reporting the emissions from this category for the next submission of GHG inventory.

3.6.6.3. Domestic and Commercial Wastewater- CH_4

Domestic and commercial wastewater management releases anthropogenic emissions of CH_4. As domestic and Commercial Wastewater were not collected and sewered for treatment in centralized plants, which were not available in the country in 2000, the CH_4 emissions were not occurring from this category. Nonetheless, centralized plants, if exist, and on site-specific systems (septic tanks, open pits/latrines) with updated emission factors, which have already been provided in volume 5, IPCC 2006 Guidelines, will be explored to improve the completeness of GHG inventory for future GHG inventory submissions.

3.6.6.4. Domestic and Commercial Wastewater- N_2O

Nitrous Oxide emissions from this category were not estimated due to time limitation. However, to improve the completeness of the inventory, Eritrea will explore the possibility of estimating and reporting the emissions from this category for the next submission of GHG inventory. Most of the necessary activity data could be obtained from FAOSTAT on protein consumption and in the IPCC 1996 Guidelines are provided default values for the emission parameters.

3.7. Summary of National GHG Inventory

For the purpose of reporting of the national GHG inventory as required by the UNFCCC Secretariat, it is summarized in Table 3.6 as per decision 17/CP.8.

Table 3.6 Summary Report for National GHG Inventory -2000

Country	Eritrea
Inventory Year	2000

National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol and greenhouse gas precursors

Greenhouse gas source and sink categories	**CO_2 emissions (Gg)**	**CO_2 removals (Gg)**	**CH_4 (Gg)**	**N_2O (Gg)**	**NO_x (Gg)**	**CO (Gg)**	**NMVOCs (Gg)**	**SO_x (Gg)**
Total national emissions and removals	**8,826**	**-125**	**147**	**1**	**6**	**220**	**3**	**0**
1. Energy	**586**	**0**	**8**	**0**	**0**	**147**	**0**	**0**
A. Fuel combustion (sectoral approach)	586		8	0	5	147	1	0
1. Energy Industries	147		0	0	0	0	0	0
2. Manufacturing industries and construction	71		NO	NO	0	NO	NO	NO
3. Transport	199		0	0	2	7	1	NO
4. Other sectors	169		8	0	3	140	0	NO
5. Other (please specify)	0		0	0	0	0	0	0
B. Fugitive emissions from fuels	NO		NO		NO	NO	NO	NO
1. Solid fuels	NE		NO		NO	NO	NO	NO
2. Oil and natural gas	NE		NO		NO	NO	NO	NO
2. Industrial processes	**35**	**0**	**0**	**NO**	**NO**	**NO**	**2**	**NO**
A. Mineral products	35				NO	NO	1	0
B. Chemical industry	NO		NO	NO	NO	NO	NO	NO
C. Metal production	NO		NO	NO	NO	NO	NO	NO
D. Other production	NO		NO	NO	NO	NO	1	0
E. Production of halocarbons and sulphur hexafluoride	NE	NE	NE	NE	NE	NE	NE	NE
F. Consumption of halocarbons and sulphur hexafluoride	NO	NO	NO	NO	NO	NO	NO	NO
G. Other (please specify)	NO		NO	NO	NO	NO	NO	NO
3. Solvent and other product use	**NE**			**NE**			**NE**	
4. Agriculture			**133**	**1**	**0**	**0**	**0**	**0**
A. Enteric fermentation			128					
B. Manure management			5	0			0	
C. Rice cultivation			NO				NO	
D. Agricultural soils				1			0	
E. Prescribed burning of savannahs			NO	NO	NO	NO	NO	
F. Field burning of agricultural residues			NO	NO	NO	NO	NO	
G. Other (please specify)			NO	NO	NO	NO	NO	

5. Land-use change and forestry [1]	**8,205**	**0**	**4**	**0**	**1**	**73**	**0**	**0**
A. Changes in forest and other woody biomass stocks	4,722	0	4		1	73		
B. Forest and grassland conversion	3,608	0	0	0	0	0		
C. Abandonment of managed lands		NO						
D. CO_2 emissions and removals from soil	0	-125						
E. Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO
6. Waste			**2**	**0**	**0**	**0**	**0**	**0**
A. Solid waste disposal on land			2		NO		NO	
B. Waste-water handling			NO	NE	NO	NO	NO	NO
C. Waste incineration			NE	NE	NE	NE	NE	NE
D. Other (please specify)			NE	NE	NE	NE	NE	NE
7. Other (please specify)	**0**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo items								
International bunkers	**72**		**0**	**0**	**0**	**0**	**0**	**0**
Aviation	72		0	0	0	0	0	0
Marine	NE		NE	NE	NE	NE	NE	NE
CO_2 emissions from biomass	**1,903**							

Source: NGHGITWG, 2009. N.A= Not available, N.E = Not estimated, N.O = Not occurring

3.8. Aggregated Emissions and Trends

The reporting in terms of aggregate emissions, i.e. applying the Global Warming Potentials (GWPs) in order to convert the emissions into CO_2 equivalent, facilitates comparison between sectors or comparing the relative importance of each direct GHG. In this context, Eritrea opted to use GWPs and apply those provided by the IPCC in its Second Assessment Report (SAR) (i.e. 1 for CO_2, 21 for CH_4 and 310 for N_2O for 100 years time horizon).

The absolute emissions of GHG from various sectors for the year 2000 are provided in Table 3.7. It can be seen that the key share of GHG, primarily CO_2 is from LUCF, accounting for about 93% of the total absolute CO_2 emissions. This is followed by energy use from fuel combustion which accounts for 7 % of the total absolute emission of CO_2. Key share of CH_4 is from Agriculture, accounting for about 90 % of the total absolute CH_4 emissions. This is followed by energy use from fuel combustion which accounts for 5.4 %, LUCF 2.7% and waste 1.4 %.

The resultant GHG emissions in Eritrea therefore amounted to 12,223 Gg CO_2 equivalents in 2000. In this context, the country's source of GHG emissions, by sector, mainly comes from LUCF, agriculture and fossil fuel combustion accounting for about 67.8 %, 25.4 %, and 6.2% respectively of total CO_2 equivalents. When viewed by gases, CO_2, CH_4 and N_2O are the main pollutants, accounting for 72.2 %, 25.3 %, and 2.5 %, respectively.

Table 3.7: Emissions in Absolute Values (Gg) and Aggregated Emissions in CO_2 Equivalent (Gg)- 2000

GHG Sources	Emissions in Absolute Values (Gg)			CO_2 Equivalent Emissions				%
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**Aggregated Emissions**	
Fuel Combustion	586	8	0	586	168	0	754	6.2
Industrial Processes	35	0	0	35	0	0	35	0.3
Agriculture	-	133	1	-	2,793	310	3,103	25.4
LUCF	8,205	4	0	8,205	84	0	8,289	67.8
Waste	0	2	0	0	42	0	42	0.3
Total Emission	**8,826**	**147**	**1**	**8,826**	**3,087**	**310**	**12,223**	
%				**72.2**	**25.3**	**2.5**	**100**	**100**

Source: NGHGITWG, 2009

3.9. Key Source Analysis

NAI Parties are encouraged, to the extent possible, to undertake any key category analysis (level/trend or both) to assist in developing inventories that better reflect their national circumstances. In this context, Eritrea provides qualitative information in this section on key categories based on the key share of each sector. Nonetheless, Eritrea acknowledges that this assessment is too aggregated, separate by GHG and not documented appropriately. In the future inventory submission and when more time is available, Eritrea will perform this analysis considering the contribution of CO_2 eq each category assessed in the inventory, and not by specific GHG. Eritrea will also explore the possibility to perform a quantitative determination of key categories. For this analysis, the advice of the IPCC GPG, 2000 and the IPCC GPG LULUCF, 2003 and the tool provided in the UNFCCC- NAI Software for this purpose will be consulted. Eritrea has fully underlined that the key category analysis is an important part of inventory development and a driving factor for improving the inventory.

Land use was the major contributor to the emission of greenhouse gases in 2000. Clearing land for agriculture, for settlement and for fuel wood contributed the highest. The lack of appropriate technology was compensated by using large area for every activity.

The nature of ***energy industry*** in Eritrea was mainly from fossil fuel and electrification coverage was quite small in 2000. But there has been a practical action plan to increase the electrification coverage in the country and the contribution of this in the increase of greenhouse gasses emissions is eminent. There has been significant change in the electricity production and oil products use in the generation of energy for residential and commercial purposes. Right now the major source of energy in Eritrea is fuel wood. This has been not on the decrease direction, rather increasing from time to time. The burden that energy production puts on the ecosystem and forest resource in Eritrea is quite high. The use of fuel wood for energy production is very much unsustainable. Thus, increasing energy production from fossil fuel cannot be compromised at this point in time. To minimize the use of fossil fuel for the production of energy, alternative sources should be thought over.

As can be seen from the results of both first and second national GHG inventories for 1994 and 2000 respectively, it was shown that the key share of CO_2 was from LUCF, accounting for about 70 and 93% for 1994 and 2000 respectively of the total absolute CO_2 emissions. This was followed by energy use from fuel combustion which accounts for 29 and 7 % for 1994 and 2000 respectively of the total absolute emission of CO_2. The Key share of CH_4 was from energy in 1994, accounting for about 53 % of the total absolute CH_4 emissions followed by Agriculture from livestock which accounts for 45 % of the total absolute methane emission. The Key share of CH_4 was from Agriculture in 2000, accounting for about 90 % of the total absolute CH_4 emissions followed by energy use from fuel combustion which accounts for 5.4 %, LUCF 2.7% and waste 1.4 %.

Hence, in terms of source categories, the LUCF, Energy and Agriculture Sectors are key sources while in terms of greenhouse gases CO_2 and CH_4 are key greenhouse gases in terms of absolute level of emissions and trends of emissions. Therefore, the limited resources available for preparing GHG inventory in Eritrea should be prioritized to address primarily the LUCF, Energy and Agriculture Sectors. In the subsequent national GHG inventories, more detailed higher tier methods should be selected. Moreover, additional attention should be given to LUCF, Energy and Agriculture Sectors with respect to quality assurance, quality control and verification. The key categories LUCF, Energy and Agriculture Sectors and the key greenhouse gases CO_2 and CH_4 have been, therefore, prioritized for consideration in the GHG Mitigation Assessment and Analysis.

3.10. Uncertainty Assessment

In Decision 17/CP.8 Non-annex I Parties are encouraged to provide information on the level of uncertainty associated with inventory data and their underlying assumptions, and to describe the methodologies used, if any, for estimating these uncertainties. Uncertainty estimates are an essential element of a complete emissions inventory. They should be derived for both the national level and the trend estimates, as well as for the component parts such as emission factors, activity data and other estimation parameters for each category.

Eritrea described, qualitatively, the main sources of uncertainties in each sector of the activity data and emission parameters used under this section. Nonetheless, Eritrea acknowledges that this is not adequate and will create conditions to perform, in future inventories submissions, the quantitative determination of uncertainties at least using the method Tier 1 and following the advice of IPCC GPG, 2000 and the IPCC GPG LULUCF, 2003 in this respect. Eritrea has underlined that the uncertainty analysis is a driving factor for improving the inventory.

The methodology with ***cement production and lime production*** estimation of CO_2 is relatively simple. The emission factors are more certain but there is uncertainty associated with activity data. With lime production, the data is collected from the report of the Ministry of Energy and Mines. The producers are not reporting the accurate data as their tax payment is based on this report. There is potential practice of tax eviction.

The ***livestock*** population data for GHG inventory came from the 1997 Survey done by National Agricultural Statistics Office. Annually updated and properly published activity data were not available which create obstacle to estimate emissions for three years average as required by the Guidelines. The activity data for 2000 was extrapolated from the survey results of the 1997 taking 5% annual increment rate. This possibly contributed to the uncertainty of the emission calculations because fluctuations and variations in animal populations throughout the year were not captured. Also, the other factor of uncertainty is the use of default IPCC emission factors in calculations. These default factors do not take into account the national feeding situation, the work performed, and the feed digestibility by the animals. Thus default factors have associated uncertainty. Another uncertainty source is the use of basic livestock characterization. In this line, temperature and humidity factors were not well accounted could introduced associated uncertainty in the amount of methane produced.

Due to diverse soil properties, land-use types and climatic conditions, there are uncertainties in quantification of greenhouse gas emission from ***agricultural soils***. Data were unavailable to estimate many potential sources of nitrous oxide. This lack of data means there could be a substantial percentage error in the estimates of nitrous oxide emissions. The estimates of emissions from fertilizers are also uncertain. There are many factors that affect N_2O emissions from fertilizer use, including soil pH and temperature, for which data are not available. IPCC gives the same default values and coefficients for a particular agricultural soil irrespective of soil conditions and production system management. Of course, since emissions of N_2O make up an extremely small portion of the total greenhouse gas emissions in Eritrea, this data gap introduces very little uncertainty into the overall inventory estimates.

Although ***LUCF*** is a key category, default factors are used to estimate emissions as there is lack of detailed and regularly updated, checked and published activity data or experimentally measured parameters that assist in the determination of country specific emission factors. Emission factor and Default Value Sources have been obtained from 2006 IPCC - NGGI Guidelines, Vol 4 and GPG 2003.These values are regional values that do not take national circumstances in to consideration. The statistics of traditional wood that is gathered and used directly for household firewood purposes and the coverage of forest area burnt are of very high uncertainty as such activities are usually not reported. Also there is high uncertainty in the annual forest clearing rates and the amounts of biomass and therefore carbon removed from the given forest. Country specific emission factors and emission ratios are critical for undertaking a national GHG inventory. These values are lacking in Eritrea, and hence the IPCC default values are adopted to serve a purpose. Lack of time series data was another obstacle to the national inventory of GHG. Relatively speaking the lack of data was more limiting in the LUCF sector as compared to the other sectors. In light of this situation the uncertainties could be quite high. Future GHG inventory works need to take these gaps into consideration.

GHG emission from the ***waste sector*** is highly dependent on population growth and economic activity. No data was available for all cities except Asmara. In the waste sector there is time series data gap. Managed SWDS are being started lately for the urban and semi urban sites except that of Asmara. Due to data gaps; only methane emission from Asmara waste disposal site was estimated.

3.11. Recalculations and Time-Series Consistency

When occur changes of methods, emission factors, or have been obtained new or better activity data, or have been considered new source categories, is recommended to recalculate the emissions of previous inventory reports. This guarantees the consistency of the series of emissions. Eritrea acknowledges the fact that there is a need to perform recalculations for its previous inventory corresponding to 1994 included in the Initial National Communication (INC). In this context, Eritrea will explore the necessity to perform the recalculation of emissions of the 1994 inventory, especially in the LULUCF sector where currently new methods and emission parameters have been introduced from the 2006 IPCC Guidelines and the IPCC GPG LULUCF, 2003 instead of the IPCC 1996 Guidelines.

3.12. Quality Assurance and Quality Control (QA/QC)

Eritrea has developed QA/QC Plan which has been elaborated in the internal documentation of the NGHGI. The major issues addressed in the plan are elaborated in brief as follows. The basic indicators which are being used by the NGHGITWG for measuring the quality of the NGHGI include *completeness, consistency, comparability, transparency and accuracy of emission estimates.*

Regarding the completeness issue, the GHG inventory covers most of the categories and gases for which GHG occur in Eritrea and adequate information as required by the COP of the UNFCCC is available. Also the geographical coverage of the inventory is for the whole country, except for the solid waste category where emissions were estimated only for the Municipality of Asmara due to unavailability of activity data.

At this juncture, the SNC Project Team would like once again to extend its appreciation to the National Communication Support Programme (NCSP), located in New York, for its successful coordinating efforts to bring experts together to review the Eritrean SNC, in general, and the GHG inventory, in particular. The independent review, which was taken as QA measure, for Eritrean GHG Inventory took place from 2 February to 8 February 2012 in Havana, Cuba.

CHAPTER 4

NATIONAL GHG MITIGATION ASSESSMENT AND ANALYSIS

4.1. Introduction

Articles 4.1 and 12.1, of the United Nations Framework Convention on Climate Change (UNFCCC) commits Parties to develop national and, where appropriate, regional programmes and measures that will result in the mitigation of anthropogenic climate change.

Although Eritrea is not required to take on emission reduction commitments, undertaking climate change mitigation and assessment could provide ancillary benefits for national sustainable development objectives. A mitigation assessment provides policy makers with an informed evaluation of technologies and practices that can mitigate climate change and also contribute to national development objectives. The assessment could also identify potential projects for funding. Acknowledging this fact, the country has established a National GHG Mitigation Assessment and Analysis Thematic Working Group (NGHGMTWG) drawn from relevant government ministries and institutions including, inter alia, the Ministry of Land, Water & Environment, Ministry of Energy and Mines, Ministry of Agriculture, Ministry of Industry and Trade, Ministry of Transport and Communication and National Statistics and Evaluation Office entrusted to undertake the task of national GHG mitigation assessment and analysis. Other stakeholders such as existing NGOs, CBOs and scientific community have also been engaged at various stages of the process.

As per the outcome of the key source category analysis, conducted in the earlier chapter, the LUCF, Energy and Agricultural sectors have been identified to be priorities for mitigation assessment and analysis. In terms of direct greenhouse gases, Carbon Dioxide (CO_2) and Methane (CH_4) have gained attention as priority GHGs. Nonetheless, the highest contribution of unsustainable uptake of biomass for energy from forest and other woody biomass stock necessitates the energy sector and CO_2 to be the most priorities and synergistic for national GHG mitigation study. Hence, the existing limited resources have been channeled mainly to GHG mitigation assessment and analysis on the energy source category and CO_2 emissions.

4.2. Methodological Approaches

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) modeling tool. **LEAP** is a tool for strategic integrated energy-environment scenario studies including energy outlooks (forecasting), integrated resource planning, greenhouse gas mitigation analysis and energy balances and environmental inventories. Key characteristics of LEAP include accounting framework, user-friendly, scenario-based, and integrated energy-environment modeling building tool. The scope of the model includes energy demand, energy supply, resources, environmental loadings, cost-benefit analysis and non-energy sector emissions.

The major criteria for the selection of LEAP for Eritrea include, inter ali, its flexible approach to modeling, low initial data requirements, low-medium level of effort required, advanced reporting capabilities, windows software requirements, availability of adequate reference materials and technical support throw phone, email and web forum. LEAP also permits default data and emission factors included in its built-in Technological and Environmental Data (TED) Database.

Besides LEAP and for verification purpose, another bottom-up energy demand model known as Model for Analysis of Energy Demand (MAED) has also been used to project Eritrea's Energy Demand. **MAED** is one of the **ENPEP** tools. The Energy and Power Evaluation Programme (ENPEP) is a set of ten integrated energy, environmental, and economic analysis tools.

4.3. Objective of the Study

The objective of the study was to conduct strategic integrated energy-environment scenario studies to comply with the reporting commitment of Eritrea to the UNFCCC. The major outputs of the study has been energy outlooks (forecasting), integrated resource planning, greenhouse gas mitigation analysis and energy balances and environmental inventories for the country.

4.4. Scope of the Study

The scope of the study was to conduct 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.

4.5. Time Frame

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 (10-30 years) based on national plan and sectoral assessment is more practical. Hence, the time frame 2000-2030 was selected for the study.

4.6. Data Sources

Most of the national energy balance data was sourced by the Ministry of Energy and Mines and National Statistics and Evaluation Office. Depending on national circumstances and data requirement by the modeling tools for the base years, secondary data have been collected and assumptions and expert judgments have also been established in order to fill data gaps to help formulate projections for future trends. The GHG mitigation analysis also makes use of the default emissions factors embedded in the LEAP model's TED Database whenever required to fill those data gaps.

4.7. Energy Sector Overview

In Eritrea, like in other Sub-Saharan Countries, the energy sector is characterized by massive dependence on traditional biomass fuels (wood, charcoal, animal waste and agricultural residue) to cover domestic energy requirements; lack of easy access by the majority of the country's population to modern energy and total reliance on imported oil as a source of modern energy. The current energy system in Eritrea can be characterized by:

i. A serious shortage of foreign exchange;
ii. High dependence on scarce wood and other biomass resources;
iii. Inadequate technological interventions in harnessing locally available resources; and
iv. Inadequate capacity in energy demand management both at the supply and end use levels.

Annual per capita total energy consumption (less than 200 kgoe) in Eritrea is lower than most African countries. According to the annual report of the Department of Energy, a third of this amount is regarded to be commercial or modern energy. Biomass remains the main source of energy, particularly for rural households, which derive 95 percent of their requirements. Eritrea's current pattern of energy consumption is unsustainable as biomass is becoming increasingly scarce and the scarcity of foreign exchange for importing petroleum products is severe. The priority for the energy sector is, therefore, to promote energy conservation and encourage development of efficient new sources of energy. The government is encouraging private investment through favourable proclamations including joint ventures in prospecting, exploration and development of viable energy resources from the conventional oil and gas and the renewable energy mainly geothermal, wind, solar and modern biomass. The government is also promoting the use of an improved and more energy efficient biomass stove in rural areas.

4.7.1. Biomass

Biomass forms of energy are the major sources of energy in Eritrea. In the energy balance it accounts for more than 65 % of the total primary energy supply; and about 70 % of the total final energy supply. Figure 4.1 shows time series consumption of biomass fuels, based on surveys 1995, 1998 and 2004 and interpolation or extrapolation in between those years or beyond. The consumption of biomass is decreasing with time. The reduction may be attributed to the introduction of improved biomass stove, shift to modern energy sources and scarcity of supply.

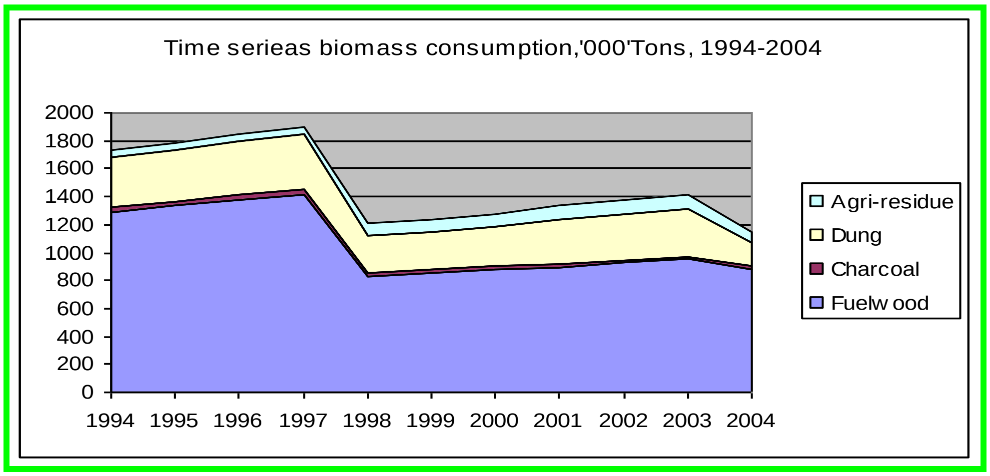


Figure 4.1: Time Series Biomass Consumption (Source: NGHGMTWG, 2009)

4.7.2. Petroleum

Petroleum is the second largest primary energy source in Eritrea. The country is totally dependent on imported oil products to meet its modern energy requirements. This makes the country’s energy supply and economy extremely volatile to international oil price rise. Petroleum products accounts for about 35 % of the total primary energy supply and 28 % of the total final energy supply. Of the total primary supply of oil products, 27.5 % dissipated during energy transformation (electricity generation) and the remaining 72.5 % was consumed by consumer sectors. Figure 4.2 shows the time series statistics of fuel consumption. The consumption of fuel oil is increasing since 2003 with the commissioning of Hirgigo Power Plant.

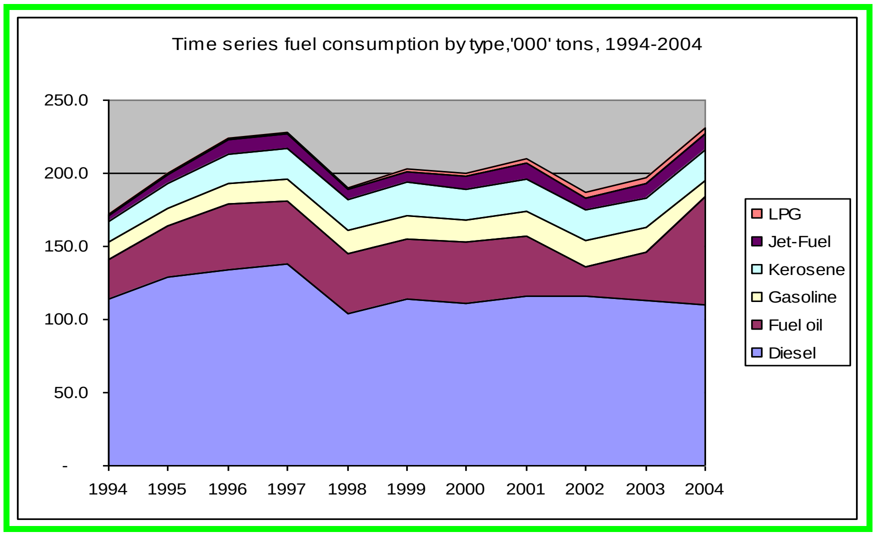


Figure 4.2: Time Series of Fuel Consumption by Type (Source: NGHGMTWG, 2009)

4.7.3. Electricity

Main source of electricity in Eritrea is thermal generation (98 %), whereas Renewable Energy mainly solar and wind electricity accounted for only 2 % as of 2008. In the country, where the majority of the population lives below the poverty line, the overall access to modern electricity services continues to be among the lowest in the world. At the national level, only 32 % of the population has access to electricity (78 % in urban areas compared to 3 % in rural areas) (EDHS, 2004). Electricity contributes less than 3 % in the final energy supply of the country. As shown in Figure 4.3, electricity generation grew by more than 100 % in the 10 years period 1994-2004 from as low as 110 Gwh to around 240 GWh. Share of electricity consumption by domestic sector was increasing at a higher rate due to rural electrification program thereby increasing domestic customers, whereas, share of industrial consumption declined since 2000 due to lowering of industrial activities due to boarder war.

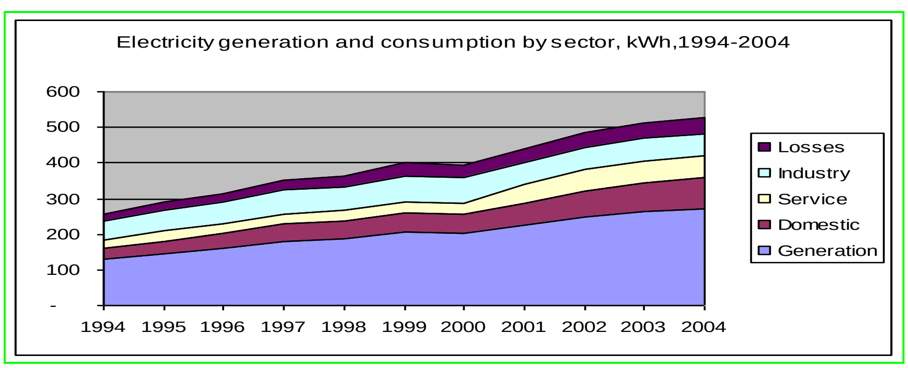


Figure 4.3: Time Series Electricity Generation and Consumption (Source: NGHGMTWG, 2009)

4.8. Projected Energy Demand

4.8.1. Projection of Energy Demand- Model for Analysis of Energy Demand (MAED)

A review of national energy demand forecast was carried out taking 2004 as a base year and using a model known as Model for Analysis of Energy Demand (MAED), Figure 4.4. The review considered the following key assumptions: growth in GDP, growth in mining and industrial activity, population growth, urbanization and political stability of the nation. Based on these assumptions, the analysis revealed that total final energy demand grows by 2.7 times at the end of the model year (2030) compared to the base year. It also showed that there was a shift from traditional biomass fuel to modern biomass and other commercial fuels such as electricity and fossil fuels. However, modern biomass and soft solar remained insignificant compared to the other supply sources of energy. Demand for oil products and electricity has grown 5.9 and 11.3 times respectively, while, demand for biomass declined to 0.9 times by the end of the model year. To meet the growing demand, the supply system also would grow along with the associated GHG emissions.

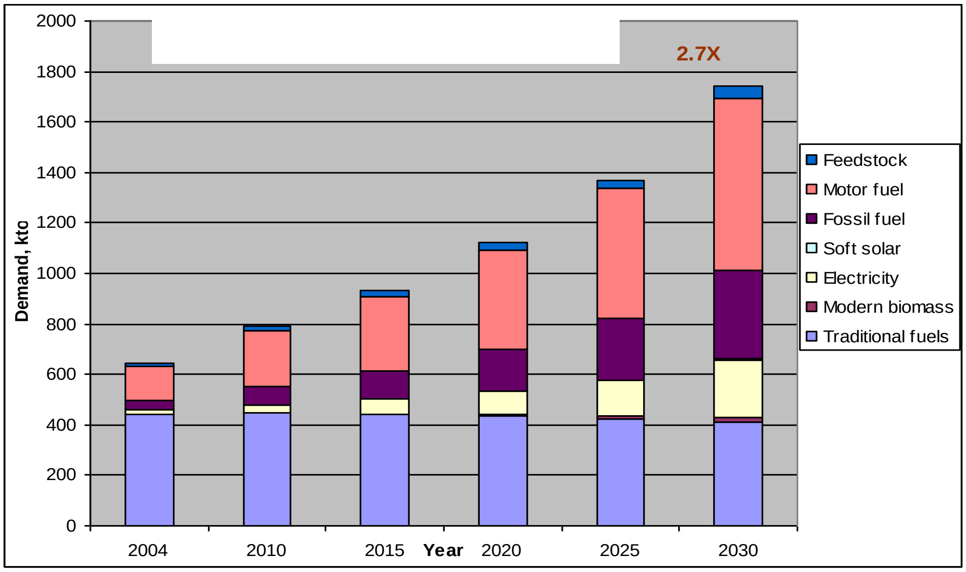


Figure 4.4: Energy Demand Projection by Type of Fuel (ktoe), (Source: MOEM, 2004)

4.8.2. Projection of Energy Demand-Long range Energy Alternatives Planning (LEAP)

LEAP considered the base year 2000 to project energy balance and future demand forecast for Eritrea. The time horizon of projection was 2000-2030. In estimating the demand projections two scenarios, namely, Reference (business as usual) and Mitigation Scenarios were considered. For both scenarios corresponding assumptions were established. Key assumptions for projecting energy demand and estimating GHG emission for the Reference and Mitigation Scenarios were:

1. For the **Reference Scenario**:
    a. Population grows by 2.4 annually (initially growing at 2.7, towards the end growth rate is considered at 2);
    b. Household size decrease but total number of households increases;
    c. Urbanization is assumed to grow to 45 % from present rate of 30 %;

d. Share of the economic sector industry to GDP is assumed to grow from 20 % to 28 % due to commencement of mining sector, share of agriculture is assumed to remain as it is but mechanization and increase in production / ha is expected;
e. Improvement of life style (fuel shift from traditional biomass to modern commercial fuel, and use of new appliances) is assumed;
f. Increase access to modern energy sources (rural access to electricity is assumed to grow form 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 is also assumed

2. For the **Mitigation Scenario:**
   a. Improvement of efficiency of end use devices is assumed (dissemination of improved traditional biomass stove, replacement of inefficient lamps by efficient Compact Flourcent Lamp (CFL), reduction of transmission and distribution losses);
   b. Use of mass transportation and introduction of train electric in the capital Asmara, is assumed;
   c. Introduction of indigenous renewable energy resources for power generation (solar, wind and geothermal power generation) is assumed.

Based on the above assumptions, energy demand projection for the model years is presented on Table 4.1. Total energy demand projection was growing by 2.8 times compared with the base year value which was the same as that projected by MAED. Industrial energy demand would be growing by 12 times due to potential demand from the mining sector followed by 5 times for both transport and service sectors and 2 times for household sector at the end of the model year.

Table 4.1: Energy Demand Projection by Sector (ktoe) (2000 – 2030)

Sub Sector	***2000***	***2005***	***2010***	***2015***	***2020***	***2025***	***2030***
Household	460.3	505.3	568	634	699.7	763.4	825.9
Public and Commercial	73.8	88.4	122.7	165.4	223	287.6	370.8
Industry	17.9	24.4	39.8	62.4	97.6	144.2	212.5
Transport	76.5	91.7	127.3	171.6	231.4	298.4	384.7
Total	628.6	709.9	857.8	1,033.50	1,251.70	1,493.60	1,793.90

Source: NGHGMTWG, 2009

The projected demand was growing more in the economic sectors which attributed to the close relationship between energy and economic activities, Figure 4.5.

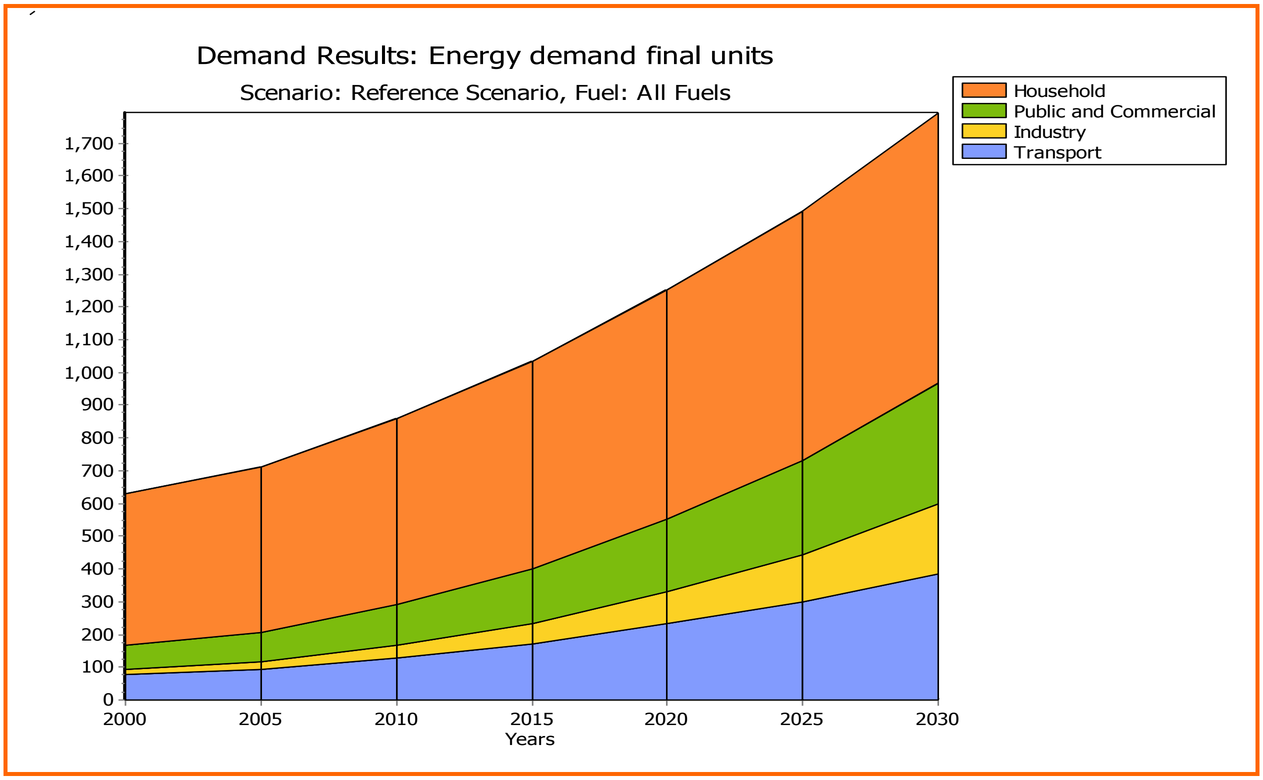


Figure 4.5: Total Final Energy Demand Projection all Fuels (ktoe), (Source: NGHGMTWG, 2009)

The energy policy of Eritrea encourages utilization of the energy resources for sustainable development. The main objective of Eritrea's energy policy is to promote optimum supply and utilization of energy, especially indigenous energy resources, conservation of both traditional and non-traditional sources and transition from traditional energy sources to modern and clean energy to facilitate socio-economic development of the country. In addition to this, it introduces and exercises policy measures to improve end-use efficiency and energy conservation.

Under the mitigation scenario, these issues were reflected, i.e., on the mitigation scenario i) dissemination of improved biomass stoves, where penetration level of 60 % by 2030 was assumed ii) a wind park of capacity 20 MW and a 50 MW geothermal energy, to be commissioned by 2020, and 750,000 energy saving lamps or CFLs operational by the end of 2010 were assumed. Moreover, reduction of power transmission and distribution loses from the current 17 % to about 10 % was assumed to be achieved after the capital city-Asmara distribution rehabilitation project was implemented. Figure 4.6 summarizes and compares energy demand projections under both scenarios.

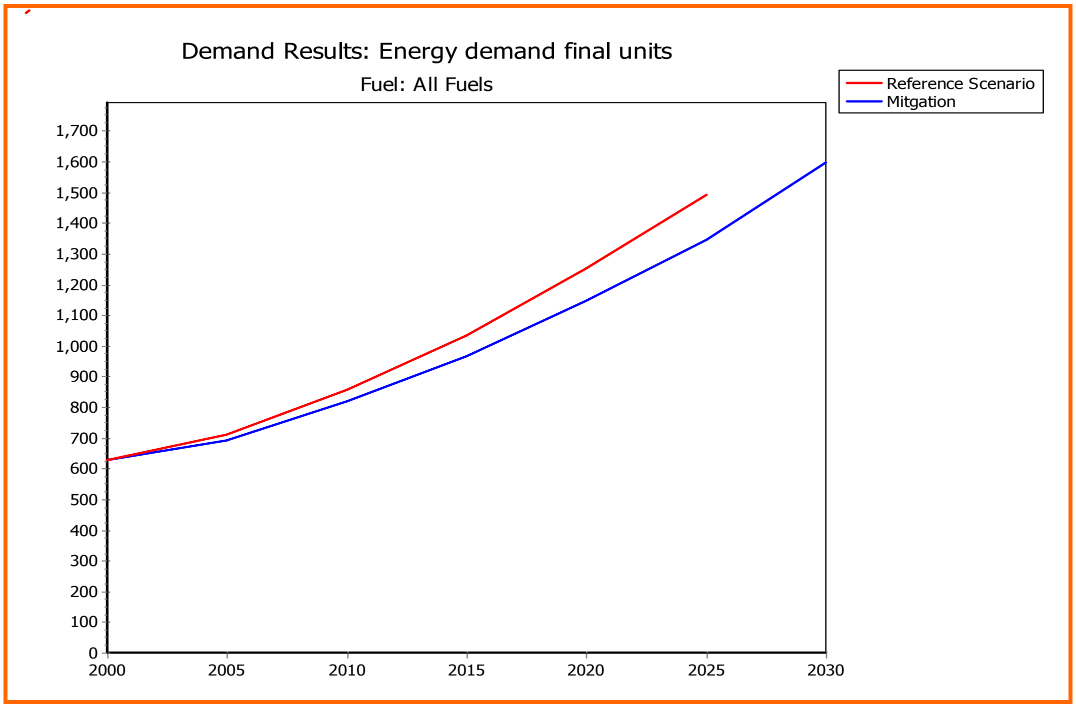


Figure 4.6: Comparison of Energy Demand Projection under Reference and Mitigation Scenarios (ktoe)

Under the Mitigation Scenario assumption, total energy demand would be less by 11% compared to the Reference Scenario. Note that this was the resultant between fuel switches from biomass based energy to modern fuels electricity and oil products which would tend to increase demand for commercial energy coupled with population pressures in the Reference Scenario and the Mitigation Scenarios where the energy demand tended to decrease due to efficient utilization and conservation measures. Figure 4.7 summarizes total energy demand projection for Reference Scenario.

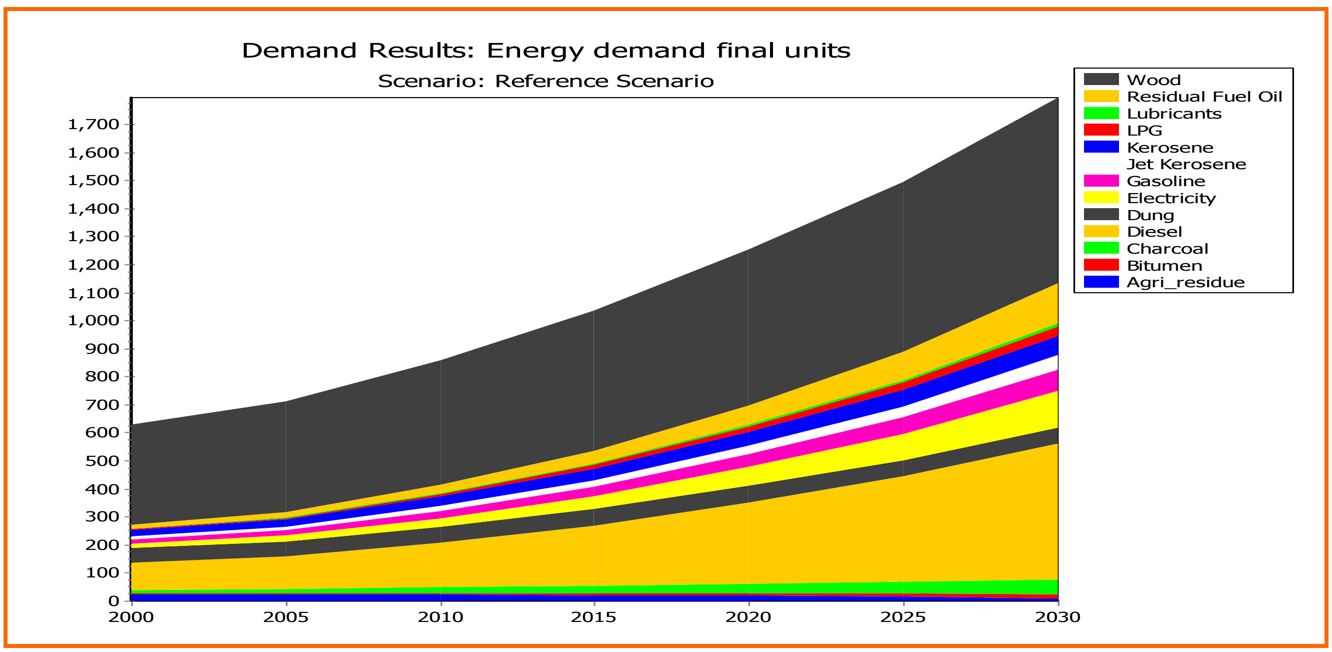


Figure 4.7: Total Projected Energy Demand by Type of Fuel- Reference Scenario (ktoe), (Source: NGHGMTWG, 2009)

Eritrea enjoys much sunshine with yearly average insulation levels of about 6 k Wh/m^2 per day, and wind regime for many localities with annual average wind speed of 4 - 7 m/s at 10 m height. Such renewable resources are good enough for electricity generation and if developed could substitute for fossil-based energy sources. Renewable energy sources are competitive in remote areas, especially for water pumping, electrification of rural villages, health and school facilities, etc. However, the share of renewable energy in the national energy balance is not expected to be a major player yet where the main constraint being high initial costs, which are quite prohibitive. Despite this, under the Mitigation Scenario the assumption of 20 MW wind and 50 MW geothermal power generations was assumed by 2020.

Electricity demand will exceed beyond the generation capacity of the existing power plant by 2015, Table 4.2 and Figure 4.8. Implying additional power plant is required by 2010 for the Mitigation Scenario and by 2015 for the Reference Scenario to meet the projected demand.

Table 4.2 Transformation Results: Actual Reserve Margin (%)

Year	***2000***	***2005***	***2010***	***2015***	***2020***	***2025***	***2030***
Reference Scenario	42.6	165.6	81.2	24.9	-14.3	-39.1	-56.5
Mitigation	42.6	143.7	54	7.1	-23.5	-25.5	-47.5

Source: NGHGMTWG, 2009

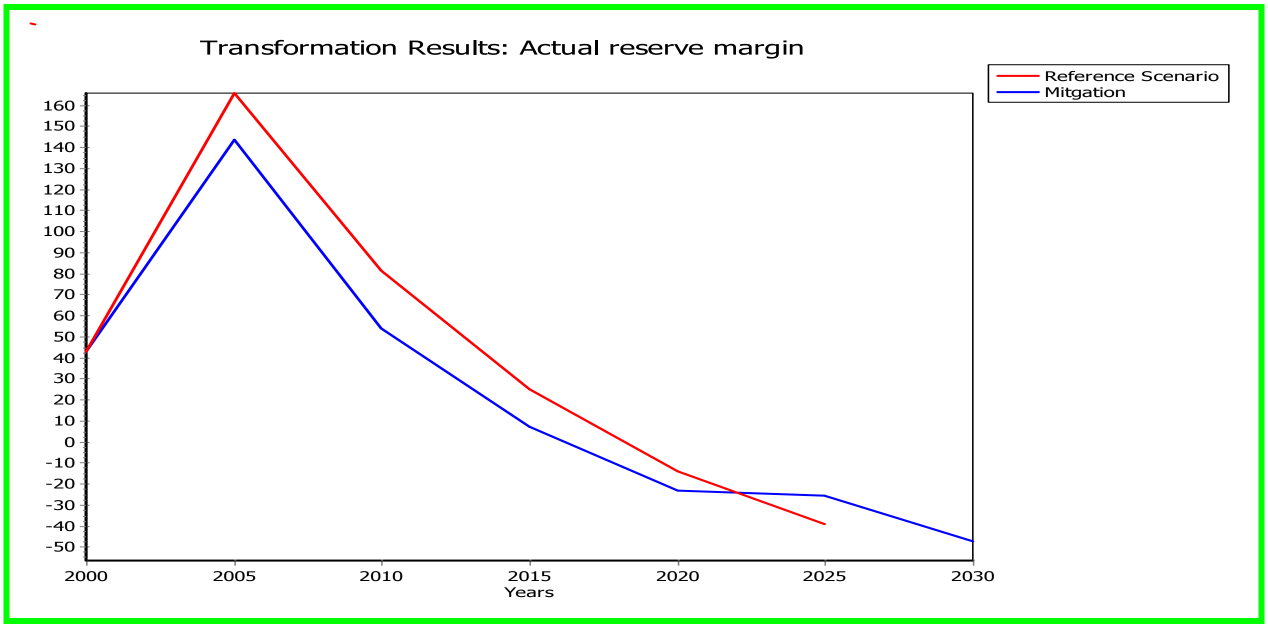


Figure 4.8: Actual Reserve Margin under Both Reference and Mitigation Scenarios, (Source: NGHGMTWG, 2009)

4.9. GHG Mitigation Analysis

In the context of UNFCCC, a mitigation analysis is a national level analysis of the various technologies and practices that have the potential to mitigate climate change. Mitigation does not necessarily imply an absolute reduction in emissions in relation to a given base year, rather it 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 a counterfactual baseline/ reference scenario.

Reducing GHG emissions is not an easy task, since in both developed and developing countries the sources and sinks of these emissions are directly tied to key economic sectors, particularly the energy, industry, transport, agriculture, forestry and waste management sectors. Having ratified the UNFCCC, however, Eritrea has recognized the threat of climate change is real and that action needs to be taken. Eritrea's mitigation analysis utilizes LEAP modeling tool and involves two tasks: (1) identifying potential national appropriate mitigation actions (NAMAs) and (2) estimating the magnitude by which GHGs could be reduced.

4.9.1. GHG Mitigation Options and GHG Mitigation Potentials

Mitigation options in the energy sector may be viewed in terms of short and long-term strategies. Over the short term period energy efficiency improvements and the use of small-scale renewable energy alternatives will be pursued, while in the longer-term, efforts will be made to introduce new power supply such as CHP and advanced renewable technologies.

From the stand point of GHG mitigation analysis, what is important in the context of long-term scenarios is the behaviour of the socio-economic sectors. Decisions about which mitigation options should be pursued in the future depend on the constraints and opportunities that sectoral development offers to the diffusion of different technologies. Therefore, the development characteristics of economic sectors define the potential pace for the successful implementation of mitigation strategies. When dealing with fossil fuels, a simplified approach would entail reducing energy consumption to reduce GHGs, but such an approach would be tantamount to slowing economic development; a strategy which Eritrea would not be willing to adopt.

Eritrea, which has limited GHG mitigation capacity and resources, will continue to depend on fossil fuel for the foreseeable future in order to achieve its economic growth. Under this circumstance, consideration should be given to optimizing the production per unit energy that is reducing the energy intensity of production. In this regard, the net GHG emitted may not be reduced but, instead, the rate of GHG emission is reduced per unit production. This strategy is the recommended approach to mitigation for Eritrea.

Although CO_2 is generally the key GHG for mitigation, the options which can also reduce other non-CO_2, mainly CH_4, besides CO_2 can be preferred to those options which only reduce CO_2 emissions. The best options are those which can address the issues of equity, national security, public acceptability, and ancillary environmental and economic benefits such as increase in employment, particulate pollution reduction objectives, reduction in road congestion, improvement in the security and availability of power supply and increase in technological efficiency and effectiveness. The technologies involved in the chosen options should be available within the time-frame considered and the process should allow technology transfer and absorption. In this context, a list of possible abetment options is, therefore, presented in Table 4.3.

Table 4.3: Mitigation Options Considered in GHG Analysis for Eritrea

Sub sector	**Option considered**	**Description**
Energy Supply	Renewable energy Technologies for power generation	Development of renewable energy technologies: Solar, wind, and Geothermal.
	Efficiency improvement	Increase the efficiency of exiting power generation systems and improvements in transmission and distribution systems.
Transport	Improvement in system efficiency	Increase vehicle load factor (use of mass transportation) rehabilitation and development of rail system
Household	Efficiency improvement and fuel shift	Dissemination of traditional biomass stove, use of CFL for lighting, shift from inefficient traditional biomass fuel to efficient modern fuel.

Source: NGHGMTWG, 2009

An option to tackle the prevalent household energy problem considered in this study was dissemination of improved traditional biomass stove, replacement of inefficient lamps by efficient compact fluorescent lamps (CFLs) and fuel shift from biomass energy carriers to modern energy carriers such as LPG, electricity, and kerosene. Based on these measures, the global warming potential in CO_2 equivalent for the GHG Mitigation Potential was 14 % less compared to the Reference Scenario as shown in Figure 4.9.

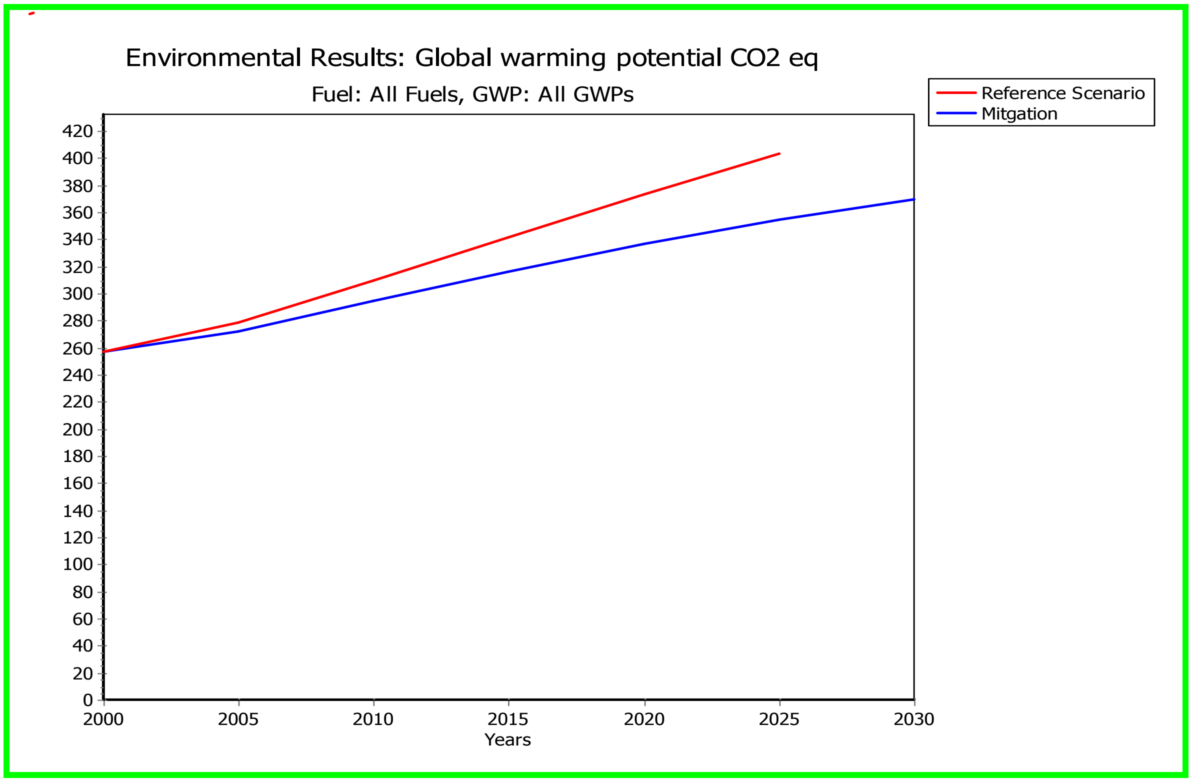


Figure 4.9: Trends for GHG Mitigation Potentials CO_2 equivalent (Source: NGHGMTWG, 2009)

Moreover, the model revealed that the household sector showed a drastic reduction in GHGs emission per national GDP, due to efficiency improvement in lighting and cooking devices (dissemination of traditional improved stove and compact fluorescent lamps). The commercial and transport sectors were also showing decreasing tendency during the model year due to efficiency improvement, Figure 4.10.

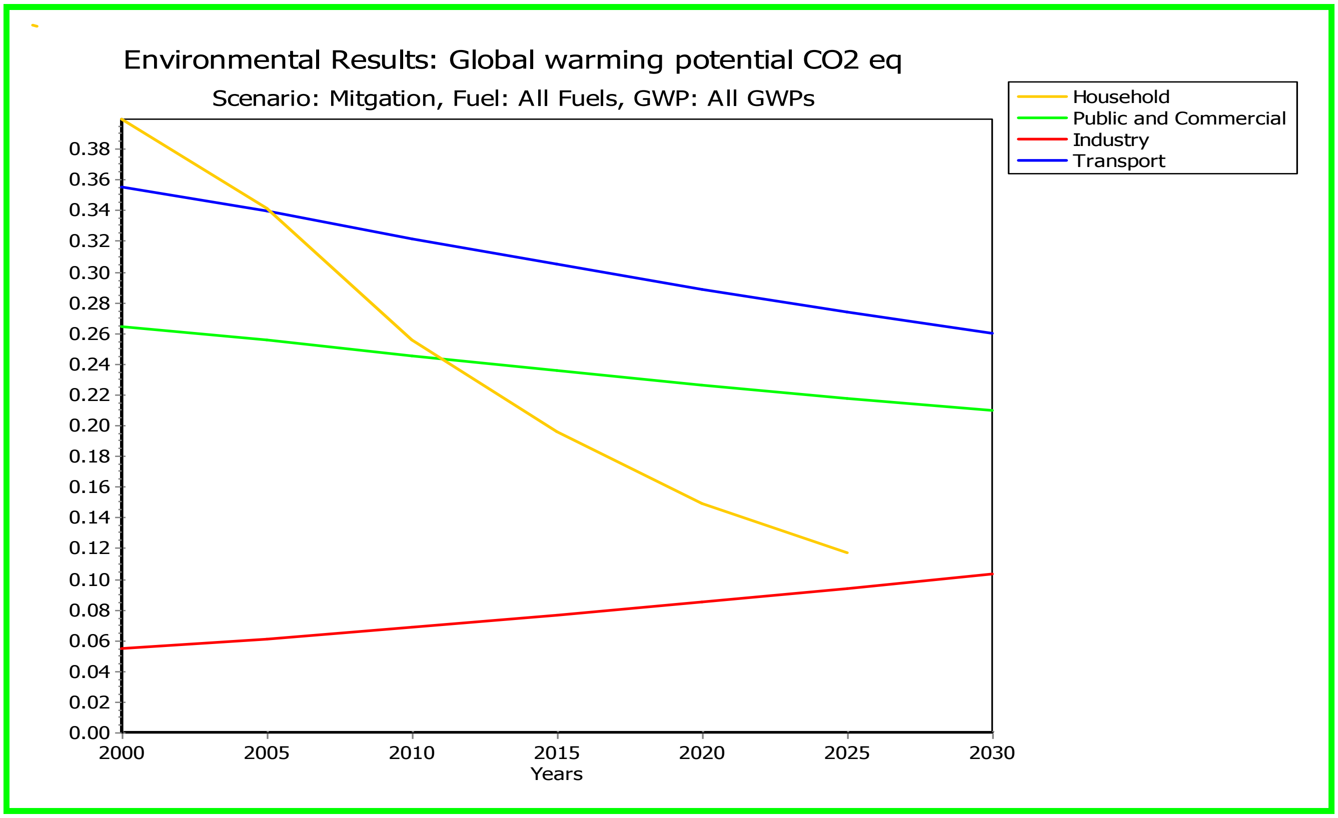
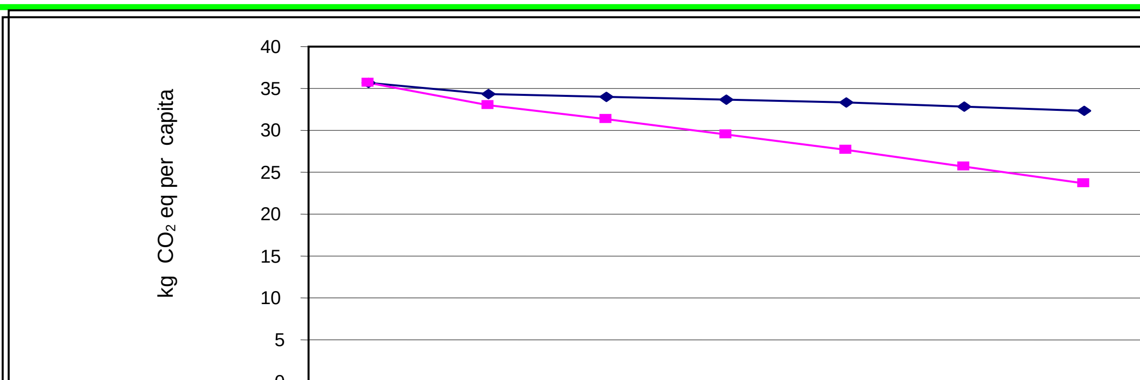


Figure 4.10: GHG Mitigation Potentials by Sector- all Fuels (2000-2030), (Source: NGHGMTWG, 2009)

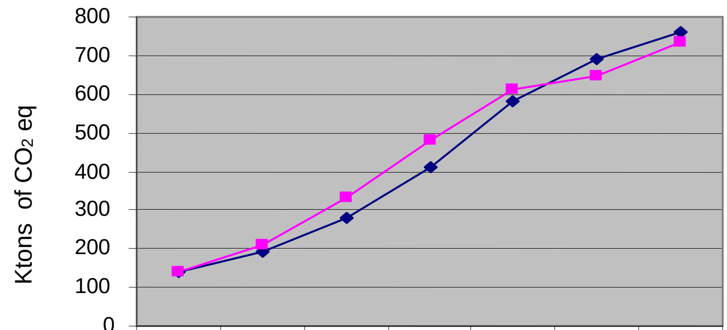
When compared with the baseline scenario, the mitigation scenario demonstrates an emission reduction potential of 30 % for the scenario period, Figure 4.11. Therefore, the household sub sector is the most important sector for abatement of GHGs emission in the short-term program.



	2000	2005	2010	2015	2020	2025	2030
Reference Scenario	35.74	34.32	34.08	33.74	33.36	32.85	32.36
Mitigation scenario	35.74	32.97	31.31	29.5	27.67	25.67	23.64

Figure 4.11: Global Warming Potential per Capita CO_2 Equivalent- Household Sub-sector

For the power sub sector, GHG emission showed a decreasing tendency under the Mitigation Scenario since 2020, Figure 4.12.



	2000	2005	2010	2015	2020	2025	2030
Reference Scenario	138.9	190.6	281.8	409.7	581.4	688.9	759.2
Mitigation Scenario	138.9	209.2	334	482.2	614.2	644.9	735

Figure 4.12: GHG Mitigation Potential for Power Sub-sector-CO_2 Equivalent (2000-2030)

4.10 Key Barriers to GHG Mitigation

The NGHGMTWG has identified the following key barriers to GHG mitigation in Eritrea:

- High initial cost associated with technologies;
- Lack of historical data;
- Inadequate human and institutional capacities at all levels;
- Uneconomic electricity tariffs, which discourages potential investors;
- Inadequate skilled manpower;
- Access to technology information (e.g. cost, performance, vendors, etc.);
- Lack comprehensive technology transfer policy;
- Weak local currency; and
- Complicated CDM approval process discouraging the country's effort to access funding from the proceeds of CDM

4.11 Key Opportunities for GHG Mitigation

The identified key opportunities to mitigate GHG include, inter alia:

- National Energy Research and Training Center under the Ministry of Energy & Mines has been established with the purpose to undertake research activities on RETs, conservation of energy and training of technicians;
- The Government advocates for making concerted efforts in public education to promote energy conservation and efficiency. One of the energy-conserving measures that the Government has taken is the improvement of the widely used traditional stove - the Mogogo which has gained both national and international recognition;
- Opportunities abound for the promotion of RET in the East African Region. Eritrea can be used as the gateway for such a project. Already, the Government of Eritrea has started to set up free trade zone in the strategic town of Massawa where incentives exist for international companies to set up production plants;
- Promote cooperative programmes between researchers in local universities, research institutions, public and private sector institutions to have access to facilities in advanced countries in order to help update and improve skills and consequently strengthen the local capacity;
- The Government reforms and deregulate the sector and avoid any form of subsidy;
- Availability of vibrant experts in the country to design and implement CC activities; and
- Adoption of new energy technologies could be encouraged through credit incentives and other purchase arrangements that would allow the rural inhabitants to use the systems on rental or hire purchase basis

4.12. Institutional Capacity-Building to Sustain Mitigation Work

Eritrea has sound energy policy and strategy. Besides, it has other supplementary policies supporting the assessment of environmental and social impacts of projects and programmes at all stages of project /programme cycle. Nonetheless, Eritrea has significant financial and institutional capacity limitation in implementing effectively these policies and strategies. Moreover, there are a number of capacity limitations in quantifying and certifying emission reductions (CER) from RET and energy efficiency measures. Therefore, human and institutional capacity-building activities should be identified and implemented to address capacity limitations in order to sustain mitigation work and further improve the national decision framework.

4.13. Key Findings

The ***energy sector*** was responsible for large GHG emissions following the LUCF sector in Eritrea in 2000. The energy sector includes both supply and demand sectors including energy transformation mainly electricity generation and charcoal production, electricity transmission and distribution, fuel storage and distribution and all end-use consumer sub sectors including transport, industry, commercial, domestic, agricultural/fishery/agriculture sub sectors. Major identified mitigation options in the energy supply sub sector include increasing plant efficiency, reducing losses in the transmission and distribution of electricity and fuels, and increasing the use of renewable energy forms including solar, wind, and geothermal energy.

Road transport sub sector was the highest CO_2 emitter (199 Gg) of all energy demand sub sectors in 2000, emission from road transport was a result of many factors including the type of fuel used to power transport, fuel efficiency, type of mode of transportation used, poor quality of road infrastructure and use of old and inefficient means of transport. Mitigation measures in the transport sub sector hence include fuel efficiency improvements, such as changes in vehicle and engine design (e.g. hybrids), expansion of public transport infrastructure, raising public awareness and introducing public transport technologies such as buses and trains.

In the ***household sub sector***, the main source of energy in 2000 was biomass including firewood, charcoal, dung and agricultural residue. Biomass provided up to 95 % of the total energy demand in this sub sector. Though there was variation in percentage of users, it was used in both urban and rural areas. Mainly it was used for cooking in traditional stoves for which energy efficiency was less than 10 %. Besides, charcoal was produced in traditional earth kilns using local wood resources having conversion efficiency not more than 30 %. About 32 % of the total population of which 3 % was rural population had access to electricity. This diffusion rate calls for concerted efforts towards electrification to allow replacement of traditional biomass stoves with electric stoves and kerosene lamps with electric lamps. Mitigation options in the household sub sector, therefore, include electrification of households, replacement of inefficient incandescent lamps with more efficient compact fluorescent lamps (CFLs), improvement of efficiency of traditional biomass stove, increase supply of modern fuels to allow fuel substitution. These options are also synergistic at reducing the pressure on forest degradation and reducing CO_2 emissions from LUCF sector.

Identified ***market-based instruments*** include GHG emissions and fuel carbon content related taxes, 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 include tradable emissions permits and renewable portfolio standards. Government funded research, development and demonstration activities are also vital in establishing a low-carbon energy system and mitigation costs.

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. Since this is a very important part of the mitigation analysis, GHG reductions and costs across all sectors, especially for LULUCF which is the main source of GHG emissions, and detailed assessment of technology options for the different mitigation options in the various sectors of the economy will be explored for reporting in subsequent GHG mitigation assessment and analysis study submissions.

CHAPTER 5

IMPACTS, ADAPTATION AND VULNERABILITY ASSESSMNET

Introduction

In acting to achieve the ultimate objective of the UNFCCC, the Parties to the UNFCCC must periodically communicate information on their implementation efforts, as well as on constraints, problems, and gaps, to the Conference of the Parties. This information is provided in the form of national communications, which include, inter alia, information on national and regional programmes containing measures to facilitate adequate adaptation to climate change.

In this setting, Eritrea has exerted all efforts to understand national vulnerability and impacts of, and adaptation to, climate change as part of the preparation of SNC. Based on earlier analyses conducted in the EINC and NAPA, it has been recognized that all sectors are potentially vulnerable to the adverse impacts of climate change. Nonetheless, the water resources and agricultural sectors are the most visible ones to have been impacted spatially and temporally by climate variability and change. Due to financial limitations, however, the vulnerability and adaptation assessments have focused on the water resources and agricultural sectors. Both sectoral assessments focus on the Mereb-Gash Basin which is socially and economically significant. Nonetheless, integration of indirect effects of climate change in other related sectors including human health, settlement, ecosystem, crop and livestock have been addressed and adaptation options are identified.

The main limitations of the vulnerability and adaptation assessment are, mainly, reflected in the uncertainties embedded in climate change models, methodologies, technical and institutional capacities surrounding the assessment, and inadequacy of financial resources to address all vulnerable sectors. Information relating to the impact, adaptation and vulnerability assessments in Eritrea has been based on current knowledge of climate variability and change which is inadequate due to the often incomplete nature of potential vulnerable sectors being tackled. Thus, complete understanding of the severity of climate change, and also how climate change could affect sustainable development (e.g., meeting MDG) is inadequate and the endeavor of understanding climate change is a continuous process.

5.1. National Baseline Conditions and Linkages

The realization of adaptive capacity (i.e., actual adaptation) may be frustrated by outside factors; these external barriers, therefore, must be addressed. At the local level, such barriers may take the form of national regulations or economic policies that hinder certain adaptation strategies unviable. These potential national level baseline conditions and linkages which could affect adaptive capacity at local level deserve detailed treatment.

5.1.1 Climate-Related Disaster Effects and Response Capabilities

Global warming has begun to affect Eritrea's weather patterns, socio-economic and natural systems. The main climatic hazards in Eritrea, which were identified in the course of the desktop and participatory vulnerability assessments during the preparation of Eritrean NAPA, are increased climatic variability both in intensity and frequency, recurrent drought, flash flooding and Sea level Rise (SLR). Relative to baseline conditions, there have been observed changes in mean, range and variability of temperature and precipitation throughout the country. The occurrences of dry spells, seasonal droughts and multi-year droughts are more frequent than in the past. There has been a perceived increase in episodes of torrential rainfall with heavy runoff and flooding.

Coastal areas and the hundreds of Eritrean islands in the Red Sea are susceptible to rising sea levels associated with climate change.

Impacts are already being observed in water resources, agriculture, coastal environments, forestry, livestock and human health. Eritrea has an extensive river system with seasonal flow pattern. However, recurrent drought, warmer temperature and high evaporation pattern are resulting in smaller stream flows, lower groundwater level, deterioration in water quality, and disappearance of base flows which are the sources of water supply for urban, rural, livestock and industry. The distress of coral reefs in the Red Sea as a result of temperature rise has had a devastating effect both on Eritrean fisheries as well as the reefs themselves. Temperature changes affect through impacts on food and nutrient supply, growth, survival, reproduction, prey-predator dynamics and habitat. Similarly, temperature increase causes toxic algal blooms (such as red tide) that threaten the shellfish population through lethal and chronic impacts. Climate change is likely impacting mangroves and sea grasses through altered sediment budgets. Eritrea's land areas are characterized by sparse to medium coverage of shrubs with areas almost not covered with trees. Climate variability impacts soil moisture and adversely affects the growth of shrubs and trees. As temperature increases, it has been observed that there are increasing shortages of biomass both for energy and local house construction, as well as declines of biomass products such as frankincense, gum arabic, doum palm leaves, wild fruit, wild medicine and fodder. Frequent droughts between 1992 and 2004 have led to the deaths of thousands of cattle and camels. In addition, thermal stress is increasingly exceeding thresholds that animals can tolerate, leading to decreased feed intake, interference with animal productive and reproductivty functions, requiring a shortening of grazing hours, and increasing exposure to pathogens. Pastoralists in the eastern lowlands and north-western rangelands are the most vulnerable to these patterns. The human and financial costs to Eritrea of coping with extreme weather events, crop failures and other emergencies related to climate are growing higher. Eritrea already facing difficulties in alleviating poverty is vulnerable to the adverse effects of potential climate change. Hence, climate-related disaster effects could be worse as adaptive capacity is limiting.

Regional climate pattern shifts are also affecting watersheds and ecosystems (IPCC TAR, 2001). The historical climate record of Africa shows a warming of approximately 0.7^{0}C over most of the continent during the 20^{th} century, a decrease in rainfall over large portions of the Sahel, and an increase in rainfall in east central Africa (IPCC TAR, 2001). Climate Change scenarios for Africa, based on results from several general circulation models using data collected by the Intergovernmental Panel on Climate Change (IPCC) Data Distribution Center (DDC), indicate future warming across Africa ranging from 0.2^{0}C per decade (low scenario) to more than 0.5^{0}C per decade (high scenario). This warming is greatest over the interior of semi-arid margins of the Sahle. Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent (SPM, 2007). Projected future changes in mean seasonal rainfall in Africa are less well defined. Under the low-warming scenario, few areas show trends that significantly exceed natural 30-year variability. Under intermediate warming scenarios, most models project that by 2050 in parts of equatorial east Africa, rainfall is predicated to increase in December-February and decrease in June-August. With a more rapid global warming scenario, large areas of Africa would experience changes in December-February or June-August rainfall that significantly exceed natural variability.

Africa is the continent with the lowest conversion factor of precipitation to runoff, averaging 15% (IPCC TAR, 2001). Current trends in major river basins indicate a decrease in runoff of about 17 % over the past decade. Reservoir storage shows marked sensitivity to variations in runoff and periods of drought. Model results indicate that global warming will increase the frequency of such low storage episodes. Land-use changes as a result of population and development pressures will continue to be the major driver of land-cover change in Africa, with climate change becoming an increasingly important contributing factor by mid-century (IPCC TAR, 2001). Resultant changes in ecosystems will affect the distribution and productivity of plant and animal species, water supply, fuelwood, and other services. Projected climate change is expected to lead to altered frequency, intensity, and extent of vegetation fires, with potential feedback effects on climate changes. For a global temperature rise of 2^{0}C, a high forest-fire danger is projected in east Africa and the Sahel (Met Office, Hadley Centre, 2009).

5.1.2. Population, Food Security and Agriculture

The food security strategy of Eritrea has two dimensions: National and Household Food Security Strategies. The National Food Security ensures food availability in market throughout the country from domestic production, commercial imports and / or food assistance. On more specific basis, the Household Food Security ensures affordable accessibility of food to all household members at all times for a healthy life.

The occurrence of subsequent drought in the country is mostly accompanied by failure of agricultural production causing tremendous economic problems to rural populations and as a whole to the country. There are many serious challenges that must be overcome to develop the agriculture sector to fully realize its potential. Improving the technology base and total factor productivity of agriculture by reducing its dependency on uncertain and erratic rainfall patterns are the major challenges.

5.1.3. Poverty

The Interim Poverty Reduction Paper (I-PRSP) provides an overview of the nature of poverty in Eritrea and a statement of the Government's commitment to poverty reduction. It lays out the Government's macroeconomic framework and steps to create the conditions for resuming rapid economic growth, and policies and programs for poverty reduction. Poverty reduction is Eritrea's major challenge and is therefore, placed at the top of the development agenda. Poverty is seen as more than inadequate income or lack of human development; it encompasses managing vulnerability and encouraging popular participation to ensure inclusive growth.

5.1.4. Urbanization, Housing and Water Resources

Housing construction was almost at standstill during the 30 years of national struggle. And, despite substantial efforts made since liberation to improve the housing stock and related physical infrastructure, Eritrea still faces serious housing and urban development challenges. It has acute housing shortages in most of its urban centers. This is resulting in overcrowding and the establishment of informal slum-type accommodation facilities with limited access to safe water and sanitation in many urban centers. Access to housing and sanitation is severely constrained by poverty, inadequate institutional capacity to deliver the inputs critical to housing development, such as access to land, provision of urban planning services, infrastructure development, suitable long–term financing, and shortages of skilled labor and building materials. The situation was further exacerbated by the heavy property damage caused by the Ethiopian invasion in 2000, and influx of refugees, returnees, displaced persons and deportees who settled in urban centers. There is, therefore, an urgent need to build new houses and to rehabilitate existing ones, especially in the informally built areas, with an emphasis on the middle and lower income groups.

While the long-term prospects for solving Eritrea's water supply problems are good if only substantial investments are consistently undertaken to develop its surface and ground water potentials, the short-term prospects remains difficult, and costly. Most of Eritrea's major urban and semi-urban centers are located on top of escarpments where the availability of surface water is limited. Water for the residents of these centers has to come from the middle and lower parts of the main river basins and their tributaries. Taking this into account, future urban development activities would need to be carefully planned to assure residents with reliable water supply at affordable costs.

5.1.5. Climate and Health

To reduce the high disease burden, the Ministry of Health has adopted a two-pronged strategy: First, it has been striving to improve further the delivery of healthcare services. It has been working so by providing comprehensive clinical care in healthcare facilities, establishing functional Accident and Emergency Care

Units in all hospitals, making available quality and affordable potent drugs and providing rehabilitative services. Secondly, to expand and deepen the use of healthcare services, it has launched a health awareness and education campaign in all parts of the country.

To improve access to healthcare services, the Ministry has been working with Regional Administrations, Ministries of Transportation and Communication, Public Works, Land, Water and Environment, Energy and Mines, and Eri-Tel to ensure availability of basic infrastructure necessary for providing transportation, clean water, electricity, and telecommunications services. It will also collaborate with other partners in the public and private sectors that are engaged in health related activities in order to ensure better access to healthcare services for all citizens. Hence, there is an opportunity, if properly used, to mainstream climate change concerns in human health issues in the country.

5.1.6. Environmental Challenges

As a result of the negligent practices, its physical features, and the increasingly adverse weather and climatic conditions, Eritrea is now facing serious environmental challenges. They need to be urgently tackled in order to promote sustainable economic development and social transformation. This is especially true in the agricultural sector where poor agricultural practices and deforestation have resulted in serious land degradation by water and wind erosion, resulting in serious loss of soil fertility. The carrying capacity of natural biological systems and resources (woodlands, croplands, grassland, soils, etc.) has already been substantially destroyed and is continually deteriorating at alarming rates. The continuing shrinkages of the carrying capacity of biological systems and natural resources are being exacerbated by the prevailing insecurity of land tenure. This results in what is often called the tragedy of the commons associated with private and public use of publicly owned common resources. The solution to this is to effectively regulate and limit private use of public resources to a sustainable level and to find a just and enforceable way to adjudicate claims. Additionally, municipal and industrial waste is becoming an increasing environmental and health problem. Municipal waste in particular is a growing issue not only in urban and semi-urban centers but also the rural communities and villages. Accordingly, there is an urgent need for adopting sound policies and standards to protect, restore and enhance the country‘s overall environment.

5.1.7. Financial Services, Insurance and Economic Services

In Eritrea, the financial system is presently highly repressed and at an early stage of development. It is currently composed of the Bank of Eritrea, Commercial Bank of Eritrea, Housing and Commerce Bank of Eritrea, Development and Investment Bank of Eritrea, Himbol Exchange Services, the National Insurance Corporation of Eritrea and several micro-credit institutions that provide small amounts of credits to borrowers who cannot access the banking system. There is a strong recognition in Eritrea that a dynamic and resilient financial system is critical to promoting an expedited economic recovery and to assuring sustainable growth and development in the medium to long-run. Accordingly, the prevailing challenges related to inefficiency, ineffectiveness and unviablity of the financial system, which, if are allowed to continue, would adversely affect and retard the development of all sectors of the economy, would need to be systematically tackled and alleviated.

The National Insurance Corporation of Eritrea (NICE), which has a virtual monopoly of the insurance business in the country, is a public and privately owned firm headquartered in Asmara. Presently, it provides risk protection in the areas of motor, fire and accident, marine, aviation, and life. Its vision is to be a leader in the provision of risk management products and services and to promote business and economic development in Eritrea and beyond. Hence, in insurance systems in Eritrea, there is an opportunity, if properly used, to mainstream risk transfer mechanisms as related to climate variability and climate change.

5.2. Scope of the Vulnerability and Adaptation Assessment

5.2.1. Purpose and Objectives of the Assessment

The V & A assessment will enable Eritrea to provide the COP of UNFCCC information on the general descriptions of steps taken or envisaged towards formulating and implementing national and regional programmes containing measures to facilitate adequate adaptation to climate change relevant to the achievement of the objective of the Convention.

The study will also provide the Government of the State of Eritrea with a means for proper planning in natural resources so as to contribute to the rational and sustainable use of resources and maximise the social, environmental and economic benefits. Thus, the study will enhance the adaptive capacity of the country in general and the communities living in the study boundary in particular in the face of climate variability and climate change. The scope of the study is impact, adaptation and vulnerability assessment.

5.2.2. Organization of the V&A Assessment Work

The organization of the vulnerability and adaptation assessment work is outlined as follows:

- Section 5.1: provides a brief background to the V & A assessment and national baseline conditions and their linkages as a basis for external factors affecting assessment boundary's adaptive capacity;
- Section 5.2: presents the scope of the V & A assessment;
- Section 5.3: describes frameworks, approaches, methodologies and tools;
- Section 5.4: presents current socio-economic indicators of the study boundary;
- Section 5.5: assesses current climate variability;
- Section 5.6: develops future socio-economic scenarios;
- Section 5.7: presents modelling of future climate change scenarios;
- Section 5.8: elaborates impact, adaptation and vulnerability assessment on water resources and linkages with other natural and human systems; and
- Section 5.9: describes impact, adaptation and vulnerability assessment on agricultural sector

5.2.3. Participation of Stakeholders

Primary and secondary stakeholders were identified based on comprehensive stakeholder analysis regarding their roles, responsibilities, mandates and contribution towards the preparation of Eritrean SNC. Subsequently, they have been actively engaged since the inception workshop conducted for the scoping and designing phases to the completion of SNC. Moreover, an in-country National Vulnerability and Adaptation Assessment Thematic Working Group (NVATWG) drawn from vulnerable and influential sectors has been engaged under the supervision of the Department of Environment of the Ministry of Land, Water & Environment. Participation of stakeholders is currently ongoing for continuing the adaptation process.

Adequate time has been dedicated to consult key stakeholders at various stages to identify the policy questions that need to be addressed by the V& A assessment. These stakeholders include, among others, policy makers, resources managers, CBOs, community villages and local authorities distributed in the line ministries and research institutions.

5.2.4. Sectors and Areas Identified and Studied

Based on agreed impact and importance criteria, Department of Environment along with stakeholders and the National Vulnerability and Adaptation Assessment Thematic Working Group (NVATWG), identified the water resources and agricultural sectors to be priority critical sectors for vulnerability and adaptation assessment. As summarized in Table 5.1, they ranked vulnerabilities of sectors to climate change based on *certainty of impact* (confidence an impact would happen); *timing of impact* (how soon it would be realized, e.g., now, in the next few decades, not for many decades); *severity of impact* (how large the impacts would be); and *importance* (significance). Thus, water resources and agricultural sectors have the greatest relative vulnerability because both receive aggregated high rankings followed by the marine, coastal and island environment. The impact has been determined based on the assessment elaborated in section 5.1.1 and previous studies such as EINC, NAPA and its follow up activities.

Table 5.1: Ranking Vulnerability across Multiple Sectors

Resource/ ranking	Certainty of Impact	Timing of Impact	Severity of Impact	Importance of Resource
Water Resources	High	High	High	High
Agriculture	High	High	High	High
Marine, Coastal & Island	Medium-high	Medium-high	Medium-high	High
Forestry	Medium	Medium	Medium-low	High
Human Health	Medium-low	Medium	Medium-high	High
Biodiversity	Medium-high	Medium-high	Medium-high	Medium-high

Source: NVATWG, 2009

5.2.5. Spatial Boundary and Time Horizon

The next step was to determine the spatial boundary and time horizon of the study. To decide the spatial boundary, a watershed approach was followed. The Mereb-Gash Basin has been identified to be the geographical boundary for the impact, adaptation and vulnerability assessment based on general consensus among stakeholders mainly because the basin, besides its economic importance, has the highest potential for water resources utilization and agricultural activities, both for rain-fed and irrigated agriculture. Mereb-Gash River, though a seasonal river, can be strategically harnessed to enhance the availability of water for reliable domestic use, agricultural productivity and production thereby enhancing the adaptive capacity of vulnerable communities by expanding water supply, small-scale irrigation for grain, vegetable and rangeland production and development.

The time horizon of the assessment is 30 years (2007-2035) based on time series data availability for the Basin. The time step of the assessment is monthly. The base year data has been gathered from the Ministry of Land, Water and Environment, the Ministry of Agriculture and other related sectors for 2006. The data used in the assessment has been well documented in the respective models used for the analyses.

5.2.6. Description of Exposure Units and Sectors Studied

The focus of the study under the water resources were streamflow, groundwater, water supply and demand and catchment processes while for the agricultural sector the study addressed major cereals, namely, sorghum, barley and wheat cultivated in the Mereb-Gash Basin.

Eritrea is an arid and semi-arid country and is not endowed with rich **water recourses**. Besides being part of Sahelian Africa, it has been the victim of recurrent and devastating droughts. It is also a country predominantly dependent on rain fed agriculture. The majority of the population depends on ground water as its main water supply source. Rainfall in Eritrea is torrential, is of high intensity over a short duration very unpredictable and occurs sporadically. Owing to the rugged nature the highlands (highest rainfall areas), thin soil formations, and deforestation most of the rain develops in to flash floods. Thus, soil-water infiltration is low. In the lowland areas, even though there are favorable conditions, infiltration is low owing to high evaporation rates and low amount of rainfall.

Agriculture is the most important contributing sector to Eritrea's economy. About 80% of the population of Eritrea is earning its livelihood from agriculture and the rest 20% are urban population. The physical environment of Eritrea is very varied with difference in altitude from 120 m. b.s.l. in the Danakil depression to over 2,400 m.a.s.l. in the Sub-humid escarpment. The topographic aspect of the country is also varied ranging from hilly to rugged mountainous to undulating and flat plain. More than half of the country is unsuitable for rain fed crop production mainly due to lack of sufficient rainfall (MOLWE 1999). Drought, which means deficit of moisture in the soil, affects growth and development of natural vegetation and crops. Although it is difficult to assess the extent of its damage, drought is no stranger to the country and its effects have been very severe during the last 50 years. Historical records of rainfall indicate that drought is quite important climatic hazard on crop production in the country.

Out of the **crops** grown in Eritrea, sorghum is the most important in terms of total area. Other cereals combined mainly barely, wheat, finger millet, and taff account for about 18 percent. Pearl millet (12 percent) in the lowlands and barley (11 percent) in the highlands occupy large area. The leading commodities as far as consumption is concerned are wheat (41 percent), sorghum (14 percent) and other roots and tuber crops (11 percent). Sorghum is a staple food crop consumed in different forms. Most of the wheat consumed is imported and much remains to be done to produce sufficient maize for domestic consumption (MoA, 2003).

5.2.7. Possible Follow-Up of the Assessment

The follow-up to the V & A assessments is formulation of comprehensive adaptation strategy for integration into national development plan and sectoral policies and prepare concrete projects and programmes for sizeable funding. Effectively incorporating adaptation into Eritrea's development planning is a challenging endeavour. It requires cross-sectoral cooperation, an interdisciplinary approach and considerable political will. Monitoring implemented adaptation strategies is also demanding. It requires both an ongoing commitment to monitoring and evaluation (M & E) and a high-level government response to addressing barriers that are retarding adaptive capacity.

5.3. Description of Frameworks, Approaches, Methods and Tools

The *Adaptation Policy Framework* (APF) has been used as a Vulnerability and Adaptation Framework. The APF is a flexible process to formulate and implement climate change adaptation strategies. It can be applied at various levels including policy development, project formulation and multi sectoral studies. In Eritrean case, the APF has been applied to conduct an integrated assessment on sectoral climate change studies in order to offer valuable input to the preparation of Second National Communication (SNC). The *Intergovernmental Panel on Climate Change (IPCC) seven steps*, the *UNEP Handbook* (Feenstra et al., 1998) and the *NAPA guidance* have also been used, as appropriate. Within the APF, the *vulnerability-based approach* has been used to assess current climate risks while the *natural hazards-based approach* has been used to assess future climate risks. In some point of the assessment discourse the combination of both approaches has been applicable. Whenever most appropriate, the *policy-based* and the *adaptive capacity approaches* have also been applied. The policy-based approach has been used to investigate the efficacy of an existing and proposed policy in light of a changing climate exposure or sensitivity while the adaptive capacity approach has been applied to assess actions on increasing adaptive capacity and removing barriers to adaptation.

The selection of *methods* will often flow from the selection of approach. Both natural hazard and vulnerability-based approaches call for the use of climate scenario methodology using climate models. In this context, an integrated *climate model* known as SimCLIM has been used to develop future climate and climate change scenarios. SimCLIM was developed by CLIMSystems Ltd. based in Hamilton, New Zealand, info@climsystems.com. The APF guidelines are also followed carefully to develop socio-economic scenarios. The sectoral *impact models* applied include the *CropWater 4 Windows 4.3 agricultural model*, *FAO crop coefficient model*, *Rainfall-runoff hydrological model* developed for Eritrea and *Water Evaluation and Planning (WEAP) model* developed by SEI. Climate change and Socio-economic Scenarios have been linked to the sectoral impact models.

5.4. Baseline Socio-Economic Condition of Mereb Gash Basin

The purpose of this section was to assess current socio-economic conditions specific to the Mereb-Gash Basin in terms of agreed indicators comprising physical, demographic, economic, and governance and policy reflecting internal and external factors.

5.4.1. Physical State

The Mereb-Gash basin has a total area of 23,200 km^2, of which about 21,000 km^2 is within Eritrea. The ***Mereb*** rises near Asmara and flows southwards, then turning west to form the border between Ethiopia and Eritrea in the central part of the country. Only small part of the basin is in Ethiopia. Further west, it becomes the ***Gash*** and flows into Sudan, but does not reach the Red Sea, instead forming an inland delta north of Kassala. Flows in this basin are seasonal with intermittent periods of rapid runoff in the rainy season.

The dominant geology of the Mereb catchment is made up of basement rocks which have very low porosity and permeability (NEMP-E, 1995). Rain does not efficiently percolate to become a stored water resource. This fact, coupled with deforested and rugged terrain, result in short duration flash floods and low seepage of water into the ground. Moreover, because of excessive extraction from wells in some areas, water tables have dropped. Estimates indicate that water levels in the main aquifers are diminishing up to 0.5 m to 1.0 m annually (WRD, 2007). Considerable expansions in the number of wells have occurred during the last 10 years in Mereb catchment. Declining water tables in wells create conditions of uncertainty and scarcity, which may have to be deepened or re-drilled, which is an expensive process. Thus, the possibility of tapping favourable amounts groundwater is very low in the Mereb catchment. The Gash catchment has relatively richer aquifers in the soft rock and alluvial formations.

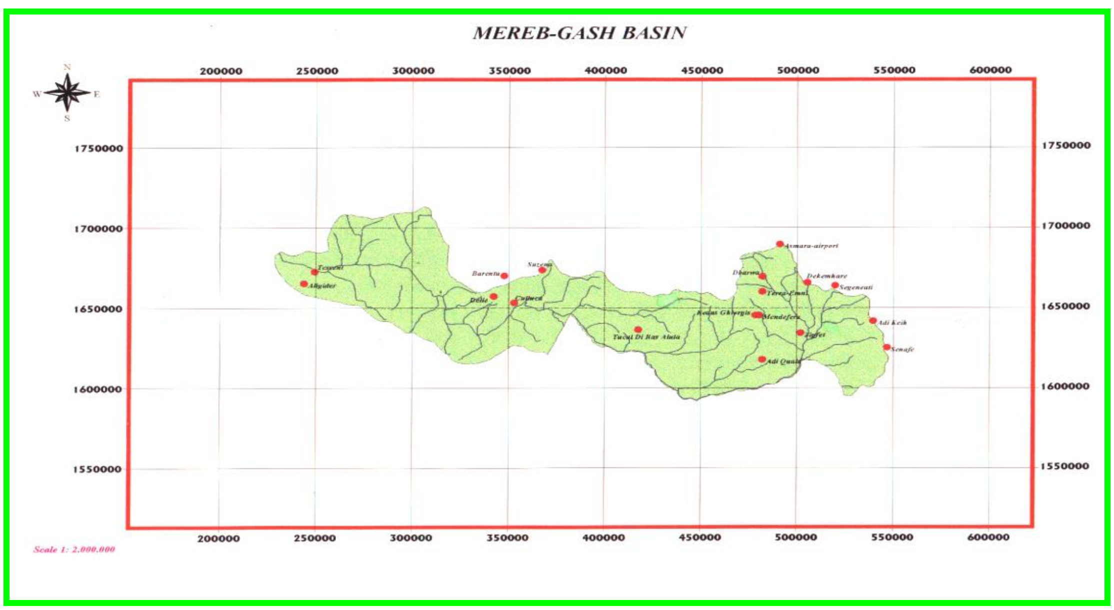


Figure 5.1: Location Map of Mereb-Gash Basin including River Network (Source: MOLWE, 2000)

5.4.2. Demographic State

Mereb-Gash Basin supports 34 % of Eritrea's population, MoLWE 2007, of which 83% resides in rural area. Piped water is mainly accessible in urban areas by six in ten households and 18 percent (all from public tap) in rural areas use piped water (NDHS, 2002). Around one-fourth of households in major towns depend on tanker trucks to deliver water. More than half of households in rural areas have access to public wells where half of them protected and the other half unprotected and 17 percent use spring water. Overall, about half (50%) of rural and 70% of urban households have access to clean water, (NDIP, 2009). Regarding urban-rural variation in present water consumption per capita per day, rural consumption is 15 liter while urban water consumption is 40 liter. Water use efficiency for rural and urban is 80 and 70 percent, respectively.

Present potential of total available water in the Mereb-Gash Basin is estimated to 1,684.3 Mm^3/yr of which the total runoff accounts for 1,422.7 Mm^3/yr and the Ground water recharge contributes about 261.6 Mm^3/yr. The total water availability in the Mereb-Gash Basin accounts for 15 % of the national water availability considering all drainage basins. Based on the present water balance calculation conducted for the Basin, withdrawal as a percent of water availability is estimated at 32%. Thus, the surplus as percent of availability amounts to 68%. Specifically, withdrawal from surface water as percent of total surface water availability amounts to 22% while withdrawal from groundwater as percent of total groundwater availability estimated at 87 %. This is true since the majority of households (80%) depend on groundwater as the main water supply. Nonetheless, as explained earlier with the increase in the frequency and magnitude (duration) of recurring drought, the groundwater scarcity is worsening even for drinking water in the Basin.

The total water need by the basin with respect to the total national water need is estimated at 45 percent. The percent shares of total water use by domestic, livestock, agriculture and other sectors in the Basin is estimated as 41, 41, 45, and 45 percent, respectively (NVATWG, 2011). The other sector comprises manufacturing industries and construction and other activities dominant in the Basin. In all sectors, water use rate is increasing significantly in recent years.

Access to adequate sanitation facilities is an important determinant of health conditions. Three fourths of households in Mereb-Gash and almost all households in rural areas (96 percent) have no toilet facility. Half of the households in other towns of the basin and slightly more than one-fourth of the Capital, Asmara, also do not have any toilet facility. Since 1995, access to flush toilets has increased from 12 percent to 17 percent, mainly because of better toilet facilities in other towns of the Basin. In general, only approximately 18% (consisting 44% urban and less than 2% of rural) have access to adequate sanitation facilities, which is unacceptably low (NIDP, 2009).

Several types of fuel are used for cooking in Mereb-Gash Basin. 59 percent of the households use wood or straw for cooking, 28 percent use kerosene, and 5 percent each depend on animal dung cakes and gas (NDHS, 2002). Regarding urban-rural variation, wood or straw is more commonly used for cooking in rural areas (82 percent) than in urban areas (23 percent). In Asmara, most households use either kerosene (70 percent) or gas (22 percent) as fuel for cooking (NDHS, 2004).

5.4.3. Economic State

Mereb-Gash Basin is increasingly contributing to about 40 % of the country's agricultural and industrial GDPs (NSEO, 2003). The most important economic activities are rainfed crop and livestock production. Both rainfed and irrigated agriculture are dominant in the basin with landholding of less than 1ha by each household. Out of the crops grown in the Basin, sorghum is the highest. Other cereals mainly barely, wheat, finger millet, and taff are also important. Pearl millet in the lower Gash catchment while barley in the highlands or Mereb catchment occupies large area. Oil crops also, mainly sesame, are common in the lower catchment. The basin has the highest potential for irrigated agriculture. The most important livelihoods under existing irrigation are village farm comprising spate (18,950 ha) and under dam (669 ha), estate farm (5,650 ha) and concession (9,381 ha) (MOND & MoA, 2000). Thus, the total existing land under irrigation was 34,650 ha in 2000. By source of water, spate and estate farms (23,600 ha) were sourced by surface water while under dam and concession (10,050 ha) get water from ground water. Existing irrigated agriculture water need in the Mereb-Gash Basin is about 36 % of the total national water need while irrigated agriculture water need in all drainage basins is about 93% of the total national water need.

Present livestock population in Mereb-Gash basin is estimated at 4,015,303 which is 39% of the national total. 40 percent of the livestock is located in the Mereb catchment while the remaining in the Gash catchment. The largest percent shares are goats, cattle and sheep, respectively while the lowest share is horses. The main source of water for livestock in the basin is groundwater which is estimated at 41% of the national livestock groundwater use which is similar estimates for surface water livestock water use in the basin as compared to the national livestock surface water use.

However, in all cases, no metered payment is required by farmers for irrigation water, as is the case for urban users. Thus, the incentive to use groundwater efficiently does not exist. This situation could be politically sensitive, but the fact remains that, "providing free water looks to be both bad economics and bad water management" (Mazumdar 1994). The provision of free water is in total contradiction to the principle that "water has an economic value in all its competing uses" (ibid).

There were about 1,238 water supply dams, ponds, etc as of 2000 in the basin of which boreholes, protected dug wells and open dug well comprised 515, 377 and 346 respectively. The water points surveyed in the Mereb-catchment for bacteriological contamination in 2002 showed that 92.4 % of the water points were found to be contaminated (WRD, 2002). Out of these, 46.2% were mildly contaminated and 46.2% were highly contaminated. Due to overexploitation, dry up of wells, siltation and salinity problems have occurred in some areas and substantial drops in groundwater levels have been noted in others. It appears that overexploitation is presently the greatest threat to the groundwater resources. Overgrazing is also major environmental problem around water points (MOLWE, 2007).

5.4.4. Governance and Policy State

Some existing assessments have shown that the water supply trend in Eritrea has been worsening over the years due to rapid urbanization, competition of water among sectors, inadequate investments on operation, maintenance, water infrastructure, water losses in conveyance systems, poor governance of water systems, degradation of water quality and the impacts of extreme weather changes. As the total amount of water resources that the country has is not yet explored, it is difficult so far to budget the water among the sectors.

It has been recognized that the overall goal for a legal framework development process is to ensure that the key policy aims can be pursued with a legal backing and that there is consistency in laws and regulations across all sectors that impact water resources. In Eritrea, one of the major obstacles in water management issues is the absence of water laws and policies. So far, water is managed at the regional government level. Sectoral and / or regional approaches to water resources management have dominated and are still prevailing. This has lead to the fragmented and uncoordinated development and management of the resources. Government is the sole player; a regulator, controller and service provider. In actual terms, there is practically no separation of regulatory and implementation functions, and results in lack of tangible and sensible transparency and accountability. There are draft water policy and water law papers which are not yet enacted. Therefore, Eritrea currently lacks a water resources laws per se.

Regarding water resources management, use and development, it has been identified that currently the available situation is far from satisfactory. The current states of the country's in general and the Mereb-Gash Basin's in particular water resources management and use show unfavorable conditions because a comprehensive water resources development and management plan and policy are not adequately in place. This has resulted in adverse situations on several aspects of the development and management of the nation's water resources. It is understandable that the water sector activities are shared among different institutions such as Ministry of Land, Water and Environment, Ministry of Agriculture, Ministry of Health, Ministry of Public works, Ministry of Trade and Industry and the Local Government. The roles and responsibilities of these ministries are not clearly identified. There are a number of overlapping activities among these Ministries. Due to this unclear mandate of the ministries there is a misuse and poor management of water resources.

Regarding water treaties, ten countries share the Nile: Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Eritrea, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The Nile River Basin encompasses an area of 3 million square kilometers - one tenth of Africa's total land mass and is home to an estimated 300 million people within the ten countries that share the Nile waters. Eritrea is participating in the Nile Basin Initiative as an observer state. The major water bodies which Eritrea shares with neighboring countries include: Mereb-Gash River is an inland drainage basin shared between Sudan, Ethiopia and Eritrea. Danakil water basin, Mereb and Setit water courses are shared between Ethiopia and Eritrea The water resources development and management of these states is generally fragmented (GWP, 2007).

5.4.5. Exploring Specific Current Socio-Economic Indicators

At this point, adequate information has been gathered about the present and past as a basis to project future socio-economic conditions. Specifically, four major indicators, namely, physical, demographic, economic, governance and policy indicators have been identified to describe *baseline socio-economic conditions* in the study area, Table 5.2. These indicators are intended to (1) summarize, quantify and simplify relevant information; (2) capture phenomena of interest; and (3) communicate relevant information. They are both qualitative and quantitative.

There are two remaining tasks. The first is to develop alternative *"storylines"* of development paths of the future for a time period of 20 years policy and 50 years planning horizons into the future. The second task is to make projections about how socio-economic conditions- indicators will change in the future under the alternative storylines. This will be explored in the next section under *socio-economic scenarios*.

Table 5.2: Socio-economic Indicators for Mereb-Gash Basin with Current Value / State

Indicators	Sub-Indicators	Current value/ State
Physical	Amount of mean annual runoff (Mm^3/yr)	1,422.7
	Amount of mean annual groundwater recharge (Mm^3/yr)	216.6
	Mean annual runoff as % of national runoff	14
	Mean annual groundwater recharge as % of national recharge	16
	Annual decrease in aquifer water level (m)	0.5-1.0
Demographic	Access to clean water in % rural & urban , respectively	50 & 70
	Basins population as % of national total	34
	Population growth rate %	2.74
	Urbanization growth rate %	30
	HDI (includes life expectancy at birth, literacy & purchasing power adjusted GDP per capita) & GDI	0.472 & 0.459
	Access to sanitation in % rural, urban respectively	3, & 32
	% share of total water use for domestic, livestock, agriculture and others (industry, manufacturing & construction, etc)	41, 41, 45 & 45
	Basin water need as % of national water need	45
	Water consumption (liter) per capita per day rural & urban, respectively	15 & 40
	Water use efficiency rural & urban, respectively	70, & 80
	Withdrawals as % of total national available water	32
	Surface water (SW) withdrawals as % of national available surface water	22
	Groundwater withdrawals as % of national available groundwater	87
	Groundwater surplus	13
	% of Basin's population using groundwater (GW) supply	80
Economic	GDP US $	626
	% of Basins contribution to national agricultural & industry GDPs	40
	Amounts/Kinds of water infrastructure (boreholes, protected dug wells & Open dug wells, respectively)	515, 377 & 346
	Basin's irrigation water need as % of total national water need	36
	Presence or absence of water market/water tariff in place including irrigation	No water tariff
	Share of irrigated hectares in Mereb as % of Mereb Catchment	1.3%
	Share of irrigated hectares in Gash as % of Gash Catchment	3.3%

	Maximum Potential Yield in Mereb for Barley, Sorghum & Wheat (kg/ha)	1,500, 1,500, 600
	Maximum Potential Yield in Gash for Barley, Sorghum & Wheat (Kg/ha)	1,650,1.650, 650
	Yield response factor for Barley, Sorghum & Wheat (Kg/ha)	0.67,0.67 & 0.5
	Share of rainfed in Mereb as % of Mereb Catchment	14
	Share of rainfed in Gash as % of Gash Catchment	14.3
	Share of rainfed barley, sorghum & wheat as % of Rainfed Gash Catchment, respectively	5, 60 & 5
	Share of rainfed barley, sorghum & wheat as % of Rainfed Mereb Catchment, respectively	25,40 & 20
	Share of irrigated barley, sorghum & wheat as % of Irrigated Gash Catchment, respectively	2, 30 & 2
	Share of irrigated barley, sorghum & wheat as % of irrigated Mereb Catchment, respectively	10, 30 & 20
	Basin's livestock population as % of national livestock total	39
	Livestock growth rate	5
	Basin's livestock GW use as % of national livestock GW use	45
	Basin's livestock SW use as % of national livestock SW use	45
	% of water points in the basin contaminated, highly & mildly	92, 46 & 46
	Price of Sorghum per quintal (Nakfa)	1,950.00
	Price of Wheat per quintal (Nakfa)	3,000.00
	Price of Barley per quintal (Nakfa)	2,250.00
Governance and Policy	Treaties or agreements regarding water resources	Observer (Nile Init.)
	Treaties or agreements regarding agriculture	UNCCD, CITES,POP
	% of water resources not under regional control	0
	Water resources development and management plan in place	Not available
	Availability of water resources laws & policies	Not enacted
	Water resources financial institutions in place	Not available
	Irrigation efficiency (%) or % of supplied water available for evapotranspiration	30

Source: NVATWG, 2011

5.5. Current Climate Variability

Climate variability describes the variability of climate from the mean state. Mean annual temperature in Eritrea has increased by 1.7 ^{0}C since 1960, an average rate of 0.37^{0}C per decade[21]. The increase is most rapid in JAS[22] at a rate of 0.55^{0}C per decade. While increases in the frequency of 'hot' days have been small, increases in the frequency of hot nights are larger, and statistically significant in JJA, OND, and in the annual data. The average number of 'cold' nights per year has decreased by 34 (9.3% of days).

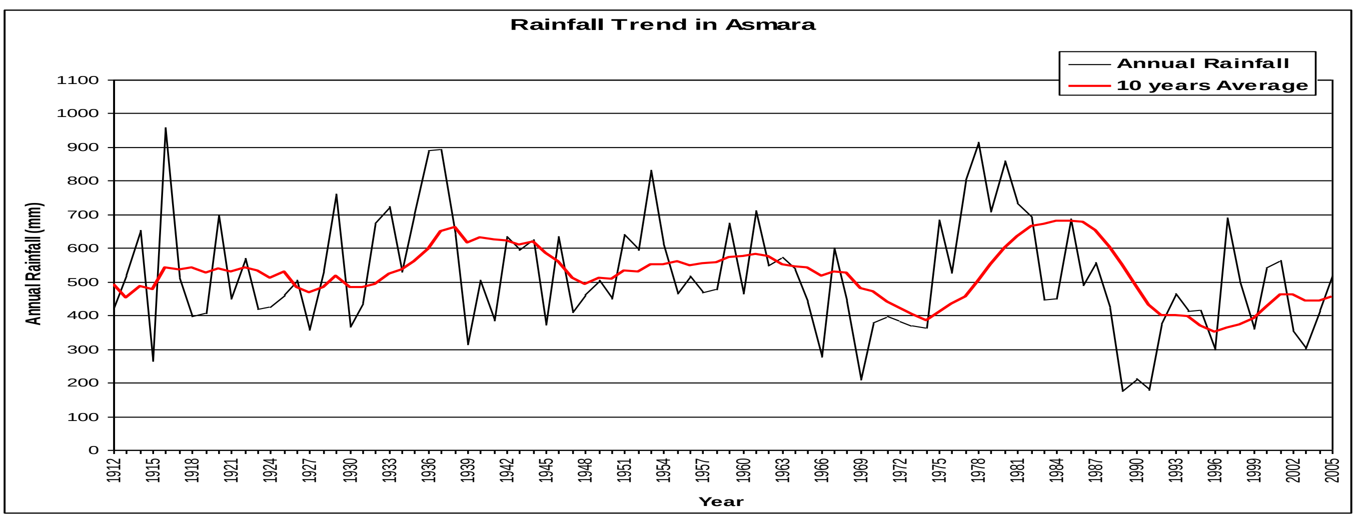


Fig.5.2: Rainfall Variability in Asmara Station (1912-2005), (Source: MOLWE 2006)

The 1912-2005 data suggests that rainfall has been declining for central and southern highlands on average by circa 0.4 mm/year, Figure 5.2. Seasonal rainfall in Eritrea is driven mainly by the position of the Inter-Tropical

[21] UNDP country-level climate profile
[22] July, August, September

Convergence Zone (ITCZ), a relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator. The exact position of the ITCZ changes over the course of the year, oscillating across the equator from its northern most position over northern Ethiopia and parts of Eritrea in July and August, to its southern most position south of the equator in January and February. The central regions of Eritrea experience one main wet season from mid-June to mid-September (up to 250 mm per month in the wettest regions), when the ITCZ is at its northern-most position, but also a short rain season of lighter rainfall in preceding months of April to June (MOLWE, 1995). The northern most and eastern most parts of the country receive very little rainfall at any time of year. The movements of the ITCZ are sensitive to variations in Indian and South-western Atlantic Oceans sea-surface temperatures and vary from year-to-year, hence the onset, duration and intensity of these rainfalls vary considerably inter-annually.

Nonetheless, Climate models do not reliably reproduce the position and movements of the ITCZ, generally placing it too far south and causing systematic errors in simulated rainfall (Christensen et al., 2007). This makes it difficult to assess the changes in rainfall in regions where rainfall is heavily dependent on this feature. Model simulations show wide disagreements in projected changes in the amplitude of future El Niño events (Christensen et al., 2007). East Africa's seasonal rainfall can be strongly influenced by ENSO, and this contributes to uncertainty in climate projections, particularly in the future inter-annual variability.

5.6. Socio-Economic Scenarios

Understanding the socio-economic pattern(s) of any system(s) is essential for adapting to climate change. Vulnerability to climate change depends on the interaction between changing socio-economic conditions and climate hazards; the feasibility of its adaptation options requires socio-economic analyses of the underlying barriers and opportunities. Therefore, socio-economic conditions must be described in enough detail to evaluate the merits of policy options.

5.6.1. Developing Alternative Storylines

The Special Report on Emission Scenarios (SRES) was developed for the specific purpose of projecting future emissions of greenhouse gases. That means the emission scenarios are not ready made answers to the problem of Eritrea. They are a good starting point for considering such important factors as population growth, economic conditions, and technological change. Nonetheless, they do not represent other social institutions, such as farming, labour organizations, or the way in which government provides for the welfare of its citizens.

In the development of national scenario storylines for Eritrea, the worst case and best case, i.e., the A2 and B2, IPCC (SRES) emissions scenarios have been adapted for reference use and to ensure consistency. The Reference and mitigation scenarios which have been developed in earlier section for GHG mitigation assessment and analyses are also preserved for consistency with socio-economic scenarios developed for the V & A assessment. The A2 and B2 emissions scenarios are further used to develop climate change scenarios under modeling of climate and climate change scenarios.

The A2 Scenario storyline**:** Characterized by heterogeneity, self-reliance and local identities are emphasized. Population increases continuously. Economic development is regionally oriented, and economic and technological growth is relatively slow compared to other storylines.

The B2 Scenario storyline: Characterized by local solutions to economic, social and environmental sustainability are emphasized. Global population grows continuously, but at rate lower than that of A2.

Reference and Alternative Scenario Storylines for Eritrea

Three scenario storylines are constructed for Eritrea. The Reference Scenario storylines does not consider climate change. The second and third scenario storylines are two significantly different projections in which development will proceed, taking climate change into account through adaptation polices. One set of policies attempt to preserve current economic activities and socio-economic conditions using technologies; another set of policies alternatively emphasize manufacturing and service sectors attempting to reduce agricultural activity.

Reference Scenario Storyline 1

The "current socio-economic conditions", already discussed (Table 5.2), is projected into the future.

Alternative Scenario Storyline 2 (A2)

Preserve current way of life with responsibility for action at individual level, ***Demography*****:** Population increases at higher rate, Urbanization grows at higher rate, ***Economy:*** Annual GDP increases moderate, Eritrea graduates from LDCs, *Fast growing sectors*: Agriculture, Fishery, Mining, Infrastructure, self-reliance in food production and a path of agricultural export-led growth, expansion of irrigation to grow more own food, allocate more land for irrigation and gradual shift from rainfed to irrigation agriculture with change from farrow or basin irrigation to promising irrigation technologies, introducing more efficient water harvesting techniques, improved life style (fuel shift from traditional biomass to modern commercial fuel, and use of new appliances), some pastoralists shift to cultivation activities, ***Governance and Policy:*** Water is managed at the regional government level without enabling environment (water policy, law, etc), Government protect and support its farmers, ***Global carbon emissions***: High increase from 1990 levels.

Very weak climate regime, increased emissions. No controls. Voluntary action

Alternative Scenario Storyline 3 (B2)

Responsibility for action at collective level with supportive governmental framework, ***Demography:*** Upstream users recognize the legitimate demands of downstream users to share the available water resources and sustain usability, population increase but at lower rate than A2, household size decrease but total number of households increases, higher employment rate; ***Economy:*** Medium annual GDP increases, Eritrea graduates from LDCs, *Fast growing sectors*: small-scale manufacture, tourism, fishery, construction, mining, industry, water marketing, local enterprises, service sector, *Declining sectors:* Agriculture especially pastoralism, improvement of efficiency of end use devices is assumed (dissemination of improved traditional biomass stove, replacement of inefficient lamps by efficient CFL lamps, reduction of transmission and distribution losses), ***Governance and Policy:*** Defined according to natural boundaries or adopting a river basin approach or at least considering the river basin as a logical planning unit with national water resource and water services policies, laws and regulations, as well as financing and incentive structures in place, high opportunity for implementation of IWRM, private sector involvement in providing water service, if chosen requires more government regulation – to ensure adequate provision at reasonable prices, ***Global carbon emissions***: Medium low increase from 1990 levels.

Strong/weak climate regime, uneven emission controls, fragmented regulatory approach.

Hence, these alternative storylines along with the current indicators established, as appropriate, will guide the ***projection*** of socio-economic changes or development of socio-economic scenarios to be linked with sectoral impact models along with climate change scenarios. The projected values for each alternative socio-economic scenario along with the climate change scenarios are linked in the impact models used and fully documented.

5.7. Modeling of Climate Change Scenarios

The major methods for constructing climate and climate change scenarios utilize results from climate model simulations. The current generation of GCM is the coupled GCM, or AOGCM, that links a three-dimensional representation of the ocean to the atmosphere. In these experiments, the enhanced greenhouse effect is simulated by gradually increasing the radiative forcing equivalent to historical increase in greenhouse gases and sulphate aerosols to 1990 to 2000, then simulating the response to greenhouse gas and aerosol scenarios to 2100 or beyond.

5.7.1. Selecting Climate Modeling Tool for Eritrea

SimCLIM, available at info@climsystems.com, has been selected to develop a comprehensive annual and seasonal climate and climate change scenarios of precipitation, maximum and minimum temperature and mean temperature, relative humidity, wind, sea surface temperature and SLR for Eritrea. SimCLIM uses the results of Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) and the outputs of 21 General Circulation Models (GCMs) drawn from different modeling centers. It is a customized GIS which includes tools for the spatial analysis of climate variability and change and associated impacts on various socio-economic sectors. SimCLIM being equipped with 21 AOGCMs, six SRES emission scenario markers and three climate sensitivities (low, medium & high) can simulate a number of annual and seasonal site specific and spatial climate and climate change scenarios including SLR for any place in the world. SimCLIM has also the capability of simulating extreme climates using daily data input, if daily time series data is available for the site in consideration.

SimCLIM has been selected for Eritrea for a number of factors including, inter alia, the following:

- SimCLIM can provide baseline climatologies for Eritrea where standardized time series baseline climate data for 1961-190 is limiting;
- Its "open-framework" features allow Eritrea to customize the model to its own geographical areas and spatial resolution and to attach impact models;
- It can use the outputs of 21 GCMs capturing uncertainty arising from differences in model formulations;
- SimCLIM can provide wider options of climate sensitivities (low, medium and high), hence capturing uncertainty due to climate sensitivity;
- SimCLIM can provide options for developing both future climate scenarios and output changes from baseline up to 2100 in user-friendly manner;
- SimCLIM is a PC based modeling system for examining the effects of climate variability and change over time and space;
- It can provide wider options for developing future scenarios and output changes from baseline using linked, synthetic and ensemble methods. Linked and ensemble methods apply GCM patterns whereas synthetic method applies sensitivity analyses to identify critical thresholds and non-linear responses of sectors/systems;
- It can simulate as many climate variables as possible which are consistent; and
- It can provide options to develop seasonal and annual climate and climate change scenarios.

5.7.2. Data for Defining the Baseline Climate for Eritrea

There are a number of alternative sources of baseline climatological data that can be applied in impact assessments. However, they are not mutually exclusive, and include: National Meteorological Agencies and Archives, Supranational and Global Data Sets, Climate Model Outputs, and Weather Generators.

In the case of Eritrea, Supranational and Global Data Sets are used to construct baseline climate. SimCLIM has been used to develop the baseline climate for 1961-1990 for basic climate impact variables of precipitation, maximum temperature, minimum temperature and mean temperature from *Global Data Set*. The original baseline model climatology data (1961-1990) for precipitation and temperature data came from WORLDCLIM, a global monthly climatology. The data sets include observations of surface variables at a monthly time step over land and ocean, surface and upper air observations at a daily time step from sites across certain regions and, for recent decades, satellite observations. The data sets are available as mean values, for various periods, often interpolated to a regular grid. The following questions have been considered when accessing and applying this source of baseline climatological data for Eritrea:

- Are the original data sources, or the approach, well documented?
- Have the data been quality controlled and, if so, how?
- Have the original data been corrected, transformed, homogenized or modified in any way?
- Is there published information describing the dataset or approach and comparing it with others?

The result of analysis for these questions could be summarized as follows. The original data sources are well documented. These global data sets over historic periods are processed from observations obtained from a *global network of stations*. Their accuracy and applicability for a particular region are dependent on the validity of the algorithm used to interpolate and aggregate *observational data from weather stations*. The data have been quality controlled. The QC has been carried out through activities including accuracy checks on data acquisition, calculation and the validity of algorithm used and the use of approved standardized procedures for measurements, estimating uncertainty and archiving information and reporting. It also includes routine and consistent checks to ensure data integrity, correctness and completeness. Besides, it identifies and addresses errors and omissions. The original data have been corrected, homogenized and standardized to a uniform or standard period 1961-1990. There is adequate published information describing the dataset and comparing it with others. In this regard, information is available in IPCC-TGCIA, 1999: *Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment, Version 1*, Lu, X. (2006), *Guidance on the Development of Regional Climate Scenarios for Application on Climate Change Vulnerability and Adaptation Assessments* and also at http://www.worldclim.org/.

5.7.3. Methodology for Constructing Climate Change Scenarios for Eritrea

After defining the baseline climate for 1961-1990, an *ensemble method* for developing annual and seasonal future climate and climate change scenarios has been applied. In this method, 21 transient AOGCMs, Table 5.3, have run simultaneously for Eritrea for different time slices (2020s, 2030s and 2050s) with A2 and B2 emission scenarios and selected climate sensitivity (low (1.5^{0}C) or mid (2.5^{0}C) or high (4.5^{0}C)) to generate 10 and 90 percentiles and median projections.

Table 5.3: Ensemble AOGCMs used to Generate Climate and Climate Change Scenarios for Eritrea

BCCRBCM2	**ECHO---G**	**INMCM-30**	**NCARPCMI**
CCCMA-31	**FGOALSIG**	**IPSL_CM4**	**UKHADCM3**
CCSM-30	**GFDLCM20**	**MIROC-HI**	**UKHADGEM**
CNRM-CM3	**GFDLCM21**	**MIROCMED**	
CSIRO-30	**GISS—EH**	**MPIECH-5**	
CSIRO-35	**GISS--ER**	**MRI-232A**	

Source: NVATWG, 2010

5.7.4. Validation of Climate Model Performance

The model performance was validated by comparing the locally derived observed baseline climate with the observed spatial baseline climate derived from global data set which has been embedded in SimCLIM.

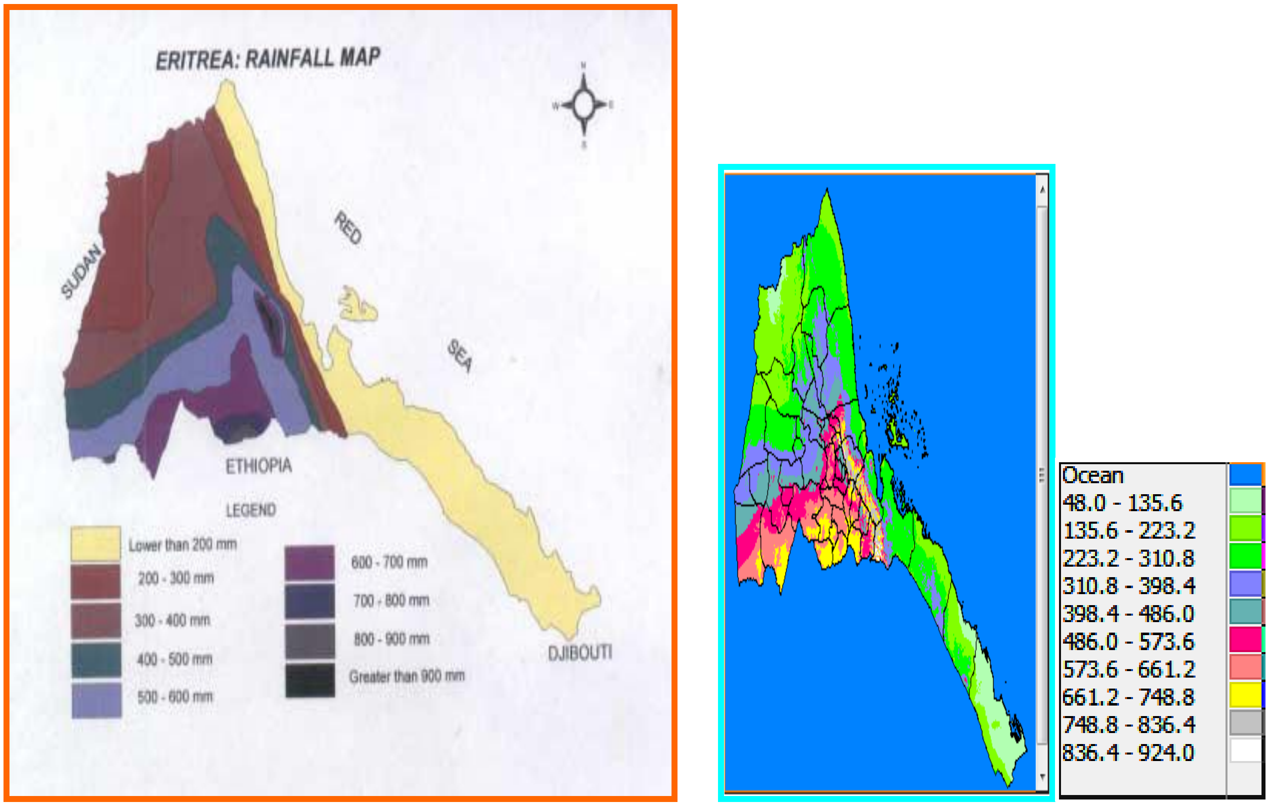


Figure 5.3: Locally Derived Observed Spatial Baseline (1902-1996) Mean Annual Rainfall (left) and Spatial Baseline (1961-1990) Mean Annual Rainfall Derived from Global Data Set (WORLDCLIM) (right): (Source: Local Spatial Baseline Mean Annual Rainfall, MOLWE, 1998)

The model data surprisingly well simulated the Eritrean current climate both in pattern and magnitude as shown in Figures 5.3 and 5.4. The *locally derived observed baseline mean annual rainfall* and *the model spatial baseline mean annual rainfalls* of Eritrea share the following common characteristics:

- Mean annual rainfall generally decreases from south to north;
- The lowest mean annual rainfalls are for the northwestern parts bordering the Sudan and the eastern costal lowlands especially southeastern corner;
- The highest mean annual rainfall is for the southern and central highlands and areas bordering Ethiopia;
- Some pockets in the eastern escarpment receive the maximum mean annual rainfall; and
- In all regions, the magnitudes of the mean annual rainfalls received are comparable

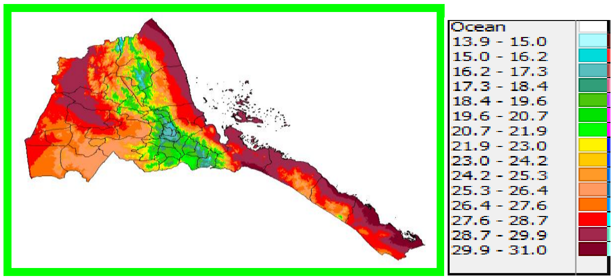


Figure 5.4: Spatial Baseline Mean Annual Temperature (1961-1990) Developed from Global Data Set (WORLDCLIM)

There is no to date spatial baseline mean annual temperature map for the country which has been developed from locally observed data. Nonetheless, despite the records are too broken and cover too wide a variety of periods, locally observed and processed long-term time series (1885-1996) records of mean annual temperature are available for wide area in the country. These locally recorded time series data have been used to ground truth the applicability of the standardized WORLDCLIM's spatial baseline mean annual temperature for Eritrea. In this backdrop, the two sets of mean annual temperature data for Eritrea share the following common characteristics:

- Mean annual temperature generally increases from the highland towards the eastern and western lowlands. Typically, mean annual temperature increases by 1°C for each 200-metre drop in elevation;
- The lowest mean annual temperatures are exhibited in the southern and central highlands;
- The highest mean annual temperatures are exhibited in the arid zones of eastern coastal lowlands and the northwestern corner of the country bordering the Sudan; and
- In all areas, the magnitudes of the mean annual temperatures received are comparable

Moreover, the regional and temporal characteristics as well as the magnitude of the locally observed pattern of baseline seasonal precipitation and temperature of the country have been well simulated by SimCLIM. Hence, the model performance is adequate and has been accepted for further modeling of future climate and climate changes for Eritrea. However, it should be noted that the locally derived baseline climate for both temperature and precipitation have not been standardized to a uniform period, such as the standard period 1961-90, because the records are too broken and cover too wide a variety of periods to make this practical. Due to this fact, the global data set has been preferred for defining baseline climatology of Eritrea for the purpose of impact, vulnerability and adaptation assessments.

5.7.5. Selecting Planning and Policy Horizons

Planning horizons will affect how far into the future a risk assessment may be projected. Planning horizons relate to the lifetime of decision-making associated with a particular activity- how far into the future is it planned? Is climate change likely to occur with this planning horizon? Do current planning decisions assume the continuation of historical conditions? How do we incorporate climate change into long-term planning?

The policy horizon is related to the period of time over which a particular policy is planned to be implemented. This may not be on the same time scale as a planning horizon. Planning horizon is mostly over longer time-50+ years. Most natural resource policies in Eritrea are implemented 5 to 15 years. Thus, planning and policy horizons influence the choice of climate scenario. Therefore, the climate scenarios in Eritrea are developed for a time slices of 2030s and 2050s in the future. It has also been ensured that this time horizons are in consistent with the socio-economic planning and policy horizons discussed in the previous section for developing socio-economic scenarios.

5.7.6. Climate Model Outputs

5.7.6.1. Projected Changes in Mean Annual Precipitation

The spatial mean annual precipitation changes from the baseline (%) for time slices of 2030s and 2050s are shown below. The changes for the Mereb-Gash Basin were projected by averaging the values of several sites in the respective catchment by left clicking of the mouth and displaying the value for any site in the spatial map. The most likely climate change scenarios have been determined by expert judgment. Under the A2 and B2 emission scenarios and selected climate sensitivity, the mean annual precipitation of Mereb-Gash Basin is expected to change from the baseline as follows:

- The B2 High Climate Sensitivity (HCS) scenario projects that the mean annual precipitation will likely change between -20 % and 26 % in 2030s for 10 and 90 percentile, respectively;
- The B2 Low Climate Sensitivity (LCS) scenario projects that the mean annual precipitation will likely change between -8 % and 10 % in 2030s for 10 and 90 percentile, respectively;
- The A2 High Climate Sensitivity (HCS) scenario projects that the mean annual precipitation will likely change between -19 % and 25 % in 2030s for 10 and 90 percentile, respectively;
- The A2 Low Climate Sensitivity (LCS) scenario projects that the mean annual precipitation will likely change between -8 % and 10 % in 2030s for 10 and 90 percentile, respectively; and
- The B2 High Climate Sensitivity (HCS) scenario projects that the mean annual precipitation will likely change between -33 and 44% in 2050s for 10 and 90 percentile, respectively

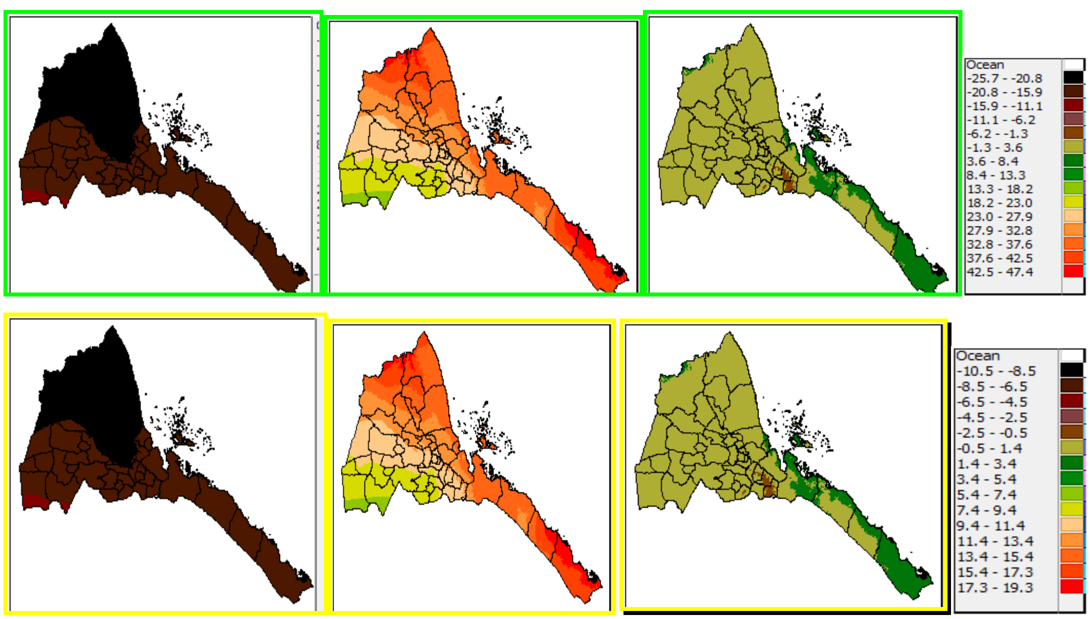


Figure 5.5: Change in Mean Annual Precipitation (%) in 2030s, B2 High (Top) and B2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians (Source: NVATWG, 2010)

Table 5.4: Mereb-Gash Basin: Change in Mean Annual Precipitation (%) in 2030s- B2 Emission Scenario

Catchment	B2 High Climate Sensitivity			B2 Low Climate Sensitivity		
	10%	90%	Median	10%	90%	Median
Headflow	-21	25	-0.8	-8.8	10	-0.2
Mereb	-20	26	-1.6	-8.2	10.5	0.4
Gash	-17	20	0.8	-6.7	8	0.4

Source: NVATWG, 2010

NB: Hedaflow = Average of Central highlands
Mereb = Average of Central highlands and Southern highlands
Gash= Average of Southwestern lowlands and Central western lowlands

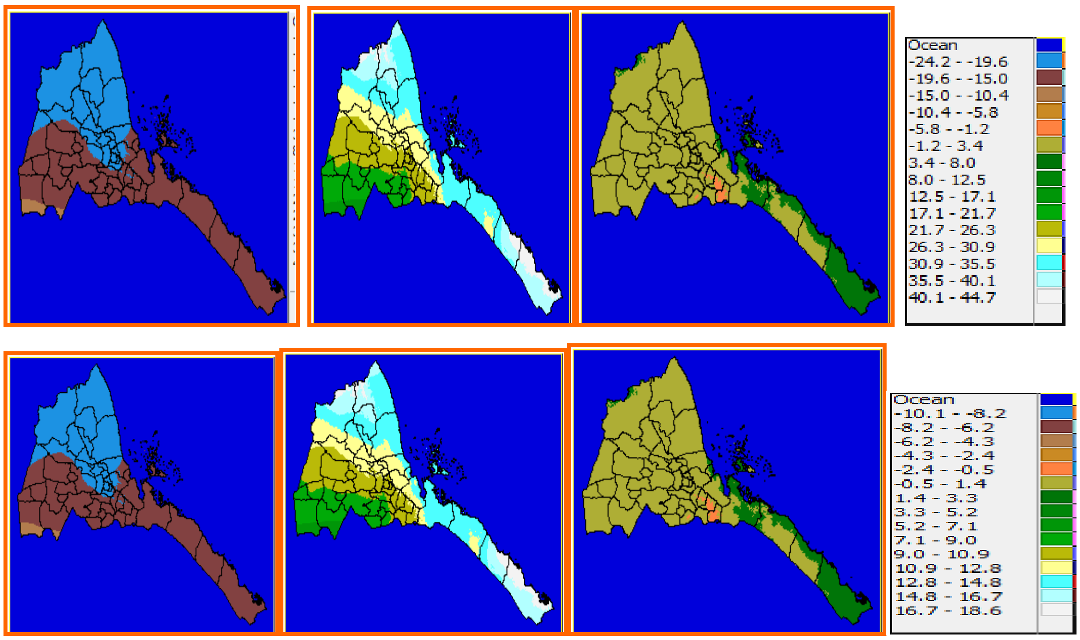
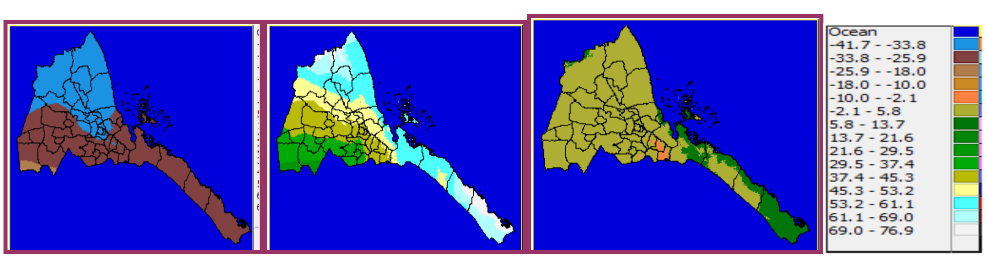


Figure 5.6: Change in Mean Annual Precipitation (%) in 2030s, A2 High (Top) and A2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians (Source: NVATWG, 2010)

Table 5.5: Mereb-Gash Basin: Change in Mean Annual Precipitation (%) in 2030s-A2 Emission Scenario

Catchment	A2 High Climate Sensitivity			A2 Low Climate Sensitivity		
	10%	90%	Median	10%	90%	Median
Mereb Headflow	-20	24	-0.01	-8	11	0.4
Mereb	-18.5	25	-1.3	-7.5	10	-0.3
Gash	-16	19.5	0.5	-6.5	8	0.3

Source: NVATWG, 2010



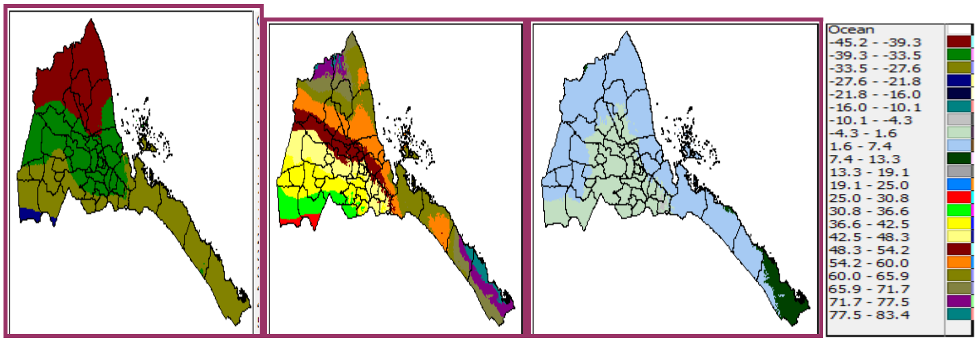


Figure 5.7: Change in Mean Annual Precipitation (%) in 2050s with B2 High (Top) and B2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians: (Source: NVATWG, 2010)

Table 5.6: Mereb-Gash Basin: Change in Mean Annual Precipitation (%) in 2050s-B2 HCS Emission Scenario

Catchment	**Change in mean annual preci. (%)**		
	10%	90%	Median
Mereb Headflow	-35	42	-0.6
Mereb	-33	44	-2.3
Gash	-28	34	1.3

Source: NVATWG, 2010

5.7.6.2. Projected Changes in Mean Annual Temperature

The spatial mean annual temperature changes from the baseline (^{0}C) for time slices of 2030s and 2050s are shown below. The changes for the Mereb-Gash Basin are also tabulated as summary. Under the A2 and B2 emission scenarios and selected climate sensitivity, the mean annual temperature of Mereb-Gash Basin is expected to change from the baseline as follows:

- The B2 High Climate Sensitivity (HCS) scenario projects that the mean annual temperature will likely change between 1 and 2 ^{0}C in 2030s for 10 and 90 percentile, respectively;
- The B2 Low Climate Sensitivity (LCS) scenario projects that the mean annual temperature will likely change between 0.4 and 0.8 ^{0}C in 2030s for 10 and 90 percentile, respectively;
- The A2 High Climate Sensitivity (HCS) scenario projects that the mean annual temperature will likely change between 0.9 and 1.9 ^{0}C in 2030s for 10 and 90 percentile, respectively;
- The A2 High Climate Sensitivity (LCS) scenario projects that the mean annual temperature will likely change between 0.4 and 0.8 ^{0}C in 2030s for 10 and 90 percentile, respectively; and
- The B2 High Climate Sensitivity (HCS) scenario projects that the mean annual temperature will likely change between 1.6 and 3.2 ^{0}C in 2050s for 10 and 90 percentile, respectively

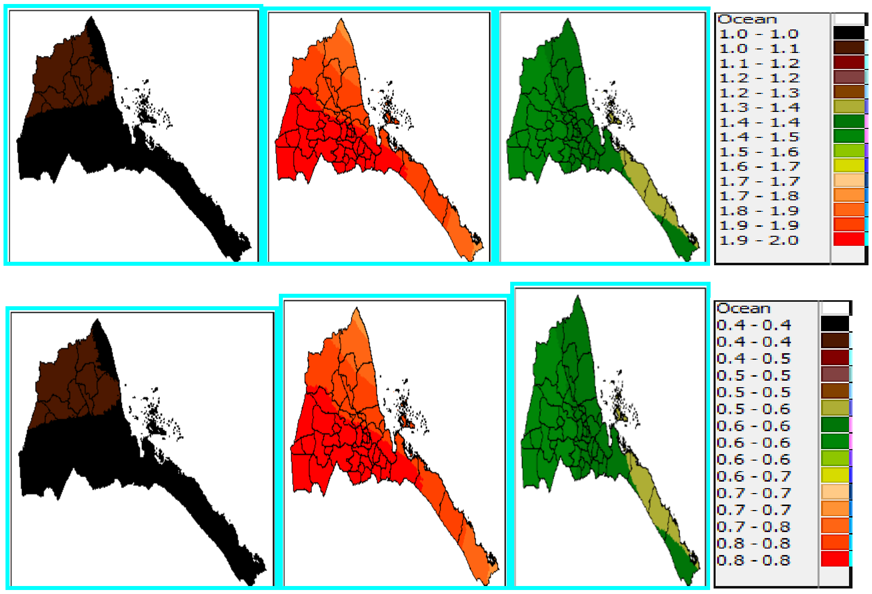


Figure 5.8: Change in Mean Annual Temperature (^{0}C) in 2030s, B2 High (Top) and B2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians: (Source: NVATWG, 2010)

Table 5.7: Mereb-Gash Basin: Change in Mean Annual Temperature (^{0}C) in 2030s- B2 Emission Scenario

Catchment	B2 High Climate Sensitivity			B2 Low Climate Sensitivity		
	10%	90%	Median	10%	90%	Median
Mereb Headflow	1	2	1.4	0.4	0.8	0.6
Mereb	1	2	1.4	0.4	0.8	0.6
Gash	1	2	1.5	0.4	0.8	0.6

Source: NVATWG, 2010

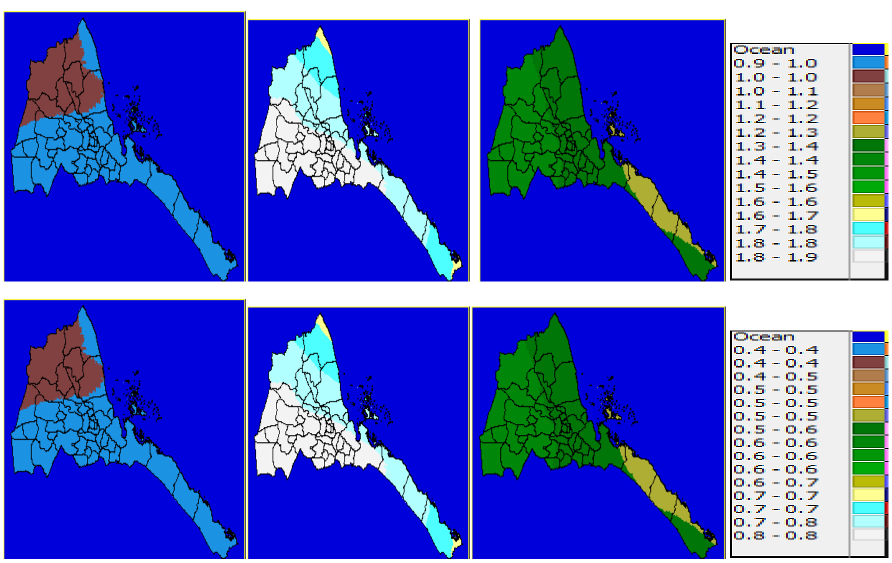


Figure 5.9: Change in Mean Annual Temperature (^{0}C) in 2030s, A2 High (Top) and A2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians: (Source: NVATWG, 2010)

Table 5.8: Mereb-Gash Basin: Change in Mean Annual Temperature (^{0}C) in 2030s-A2 Emission Scenario

Catchment	A2 High Climate Sensitivity			A2 Low Climate Sensitivity		
	10%	90%	Median	10%	90%	Median
Mereb Headflow	0.90	1.8	1.4	0.4	0.7	0.6
Mereb	0.90	1.9	1.4	0.4	0.8	0.6
Gash	0.95	1.9	1.4	0.4	0.8	0.8

Source: NVATWG, 2010

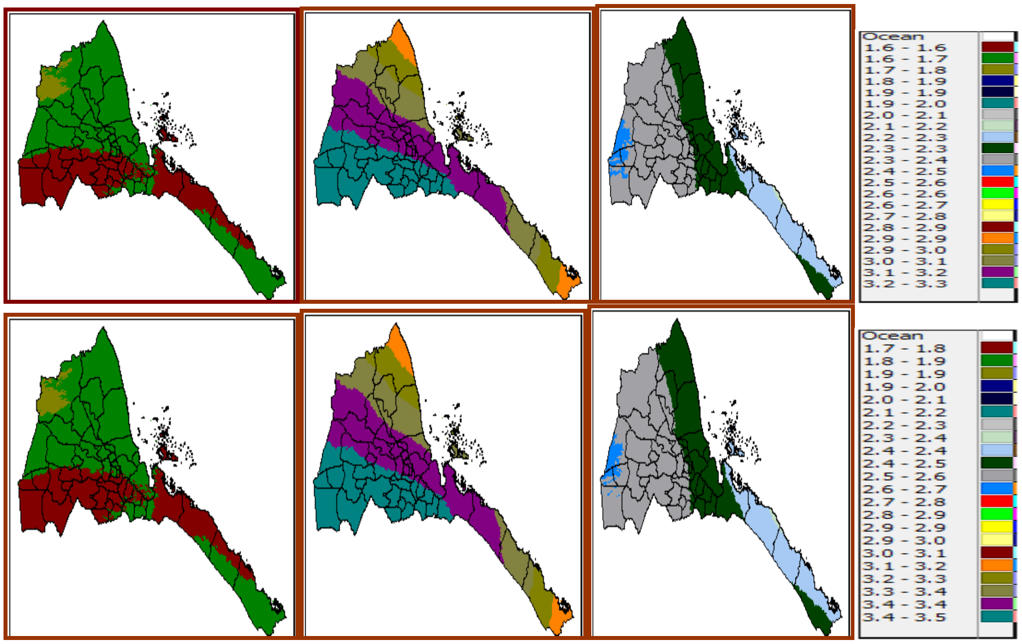


Figure 5.10: Change in Mean Annual Temperature (%) in 2050s, B2 Emission Scenario High (Top) and B2 Low (Bottom): left 10 percentiles, middle 90 percentiles and right the medians: (Source: NVATWG, 2010)

Table 5.9: Mereb-Gash Basin: Change in Mean annual Temperature (^{0}C) in 2050s,-B2 Emission Scenario HCS

Catchment	Change in mean annual temperature (^{0}C)		
	10%	90%	Median
Mereb Headflow	1.6	3	2.3
Mereb	1.6	3.2	2.3
Gash	1.7	3.2	2.4

Source: NVATWG, 2010

5.7.6.3. Data Summary of Climate Change Profile of Eritrea

A project, financed by the Global Environment Facility/ UNDP/United Nations Environment Programme (GEF/UNDP/UNEP) / National Communications Support Programme (NCSP) and the UK Department for International Development , aimed to address constraints in technical capacity, data and information availability, and financing which obstruct the ability of developing countries to generate climate scenarios of satisfactory quality. Under the project, climate profile for Eritrea was created to provide an 'off-the shelf' analysis of climate data, including historic trends and projected future changes, using up-to-date Global Climate Model (GCMs) experiments and robust analytical tools. The outcome of simulation of potential future climate changes for the near to mid-future along with the changes and observed trend registered during the last 50 years for Eritrea is summarized Table 5.10. The result of simulations for temperature corroborates those developed by SimCLIM for Eritrea and could complement it especially for A1B and B1 emission scenarios. Nonetheless, the results of simulations for precipitation are too exaggerated for both minimum and maximum scenarios for near-term such as 2030s.

Table 5.10: Data Summary of Climate Change Profile for Eritrea

	Observed Mean 1970-1999	**Observed Trend 1960-2006**		**Projected changes by the 2030s**			**Projected changes by the 2060s**		
				Min	**Median**	**Max**	**Min**	**Median**	**Max**
					Temperature				
	(^{0}C)	(Change in ^{0}C per decade)			Change in ^{0}C			Change in ^{0}C	
Annual	26.8	0.37*	A1B	0.8	1.5	1.9	1.6	2.7	3.3
			B1	0.5	1.1	1.6	1.1	1.9	2.4
			A2	0.7	1.1	1.7	1.8	2.5	3.0
JFM**	24.1	0.18*	A1B	0.7	1.4	1.7	1.3	2.5	3.0
			B1	0.1	1.0	1.4	0.7	1.9	2.2
			A2	0.9	1.4	1.9	2.0	2.9	3.8
AMJ**	29.2	0.39*	A1B	1.0	1.5	2.2	1.7	2.7	3.6
			B1	0.6	1.2	1.8	1.4	1.9	2.7
			A2	0.7	1.3	1.9	1.9	2.8	4.6
JAS**	28.3	0.55*	A1B	0.8	1.5	2.3	1.8	2.9	3.5
			B1	0.6	1.1	1.6	1.0	2.2	2.5
			A2	0.8	1.4	1.9	2.0	2.8	3.7
OND**	25.4	0.35*	A1B	0.8	1.4	2.0	1.5	2.7	3.3
			B1	0.4	1.1	1.8	1.0	1.9	2.6
			A2	0.9	1.4	1.7	2.0	2.8	3.8
					Precipitation (%)				
	(mm per Month)	**(Change in % Per decade)**		**% Change**			**% Change**		
				Min	**Median**	**Max**	**Min**	**Median**	**Max**
Annual	29.2	4.0	A1B	-4	4	31	-21	-2	41
			B1	-14	4	16	-11	2	32
			A2	-63	-7	124	-79	-15	55
JFM	9.4	12.2	A1B	-90	-3	55	-72	-16	58
			B1	-42	-12	44	-72	-11	67
			A2	-28	-8	37	-55	-6	19
AMJ	22.5	6.5	A1B	-43	-10	22	-41	-18	50

			B1	-34	-2	30	-42	-16	40
			A2	-25	5	39	-37	2	43
JAS	73.4	2.5	A1B	-18	2	47	-27	0	52
			B1	-20	0	23	-15	1	38
			A2	-19	24	84	-22	8	99
OND	11.4	2.0	A1B	-14	19	56	-22	26	81
			B1	-41	10	49	-23	15	59
			A2	-15	3	26	-31	3	34

Source: Country Profile, UNDP/UNEP/NCSP

* Indicates trend is statistically significant at 95% confidence

** **JFM** = January, February, March, **AMJ** = April, May, June, **JAS** = July, August, September, **OND** = October, November, December

5.7.7. Sea Level Rise Scenarios for the Red Sea

Socio-economically important cities have been selected along the coast of the Red Sea for projecting potential future Sea level Rise. In this context, an analysis has been made for Massawa and Assab using the worst-case A2 GHG emission scenario. It has been possible to develop SLR scenarios for other SRES emission scenarios but what is intended here is to evaluate the sensitivity of the Red Sea to potential SLR. For both sites, the Global Total Sea Level Rise data for the adjacent sites have been taken as there is no SLR grid data along the Eritrean coast of the Red Sea. Ensemble of 13 GCMs has run simultaneously. The median projection of total sea level rise in cm has been then simulated for high, medium and low climate sensitivities, Figures 5.11 and 5.12.The SLR is further summarized in Table 5.11 for the time slices of 2030s, 2050s and 2100s. This result along with additional simulations using other SRES emission scenarios could be used as input for impact, vulnerability and adaptation assessments on costal, marine and island environments for next submission of national communication.

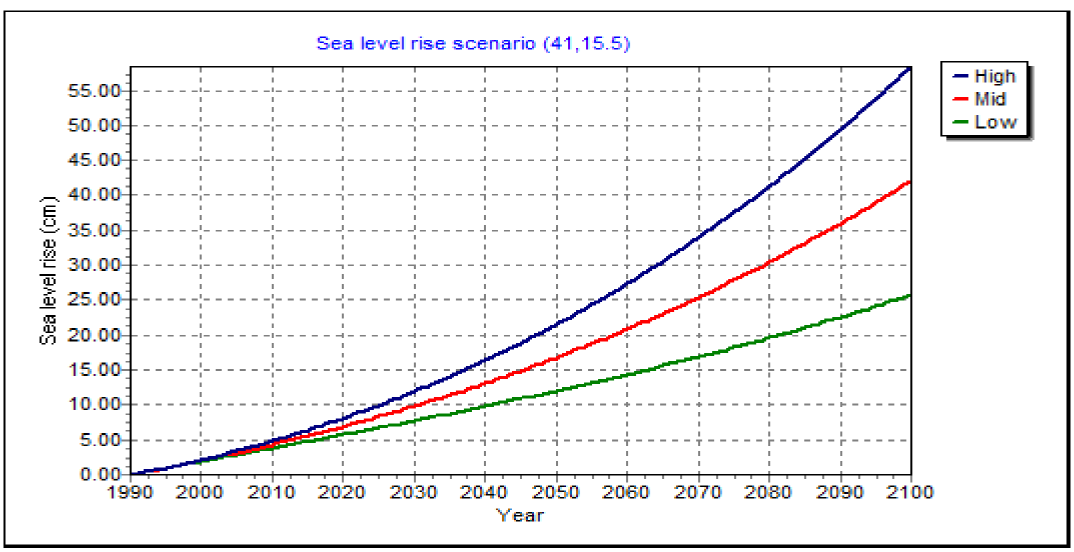


Figure 5.11: Sea Level Rise (Median Projection) from 1961-1990 (cm) near Massawa using Ensemble Method of projection for A2 Emission Scenario (Source: Seid Salih, 2010)

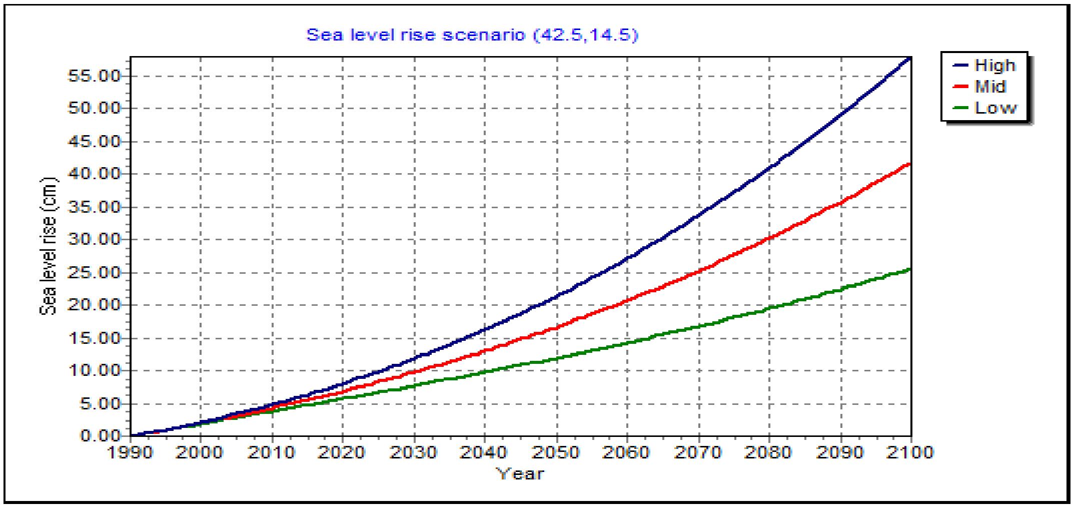


Figure 5.12: Sea Level Rise (Median Projection) from 1961-1990 (cm) near Assab using Ensemble Method of projection for A2 Emission Scenario (Source: Seid Salih, 2010)

Table 5.11: Sea Level Rise (cm) for Massawa and Assab from Ensemble run of 13 GCMs under A2 Emission Scenario for Median Projection

Year	Low Climate Sensitivity	Medium Climate Sensitivity	High Climate Sensitivity
		Massawa	
2030s	8.0	10.0	12.0
2050s	12.0	17.0	22.0
2100s	26.0	42.0	58.0
		Assab	
2030s	6.0	8.0	10.0
2050s	10.0	15.0	17.0
2100s	23.0	39.0	53.0

Source: Seid Salih, 2010

It can be concluded that in all future time slices, the potential SLR at Massawa will likely be slightly higher than that of Assab under the A2 Emission Scenario.

5.8. Impact, Adaptation and Vulnerability Assessment of Water Resources Sector

5.8.1. Current Climate Vulnerability and Adaptation of Water Resources

The overall purpose of assessing current vulnerability and adaptation has been to understand the characteristics of climate-related vulnerability in water resources sector in Mereb-Gash Basin and the scope of its adaptive responses. This section has addressed three key policy questions: (1) what is the status of national development policies and plans with respect to the vulnerability of water resources to current climate risks? (2) Which factors determine the vulnerability of the water resources sector? (3) How successful are current adaptations?

5.8.1.1. Current Adaptation in Water Resources Sector

The specific purpose of this section has been to evaluate the success of the water resources current adaptation for coping with today's climate (adaptation baseline). This baseline is a description of the recent and current adaptation experience, including policies and measures currently in place, as well as an assessment of current adaptive capacity. Both autonomous and planned adaptations have been explored.

Assessing adaptation experience involves two main processes. First, through scoping and synthesis of information on existing polices and measures relevant to adaptation in the water resources sector. Second, an assessment of the system's capacity to adapt to current hazards- i.e., how well have these polices and measures worked?

5.8.1.1.1. Scoping and Synthesis of Information on Existing Policies and Measures

Comprehensive scoping of autonomous and planned adaptations as related to water resources has identified a number of ongoing polices and measures in the country which can be categorized into the following broad categories:

- Legal framework of water resources management;
- Water resources management, use and development;
- Modeling of Water Resources;
- Water Resources Information Management System;
- Human Resource Development;
- Monitoring and Evaluation; and
- Other Related National Development Plans and Action Plans

A. Legal Framework of Water Resources Management

The major planned polices related to enabling environment are water policy, water law; and financing structures. The overall goal for a legal framework development process is to ensure that the key policy aims can be pursued with a legal backing and that there is consistency in laws and regulations across all sectors that impact water resources. In this line, there are draft water policy and water law papers, which are not yet enacted. Therefore, Eritrea currently lacks a water resources laws per se. At present, water is managed at the regional government level.

Nonetheless, there is much logic in adopting a river basin approach or at least considering the river basin as a logical planning unit. The effects of human activities lead to the need of recognition of the linkages between upstream and downstream users of water. Upstream users must recognize the legitimate demands of downstream users to share the available water resources and sustain usability. Excessive consumption, use or pollution of water by upstream users, may deprive the downstream users of their legitimate use of the shared resources.

B. Water Resources Management, Use and Development

Existing specific current policies and measures being adopted to deal with the challenges faced by the water sector in this category include:

- Sectoral water management;
- Watershed management;
- Land use management;
- Arable land water management;
- Irrigation infrastructure;
- Water management and water allocation for irrigation;
- Water supply system management;
- Water harvesting structures; and
- Soil and water conservation

B.1. Sectoral Water Management

Water Sector activities are shared among different institutions such as MOLWE, MOA, MOH, MOPW and the local government. The roles and responsibilities of these ministries are not clearly identified. There are a number of overlapping activities. For example, water quality monitoring and testing fall under WRD and at the same time under the Ministry of Health. Due to unclear mandate of the ministries there is misuse and poor management of water resources in the country.

B.2. Watershed Management

Large scale soil and water conservation programmes to address problems of land degradation were initiated as far back as the Italian colonial period and the activities have continued onwards until today in a more or less unified/cohesive but generally extensive manner. Natural resource management activities have also been carried out in a watershed approach fashion in several highlands part of the country, starting in the late seventies. During this period the activities were exclusively focusing on the physical and the biological dimensions of intervention and did not aim at addressing other aspects of the farming system and increment of incomes of the local communities. The inhabitants of the watershed were thus not considered much in the land development process.

The principle of the new watershed management came into existence in Eritrea with the initiation of the Integrated Watershed Development Programme, in 1996 which was supported by the Government of Eritrea (MOA) and the Government of Denmark (DANIDA). The basic aim of watershed management in Eritrea has been to establish a sustainable framework for management of selected watersheds in the country in order to improve the living conditions of the people, enhance agricultural productivity, protect the environment, reduce sediment transport and siltation of infrastructure, and prepare for sustainable development oriented investments. Various types of soil and water conservation (planting of seedlings, check dams, stone bunds, and earth bunds and terracing etc) have been underway.

B.3. Arable Land Management

The farming system in Eritrea is determined by seasonal distribution, amount of rainfall and efficient use of water resources. Arable land farming consists of rain fed-crop production and irrigated agriculture including spate irrigation. The main rain fed crops are cereals, pulses and oil crops. Production of rain fed crops had been highly affected in the past history by the uneven and limited amount of rainfall received in the seasons. Besides, inefficient use of the water resources has also contributed to the low yield in production to date.

B.4. Irrigation Infrastructure

The irrigated system consists of seasonal and perennial alternatives. Under the seasonal variant, irrigation is carried out through river flood diversion and water is either stored in ponds or dams to supplement rainfall or is directly flooded on the fields. In the perennial irrigation variant, underground aquifer reserves (hand dug wells, boreholes and so on) are the main source of water.

The main problems of water shortage, among others, include shortage of rainfall, uneven distribution throughout the season, and inefficient use of water resources, which makes rain-fed agriculture a risky enterprise. Therefore, extensive agricultural production, both crop and livestock has to be achieved through supplemental irrigation and efficient use of the available water resources.

Several dams now exist in the country. The construction of micro dams has been both for human and livestock domestic use and for irrigation purpose. Their capacity ranges from 20,000 m^3 to over 1.5 million m^3, most being in the range of 150,000 to 350,000 m^3.

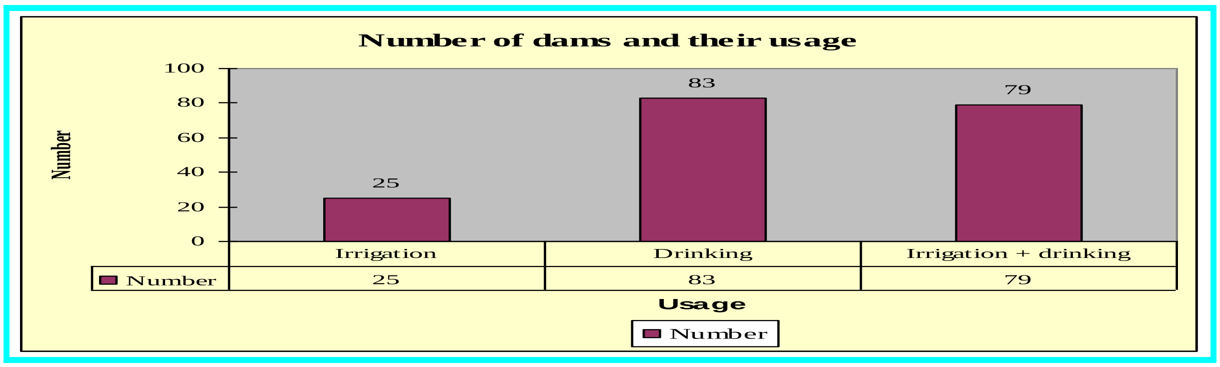


Figure 5.13: Number of Dams and their Usage (Source: MoA, 1999)

Spate irrigation structures are common in the eastern and western lowlands of the country. Spate irrigation practices in these regions are traditional, which are made of local materials like soil, stone, riverbed sand and gravel, tree trunks and brushwood. They are normally constructed across a riverbed to divert flow into farm areas to irrigate fields. During heavy floods, these structures are partially damaged or washed away completely. During reconstruction of these structures their location and shape are readjusted to suit the existing riverbed conditions. The efficiency of these traditional diversion systems is very low.

B.5. Water Management and Water Allocation for Irrigation

Despite the fact that, water is one of the scarce resource in Eritrea, most of the irrigation schems use farrow or basin irrigation. Extensive use of these methods has lead to water wastages as run off, deep percolation and evapotranpiration. Lack of approprate and affordable irrigation technologies at present is a major constraint to spread irrigation in Eritrea. The GSE is making efforts to introduce appropriate irrigation thecnologies in the country. There are a number of promissing irrigation technologies with high water use efficiency being implemented in small and medium scale schemes. Neverthless, still there is a problem of efficient use and management of these irrigation technologies. Thus, the need for the introduction of measures that will foster sustainable increase in the productivity of water through better management of irrigation is of utmost urgency.

Besides to the above problems, water in Eritrea is considered as a free commodity. Farmers are not required to pay for the water they use for irrigation purposes. They are thus, reluctant to make the most efficient use of the water they utilize at no cost. The need for levying or charge for irrigation water use becomes another timely and urgent issue.

B.6. Water Supply System Management

Installation of water supply systems in the rural areas of the country is increasing. After completion of installations, the water supply system is handed over to the villagers. In every village a water committee is established, that is, responsible for managing the system. The operation and maintenance system is by and large standardized in many hand pump projects. This makes it easier for the Village Water Committee to follow up and monitor the system. The system is planned to have Pump caretaker, Pump Mechanic or Village Level Mechanic. However, some of the emerging issues are propagating the idea of Women Caretaker Manager to take care of the Hand pump Operation and Maintenance. To give respect to woman they may be called Caretaker Managers. Since women are mainly responsible for water in many rural areas, if women are given the responsibility, they will be in a better position to look after hand pumps.

Rural water supply systems installed in the country so far are many but their current conditions and management is poor. Currently, there is limited capacity on the basics of Operation and Maintenance skill for the water supply system in the rural area. Spare parts are inadequate. Their current situation is not yet known as Monitoring and Evaluation System is lacking.

B.7. Water Harvesting Structures

Traditional water harvesting structures have been practiced long time ago. In the highlands of the country, low earth ridges are built into basins, which trap the rain water and allow it to sink into the soil. People in these areas grow crops by capturing the runoff on nearby slopes by building contour bunds, soil and stone bunds at farmlands. In the eastern lowland of the country, where rainfall is below 200 mm, floodwater harvesting from wadis (seasonal floods) that drain huge catchments areas of highlands, is used to grow crops by constructing embankments, diagonally across the riverbed. The water is trapped and spread across the area to be cultivated for any type of production (spate irrigation). In the mountains, techniques like terracing and construction of stone lines across the slope is traditionally practiced. The villagers in the country are still using these traditional structures.

Another ancient method of water harvesting structure is cisterns that have been practiced dating back to the early Roman civilization in Eritrea. Cisterns are usually built to provide water storage. Water is collected in the form of runoff from rock-lined catchment or other suitable, non-porous surface. Water accumulation from fog has recently been commenced and used by schools for drinking and washing where fog is abundant on a daily basis.

Traditional water harvesting practices have in most cases been able to meet the needs of local population for many centuries, the systems are clearly sustainable. Ignoring this local knowledge and replacing these traditional approaches entirely with new technologies, which are foreign to local communities would seem unwise. Nonetheless, the traditional water harvesting technologies can be upgraded and improved in order to provide affordable and sustainable supplies. In general, strengthening to building the traditional harvesting systems are easy to understand and usually well adapted to the particular area in which they are practiced so that their efficiency can be improved by making simple adjustments. Water harvesting structures to ease future water scarcity in the country is a priority area to the Government of Eritrea in general and for the local communities in particular.

B.8. Soil and Water Conservation

Large scale soil and water conservation programmes to address problems of land degradation were initiated as far back as the Italian colonial period in the country and evidence of bench terracing and contour bunding, dating from 45 to 60 years ago are still clearly visible in many areas of the highlands.

A century ago, different types of forest covered 30 % of the total landmass of Eritrea. By 1952, the area had decreased to 11 %. Eight years later in 1960, 5 % of the landmass was left as forested. In the late 1980s, it was reported that less than 1% of the landmass was forest (GSE, 1996). The main causes of forest destruction in Eritrea are expansion of agriculture, unwise land use, overgrazing, traditional house construction (Hidmo), fuel wood need, charcoal making and excessive logging for timber production. At present, soil and water conservation is a priority area of the GSE. This is reflected in the large soil and water conservation programmes that have already been implemented, others are under implementation and yet more are being planted.

C. Modeling of Water Resources

Among the outputs of the Water Sector Study on National Water Resources and Irrigation Potential (1998), are the assessment of the availability of surface water in selected catchments, and the development of models and methods for surface water assessment, along with related planning parameters. Computer model was developed for rainfall runoff generation. The general finding is that in Eritrea rainfall is of moderate to high intensity but with short duration and over limited areas, usually less than 20-30 km wide, and often in much smaller amount. The data at hand show that for all stations, regardless of the annual rainfall, the amounts of rain on a rain-day have been similar (Sector Study on National Water Resources and Irrigation Potential, 1998). High rainfall can occur at any station in any month. Thus, differences in total rainfall are mostly due to frequency of rain days and not so much from the amount of rainfall on those days. This means that if a rain-day is known, the amount of rainfall is taken to be a log-normally distributed at any location at anytime of year. This model developed by the Sector Study reproduces the statistics of observed rainfall very well in most places, and can easily be applied in areas with deficient rainfall records. A spatial map (Figure 2.1 also Figure 5.3) of mean annual rainfall has been drawn up, showing regional annual rainfall patterns. This map also assists to establish the baseline mean annual rainfall for the country. At the moment rainfall series can be generated for nearly any location in the country.

This model was applied to major tributaries in the Gash-Mereb and Barka-Anseba. Using this model, the results of the surface water assessment were long term time series of monthly flows with derived planning parameters for all the selected locations, with monthly and annual reliable flows. This model can be used at any point in Eritrean river systems. A finding important from this modeling approach for planning possible dams and diversion is that in the majority of catchments; mean annual runoff is ranging from 5% to 10% of the rainfall which corroborates the findings of IPCC, TAR, 2001 which has been discussed in section 5.1.1. This is also similar to that found in other countries with arid to semi-arid climates and similar catchment characteristics. The model output has been used in WEAP to simulate the surface and groundwater resources of Mereb-Gash River during future climate as part of the preparation of SNC.

However, no comprehensive groundwater exploration has yet been carried out except for Mereb-Gash Basin. The groundwater resources remain largely unknown, present working assumptions are therefore based on consideration of climatic zones, drainage pattern, geological and hydro geological characteristics, and assumed recharge pattern and water quality.

D. Water Resources Information System

The Water Resources Information Unit of WRD acquired Database, GIS, Remote Sensing, and documentation section established in November 1997. In the process of establishing the water resources information for the national water resources center, the inadequacy of existing spatial and non-spatial information systems was found to be a major constraint for data exchange. The absence of commonly agreed standards aiming at defining contents, formats, and qualities of information affected the usability of the information from national to professional level.

E. Human Resource Development

The serious understaffing and the shortage of resources in water sector in general have created a situation in which this sector cannot perform to the standards required. If these conditions do not improve, it will not be possible to provide proper planning, technical, regulatory and monitoring support to the GSE and its various institutions. Different types of staff, expertise and attitudes will be required for taking up policy and planning functions. This poses immediate challenges to staffing, training, planning and supervision.

Less clear is the capacity of private sector institutions. Private Sector development agencies have a checkered history of operation in Eritrea. Their possible role in water management at this stage is only hypothetical. There is no doubt that their role will have to increase but however needs analysis is required to identify them and establish what role they can play in water supply development and management. Human Resources Capacity building should be carried out to fulfill the demand of the water sector integrating all sectors of Development. With the exception of the University of Asmara (a few of whose colleges offer some water-related courses), there are presently no post-secondary institutions in Eritrea, which have training programs in water science and technology.

F. Monitoring & Evaluation System

At present, water projects are not properly monitored and evaluated and as the result many water related projects are becoming inefficient and no-effective for intended purposes. The rural water supply systems installed in the country, dams, ponds and different water structures so far are many, but their current situation is not yet monitored and evaluated.

Documentation in general, and in particular related to water sector is scattered and limited. Currently, there is no an M & E system or indicators selected for water resource management strategies and plan in the country. Indicators for water resource management strategies and plan are the basic building blocks of monitoring and evaluation systems. They are also part of assessment, which plays a crucial role at the beginning of the strategy formulation process and provides the baseline needed for M & E during implementation. As a part of assessment and M&E systems, indicators help to answer key questions at various stages in the planning and implementation process, such as where are we now, where do we want to go, are we taking the right path to get there, and, finally, are we there yet? And so on. Thus, the need of establishing M & E system for water resource management is at most urgent.

G. Other Related Action Plans

The relevant national and sub-national technical standards or regulations related directly or indirectly to adaptation to current vulnerability are the following:

- National Environmental Impact Assessment Procedures and Guidelines;
- Environmental Impact Assessment Procedure Guidelines for Agricultural Projects;
- 1988 procedure for carrying out construction projects, developed by the Ministry of Public Works;
- Standard Design and Procedures in Construction of Water Works; and
- Requirements of the National Seed Committee regarding development and dissemination of improved seeds

The National Environmental Management Plan for Eritrea was adopted in 1995 and is the basis for actions in environmental management and conservation. The programme deals with a number of priorities identified by the National Environmental Management Plan (NEMP-E) to safeguard the nation's natural resource base, including promotion of water conservation measures, arresting land degradation, increasing public awareness about land degradation, increasing soil cover, empowering farmers to improve farming methods and land husbandry, capacity building for improved rangeland management, , afforestation and soil conservation; and area closure for natural regeneration. Nonetheless, the NEMP-E is now outdated and needs updating. In 2005, Eritrea further developed Environmental Impact Assessment Procedure Guidelines for Agricultural Projects, dealing mainly with forestry, wildlife, agriculture and livestock.

For all type of contracts involving construction work there is a procedure for carrying out construction projects which was developed in 1998 by Ministry of Public Works. In addition, there are construction materials standards like bricks, masonry, beams, reinforcement bars, aggregates, concrete work etc. which were issued by the Eritrean Standard Institute in 1999 under the Legal Notice No 34/1997 in order to provide standardization and quality assurance.

Standard Design and Procedures in Construction of Water Works: As per the recent Eritrean Water Proclamation No. 162/2010 and the current practices, all type of water studies, proposals for surface and groundwater development, and technical design of water infrastructures need to pass through the Water Resources Department (WRD) of the Ministry of Land, Water and Environment for technical review and its approval.

Procedures and standards in development and dissemination of improved seed, such as drought and disease resistant and early maturing crops: The overall responsibility of producing foundation seed, the identification and development of drought and disease resistant and early maturing crops is the responsibility of the National Agricultural Research Institute (NARI), while promotion and distribution using the extension network is under the Seed Unit of the Agricultural Development and Promotion Department of the MoA. On the other hand to oversee imported seed quality, conducting pest risk analysis and issuing of phytosanitary certification is the responsibility of Regulatory Service Department of the MoA.

The interim Poverty Reduction Strategy Paper (PRSP): finalized in March 2004, is another key national planning document addressing the issue of poverty. The National Gender Action Plan has been developed and endorsed by the Government to achieve equal opportunities and capabilities for women, men, girls and boys of different categories to participate in and access resources, and benefit from a supportive, sustainable and appropriate economic, legal, social and political development system. The National Adaptation Programmes of Action (NAPA): finalized in 2007, has been developed to address urgent and immediate needs and concerns of the most vulnerable segment of population to cope with the adverse effects of current climate vulnerability due to current climate variability and change. The National Action Plan (NAP) is also another action plan that Eritrea has developed to combat desertification and mitigate the effects of drought.

5.8.1.2. Current Vulnerability of Water Resources

Any vulnerability assessment should consider all components of vulnerability including exposure, sensitivity and adaptive capacity. Hence, the purpose of this section is to assess and characterize these components in the water resources sector building on the outputs of the previous sections.

Despite there are different definitions of vulnerability, the NVATWG has adopted and agreed upon the IPCC context of vulnerability which is defined as "*The degree, to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.*" www.ipcc.ch/pub/syrgloss.pdf. Vulnerability is seen as the residual impacts of climate change after adaptation measures have been implemented.

5.8.1.2.1. Exposures

Exposure includes the population that can be affected by climate change (e.g., communities, species) and the nature of climate change itself (e.g., temperature, rainfall, drought, etc). NAPA identified several current direct and indirect climate hazards embedded in current variability. Hence, the exposure is large. These direct and indirect climate hazards in the water resources sector are summarized below:

- Recurrent Drought;
- Increased temperature;
- Decreased rainfall
- Change in rainfall pattern both spatially and temporally;
- Torrential rainfall with heavy runoff and flooding;
- Increased evapotranspiration due to increased aridity index;
- Increased long-term variability such as El Nino; and
- Observed climate change

Since water resource is cross-cutting, all sectors, mainly, domestic, agriculture, industry and ecosystems are vulnerable to reduced water resources as a result of the above climate exposures. The key vulnerable social groups in this connection are numerous and summarized as follows:

- Subsistence rain-fed farmers;
- Small-scale irrigated farmers;
- Spate irrigation farmers;
- Pastoralists and agro-pastoralists;
- Women headed families as well as women, children & elderly people; and
- Rural & Peri-urban poor population

5.8.1.2.2. Sensitivity

Sensitivity is the biophysical and socioeconomic impact of climate change such as decrease in crop yield, runoff, etc. Identified biophysical and socio-economic impacts of current variability and change are diverse in nature and are summarized in Table 5.12. There is strong interaction among these impacts and the feedback mechanisms are too complex to understand in comprehensive manner.

Table 5.12: Climate Hazards, Biophysical and Socio-Economic Impacts in Water Resources

Exposure/Climate Hazard	Biophysical Impact	Socio-economic Impact
-Recurrent Drought -Increased temperature -Decreased rainfall -Increased evapotranspiration -Heavy runoff and flooding -Etc.	▪ Groundwater level dropped (not easily accessible) and dried; ▪ Groundwater quality deteriorated; ▪ Stream flow quantity and occurrence reduced; ▪ Spring flows reduced and dried; ▪ Flooding (mainly occurs due to high intensity of rainfall and bareness of the catchments); ▪ Increased sediment load of streams and water bodies thereby decreasing their capacity; ▪ Increased salinity in inland water supplies; ▪ Siltation of reservoir and ponds (reduced capacity); ▪ Soil erosion; ▪ Drying of irrigation wells; ▪ Drying of natural vegetation;	▪ Loss of human life, animals, crops, ecosystems and rangelands due to recurrent drought; ▪ Shortage of water supply for domestic, livestock, industry, wild life and irrigation use; ▪ Loss of water supply sources; ▪ Reduced agricultural production; ▪ Reduced fodder production; ▪ Reduced river and stream flow; ▪ Increased groundwater salinity; ▪ Increased Water Tariffs; ▪ Social conflict due to water shortage; ▪ Reduction and possible extinction of wildlife and natural forest; ▪ Loss of reverine forests; ▪ Loss of irrigated farm lands and infrastructure; ▪ Damage on roads, bridges and other transport infrastructure; ▪ Damage on water Infrastructure; ▪ Reservoir and ponds capacities reduced because of siltation; ▪ Deterioration of livelihood; ▪ Loss of recreational facilities; ▪ Decreased farm income; ▪ Crop production declined; ▪ Shortage of native cultivar;

		▪ Shortage of animal product; ▪ Increased malnutrition; ▪ Long movement of herds; ▪ Migration to urban centers; ▪ Conflicts between pastoralists & cultivators for land & water use; ▪ Lowered export trade of livestock; ▪ Increased food aid dependency; ▪ Declined national and household food security; ▪ Increased food price; ▪ Increased dependency on imported food; ▪ Increased diseases & poverty; ▪ Increased burden of all three kinds of situations requiring relief efforts: sudden disasters, slow-onset disasters, and complex emergencies; ▪ Increased off-farm employment

Source: NVATWG, 2011

5.8.1.2.3. Current Vulnerability and Adaptive Capacity

Adaptive capacity is the ability of an exposed system to respond to climate change. Adaptive capacity depends on efficient use of available natural and economic resources including wealth, technology, institutions, information, infrastructure, access to ecosystem and socio capital. It has been demonstrated in earlier sections that most of these resources have not been used, when exist, effectively in Eritrean water resources management system. Identified key socio-economic barriers working in unison with climate hazards contributing to aggravated vulnerability of the Mereb-Gash Basin can be summarized as follows:

- Land degradation and deforestation of catchment areas of rivers, dams and ponds especially deforestation of reverine forests resulted in massive soil erosion entailing sediment load of water bodies, riverbeds and decreasing their capacity and recharge rate of aquifers;
- Low water resources management, integration and coordination with relevant sectors;
- Low awareness, knowledge and skill among decision makers and government experts about climate variability and climate change processes and climate change science;
- Poor design and low efficiency of irrigation systems as well as the technologies are traditional and obsolete but needs adjustment;
- Water points not properly constructed and maintained and thereby exposed to different forms of pollutions;
- Higher rate of urban and rural population growth influence already the water supply situation of the country negatively;
- Maladaptive practices such as overuse of groundwater for irrigation without paying, the use of animal manure for fuel, etc.;
- Low social services such as sanitation, water supply, transport, road, school, communication, health, etc; and
- Unplanned land and water use change

Hence, after full treatment of the components of vulnerability, it is possible to conclude that the ongoing adaptation polices and measures are not effective in coping with current climate variability and change because the level of burden due to exposure and sensitivity of water resources system is too much and the adaptive capacity is too weak. The greater the exposure or sensitivity, the greater the vulnerability while the higher the adaptive capacity, the lower the vulnerability. Therefore, autonomous and planned, reactive and anticipatory adjustment and additional types of adaptation options, polices and measures, which are effective, feasible and acceptable, have to be identified, prioritized and implemented so that current vulnerability is reduced and coping range is enhanced in so doing prepare for future to minimize the worst and maximize the benefit of future climate change and variability.

5.8.2. Future Climate Risk Assessment on Water Resources

Climate change assessments are permeated by uncertainty, requiring the use of specialized methods such as climate scenarios. This is a principle reason to recommend that adaptation assessments be anchored with an understanding of current climate vulnerability; it helps to provide a road map from known territory into uncertain future.

5.8.2.1. Selecting an Approach

The natural hazards-based approach has been used to assess future climate risks. The natural hazards-based approach is a climate scenario-driven approach. It starts with climate scenarios, applies them to impact models and determine possible changes in vulnerability. The natural hazards-based approach fixes a level of hazard (such as extreme temperature threshold of 37^0C), and then assess how changing that particular hazard, according to one or more climate scenarios, changes vulnerability. A broad formulation used is *Risk = Probability of climate hazard x Vulnerability.*

5.8.2.2. Selection of Impact Model

In the context of national circumstances, lesson learned and good practices from earlier studies and the objectives of the assessment defined earlier, a number of criteria have been established and defined for the selection of a water resources impact model. These criteria are described underneath:

Integration

- The model should be able to place the demand side of the equation- water use patterns, equipment efficiencies, re-use, prices and allocation- on an equal footing with the supply side- streamflow, groundwater, reservoirs and water transfers; and
- It should be able to integrate various additional issues, inter alia, pollution tracking, ecosystem requirements, vulnerability assessments, and project benefit-cost analysis for future application as data availability is enhanced

Suitability

- To be applicable and support planning in multiple socio-economic sectors;
- To be applicable or suitable to arid and semi-arid region;
- To yield sufficient information about reliable runoff and inter-annual variability; and
- It should be a PC microprocessor based tool

Flexibility

- To be applicable to ungauged catchments;
- To permit updating as additional data becomes available; and
- To be applicable to a wide range of spatial scales (single catchments or complex transboundary river systems), climatic conditions, and catchment responses;

Practicability

- To relay on relatively few, easily estimated calibration parameters;
- To maximise use of available rainfall and flow time series data or synthetic streamflow flow data; and
- To maximize the use of readily available catchment characteristics data

Reliability

- To replicate inter-seasonal and inter-annual variations;

- To be based on tried and tested methodologies from similar climatic and physical regions; and
- To provide a realistic interpretation of the hydrological processes

Based on these criteria and an overview of previous modelling experience in Eritrea and other countries, having similar circumstances, has been carried out prior to selecting the modelling tool. In this framework, the modelling tool satisfying the criteria established has been the Water Evaluation and Planning (WEAP) Model. Thus, WEAP has been adopted for Mereb-Gash Basin. WEAP was developed by Stockholm Environment Institute (SEI) based in Boston, USA. It has been used for projects in many similar arid and semi-arid countries in the West Africa, South Africa, Central Asia, and the Aral Sea.

5.8.2.3. The WEAP Approach

Operating on the basic principle of a water balance, WEAP is applicable to municipal and agricultural systems, single catchments or complex transboundary river systems. Appropriate use is what-if analysis of various policy scenarios and long-range planning studies, adaptive agriculture practices such as changes in crop mix, crop water requirements, canal linings; changes in reservoir operations; water conservation strategies; water use efficiency programs; changes in instream flow requirements; and implications of new infrastructure development.

5.8.2.4. Configuration of the System

To capture the features of the Mereb-Gash Basin, different types of components (or nodes) are incorporated in WEAP. A node represents a physical component such as a demand site, wastewater treatment plant, groundwater aquifer, reservoir or special location along a river. Nodes are linked by lines that represent the natural or man-made water conduits such as river channels, canals and pipelines. These lines include rivers, diversions, transmission links and return flow links. A river reach is defined as the section of a river or diversion between two river nodes, or following the last river node. WEAP refers to a reach by the node above it.

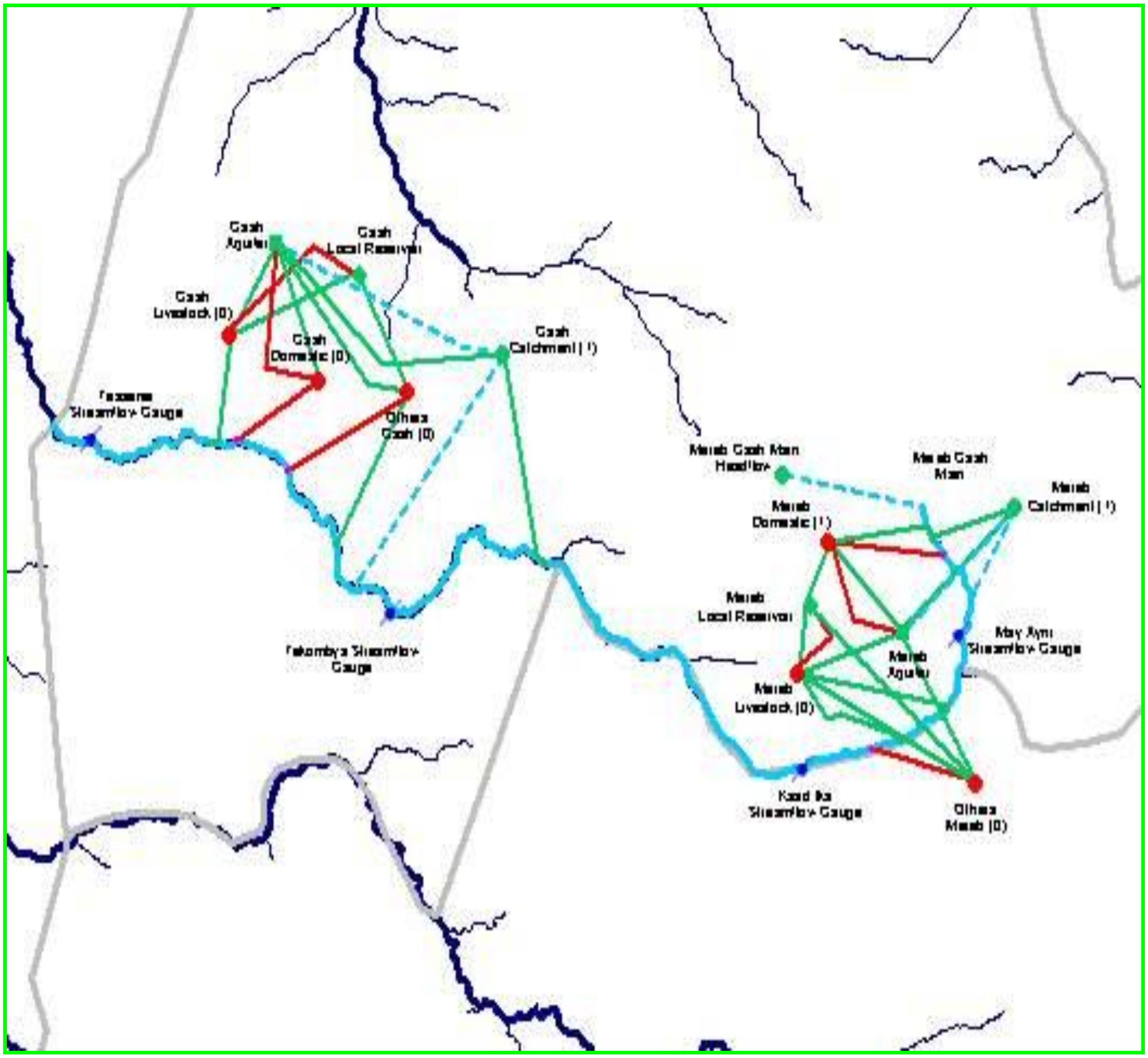


Figure 5.14: System Components and Configuration for the Mereb-Gash Basin: (Source: NVATWG, 2011)

The Mereb-Gash Basin, Figure 5.14, consists of the river, nodes, objects, transmission links, return flow links, groundwater aquifers, etc. The river is shown in blue by GIS layer and a number of reaches are defined where groundwater- river interaction has been modeled by head difference. Four streamflow gauges are defined of which the two, namely, Tekombya and Tessenei streamflow gauges, are used in calibration and validation processes, the former representing the Mereb catchment and the later the Gash catchment.

The Mereb-Gash Catchment is divided into three sub-catchments including the Mereb Headflow, Mereb catchment and Gash catchment. The Headflow is small area around the outskirt of Asmara-Debarwa area where the river is starting. Mereb catchment starts around Debarwa and ends at Tekombya which is about 16,380 km^2. The Lower Gash catchment starting from Tekombya reaches some distance below Tessenei which is less than 5000 km^2. Thus, the total Mereb-Gash catchment is about 21,300 km^2. The major land uses defined under the respective Mereb and Gash catchments are Rainfed, Irrigation, Wood land, and Disturbed forest, Plantations and Browsing and Grazing. Based on the geomorphological and soil information, the Mereb catchment has been defined as “high to mountainous relief hills” to “plateau and undulating hills” whereas the Gash catchment has been defined as “alluvial plains”. Definition of these runoff characteristic zones in each sub-catchment is considered to be decisive in determining calibration parameters such as soil water capacity, runoff resistance factor, root zone conductivity, preferred flow direction, initial moisture, natural recharge, hydraulic conductivity, specific yield, etc and these have strong implications for the state of present and future runoff and groundwater resources available in the catchment.

There are four high level demand sites containing lower hierarchies in each sub-catchment. These include Catchments, Domestic (rural & urban), Livestock (Cattle, Small Ruminant, Equine and Camel), and Others (industry, construction, etc) demand sites.

Groundwater aquifers in the Mereb-Gash Basin are much idealized by one aquifer for Mereb catchment (Mereb Aquifer) and one for Gash-catchment (Gash Aquifer). The Mereb Aquifer is assumed to be hard rock formation (13,965 km^2) while that of Gash Aquifer is alluvial (2,493 km^2) (Water Resources Frame Work, WRD, 2007). These have been assumed since the share of clayey and others is small which is 757 km^2. Thus, surface and groundwater quantifications will not be affected by these assumptions as the error is negligibly small below 4%. However, this has to be taken into account in the estimation of future precise groundwater storage simulation as data and information is available. Local reservoirs are also represented in the respective catchments.

5.8.2.5. Modeling Environment for Water Resources Impact Assessment

The conceptualized modeling environment for water resources impact assessment places the WEAP at the center of the system, Figure 5.15.

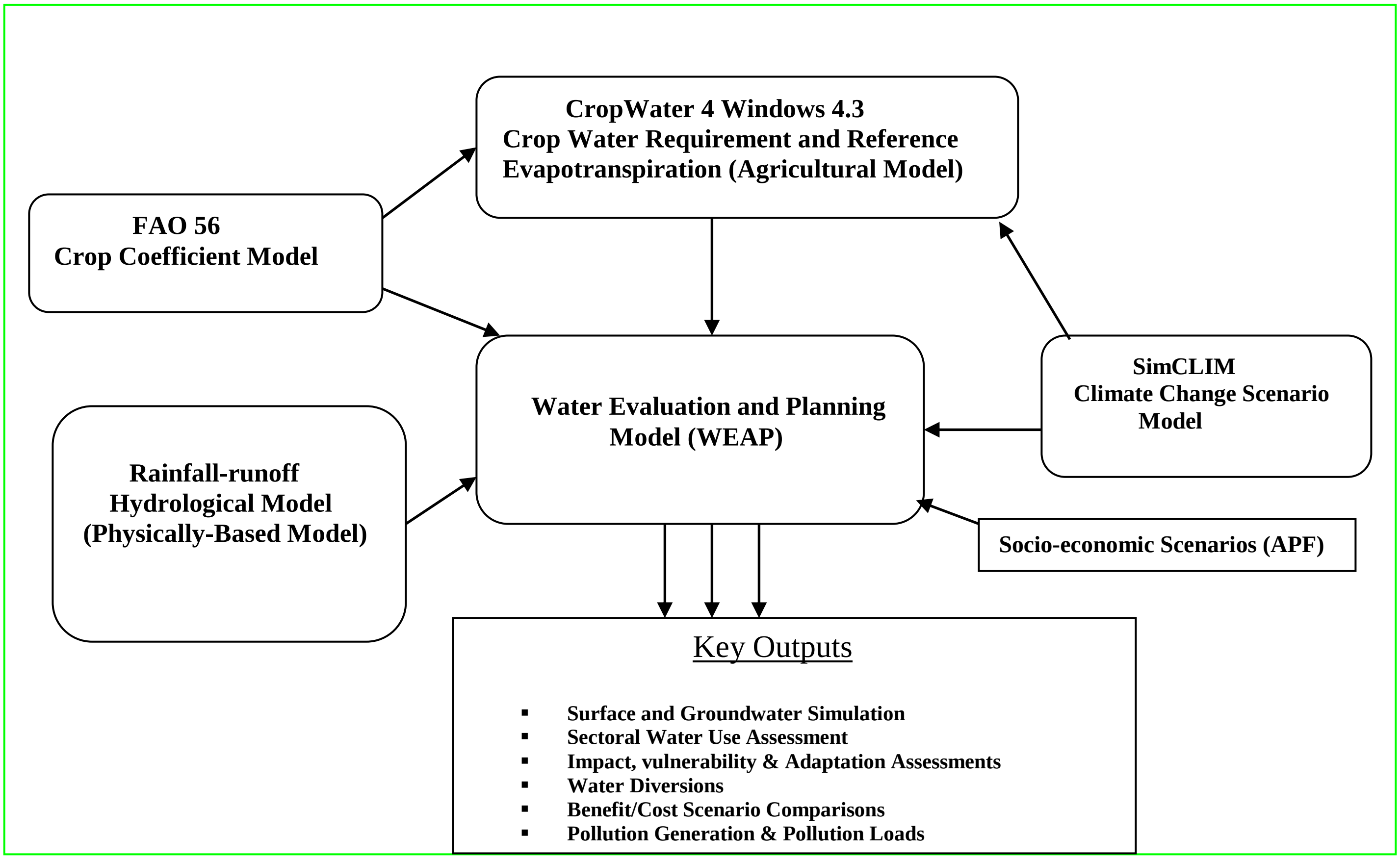


Figure 5.15: Modeling Environment Used for Water Resources Impact Assessment in Mereb-Gash Basin (Source: NVATWG, 2011)

Rainfall-runoff model developed for Eritrea has supplied modeled streamflow data (1961-2000) which has been imported into WEAP for calibration and validation stages. CropWat for Windows 4.3 is a model that uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration. FAO 56 method presents an updated procedure for calculating reference and crop evapotranspiration from meteorological data and crop coefficients for the catchment. SimCLIM besides supplying climate change scenarios directly to the WEAP, it has also been applied in the CropWater 4 Windows 4.3 model to generate future scenarios for mean monthly maximum and minimum temperatures, mean temperature, relative humidity, sunshine, and wind speed to estimate the Reference Evapotranspiration under different combined climate change scenarios which can eventually be supplied to WEAP for runoff calculation required by the FAO Rainfall-Runoff methodology.

5.8.2.6. Model Calibration and Validation

Before the WEAP model can be applied in a simulation mode, the output of the model including monthly and annual flow series need to be shown to adequately reproduce the observations. Nonetheless, as there is no long-term streamflow series data for Mereb-Gash Basin, a forty-year streamflow series data (1961-2000) has been modeled for Tekombya and Tessenei streamflow gauge stations by a physically-based hydrological rainfall-runoff model for input to the WEAP as “observed” data series. WEAP allows input streamflow data for calibration and validation from a historical record, or they may be modeled outputs from some other hydrological models. The source of data for streamflow is the Sector Study on National Water Resources and Irrigation Potential conducted in 1998. Other data requirements include land use, climate, population, livestock, annual water use rate, etc. The major data sources have been MOLWE, NSEO, MOA, and Asmara International Airport.

Model calibration and validation is a two-stage process which involves model calibration and model validation (verification). In the case of Mereb Gash Basin, there has been a need to conduct calibration and validation at two representative streamflow gauge stations, Tekombya and Tessenei, since Mereb and Gash Catchments enjoy different climatic and geomorphological characteristics. During calibration, the parameters of the WEAP have been adjusted to provide a satisfactory fit between *a-30 years “observed” data series* and a *modeled flow series* for each streamflow gauge stations. Then, retaining these calibration parameters, the *modeled flow series* has been compared with a *second set of 10 year “observed” flow series* for the same sites, as verification. *Both the calibration and verification have covered the full range of conditions that would be expected to be encountered during the subsequent simulation phase.*

The baseline time series streamflow data which has been used for calibration stage is for 1961-1990 which satisfies the World Meteorological Organization (WMO) recommended baseline period for climate change studies. Nonetheless, as the base year and the scenario period defined for the V&A study have been the year 2006 and the time period 2007-2035, respectively, the raw baseline streamflow data (1961-1990) has been first formatted in ASCII file format with a comma-separated variable (csv) file extension and then it has been read as 2007-2035 data by the WEAP model in order to perform future simulations for the scenario period (2007-2035) based on the data of Reference / Baseline Scenario. Note, however, despite the reference scenario has been read as 2007-2035 by WEAP, it still includes actual observed data. Thus, future scenarios have been each inherited from the parent reference scenario with some variables changed in order to reflect likely future changes. In fact, the reference scenario itself initially has been inherited from its parent which is the base year (2006).

In order to carry out this process, the ReadFromFile function of the WEAP has been applied. The ReadFromFile function allows one to read annual or monthly data from a text or comma-separated value (csv) file into any WEAP variable. A text or csv file can contain one or more columns of data for each year or month. There are different formats of WEAP expression for the ReadFromFile function. In Eritrean case, the format used has been *ReadFromFile(FileName, DataColumnNumber, YearOffset)*. The *YearOffse*t can be used to use data from different years. In this context, the calibration phase at Tekombya and Tessenei streamflow gauge stations has used historical streamflow data (1961-1990) for future values (2006-2035) by using the YearOffset value of -45 whereas the validation phase at Tekombya and Tessenei streamflow gauge stations has used historical streamflow data (1991-2000) for future values (2006-2015) by using the YearOffset value of -15. Each streamflow gauge station has used its own 1961-1990 baseline streamflow data for calibration and 1991-2000 data for validation. Thus, for calibration phase 1961=2006, 1962=2007, 1963=2008…… 1990=2035 and for validation phase 1991=2006, 1992=2007, 1993=2008…. 2000=2015. The files which have been used for the calibration phase at Tekombya and Tessenei streamflow gauge stations have been read by the ReadFromFile function as: ReadFromFile(Mereb_Gash_Main_3rd_node(3).csv,2,-45) and ReadFromFile(Mereb_Gash_Main_4th_node(4).csv,2,-45), respectively where the FileName for Tekombya is Mereb_Gash_Main_3rd_node(3).csv, the file type is csv, the DataColumnNumber is 2, and the YearOffset is -45.

Similarly, the files which have been used for the validation phase at Tekombya and Tessenei streamflow gauge stations have been read as: ReadFromFile (Mereb_Gash_Main_10th_node (10).csv,2,-15) and ReadFromFile (Mereb_Gash_Main_11th_node(11).csv,2,-15), respectively. These files have been saved in the directory for WEAP area: *C\Program Files\WEAP 21\Mereb Gash Basin*. Figures 5.16 and 5.17 show the calibration results at the respective streamflow gauge stations. In both stations, the general pattern of the "observed" series has been reproduced by the WEAP model and the simulated mean monthly discharges has shown a good agreement with the mean monthly "observed" data. The statistical values of the observed flow series and that of modeled for both stations have correlated 100% numerically as shown in Tables 5.13 and 5.14. Sensitivity tests have been undertaken to establish the change of calibration parameters required to give an even better fit for Tessenei. It has been found that slightly better results could be achieved at Tessenei, but this has negative impacts on the calibration results at Tekombya site. The calibration parameters that gave best results were retained.

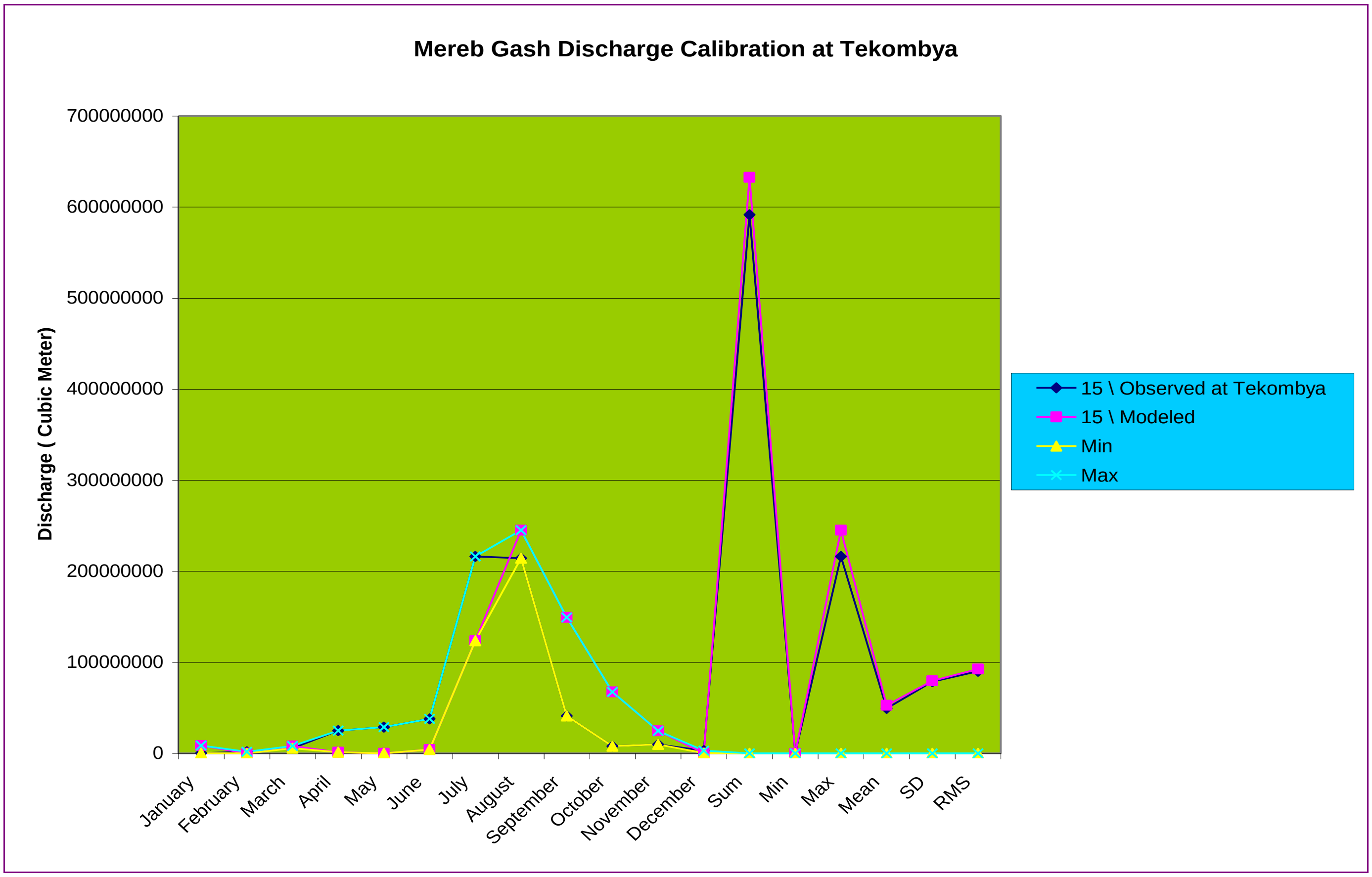


Figure 5.16: Observed and Modeled Discharge Data for Calibration of Mereb-Gash Basin at Tekombya

Table 5.13: Statistical Values for Calibration of Discharge Data at Tekombya in Mm^3

Flow Series	Mean	Standard Deviation (SD)	Root Mean Square (RMS)
Observed at Tekombya	49	79	90
Modeled	52	79	92

Source: NVATWG, 2011

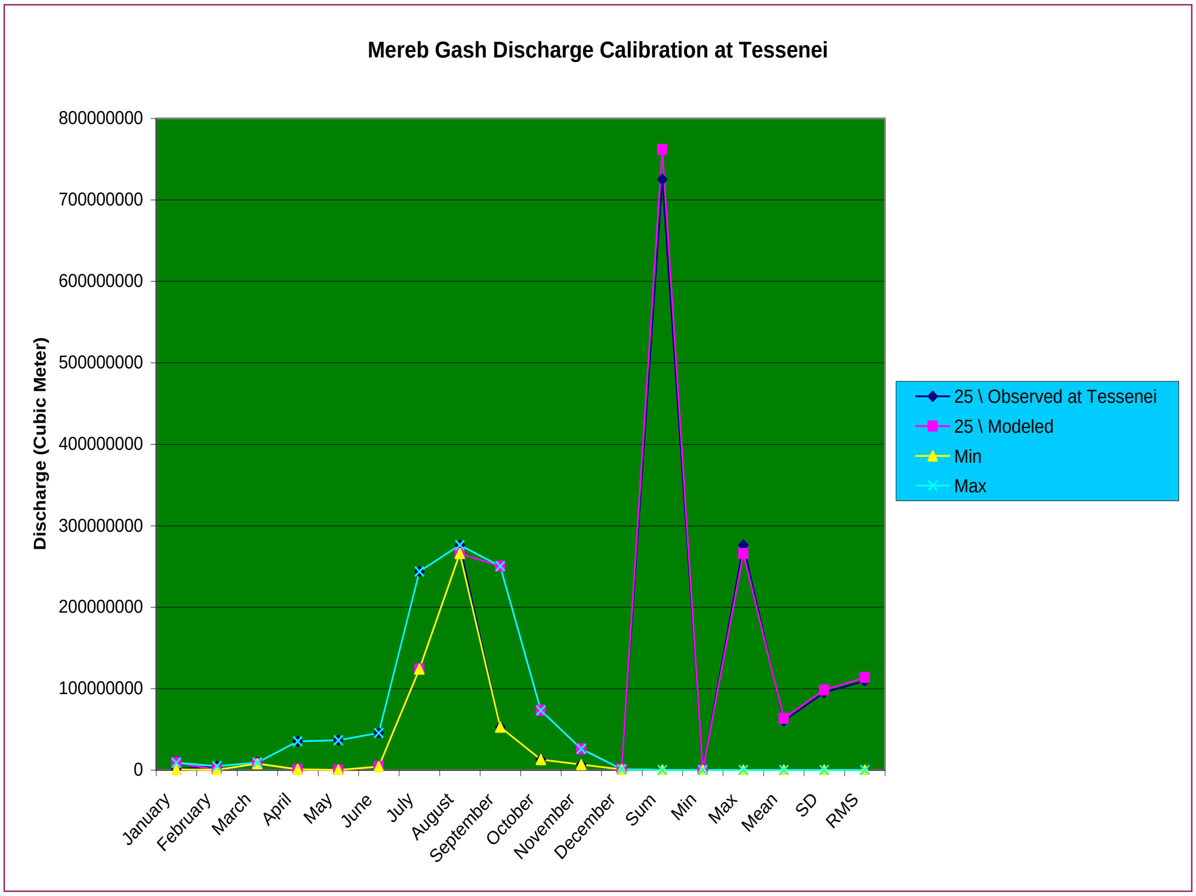


Figure 5.17: Observed and Modeled Discharge Data for Calibration at Tessenei

Table 5.14: Statistical Values for Calibration of Discharge Data at Tessenei in Mm^3

Flow Series	Mean	Standard Deviation (SD)	Root Mean Square (RMS)
Observed at Tessenei	60	95	109
Modeled	63	97	113

Figures 5.18 and 5.19 depict the validation results at the respective streamflow gauge stations. In both stations, the general pattern of the "observed" series (1961-1990) is reproduced by the WEAP model and the simulated mean monthly discharges show a good agreement with the "observed" data. The statistical values of the observed flow series and that of modeled for both stations have correlated nearly 100% as shown numerically in Tables 5.15 and 5.16.

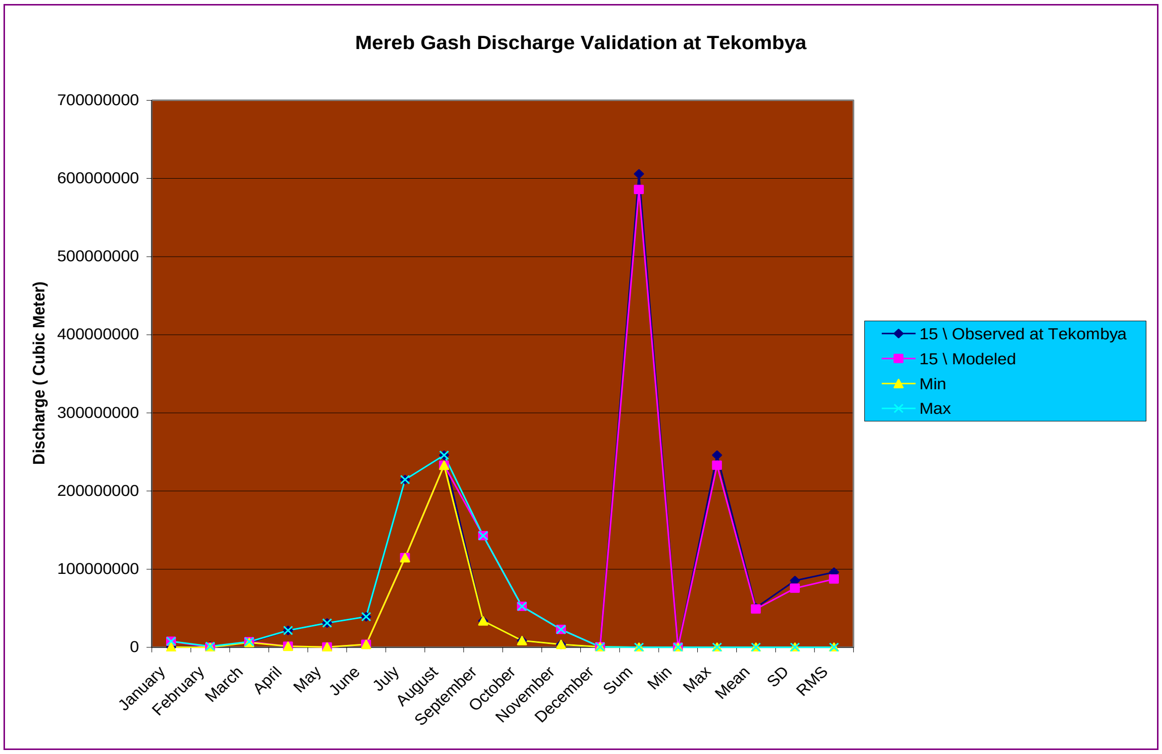


Figure 5.18 Observed and Modelled Discharge Data for Validation of at Tekombya

Table 5.15: Statistical Values for Validation of Discharge Data at Tekombya in Mm^3

Flow Series	Mean	Standard Deviation (SD)	Root Mean Square (RMS)
Observed at Tekombya	50	82	96
Modeled	48	78	92

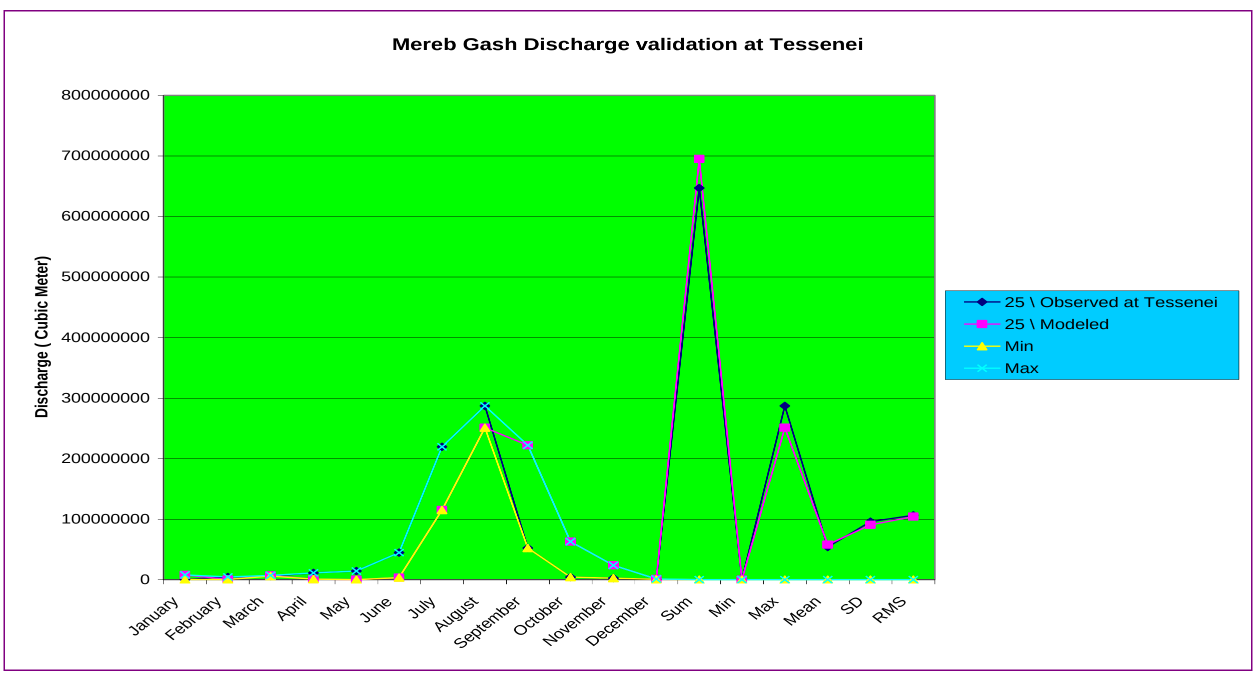


Figure 5.19: Observed and Modelled Discharge Data for Validation of at Tessenei

Table 5.16: Statistical Values for Validation of Discharge Data at Tessenei in Mm^3

Flow Series	**Mean**	**Standard Deviation (SD)**	**Root Mean Square (RMS)**
Observed at Tessenei	54	94	106
Modeled	56	93	104

Source: NVATWG, 2011

Hence, the statistics of modeled and observed streamflows at both phases of calibration and validation in both streamflow gauge stations are in full agreement. Thus, the WEAP has amazingly reproduced the Mereb-Gash River. The variability of observed annual streamflow has also been well preserved. It could be concluded that the model does perform very well and is accepted for further simulations and analyses.

5.8.2.7. Simulation of Potential Impacts of Climate Change on Mereb-Gash Basin

The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change, *Climate Change 2001*, defined impacts as "consequences of climate change on natural and human systems". Depending on the consideration of adaptation, it distinguishes between *potential impacts* and *residual impacts*. It defined *potential impacts* as "all impacts that may occur given a projected change in climate, without considering adaptation while *residual impacts* are the impacts of climate change that would occur after adaptation". Residual impacts have been assessed in earlier sections (section 5.8.1) where dealing with current climate risks. In the following sections, potential impacts of climate change will be assessed in relation to future climate risks.

5.8.2.7.1. Potential Impacts of Climate Change on Water Supply and Resources

Knowledge of current discharge and groundwater recharge in Eritrea, in general and in Mereb-Gash Basin, in particular has been inadequate; and there has been very little research on the future impacts of climate change on surface water, groundwater and groundwater- surface water interactions. This section presents the efforts taken to fill this gap.

5.8.2.7.1.1. Simulation of Potential Impacts of Climate Change on Streamflow

The simulation of potential impacts of climate change on streamflow under different climate change scenarios for model time horizon (2007-2035)[23] are portrayed in Figure 5.20 and tabulated in Table 5.17.

[23] The actual historical baseline data for 1961-1990 has been interpreted in WEAP as Reference Scenario with 2007-2035 values. The readers are kindly referred to Model Calibration and Validation Section for more detail.

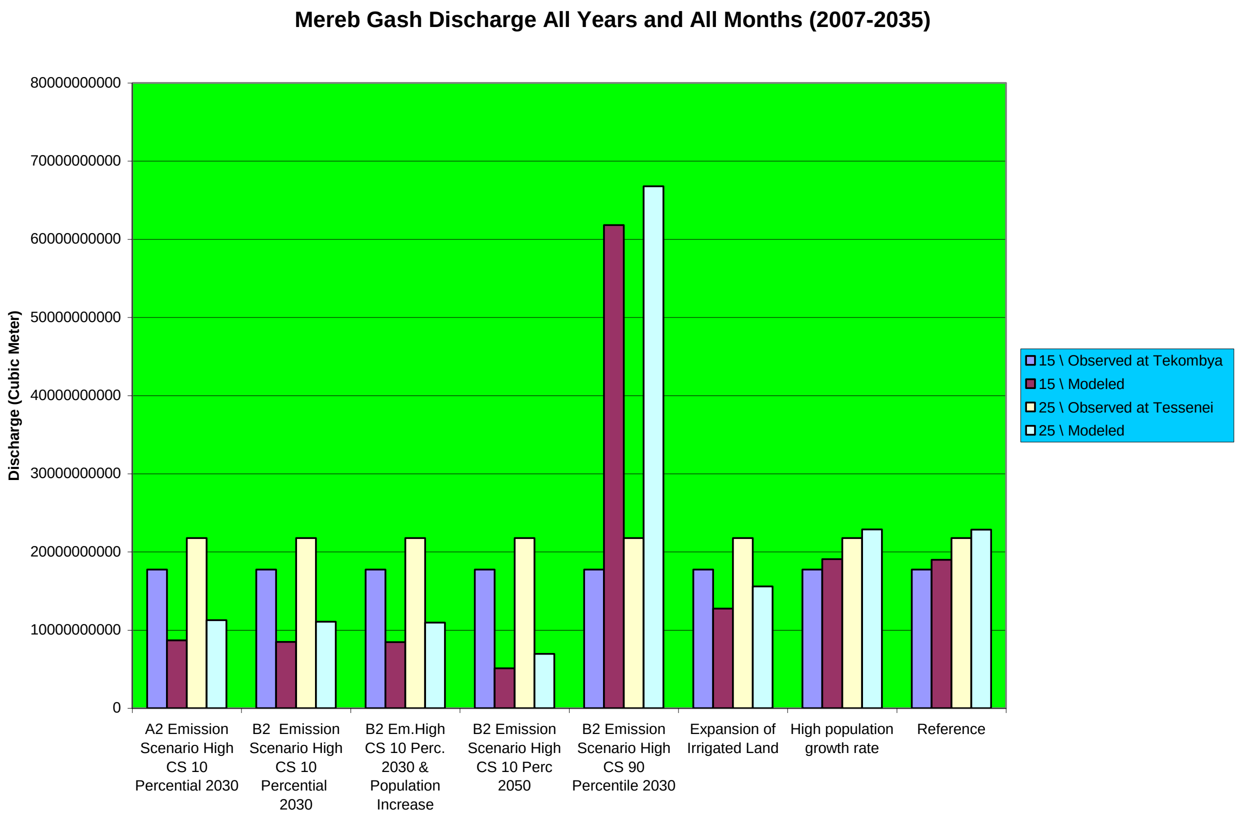


Figure 5.20: Streamflow under Different Climate Change Scenarios at Tekombya and Tessenei

Table 5.17: Mereb-Gash Basin Streamflow and Changes from the Baseline at Tekombya and Tessenei in different CC scenarios for model year (2007-2035) in Billion Cubic Meter

Streamflow	A2 HCS 10 percentile 2030s	B2 HCS 10 percentile 2030s	B2 HCS 10 percentile 2030s & Population Growth (5%)	B2 HCS 10 percentile 2050s	B2 HCS 90 Percentile 2030s	Expansion of Irrigation (5%)	Population Growth (3%)
Observed at Tekombya	18	18	18	18	18	18	18
Modeled	9	9	9	5	62	13	19
Change	-9 (-50%)	-9 (-50%)	-9 (-50%)	-13 (-72%)	+44 (+244%)	-5 (-28%)	+1 (+5)
Observed at Tessenei	22	22	22	22	22	22	22
Modeled	11	11	11	7	67	16	23
Change	-11 (-50%)	-11 (-50%)	-15 (-68%)	-15 (-68%)	+49 (+223%)	-6 (-27%)	1 (+4.5%)

NB: HCS: High Climate Sensitivity

A. Key Findings

The readers are referred to section 5.7 for projected changes in mean annual precipitation and temperature for the respective catchment and time slices.

A.1. B2 HCS 10 percentile scenario in 2030s:

This scenario projects that the streamflow will likely decrease by 50 % for both Mereb and Gash catchments in 2030s. The Mereb-Gash Basin as a whole is likely to face negative adverse effects by increased drought hazards with potential harm on biophysical and socio-economic systems including, inter alia:

- Land degradation as a result of moisture deficient;
- Lower yields / crop damage and failure;
- Increased livestock deaths;
- Increased risk of wildfire due to increased temperature;
- More widespread water stress (expressed as water withdrawal: water resources ratio);
- Increased risk of food and water shortage;
- Increased risk of malnutrition;
- Increased risk of water- and food-borne diseases (Health impacts);
- Water shortages for urban and rural dwellers;
- Water shortage for industry and settlements; and
- Potential for population migration in the Drainage Basin

A.2. B2 HCS 90 percentile scenario in 2030s:

This scenario projects that the streamflow will likely to increase by 244% for Mereb and by 223% for Gash Catchment in 2030s. Thus, with increasing climate change, Mereb-Gash Basin will likely to be impacted positively and/or negatively depending on the nature of the outcomes and the magnitude of impacts. Moreover, both the upstream and the downstream will likely be impacted but the impact in the upper catchment will likely be more obvious as the catchment is steep. Generally, heavy precipitation events with increased frequency and flash floods will likely to prevail with the following major potential biophysical and socio-economic impacts:

- Damage to crops;
- Soil erosion due to increased rainfall intensity leading to negative water quality impacts in agricultural areas;
- Inability to cultivate due to water logging of soils especially in the Gash catchment;
- Adverse effects on quality of surface and groundwater;
- Contamination of water supply;
- Water scarcity may be relieved (positive impact);
- Increased risk of deaths, injuries and infectious, respiratory and skin diseases;
- Disruption of settlements, commerce, transport and societies due to flooding;
- Pressures on urban and rural infrastructures; and
- Loss of property

A.3. B2 HCS 10 percentile scenario in 2030s with high population growth rate of 5%:

Under this scenario, the streamflow will likely decrease by 50 % and 68 % for Mereb and Gash Catchments, respectively, in 2030s. Thus, the compounded effect of climate change and increased population growth rate will likely to have more pronounced impact on Mereb-Gash Basin than that projected merely by the B2 HCS 10 percentile scenario in 2030s.

Moreover, the impact will likely be more severe on the Gash Catchment. This may be due to more irrigation activities would take place in the Gash Catchment and that would require more water demand. Both water quantity and quality may be influenced by land-use change, construction and management of reservoirs, pollutant emissions and wastewater treatment. Water use is mainly driven by changes in population, food consumption, economy (including water pricing), technology, lifestyle and societal views regarding the value of freshwater ecosystem. The vulnerability of freshwater systems to climate change may also depend on national and international water management actions.

A.4. Expansion rate of Irrigation increased to 5 %:

This scenario without considering climate change will likely to have potential negative impacts on the streamflow by decreasing it considerably by about 28 and 27 % in the Mereb and Gash Catchments, respectively (Table 5.17). Thus, with any additional combined climate change scenario, this scenario will likely have more negative consequences (e.g., A.3 above).

5.8.2.7.1.2. Simulation of Potential Impacts of Climate Change on Groundwater

As the groundwater storage potential of the Mereb-Gash Basin had never been estimated before, the first task has been to estimate its current state. Then, this baseline groundwater storage estimate has used to project the level of impacts or changes under future climate change. In fact, as groundwater both changes into and is recharged from surface water, impacts of surface water regimes which have been described above are expected to affect groundwater storage.

As a methodology, groundwater-surface water interactions have been modeled using WEAP by a stylized representation of the Mereb-Gash Basin. Groundwater aquifers in both Mereb and Gash Catchments have been represented as a wedge that is symmetrical about the river; recharge and extraction from one side of the wedge will therefore represent half the total rate. The recharge or extraction volumes are dependent on the elevation between the groundwater tables (the surface representing full saturation of aquifer pore spaces) relative to the wetted depth of the river. Modeling data variables and parameters were obtained from the Sector Study on National Water Resources and Irrigational Potential (GSE/ European Union, Vol. 2a & 2b, August, 1998) and data gaps were filled from arid and semi-arid countries having similar circumstances. Simulated groundwater storage in Mereb-Gash Basin (Mm^3) under different scenarios for the scenario period 2007-2035 is shown in Figure 5.21 and summarized in Table 5.18.

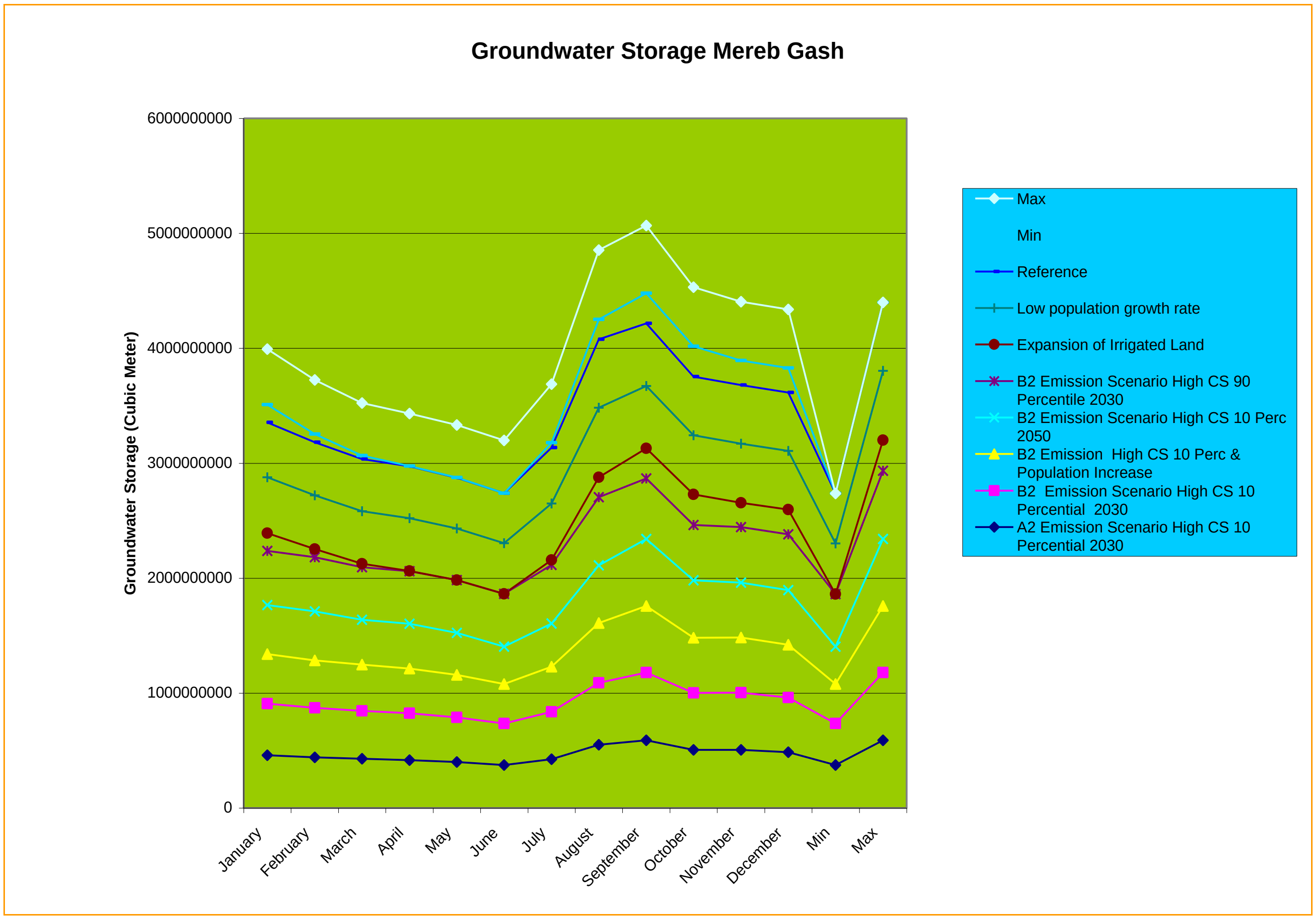


Figure 5.21: Groundwater Storage (m^3) under Different Climate Change Scenarios (2007-2035)

Table 5.18: Groundwater Storage in Mereb-Gash Basin (Mm^3) under Different Climate Change Scenarios (2007-2035)

Scenarios	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Reference[24]	477	460	451	450	442	435	485	595	544	510	513	507
Expansion of Irrigation (5%)	155	72	31	1.7	0.9	0	43	173	261	266	212	214
B2 90% 2030s	471	478	458	458	459	459	510	593	527	482	484	485
B2 10% 2050s	427	426	390	390	366	325	375	501	503	498	476	476
B2 10 % 2030s & population growth (5%)	432	413	400	389	370	344	394	520	578	480	481	459
B2 10% 2030s	448	430	418	407	388	362	412	539	589	496	497	476
A2 10% 2030s	459	441	428	418	400	374	424	551	590	506	506	485

Source: NVATWG, 2011

[24] The actual historical baseline data for 1961-1990 has been interpreted in WEAP as Reference Scenario with 2007-2035 values. The readers are kindly referred to Model Calibration and Validation Section for more detail.

B. Key Findings

B.1. Reference Scenario:

Under the reference scenario, the minimum mean monthly groundwater storage is in June just before the onset of rainy season and the maximum storage is in August when there is relatively adequate rainfall for recharge. Generally, the annual trend of the groundwater storage is linearly decreasing in the period from January to June, when there is no precipitation for recharge till the first half of June and there is intense irrigation and demand extraction activities, then starts to increase in the period from the second half of June to August and finally decreases from September onwards. This trend is in complete agreement with the situation observed on the ground.

The simulated mean annual ground water storage in the main rainy season (June-August) is about 505 Mm^3 which is consistent and comparable to the mean annual groundwater recharge estimated subjectively by WRD which is 261.6 Mm^3. Note that this estimate (261.1 Mm^3) is reflecting only the recharge not the groundwater storage which should normally include the groundwater recharge, as well.

B.2. Expansion of Irrigation (5%) from the present:

Under this scenario and without considering climate change, the groundwater storage will likely vary between zero and 266 Mm^3 where the minimum is during the first half of June and the maximum is during October when the groundwater storage equilibrates after recharge during the rainy season. Thus, the groundwater will likely to deplete by nearly 100 % in the beginning of June. Generally, the storage will likely to increase from July to October and decrease linearly from January to June near zero.

B.3. B2 High 90 percentile scenario in 2050s:

This is a scenario which projected increased precipitation intensity and considerable increase in temperature. The groundwater storage, generally, will likely to have comparable trend to the reference scenario but with higher magnitude in groundwater storage due to increased recharge. In arid and semi arid region, increased precipitation with increased precipitation variability may increase groundwater recharge because only high-intensity rainfalls are able to infiltrate fast enough before evaporating (WGII 3.4.2. AR4, IPCC). Alluvial aquifers, such as the Gash aquifer, are recharged mainly by inundations due to floods.

B.4. B2 High 10 percentile scenario in 2050s:

Under this scenario, the highest decrease in groundwater storage will likely to prevail as the increased temperature will trigger more evaporation with decreasing precipitation. It will likely to trigger potential groundwater salinisation.

B.5. B2 High 10 percentile in 2030s & population growth rate increased to 5%:

Under this combined scenario of climate change and demographic change, the compounded impact will likely to be revealed. The trend will likely be similar to that of the parent scenario which is *B2 High 10 Percentile scenario in 2030s* but as a result of additional population pressure the groundwater storage will likely to be more depleted in all months of the year at distressing rate.

5.8.2.7.1.2.1. Potential Impacts of Climate Change on Gash and Mereb Aquifers

The potential climate change impacts on the water tables of Mereb and Gash Aquifers are shown in Figures 5.22 and 5.23, respectively.

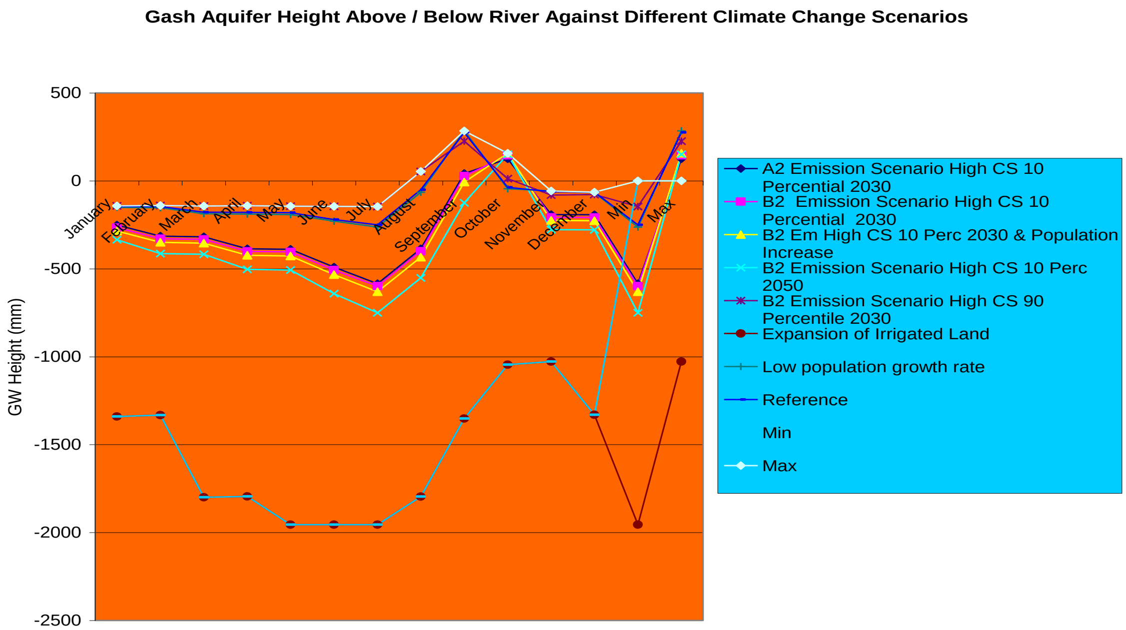


Figure 5.22: Gash Aquifer-Height Above/Below River under Different Climate Change Scenarios

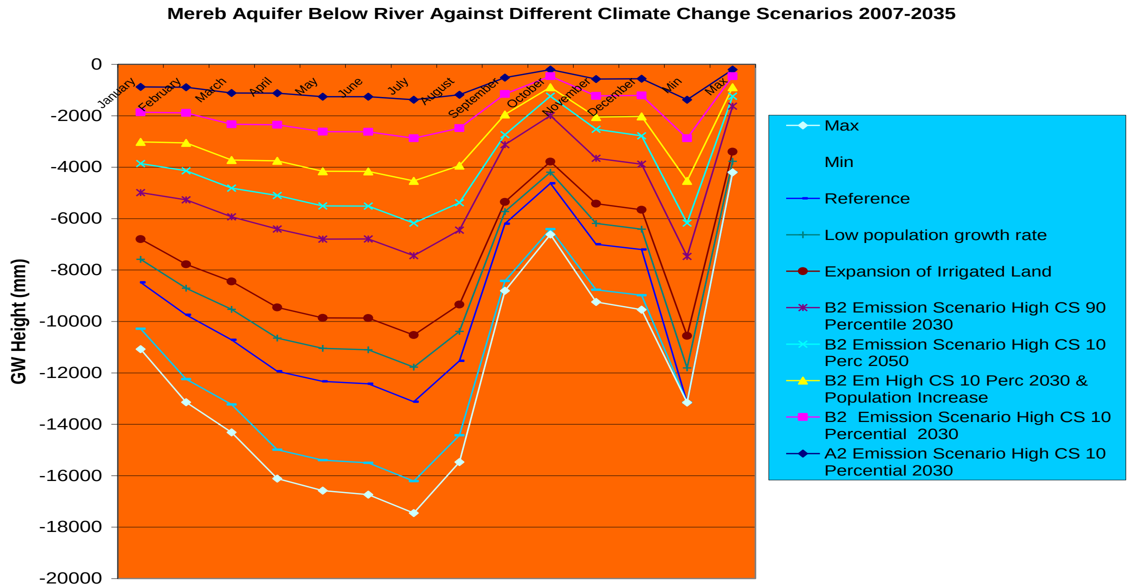


Figure 5.23: Mereb Aquifer-Height Below River under Different Climate Change Scenarios

C. Key Findings

- For both aquifers, the water tables are likely to increase slightly only during the rainy season;

- The water table of the Gash Aquifer is and will likely to continue slightly above the river surface during the rainy season under all climate change scenarios but with varying magnitudes;

- The water table of the Mereb Aquifer will likely to be significantly below the river surface at all seasons and months of the year under all climate change scenarios but with varying amount;

- These facts could be attributed to Natural and Anthropogenic factors. The dominant geology of the Mereb catchment is made up of basement rocks which have very low porosity and permeability (NEMP-E, 1995). Rain does not efficiently percolate to become a stored water resource. This fact, coupled with deforested and rugged terrain, result in short duration flash floods and low seepage of water into the ground. Moreover, because of excessive extraction from wells in some areas (Alah and Tsilma), water tables have dropped. Thus, the possibility of tapping favourable amounts of groundwater is very low in the Mereb Catchment.; and

- The Gash Catchment, on the other hand, has relatively richer aquifers in the soft rock and alluvial formations. However, in both catchments, no metered payment is required by farmers for irrigation water, as is the case for urban users. Thus, the incentive to use groundwater efficiently does not exist.

5.8.2.7.2. Potential Impacts of Climate Change on Mereb-Gash Catchment Processes

Current knowledge on catchment processes in the country, in general, and in the Mereb-Gash Basin, in particular, is inadequate. This section presents the effort undertaken to fill this gap. Therefore, before modeling the potential impacts of future climate change, the Mereb-Gash Catchment has to be simulated as it is in present day so as to establish its baseline state. In a bid to do this, the catchment has been again divided into three sub-catchments- the River Headflow, the Mereb Catchment and the Gash Catchment.

Two methodologies have been used to simulate the catchment processes; the FAO Rainfall-Runoff Method is used to simulate the Headflow process while the FAO Soil Moisture Model is used to model the Mereb and Gash Catchments. For the later method, modeling of the lower soil layer has been excluded by creating a Runoff / Infiltration flow link from both catchments to Mereb and Gash Aquifers so as to avoid more extensive soil and climate parameterization. Thus, the method used has been effectively a *one-layer soil moisture scheme*.

5.8.2.7.2.1. Simulation of Potential Climate Change Impacts on Runoff / Infiltration

The simulated Infiltration / Runoff flow under different climate changes for the model time horizon (2007-2035) and all months is shown in Figure 5.24.

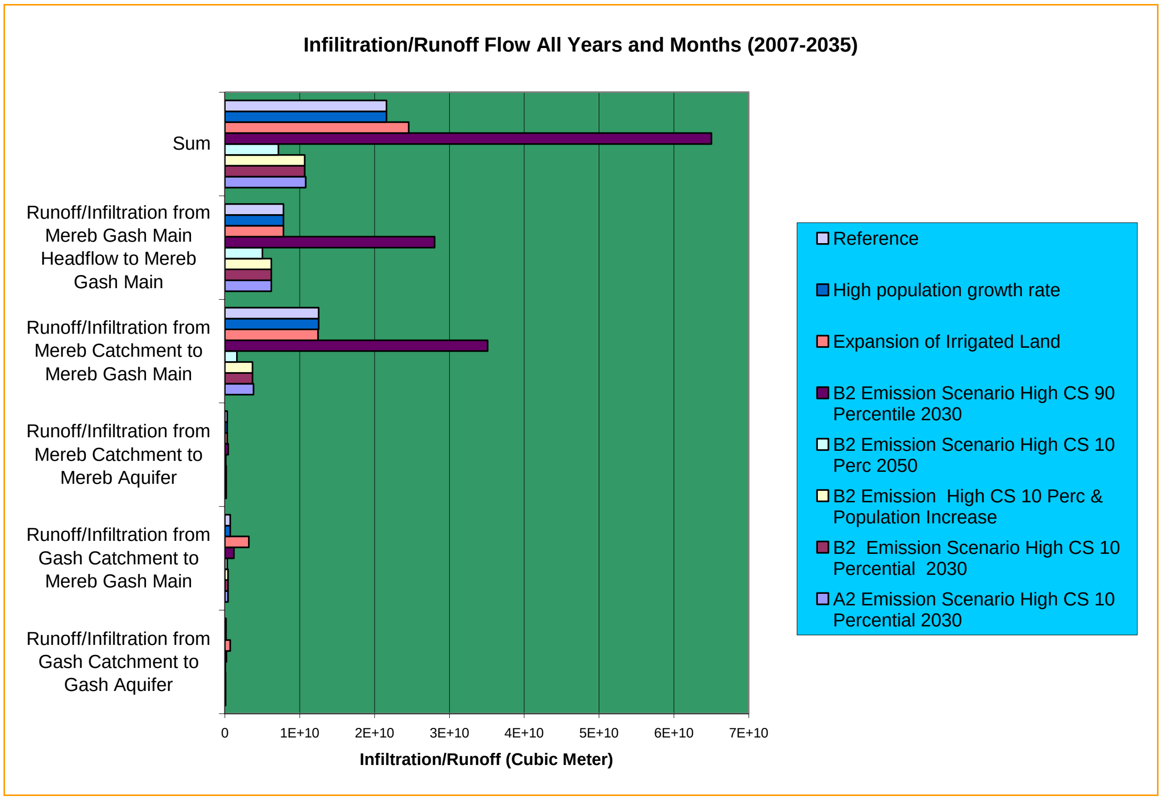


Figure 5.24: Infiltration / Runoff Flow All Years and Months (2007-2035)

D. Key Findings

D.1. Runoff / Infiltration from Mereb Catchment to River:

- The B2 high 90 percentile scenario in 2030s will likely have the largest infiltration / runoff (about twice the baseline level) probably with the risk of increased flood with potential negative consequences on infrastructure, livelihood, lives, assets and properties; and

- The B2 high 10 percentile scenario in 2050s , on the other hand, will likely have the lowest infiltration / runoff (far less than one half of the baseline level) probably with the risk of increased drought and famine with series negative consequences on agriculture, livestock and mass migration of rural dwellers to the nearest towns / cities worsening the existing fragile social services.

D.2. Runoff / Infiltration from Gash Catchment to River:

- All scenarios will likely have comparable and low runoff / infiltration to the river as much as the reference except relatively higher contribution from intense irrigation activities followed by the B2 high 90 percentile scenario in 2030s

5.8.2.7.2.2. Simulation of Potential Climate Change Impacts on Evapotranspiration

The simulated changes in evapotranspiration for all model years (2007-2035) and all months under different climate change scenarios are shown in Figure 5.25.

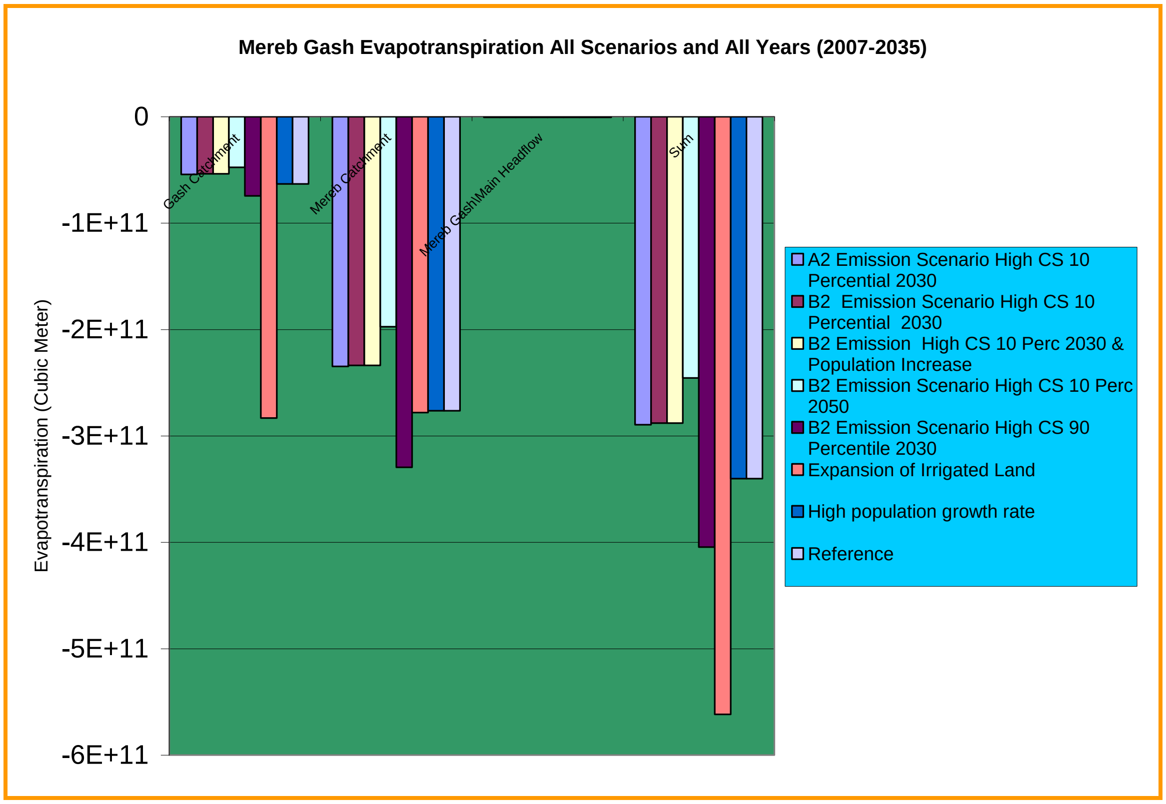


Figure 5.25: Mereb-Gash Catchment Evapotranspiration under Different Climate Change Scenarios

E. Key Findings

E.1. Headflow:

- As the area of the headflow catchment is relatively small, the change in evapotranspiration with respect to the reference will likely be negligibly small under all climate change scenarios

E.2. Mereb Catchment:

- The catchment will likely experience the highest evapotranspiration change under all climate change scenarios; and
- The highest evapotranspiration will likely be under the B2 high 90 percentile scenario in 2030s when there is much available precipitation accompanied by intense heating

E.3. Gash Catchment:

- This catchment will likely experience relatively lesser evapotranspiration change as compared to the Mereb Catchment; and

- Under the expansion of irrigation activities, it will likely to lose much water by evapotranspiration as water from frequent irrigation practices will likely be available for evapotranspiration along with the risk of soil salinisation

5.8.2.7.2.3. Simulation of Potential Climate Change Impacts on Soil Moisture

Soil moisture changes for model year (2007-2035) and all months under different climate change scenarios from different land use categories are shown in Figure 5.26.

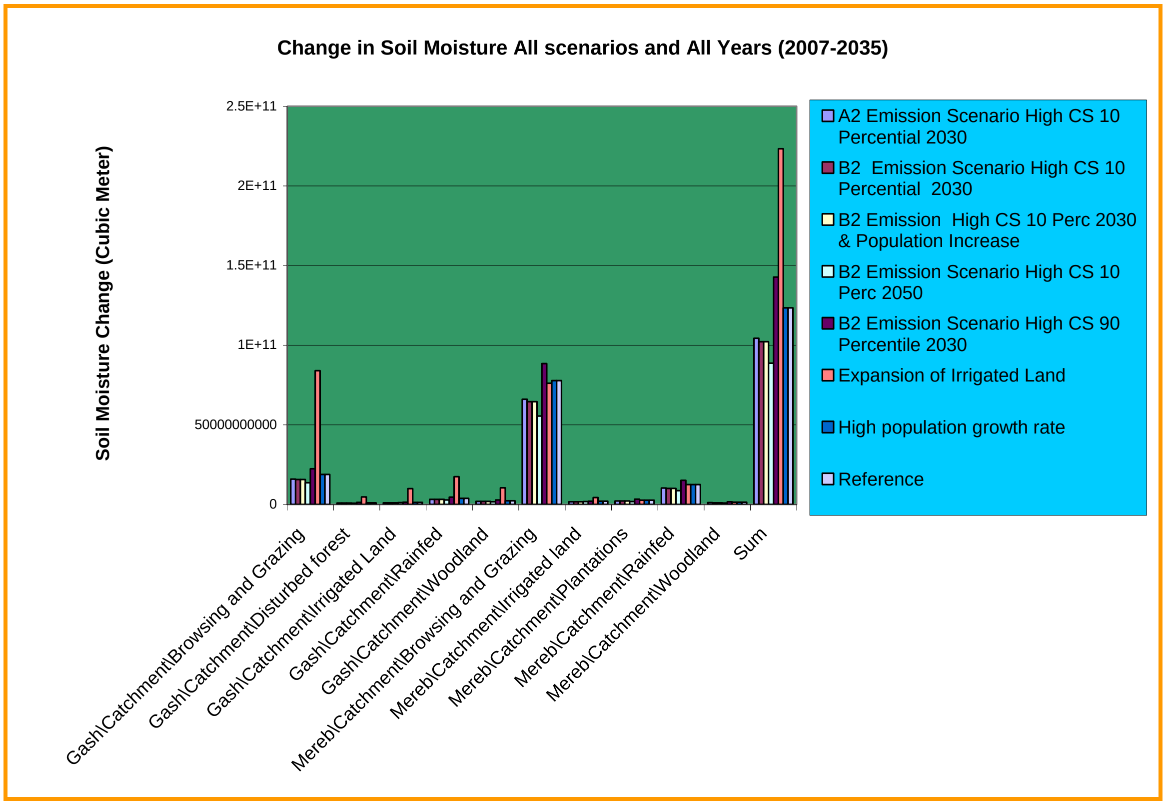


Figure 5.26: Soil Moisture Changes for Different Land Uses for All Years (2007-2035) and Months

F. Key Findings

F.1. Mereb-Gash Catchment:

- The highest soil moisture lose will likely to occur in Mereb and Gash catchments from the Browsing and Grazing Land Use;

- Gash catchment will likely to lose the highest soil moisture under expansion of irrigation followed by the B2 high 90 percentile scenario in 2030s; and

- Mereb catchment will likely to lose the highest soil moisture under the B2 high 90 percentile scenario in 2030s when the temperature change is projected to be the highest (about 3^0C). This will likely to have negative impact on livestock as a result of potential drought. Subsistence rain-fed farmers, Pastoralists and Agro-pastoralists will be key vulnerable.

5.8.2.7.3. Simulation Potential Impacts of Climate Change on Water Demand

The simulated water demands for the model year (2007-2035) under different Climate Change Scenarios are shown in Figure 5.27 and summarized in Table 5.19.

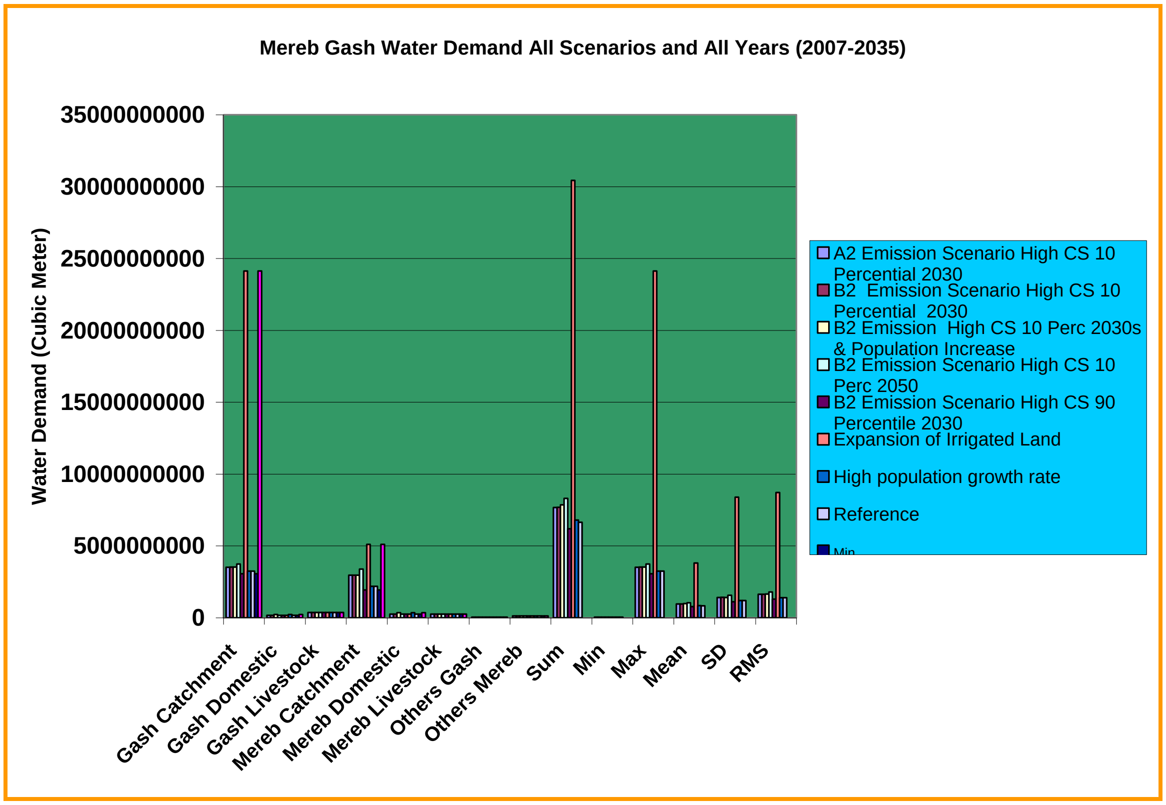


Figure 5.27: Water Demand under Different Climate Change Scenarios (2007-2035)

Table 5.19: Mereb-Gash Water Demand Under Different Climate Change Scenarios (2007-2035) (Billion m^3)

Scenario	Gash Catchment	Gash Domestic	Gash Livestock	Mereb Catchment	Mereb Domestic	Mereb Livestock	Others Gash	Others Mereb	Sum
Reference	3.2	0.2	0.4	2.2	0.2	0.3	0	0.1	6.6
High Population Growth (5%)	3.2	0.3	0.4	2.2	0.3	0.3	0	0.1	6.8
B2 90, 2030s	3.1	0.2	0.4	1.9	0.2	0.3	0	0.1	6.2
Exp.Irrigation	24.0	0.2	0.4	5.0	0.2	0.3	0	0.1	30
B2 10, 2050s	3.7	0.2	0.4	3.4	0.2	0.3	0	0.1	8.3
B2 10, 2030 & Population Growth (5%)	3.7	0.4	0.4	3.4	0.5	0.3	0	0.1	8.8
B2 10, 2030s	3.5	0.2	0.4	3.0	0.2	0.3	0	0.1	7.7
A2 10, 2030s	3.5	0.2	0.4	3.0	0.2	0.3	0	0.1	7.7

Source: NVATWG, 2011

G. Key Findings

G.1. Reference Scenario:

- The baseline water demand, without considering climate change, for all demand sites in the Mereb-Gash Catchment is projected about 6.6 Billion Cubic Meter for the model period (2007-2035)

G.2. Population Growth Rate Increase to 5%:

- Additional water demand in the whole catchment is projected to be about 200 Million Cubic Meter for the model time horizon (2007-2035) with respect to the reference (Population Growth Rate 2.74%)

G.3. B2 High 90 Percentile Scenario in 2030s:

- The water demand required from the river is projected to decrease for the scenario period by about 400 Million Cubic Meter with respect to the reference as other alternative sources for supply exist;

- The scenario will likely to have more precipitation and some of the water demand will likely to be satisfied from other alternative sources other than the river; and

- Nonetheless, increased availability of precipitation / runoff cannot be fully utilized unless there is adequate infrastructure to capture, disinfect and store the extra water for dry season

G.4. Expansion of Irrigation by 5%:

- This scenario is projected to require the highest ***additional*** supply requirement of about 23.4 Billion Cubic Meter at the end of scenario period with respect to the reference scenario. This scenario will likely have serious environmental and social consequences; and

- The Gash catchment is projected to require the highest water demand of about 21 Billion Cubic Meter which is statistically significant. *This irrigation scenario if compounded with any of climate change scenario will likely to result in an even increased additional irrigation water demand*

G.5. B2 High 10 Percentile Scenario in 2030s:

- This scenario projects an additional 1.1 Billion Cubic Meter supply of water with respect to the reference; and

- If compounded with population growth rate of 5% will likely to require an additional supply of about 2.2 Billion Cubic Meter of water. *Thus, the compounded impact of climate change and population growth would be amplified on water demand*

G.6. B2 High 10 Percentile Scenario in 2050s:

- This scenario alone will likely to have a comparable impact on the river as that of the B2 high 10 percentile scenario in 2030s combined with population growth rate of 5% in the scenario period; and

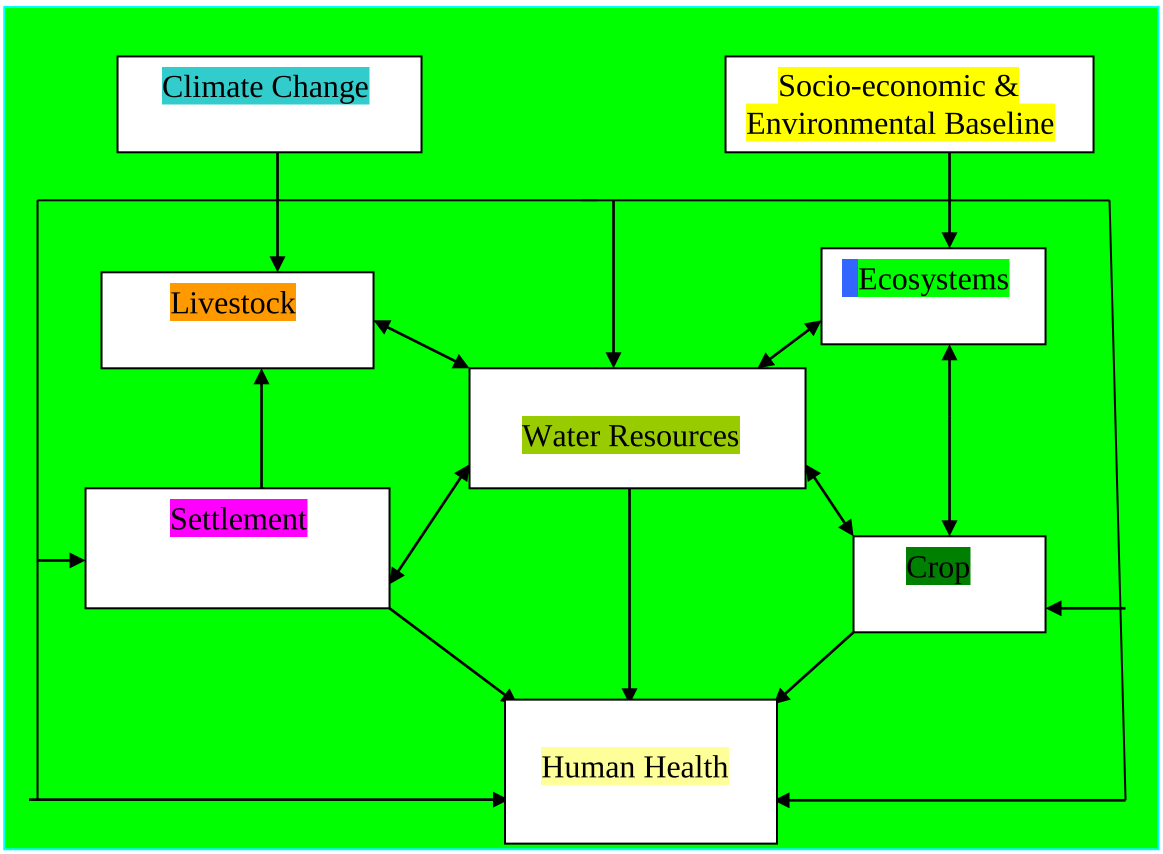
- The increase in domestic and industrial water demand, due to climate change, is likely to be small

G.7. A2 High 10 Percentile Scenario in 2030s:

- This scenario will likely to have a comparable impact on the demand sites and the river as that projected by the B2 high 10 percentile scenario in 2030s.

5.8.2.7.4. Integration of Potential Climate Change Impacts

Cross-sectoral integration, involves examining sectors that are interrelated as climate change impacts do not happen in isolation from each other. In this context, what happens in water resources affect other sectors, inter alia, crop, settlements, livestock, ecosystem and human health. Indeed, such indirect impacts are as important as the direct effects of climate change on water resources. These indirect impacts are important for policy makers and other stakeholders to understand how a community, region, even the nation could be affected in total by climate change, and what the total economic impact may be. Such information can be useful for setting priorities for adaptation. These indirect impacts are shown, Figure 5.28, and elaborated underneath.



.

Figure 5.28: Relationship between Climate Change, Water Resources and Related Sectors: (Source: NVATWG, Eritrea, 2011)

5.8.2.7.4.1. Crop-Sub Sector

The crop-sub sector will likely be most vulnerable to shortage of water and moisture under the B2 high10 percentile 2030s, B2 high10 percentile 2050s, A2 high 10 percentile 2030s, and A2 high 10 percentile 2050s scenarios. Under the A2 high 90 percentile 2030s, B2 high 90 percentile 2030s and B2 high 90 percentile

2050s scenarios, the sub-sector will likely be vulnerable to potential flooding. The projected warmer temperatures associated with high evapotranspiration will likely to negatively impact the crop water demand and soil water capacity which will in turn likely to affect the readily available soil moisture for crops resulting in potential crop wilting. Spate-irrigated agriculture will also likely to face floods damages on the irrigation infrastructures and potential water logging and salinisation.

Mereb-Gash Basin relies on rainfed agriculture for most part where the productivity of the land is highly dependent on the amount of rainfall. During rainy season, the day of onset of rainfall is already becoming late and the day of cessation is becoming earlier. This situation has already severe impact on long-cycle crops of the country such as sorghum, maize, barley, wheat and finger millet. Projected climate change will likely have much uncertainty as to how the future opens up for these cereals. Besides, decreased rainfall will likely to impact on the supply of irrigation water by reducing ground water level and drying stream flows. This will likely to cause the risk of crop failure due to insufficient spate flow. Subsistence rain-fed farmers, small-scale irrigated farmers and the rural poor, women, children and elderly will likely be the most vulnerable groups. Any adaptation effort whether it is autonomous or planned should target these key vulnerable groups.

5.8.2.7.4.2. Settlements

The groundwater supplies of all towns located in the upper part of the drainage basin, for example Mendefera and Dekemhare, and those located at the water shade dividing ridges, such as Adi- Keih and Barentu, are already vulnerable to climate variability and observed climate change. The projected increase in temperature and decrease in rainfall under the B2 and A2 10 high percentiles 2030s and 2050s scenarios will likely further lower the available water supplies and negatively affect water quality. Moreover, flooding will likely cause damage on towns and villages located in the proximity of the flood plain such as Tessenei and Tekombya.

The capital city, Asmara, is fully relied on reservoirs for its water supply. The B2 and A2 high 10 percentile 2030s and 2050s scenarios, with increase in temperature and decrease in precipitation, will likely lower the summer stream flows but increase evaporation. On the other hand, heavy precipitation events with increased frequency, B2 and A2 high 90 percentile 2030s and 2050s scenarios, will likely trigger frequent flooding which will likely increase the risk of contamination of reservoirs and increase waste water treatment cost.

5.8.2.7.4.3. Livestock

Livestock water supplies are already highly sensitive to observed climate variability and climate change. Under the A2 and B2 high 10 percentiles 2030s and 2050s scenarios ,with increase in temperature and decrease in precipitation, livestock population will likely be vulnerable to frequent drought and drying of water points. Under the A2 and B2 high 90 percentile 2030s and 2050s, alternate frequent flooding and heat stress will likely damage livestock and trigger potential diseases. Moreover, the browsing and grazing land use will likely to lose significant soil moisture as a result of intense heating which will in turn pose the risk of wind erosion and subsequent land degradation impacting livestock.

5.8.2.7.4.4. Ecosystems and their Goods and Services

The climatic and non-climatic pressures in combination have already affected and continue to affect the vitality, regenerative capacity and productivity of the forests / woodlands and their ability to supply goods and services for the livelihood of the entire population in the drainage basin. Future climate change will likely further exacerbate shortage of wood, both for energy and local house construction; decline of none-wood forest products such as frankincense, gum Arabic, doum palm leaves, wild fruit, wild medicine and fodder which are sources of income for local community.

Projected climate change under the B2 and A2 high 10 percentile 2030s and 2050s scenarios will likely impact soil moisture through increased evapotranspiration which will likely negatively affect the growth of trees. Spatial and temporal variability of precipitation reduces soil moisture and thus affects negatively the survival rate and growth of planted tree seedlings (Price, *et al*., 1999). Such phenomenon is common in some afforestation sites of the drainage basin. On average, current survival rate does not exceed from 60-70% in the Headflow and Mereb Catchment and 40 - 60% in the Gash catchment due to recurrent drought (NAPA, 2007). These survival rates will likely be further lowered under the B2 and A2 high 10 percentile 2030s and 2050s scenarios due to projected frequent and severe drought as well as under the B2 and A2 high 90 percentile 2030s and 2050s scenarios due to projected flooding. Moreover, rapid expansion of invasive alien species into the riparian area has also been seen to compete for land, water and nutrients. This invasion will likely to advance further with increasing climate change as the changing climate will likely be more suitable for these invasive species to thrive than the natives (IPCC, AR4, 2007).

The most vulnerable species of tree will likely be those shallow rooted with narrow temperature tolerance (e.g. *Dodonaea angustifolia, Psiadia punctulata, Meriandra bengalensis* and *Otostegia integrifolia* and those that have slow growing habits such as *Olea africana and Juniperus procera.*

5.8.2.7.4.5. Human Health Sector

Based on desktop qualitative assessment, diseases that are climate change and water related with certainty are malaria, malnutrition, diarrhea, schistosomiasis and leishmanisis. Relatively adequate information is available for the first four in the drainage basin.

Malaria

Malaria has the highest prevalence rate in the Basin. The main malaria transmission season is September to November following the cessation of the rainy season. The endemicity of malaria is largely dependent on the parasite species and climate variability, which broadly determine the intensity and length of transmission in a year. Malaria prevalence distribution for 2000-2001 shows that the disease has extended to the highland of the drainage basin. The situation of highland malaria is that incidence are occurring, but adequate documentation are not available, hence the need of investigation and surveillance. Variations in malaria transmission are associated with changes in *temperature, rainfall, and humidity* as well as the level of immunity (IPCC, AR4, 2007). All of these factors can interact to affect adult mosquito densities and the development of the parasite within the mosquito. Mosquito as well as plasmodium have optimum temperatures and humidity for their survival and replication where the optimum temperature range and relative humidity for mosquito are 12-35^{0}C and 60 %, respectively while the optimum temperature range for plasmodium is 10-32^{0}C. These temperature, rainfall, and humidity conditions required by malaria are increasingly met by the B2 high 90 percentile 2030s and 2050s scenarios which will likely increase malaria prevalence in the drainage basin.

Current knowledge on climate change impact in the health sector is mainly a qualitative assessment and based on literature review. Eritrea will create a condition to carry out a more in depth analysis in future NC. The analysis will include an analysis of the current occurrences and links to ENSO and other climate phenomena. This will require data compilation and more research. Related studies on malaria will be consulted such as: http://www.ajtmh.org/content/77/6_Suppl/61.full

Malnutrition

Malnutrition levels both in protein-energy malnutrition (PEM) and micronutrients are very high in the drainage basin. The acute global malnutrition in the basin ranged from 19.8 % in Gash to 7.8% in Mereb. Under the A2 and B2 high 10 percentile scenarios, malnutrition will likely to increase as a result of drought. It will also likely to increase under the A2 and B2 high 90 percentile scenarios as a result of potential inundations and subsequent decrease in crop yield. This is a very important topic for Eritrea. Eritrea will explore the possibilities to create the conditions to conduct model-based assessment for the next submission of national communication.

Diarrhea

Diarrhea is a poverty disease with high under-nutrition status, low accessibility to safe water, water sanitation and waste disposal systems. Diarrhea cases are more prevalent during higher peak of the rainy months indicating possible contamination of drinking water by flood that carries different contaminants. Only about 32% of the people have access to pipe water which is considered safer and only about 28 % have different type of latrines. Children less than five years old are the most vulnerable to diarrheal diseases mainly due to poor hygiene, very low provision of safe water, flooding, high water and food contamination due to shortage of water. The situation is worse in rural areas with only 3 % have access to proper excreta disposal system. Under climate change scenarios associated with either drought or flooding, Diarrhea will likely to increase and remain to be one of the major killers of the Poor and Children under the age of five.

Schistosomiasis

Water shortage and droughts from climate change could increase demand for irrigation particularly in arid regions and this need will expand snail populations resulting into higher risk of human infection with schistosomiasis parasite. Currently, the disease is more prevalent in Mereb-Gash Basin. Under the B2 high 10 percentile 2030s and 2050s scenarios, schistosomiasis parasite will likely further to prevail and infect more people in the drainage basin.

5.8.3. Adaptation Options to Potential Future Climate Risks to Water Resources

Adaptive capacity is the property (potential) of a system to adjust its characteristics or behaviour, in order to expand its coping range (i.e., realized adaptive capacity) under existing climate variability, or future climate changes. In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. The adaptation process requires the capacity to learn from previous experiences to cope with current climate and to apply these lessons to cope with future climate, including *surprises*.

In this setting, four steps have been followed to identify and assess adaptations. The first step involves the identification of existing and potential adaptations. The second step reviews these options in light of their actual or potential effectiveness in addressing current climate vulnerability and risk. The third step involves an assessment of the effectiveness of these options in light of potential climate futures. The fourth step which involves prioritizing certain adaptations over others, based on agreed criteria will not be undertaken at this stage due to resource and time limitations. Nonetheless, the last step could be carried out as a follow up to the preparation of SNC which will aim the formulation of adaptation strategy for inclusion in national development plans and sectoral policies and designing of concrete projects / programmes for sizeable funding for implementation.

5.8.3.1. Identification of Existing and Potential Adaptations Policies and Measures

A number of existing adaptations polices and measures as related to water resources have been identified and described in earlier sections under seven broad categories. These are summarized in Table 5.20.

Table 5.20: Existing Planned and Autonomous Adaptations

Adaptation Policies and Measures			**Type of Action**
1	**Legal Framework**		
	1.1	Water Policy	Planned
	1.2	Water Law	Planned
	1.3	Financing Structure	Planned
2	**Water Resources Management, Use and Development**		
	2.1	Sectoral Water Management	Planned
	2.2	Watershed Management	Planned + Auto.
	2.3	Arable Land Management	Planned + Auto.
	2.4	Land Use Management	Planned + Auto
	2.5	Irrigation Infrastructure	Planned + Auto.
	2.6	Water Management and Allocation for Irrigation	Planned + Auto.
	2.7	Water Supply Management Systems	Planned + Auto.
	2.8	Water Harvesting Structures	Planned + Auto
	2.9	Soil and Water Conservation	Planned + Auto
3	**Modeling Water Resources**		
	3.1	Surface Water	Planned
	3.2	Ground Water	Planned
	3.3	Agro-climatological Variables	Planned
4	**Water Information System**		
	4.1	Hydrological	Planned
	4.2	Meteorological	Planned
5	**Capacity Development**		
	5.1	Institutional	Planned
	5.2	Human	Planned
	5.3	Financial	Planned
6	**Monitoring and Evaluation Plan**		Planned
7	**National Policies and Action Plans**		
	7.1	Macro policy Document	Planned
	7.2	Poverty Reduction Strategy Paper (PRSP)	Planned
	7.3	Food Security Strategy Paper (FSS)	Planned
	7.4	National Adaptation Programmes of Action (NAPA)	Planned
	7.5	National Environmental Management Plan (NEMP)	Planned
	7.6	National Environmental Impact Assessment Procedures & Guidelines (NEIAPG)	Planned
	7.7	National Action Programme (NAP of UNCCD)	Planned
	7.8	Initial National Communication (UNFCCC)	Planned
	7.9	National Biodiversity Strategy Action Plan (UNCBD)	Planned
	7.10	National Gender Action Plan (NGAP)	Planned
	7.11	Integrated Water Resources Management Plan (IWRM)	Planned

Source: NVATWG, 2011

Additional potential adaptation options based on the assessment of current and future climate risks and vulnerabilities as well as consideration of the results of integration of climate change impacts which have been conducted earlier are listed below on sector- by- sector basis in Table 5.21.

Table 5.21: Additional and New Identified Planned and Autonomous Adaptation Options

	Additional & New Planned Adaptation Options		
1	**Water Resources**		
	1.1	**Supply-Side Adaptation**	
		1.1.1	Increasing storage capacity by building new reservoirs and dams considering CC in frontline
		1.1.2	Carry out assessment on surface & groundwater resources potential in all drainage basins
		1.1.3	Establish efficient groundwater monitoring network system
		1.1.4	Develop additional alternative water sources in a sustainable way
		1.1.5	Develop directives and regulations for drilling activities
		1.1.6	Develop integrated watershed development and regulatory plan
		1.1.7	Develop effective, feasible and acceptable water recharging mechanisms
		1.1.8	Develop and implement building code for water harvesting
	1.2	**Demand-Side Adaptation**	
		1.2.1	Develop a strategy for public awareness on linkage b/n water, socio-economic & climate change issues
		1.2.2	Develop directives and regulations to overcome groundwater overexploitation
		1.2.3	Develop sustainable water use efficiency guidelines for a better management and use
		1.2.4	Develop alternative techniques for industries. i.e. recycling, harvesting, desalination etc
	1.3	**Supply and Demand Adaptation**	
		1.3.1	Review and enact the draft water Policy and law with consideration of climate variability & change
		1.3.2	Establish a functional institutional set-up with clear mandate
		1.3.3	Introduce Watershed as a Planning Unit
		1.3.4	Develop appropriate land use classification system at watershed level
		1.3.5	Establish clear regulations and legislations in terms of pricing policy and water tariff
		1.3.6	Institutionalize water sector at all levels that recognize an integrated water resource management
		1.3.7	Develop efficient institutional framework for operations and maintenance of water utilities
		1.3.8	Establish clear strategies that enhance the management and development of water resources.
		1.3.9	Develop strategies and action plans for efficient integration, coordination and use of service utilities.
		1.3.10	Promote a comprehensive catchment treatment programs
		1.3.11	Develop indicators and introduce monitoring and evaluation system in catchments areas
		1.3.12	Develop rural water supply implementation guidelines
		1.3.13	Promote surface and groundwater modeling by factoring environmental, socio-economic and climate change scenarios
		1.3.14	Ensure community involvement at all levels of project cycle
		1.3.15	Introduce efficient water use and management technologies
		1.3.16	Develop training strategy for communities on standard soil and water conservation techniques
		1.3.17	Develop or adapt socio-economic and climate models to carry out studies on demand and supply
		1.3.18	Develop an improved supply network and water truck system according to the demand figures
		1.3.19	Build up strategies and action plans for additional water storages to meet population growth, urbanization and climate variability and change informed by scientific assessment
		1.3.20	Develop a national comprehensive systematic observation action plan factoring regional, national and international systems such as GCOS, GUAN, WMO, etc
		1.3.21	Integrate IWRM in harmonizing the land law and land use systems
		1.3.22	Establish national institution which will be responsible to coordinate all meteorological services
		1.3.23	Develop regulation and standards to introduce primary effluent treatment plant for all industrial units
		1.3.24	Streamline gender in water issues to qualify decision making and implementation processes
		1.3.25	Develop a strategy for short and long term courses including implementation plan
2	**Agriculture**		
	2.1	**Crop Sub-Sector**	
		2.1.1	Develop a strategy to promote high value added products
		2.1.2	Develop and implement sound land tenure to ensure long-term investment in agriculture
		2.1.3	Develop a strategy to promote effective, feasible and acceptable water harvesting technologies
		2.1.4	Promote soil and water conservation schemes

		2.1.5	Promote investment in irrigation schemes
		2.1.6	Develop a strategy to promote agricultural extension services
		2.1.7	Promote horticulture and sub-urban horticultural activities
		2.1.8	Update & Enforce the environmental management plan
		2.1.9	Promote effective utilization of EIA
		2.1.10	Develop public awareness strategy, implement, monitor and evaluate
		2.1.11	Adapt and implement efficient irrigation methods and techniques (drip irrigation, water sprinkler, etc)
		2.1.12	Develop Action Plan and implement PRSP
		2.1.13	Establish early warning system and preparedness strategy
		2.1.14	Develop drought-resistant, heat shock and early-maturing crop varieties
		2.1.15	Promote agricultural research factoring climate variability and change and driving socio-economic
		2.1.16	Promote technology transfer and information exchange
		2.1.17	Study and improve traditional farming skills as a means of coping with climate variability and change
	2.2	**Livestock Sub-sector**	
		2.2.1	Promote pasture water supply
		2.2.2	Promote seasonal forecasts, their production, dissemination, uptake and integration in model-based decision-making support systems
		2.2.3	Promote livelihood diversification along with expanding access to finance, insurance, market and road networks to isolated communities
		2.2.4	Intensify animal disease management through indigenous and scientific techniques
		2.2.5	Promote village level poultry farming
		2.2.6	Develop a strategy plan to enhance livestock productivity and production
		2.2.7	Support pastoralists to lead sedentary livelihood to access adequate social services
		2.2.8	Promote dairies and support to sub-urban livestock production
		2.2.9	Promote intensification of the pastoral system
3	**Ecosystem**		
	3.1	Promoting community forestry/agro-forestry such as multipurpose tree planting at home stead, etc;	
	3.2	Planting drought resistant trees or shrubs for forage development	
	3.3	Enhancing management of permanent and temporary enclosures	
	3.4	Promoting fuel wood conserving stoves	
	3.5	Promote wood energy substitutes such as solar, wind, electrical, kerosene, liquid propane gas etc	
	3.6	Substitute house roofs with corrugated iron sheets and other roofing materials	
	3.7	Institutional capacity building, awareness raising and training including organizing community-based committees to manage local forestry	
	3.8	Promote afforestation technologies	
	3.9	Promote efficient removal of invasive non-native vegetation from riparian areas	
	3.10	Promote research on fodder trees and shrubs	
	3.11	Promote and incentivize non-wood construction materials and farm implements to prevent further depletion of the country's forest resources	
4	**Human Health**		
	4.1	**Malaria**	
		4.1.1	Promote use of environmental, physical and chemical vector control
		4.1.2	Enhance early warning on weather changes
		4.1.3	Promote surveillance and research for disease and vectors
		4.1.4	Develop and implement land use planning to reduce flash floods
		4.1.5	Promote health education
		4.1.6	Develop a strategy for integrated control approach of vector and water-borne disease
		4.1.7	Institutionalize drugs and bed nets distribution systems for malaria
		4.1.8	Implement prophylactic medication against malaria during risk seasons
	4.2	**Malnutrition**	
		4.2.1	Promote supplementary feeding for children
		4.2.2	Enhance availability of clean water
		4.2.3	Promote community early warning on weather changes
	4.3	**Diarrhea**	
		4.3.1	Enhance awareness on health and disease

		4.3.2	Enhance improved health infrastructure
		4.3.3	Increase access to clean water sources
		4.3.4	Promote strategies for provision of emergency water supply
		4.3.5	Develop the culture of frequent washing of hands and body
		4.3.6	Enhance provision of sanitary facilities
		4.3.7	Improve refugee camp's water and sanitation systems
	4.4	**Schistosomiasis**	
		4.4.1	Design, construct and use irrigation systems that are discouraging vector breeding (e.g. snails)
		4.4.2	Avoid swimming in pond or stagnant riverbeds
		4.4.3	Control insect breeding sites around the home-stead and draining wet areas

Source: NVATWG, 2011

5.8.3.2. Effectiveness of Existing and Potential Adaptations in Light of Current Climate

At this stage, ongoing and potential adaptations have been identified and fully described. In this section, three policy questions have been explored in light of their actual or potential effectiveness in addressing current climate vulnerability and risk. These questions are: (1) how do these options and policies need to be improved to deal with today's climate? (2) How do these options and polices reduce vulnerability today? (3) What are the additional strategies identified?

The ongoing options and polices need to be improved in such a way that cross-sectoral approach should be adopted and pursued. The strategy should take water resources, including the point rainfall, groundwater and surface water resources, as an integrator to deal with today's climate hazards occurring across sectors in that the impacts of climate variability and change on water resources propagate naturally to other human and natural systems. Cross-sectoral strategy has to be pursued by identifying those sectors which have logical linkages with water resources (Figure 5.28), identifying the indirect effects of climate variability and change and designing additional adaptation options, polices and measures to respond to the residual impacts.

When these additional adjustments or adaptive capacities are integrated to the ongoing planned and autonomous adaptations, as appropriate, and fully realized, the coping range of systems including human and natural, managed and unmanaged will expand. This in turn displaces critical thresholds, enhances resilience while reducing residual impacts and hence reducing overall vulnerability. These strategies are listed in Table 5.21 comprising additional set of policies and measures targeted to remove actual barriers and maximize actual opportunities.

5.8.3.3. Effectiveness of Existing and Additional Adaptations in Light of Future Climate Change

The effectiveness of existing and additional adaptations in light of future climate change could be assessed in terms of three policy questions. These are: (1) how do these options and policies need to be improved to deal with future climate and variability? (2) How do these options and policies reduce vulnerability in the future? (3) What are the additional/new strategies identified?

The ongoing and additional adaptation options, policies and measures could be improved to deal with future climate and variability by developing a dynamic and process-oriented approach to adaptations referencing certain indicators. Careful monitoring and evaluation (M&E) of implemented adaptation measures can enable to assess what is working, what is not working, and why. Learning by doing is also another approach to be pursed. This approach will enable to: undertake midcourse corrections in implemented adaptations, so that they meet their objectives more efficiently; and improve the understanding of the determinants of adaptive capacity so that capacity development activities can be more successful from the outset.

Adaptation and new options, policies and measures could reduce vulnerability in the future by pursuing strategies and actions which could reduce uncertainty in climate change impact projections, by enhancing adaptive capacity inherent in the system representing the set of resources available for adaptations, as well as the ability of the people living in the system to use these resources effectively in the pursuit of adaptation. Such resources are natural, financial, institutional or human, and include access to ecosystems, information, expertise, and social networks. However, the realization of this capacity (i.e., actual adaptation) may be frustrated by outside factors; these external barriers, therefore, will be addressed. At the basin level, such barriers may take the form of national regulations or economic policies that make certain adaptation strategies unviable. New/ additional strategies are listed in Table 5.21 comprising a set of new policies and measures targeted to remove potential barriers and maximize potential opportunities.

5.8.3.4. Prioritization and Selection of Adaptation Policies and Measures

This step can be used as an entry point for future work in the third national communication to develop the recommended adaptation polices and measures in the SNC into an adaptation strategy along with the analysis of barriers, opportunities, synergies, conflicts and unintended consequences to adaptation. The objective of developing adaptation strategy must be mainstreaming adaptation into development process, national and sectoral policies and prepare fundable projects and programmes for implementation. Eritrean NAPA was developed into an adaptation strategy in the same line. Thus, there is a prior in-country experience of prioritizing adaptation options and formulating adaptation strategies which can be relied on whenever it is required.

Eritrea's National Adaptation Programmes of Action (NAPA) is one of the most dynamic NAPAs among the Least Developed Countries (LDCs) which can be seen as one of the success stories for the country. Nonetheless, this is not an end by itself. Being a framework for adaptation, NAPA has provided information to national process for adaptation, such as designing adaptation strategy and specific projects, and mainstreaming adaptation into sustainable development programmes. NAPA has articulated, inter alia, priority adaptation needs and concerns, including those considered to be most urgent; barriers to adaptation, including legal arrangements; institutional management, financial and technological aspects; and opportunities for adaptation, including policies and plans. Besides, a number of concrete adaptation projects and programmes have been prepared, submitted, approved and funded by GEF/UNFCCC under various funding sources of the Convention such as Adaptation Fund (AF), LDCF, GEF trust fund, SGP, RAF+, etc. Nonetheless, some of these projects when transmitted to their envisaged landscape for actual implementation encountered a number of external barriers. Removing these barriers is the priority if key vulnerable groups at local levels are to harvest the fruits of NAPA.

5.9. Impact, Adaptation and Vulnerability Assessment of Agriculture Sector

5.9.1. Current Climate Vulnerability and Adaptation of Agriculture Sector

Despite adaptation polices and measures implemented under water resources sector also potentially address current vulnerability and adaptation concerns of agricultural sector, there are specific vulnerabilities, autonomous and planned adaptations specific to agriculture. These specific issues have been addressed in this section.

5.9.1.1. Current Adaptation in Agriculture Sector

Adaptation baseline is a description of the recent and current adaptation experience, including policies and measures currently in place, as well as an assessment of current adaptive capacity. Assessing adaptation experience involves two main processes. First, through scoping and synthesis of information on existing polices and measures relevant to adaptation in agriculture sector. Second, an assessment of the system's capacity to adapt to current hazards- i.e., how well have these polices and measures worked?

5.9.1.1.1. Scoping and Synthesis of Information on Existing Agricultural Policies and Measures

This section has identified and evaluated a number of existing polices and measures, and current or traditional coping mechanism-strategies, that are specific to agricultural sector. The discussion is organized into crop and livestock sub-sectors.

A. Crop Sub-sector

The existing key coping strategies for the rain-fed crop production are seed selection, utilization of surface and sub-surface water sources, application of late sowing and early maturing crops, breeding of drought resistant and high yielding variety crops. Plant breeding is currently implemented Ministry of Agriculture (NARI) and other institutions. However, it is in its infant stage and it should be strengthened as a planned coping mechanisms. These key coping strategies are discussed in detail in the following sections under major farming activities.

A.1. Subsistence Farmers

From historical perspective, Eritrea's farming communities especially the poor subsistence farmers are severely affected by climate variability and extreme climate events, which have been manifested in spatial and temporal variability of rainfall patterns followed by subsequent droughts. In order to overcome these pressing problems the farmers have developed for centuries a traditional / autonomous crop production coping skills to adapt changing climate conditions including crop rotation, use of early and late season crops and cultivars, fragmented land-holding systems and mixed cropping and inter-cropping . Although the autonomous strategies are effective, their application is in decline due to less attention by the current subsistence farmers.

The major coping strategies employed by subsistence farmers comprise physical and biological soil and water conservation. Nonetheless, the implementation of both the physical and the biological soil conservation measures require skills and financial inputs for their proper implementations. Since the subsistence farmers lack these resources, the quality of the work is not properly done in many parts of the country and hence output is insufficient. In order to get good results, the farmers need complete packages of educational and financial support by the government and other private institutions.

A.2. Small-Scale Irrigated Farmers

The small-scale irrigated farmers livelihood depend on growing irrigated vegetable production such as tomatoes, red pepper, cabbage, lettuce, etc… The traditional coping strategies are using water wells, ponds, and dams for irrigation, repairing irrigation canals, replacing perennial plants by annuals, growing expensive products and mulching to prevent moisture evaporation. During drought years, the water table is getting lower and lower and the coping strategy is to increase the depth of the well. In addition, they divert any available runoff to their fields, construct small ponds, and reduce cultivated area and irrigation sequence. Few of the existing water dams, which are located in places where the local farmers have some knowledge of vegetable production, are used for irrigation and the rest are used as a source of water supply for human and livestock consumption. Nonetheless, most of these dams are constructed without consideration of the need of catchments treatment, which could result the reduction of the dams longevity due to siltation. A good example for this is the Zula dam in the eastern lowland. Even the dams with catchments treatment have land conflict problems between the farmers upstream and downstream mainly due to lack of proper planning. The coping strategy for this problem of siltation is afforestation and enclosure of the catchments area.

A.3. Spate Irrigated Farmers

The spate irrigated farmers livelihood depends on crop production by diverting rivers that flow seasonally from the highland to the lowland areas. The key autonomous coping strategies are using diversion of flood water, construction of ponds and wells, reducing irrigation field sizes, producing vegetables that require less moisture (e.g. watermelon). In this system minimum annual floods are required to produce crops and frequently the floods are inadequate in number and size. The coping strategy for this problem is by reducing irrigated fields and planting forage for animals and planting drought resistant crops. These diversion structures are made from tree branches and are constantly subject to destruction during heavy floods. In such cases, it affects the farmers not only with crop failure but also with animal feed availability, which animals depend on crop residue. The weakness of this coping mechanism is low capacity of the farmers and in particular low supply of oxen to construct water control structures at field level. The farmers need support from planned coping strategies which are currently being implemented but on a limited scale. These planned coping strategies are aimed to enhance the autonomous coping mechanism by increasing their capacity in controlling the floodwater. In severe drought years, the coping mechanism of the farmers is by selling animals and making loans.

A.4. All Farmers

However, the most important issue by all types of farmers is soil moisture conservation. The key coping strategies against low soil moisture include using conservation tillage, deep planting, mulching and use of late planting and early maturing crops. For this purpose, a pilot project involving three sites was implemented by the Research institutions of the MoA, in 2003-2004. The sites were Adilogo, Hazemo plain and Goluj. Wider application of the pilot project has not been made possible due to lack of adequate funds. This planned coping strategy should be enhanced because it has proved to be a good method for dry land farming.

B. Livestock Sub-sector

The main planned coping strategy being undertaken through projects and programmes are directed to improve feed and water supply availability for livestock in permanent villages and to provide food assistance for the neediest households. Government assisted by financing agencies has been implementing programmes/ projects to develop rangeland and water points in the lowlands. One example is the IFAD Gash-Barka Agricultural and Livestock Development. Although this approach of coping strategy to feed and water shortages is viable, the interventions taken so far are very limited in scale as compared to the needs of the pastoralists. Experience shows that these projects and programmes were not effective mainly due to inadequate implementation capacity and local level institutional arrangements for management of rangeland and water. Other planned coping strategies against shortage of feed during droughts or the dry season include conservation of standing hay and crop residue, but this practice is also very limited to become effective coping strategy for shortage of feed. In respect to coping with water supply shortage, the strategy has been building small ponds and digging wells. The strategy has been effective in many areas although it had always problems of management and maintenance because of poor local level institutional capacity. In coping with livelihoods, emergency food aid has been a major strategy.

B.1. Pastoral System

The main autonomous coping system for shortage of feed and water is extensive animal movement in all the pastoral systems. This strategy has been practiced even without the occurrence of drought; hence it is rangeland management system in dry lands. The movement varies by region in respect to distance traveled, time, destination, route and animal species involved. This coping practice is aimed to obtain feed and water during the long dry period which lasts about 8-10 months long depending on the rainfall year and region. In this way the annual grazing pattern consists of wet and dry season grazing camps where animals are in their permanent villages during the rainy season and they graze scattered over large area because water and feed is available in most of the rangelands.

During drought and low rainfall years, animal productivity and number of animals are decreased resulting into inadequate surplus animals for sale and supply of milk. Pastoralists tend not to breed or mate animals fearing that calving will coincide with period without feed which may result in death. As a sequel to this, the pastoralists suffer from shortage of milk, meat and cash to purchase cereal grains and other essential household commodities. In this situation the coping strategy is to sell more of the breeding animals in exchange of cash, thereby causing damage to their breeding herds and flocks. They also go to nearby towns to search casual /temporary work and those who have male camels and are physically abled practice activities such as collection of fuel wood and selling it in towns. The women headed families, the elderly, the disabled and those who are poor and particularly those without male camels are extremely vulnerable because they cannot practice this coping strategy. The coping strategy / maladaptation involving sales of fuel wood is detrimental to the rangeland due to the excessive destruction of vegetation. Promoting soil and water conservation and afforestation programmes involving the key vulnerable groups through incentives such as cash for work and /or food for work could ease maladaptive practices.

One of the emerging coping strategies against the failure of the pastoral system to sustain the livelihoods of the pastoral population is that many of the pastoralists are tending to practice rain-fed cropping. The practice involves diversion of small streams to the crop fields and those residing near the major river basins are planting pearl-millet on the river beds. This coping strategy could be effective in areas where rainfall is favorable, but in drier areas it is unjustified because rain-fed cropping is unviable.

Another method for coping with thermal stress is by shortening the grazing hours in a day. In that animals stay under tree shade for the most part of the day; while they graze in early mornings and late afternoons. However, this coping strategy affects animal production due to the low feed intake as a sequel to the reduced grazing hours in a day.

Thus, animal movement as a coping strategy is not effective at present because increased intensity of climate variability and climate change, changes in land and water use, land fragmentation and chronic wars which involve the grazing land that have been increasingly land mined during the past decades. Thus, its sustainability to maintain satisfactory animal reproduction and productivity has been gradually falling and as a sequel to this, the pastoral system is failing to sustain the livelihoods of the pastoralists. Therefore, this approach should be replaced by planned strategies aimed to produce adequate feed and water for livestock production in their respective villages; reduction of livestock populations or destocking, but increasing the value of individual animals which mean intensification of the pastoral system.

B.2. Agro-Pastoralist System

The agro-pastoralists' livelihood depend on livestock and crop production. From an agronomic production point of view, their coping strategies are similar to the subsistence farmers coping strategy. During severe drought, the agro-pastoralists have to migrate to wet season areas in search of water and grass for their livestock. As it was described in the pastoral system, the animals that are moved are mainly cattle; while the small ruminants remain in the villages. On the other hand, however, they cultivate crops like sorghum and maize and collect the crop residue to be used by their livestock at times of droughts.

The importance of animals in the agro-pastoralist system is that animals are sources of food, and cash (small ruminants) and most importantly oxen constitute the animal power for cultivation, hence crop production without oxen is practically impossible. The manure is also used as nitrogen source of fertilizer. This production system is practiced mainly in the upland regions (Debub and Maakel Regions) where cropping is of high intensity. It is also practiced in some parts of Anseba and Gash-Barka Regions where rainfall is favorable. The main strategy to cope with shortage of feed is through conservation of crop residues; enclosure of grazing land for use during dry season; selective feeding with priority given to oxen; and limited animal movement. In the most severe drought years, farmers also purchase wheat bran to save oxen from death, but this is practiced only by few farmers. The last option of coping strategies for their survival is selling animals, firewood and charcoal. Nonetheless, the best and lasting solutions to these pressing problems of climate variability and observed climate change require government support for establishing permanent water supply and improvement of perennial grasses and fodder species compounded with rotational grazing.

B.3. Livestock Traders

During drought and low rainfall years pastoralists and agro-pastoralists tend to sell more animals to save them from death and to increase their cash flow that will allow them to purchase food and the minimum essential commodities. In periods of successive droughts or low rainfall, livestock producers do not have surplus for sale and as a result livestock traders are unable to carryout their activities. In such situations, the coping strategy of these traders is to cross the boundaries such as that of the Sudan to purchase animals. At the same time, since there is no feed and water supply along the animal tracking routes, the coping strategy is using tracks which mean more cost for the consumer at the terminal markets.

5.9.1.2. Current Vulnerability of Agricultural Sector

Any vulnerability assessment should consider all components of vulnerability including exposure, sensitivity and adaptive capacity. Hence, the purpose of this section is to identify and characterize these components of vulnerability in the agricultural sector.

5.9.1.2.1. Exposures

NAPA identified several current direct and indirect climate hazards embedded in current variability. The direct and indirect climate hazards on agricultural sectors are summarized below:

- Recurrent Drought;
- Increased temperature;
- Decreased rainfall
- Increased hot night and days;
- Change in rainfall pattern both spatially and temporally;
- Period between onset and cessation of the rainy season has been getting shorter over the past century, thereby reducing the annual growing periods;
- Torrential rainfall with heavy runoff and flooding;
- Increased evapotranspiration due to increased aridity index;
- Desertification and increased aridity;

- Increased heat stress;
- Increased long-term variability such as El Nino;
- Increased CO_2; and
- Observed climate change

The key vulnerable social groups are numerous and summarized as follows:

- Subsistence rain-fed farmers;
- Small-scale irrigated farmers;
- Spate irrigation farmers;
- Pastoralists and agro-pastoralists;
- Women headed families as well as women, children & elderly people;
- Rural & Peri-urban poor population;
- Grazers such as Cattle & Sheep; and
- Traders

5.9.1.2.2. Sensitivity

The observed biophysical and socio-economic impacts in the agricultural sector are summarized in Table 5.22 below.

Table 5.22: Climate Hazards, Biophysical and Socio-Economic Impacts in Agricultural Sector

Exposure/Climate Hazard	Biophysical Impact	Socio-economic Impact
-Recurrent Drought -Increased temperature -Decreased rainfall -Increased hot night and days -Increased evapotranspiration -Heavy runoff and Flooding -Desertification - Increased long-term variability such as El Nino - Increased CO_2 -Etc..	▪ Groundwater level dropped (not easily accessible) and dried; ▪ Reduced soil moisture in rangelands and rain-fed agricultural field; ▪ Flooding (mainly occurs due to high intensity of rainfall and bareness of the catchments); ▪ Increased sediment load of streams and water bodies thereby decreasing their capacity; ▪ Increased salinity in inland water supplies; ▪ Decreased pesticide efficacy; ▪ Crop failure particularly early planting and late maturing crops such as sorghum, maize, finger millet; ▪ Drying of irrigation wells; ▪ Loose of genetic cultivars; ▪ Increased erosion; ▪ Increased weeds, pests and diseases; ▪ Increased acidification; ▪ Land degradation and associated desertification; ▪ Drying of natural vegetation; ▪ Declined of perennial grasses; ▪ Decreased soil fertility; ▪ Loose of stability of soil structure; ▪ Decreased soil organic matter; ▪ Shortage of crop residues; ▪ Shortage of browse plants and grasses; ▪ Decreased perennial grasses but increased annual/woody plants; ▪ Increased insect pests/red locust/African army worms; ▪ Decreased productivity of rangelands and hence decreased carrying capacity of	▪ Loss of human life, animals, crops, ecosystems and rangelands due to recurrent drought; ▪ Shortage of water supply for domestic, livestock, industry, wild life and irrigation use; ▪ Loss of water supply sources; ▪ Reduced agricultural production; ▪ Reduced fodder production; ▪ Increased groundwater salinity; ▪ Social conflict due to water shortage; ▪ Reduction and possible extinction of wildlife and natural forest; ▪ Loss of reverine forests; ▪ Loss of irrigated farm lands and infrastructure; ▪ Damage on roads, bridges and other transport infrastructure; ▪ Damage on water Infrastructure; ▪ Reservoir and ponds capacities reduced because of siltation; ▪ Deterioration of livelihood; ▪ Decreased farm income; ▪ Crop production declined; ▪ Shortage of native cultivar; ▪ Shortage of animal product; ▪ Increased malnutrition; ▪ Long movement of herds; ▪ Migration to urban centers; ▪ Conflicts between pastoralists & cultivators for land & water use; ▪ Restricted movement of livestock due to rangeland fragmentation due to land and water use change and grazing roots interfered; ▪ Lowered export trade of livestock; ▪ Increased food aid dependency; ▪ Declined national and household food security;

	rangelands; ▪ Lowered productivity and reproductivty of animals; ▪ High incidences of diseases & parasites; ▪ Animal growth impacted, reduced immunity of livestock & deteriorated livestock health; ▪ Lowered appetite of Livestock; ▪ Loss of reverine forest needed for shade, water & feed	▪ High level of illiteracy due to increased poverty; ▪ Increased food price; ▪ Increased dependency on imported food; ▪ Increased diseases & poverty; ▪ Increased burden of all three kinds of situations requiring relief efforts: sudden disasters, slow-onset disasters, and complex emergencies; ▪ Services from livestock decreases; ▪ Mortality rate increased; ▪ Market changes and volatility; ▪ Increased off-farm employment

Source: NVATWG, 2011

5.9.1.2.3. Current Vulnerability and Adaptive Capacity in Agricultural Sector

Adaptive capacity is the ability of an exposed system to respond to climate change. Adaptive capacity depends on efficient use of available natural and economic resources including wealth, technology, institutions, information, infrastructure, access to ecosystem and socio capital. It has been proved in earlier sections that most of these resources have not been used effectively in Eritrean agricultural system. Identified key socio-economic barriers working in unison with climate hazards contributing to aggravated vulnerability of the agricultural sector can be summarized as follows:

- Land degradation and deforestation of catchment areas of rivers, dams and ponds especially deforestation of reverine forests resulted in massive soil erosion entailing sediment load of water bodies, riverbeds and decreasing their capacity and recharge rate of aquifers;
- Low water resources management, integration and coordination with relevant sectors;
- Low awareness, knowledge and skill among decision makers and government experts about climate variability and climate change processes and climate change science;
- Undermining of the importance of traditional coping strategies;
- Poor design and low efficiency of irrigation systems as well as the technologies are traditional and obsolete;
- Terraces not properly constructed and well maintained to conserve soil and water;
- Maladaptive practices such as overuse of groundwater for irrigation without paying, the use of animal manure for fuel, etc.;
- Poor land management, land tenure, poor quality seeds, cultivation on steep slopes and marginal lands and overgrazing;
- Unplanned land and water use change;
- War especially land mines in the major dry season rangelands; and
- More encroachment of rangelands by cropping

As any agricultural system is dependent on availability of land, water and adaptive capacity of the institutions managing land and water, it is possible to conclude that the ongoing adaptation polices and measures in agricultural sector in Eritrea are not effective in coping with current climate variability and change because the level of burden due to exposure and sensitivity is too much and the adaptive capacity is too weak. Therefore, autonomous and planned, reactive and anticipatory adjustment and additional types of adaptation options, polices and measures, which are effective, feasible and acceptable, have to be identified, prioritized and implemented so that current vulnerability is reduced and coping range is enhanced in so doing prepare for future to minimize the worst and maximize the benefit of future climate change and altered climate variability.

5.9.2. Future Climate Risk Assessment on Agriculture

5.9.2.1. Selecting Framework, Approach and Impact Model

As explained earlier the APF is used as a framework. Within the APF, the natural hazards-based approach is used to assess future climate risks in agricultural sector. The natural hazards-based approach is a climate scenario-driven approach. The climate change scenarios using ensemble method and the socio-economic scenarios using APF guidelines have been simulated in the earlier common sections for water and agriculture. The same model WEAP is used but in different set up environment.

5.9.2.2. Sources of Base Year Data and Scenario Period

This was defined earlier. The scenario period is 30 years (2007-2035) based on the available baseline time series rainfall data for the Basin. The time step of the assessment is monthly. The base year data (2006) has been gathered from the FAO, National Statistics and Evaluation Office and MoA.

5.9.2.3. Method

The FAO irrigation demand only method has been used. It uses crop coefficients to calculate the potential evapotranspiration in the catchment, then determines any irrigation demand that may be required to fulfill that portion of the evapotranspiration requirement that rainfall can not meet.

In this method, the WEAP has been supported by the CropWater 4 Windows 4.3 and the SimCLIM Climate models. The irrigation model, CropWater 4 windows, calculates the Penman-Monteith Reference Evapotranspiration at two meter height above the reference grass from the inputs of topographic and monthly climate data including altitude, latitude, longitude, ambient mean maximum and minimum temperatures, air humidity, wind speed and daily sunshine hours. It also calculates the effective rainfall from the rainfall input. The SimCLIM simulates the future changes for these variables and precipitation in the catchment. Then, the future Reference Evapotranspiration has been calculated in the CropWater 4 Windows 4.3 based on the outputs of the SimCLIM. Finally, these inputs will be used by WEAP to simulate future grain production and irrigation water demand in the Headflow, Mereb and Gash Catchments under different climatic change scenarios.

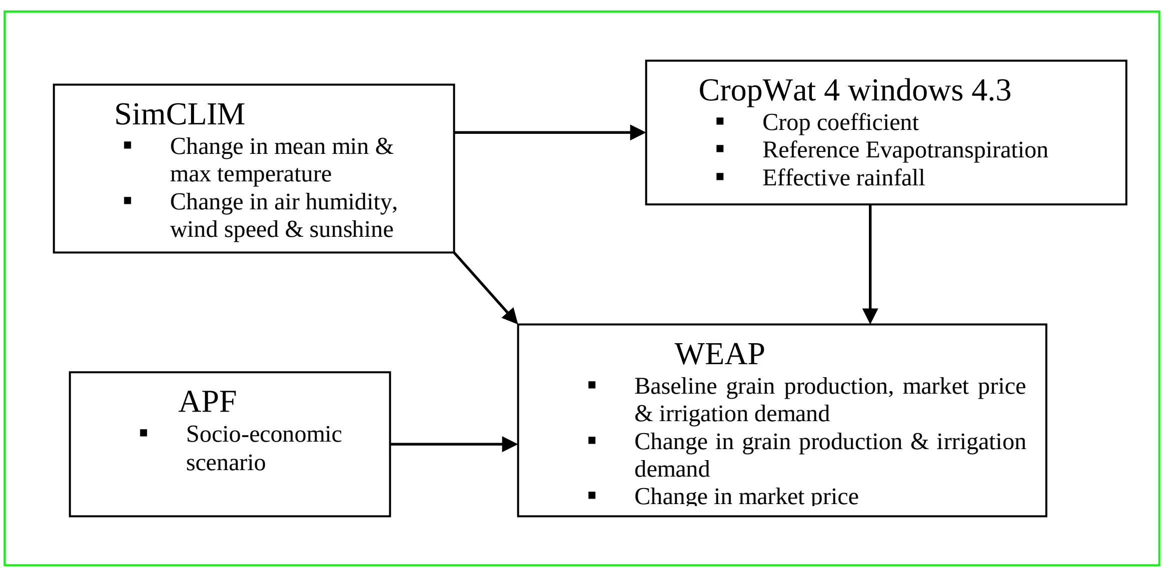


Figure 5.29: Conceptual Models Linkage for Crop Impact Assessment in Mereb-Gash Basin

5.9.2.4. Configuration of the System

The system set up used for agriculture is different from that used for the water resources impact assessments in two ways. First, each catchment is linked to the river not to any groundwater node. Hence, there is no runoff /infiltration to the groundwater and the catchment only contributes runoff to the river. Second, this method does not simulate runoff or infiltration processes.

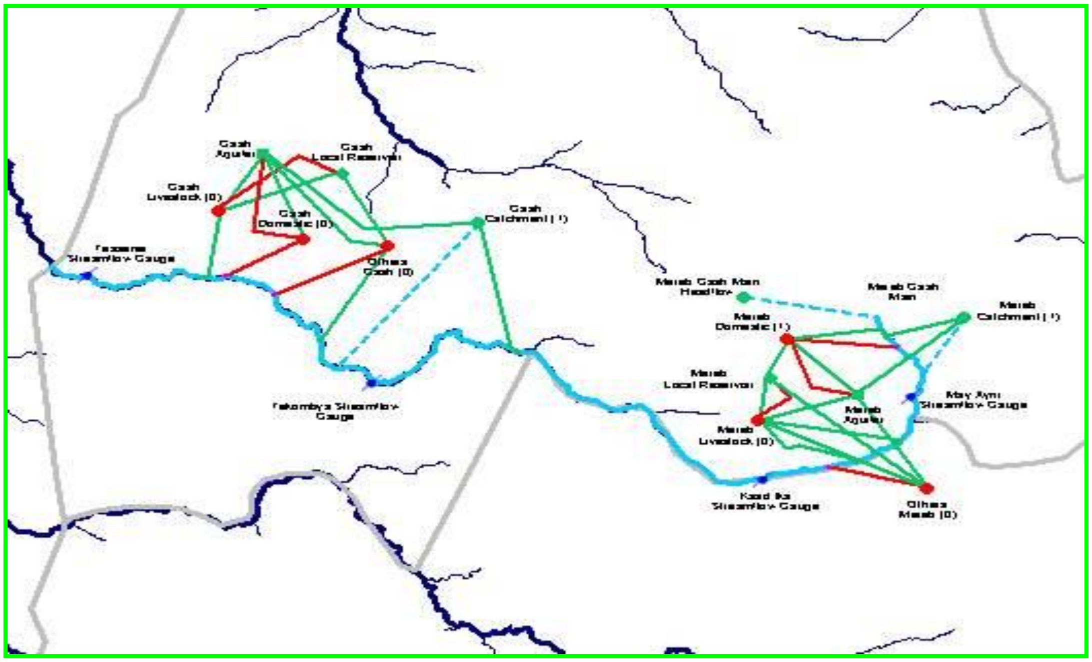


Figure 5.30: WEAP Model Configuration for Crop Impact Assessment in Mereb-Gash Basin

5.9.2.5. Modeling of Potential Climate Change Impacts on the Crop Sub-sector in the Mereb-Gash Basin

Relative to total surface area, Eritrea has modest land resources for rainfed cultivation. Mereb-Gash Basin is the major sorghum, wheat and barley producing region in the country with 53 percent for sorghum and 52 percent for wheat of the national production. Most barley is also produced in this zone. The leading commodities as far as consumption is concerned are wheat (41 percent), sorghum (14 percent) and other roots and tuber crops (11 percent). Sorghum is a staple food crop consumed in different forms. Small rains that usually occurred during April / May have all but disappeared. In recent years, the main rainy season starts later and finishes earlier than the historical pattern resulting in some wheat and millet varieties as well as some native cultivars disappearing from production due to recurring rain-fed crop failures. New crops pests are appearing that have been previously unknown or uncommon. Irrigated crops are also adversely affected due to depletion and drying of water wells on which irrigation depends as well as unusually heavy flooding during the rainy season. These circumstances are increasing the heavy toll on subsistence farmers. Hence, modeling of the impact of climate change on major cereals in the Mereb-Gash Basin has a paramount importance and priority.

5.9.2.5.1. Modeling and Analysis of Potential Climate Change Impacts on Total Yield

The simulated impacts on the total cereal yield under rainfed and irrigated farming practices and different climate change scenarios in the period (2007-2035) is shown in Figures 5.31 and summarized in Table 5.23. All climate change scenarios have been developed for high climate sensitivity (4.5^{0}C) and for the worst and best case SRES projections scenarios (A2 & B2) for the 10 and 90 percentiles. Consistency between mean annual precipitation and mean annual temperature changes has been ensured by simulating concurrent climate changes for a given period in the future. This strategy has been opted in that the lowest and the highest potential climate change impacts are assessed along with the uncertainty so that a set of no-regret adaptation options could be identified for the region.

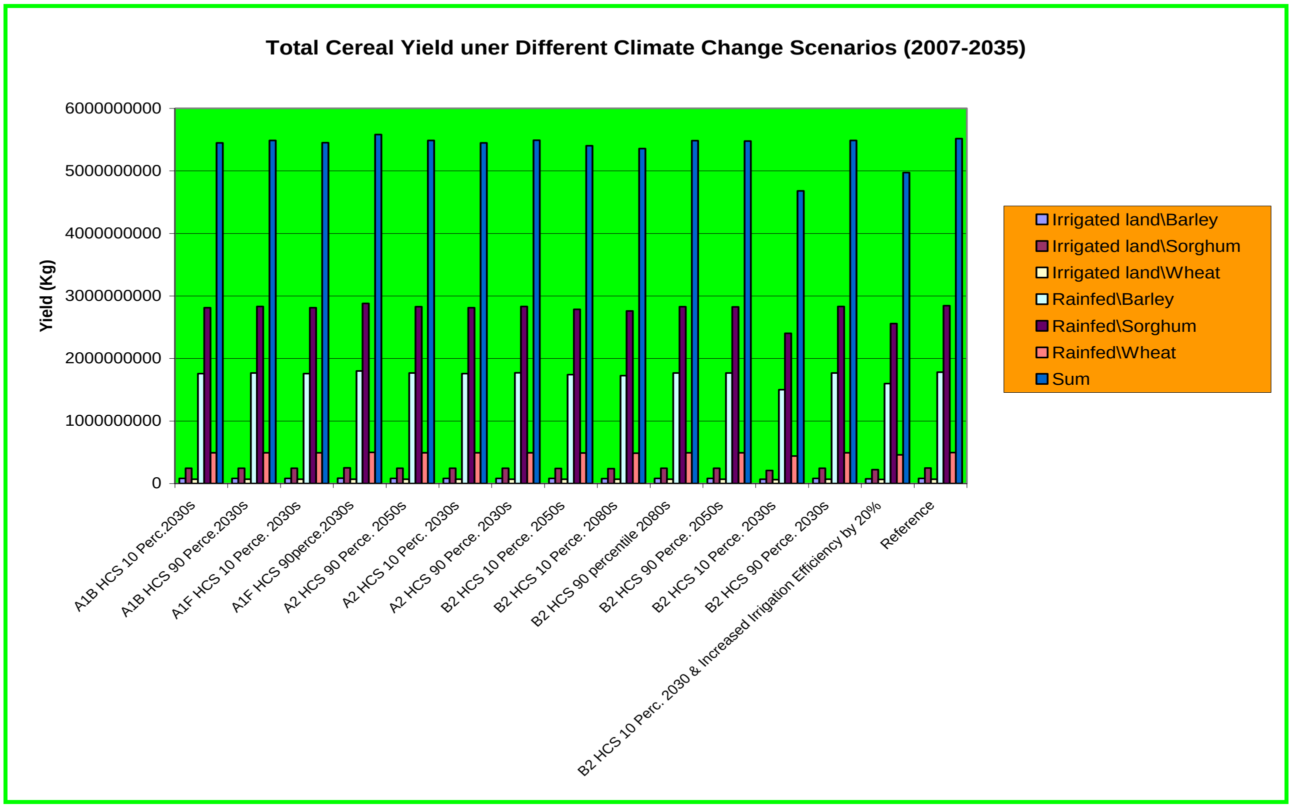


Figure 5.31: Total Yield of Major Cereals for Scenario Period under Different Climate Change Scenarios

Table 5.23: Total Cereal Yields (Million kg) and Change in Yields from the Reference (%) Under Irrigated and Rainfed Conditions Under Climate Change Scenarios in the Mereb Catchment (2007-2035): (Source: NVATWG, 2011)

	Reference	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Irrigated /Barley	82	69 (-16%)	82 (0%)	74 (-10%)	81 (-1.5%)	82 (0%)	80 (-2.4%)	82 (0%)
Irrigated/ Sorghum	246	207	244	221	243	245	238	245

		(-17%)	(-1%)	(-10%)	(-1.2%)	(-0.4%)	(-3.3%)	(-0.4%)
Irrigated/ Wheat	68	61 (-10.3%)	68 (0%)	63 (-7.4%)	68 (0%)	68 (0%)	70 (3%)	68 (0%)
Rainfed/ Barley	1778	1501 (-17%)	1768 (-0.5%)	1598 (-11%)	1756 (-1.2%)	1769 (-0.5%)	1725 (-3%)	1768 (-0.5%)
Rainfed/ Sorghum	2845	2401 (-16%)	2829 (-0.6%)	2557 (-10%)	2810 (-1.2%)	2831 (-0.5%)	2760 (-3%)	2829 (-0.5%)
Rainfed/ Wheat	495	439 (-11.3%)	493 (-0.4%)	459 (-7.2%)	490 (-1%)	493 (-0.4%)	484 (-2.2%)	493 (-0.4%)
Sum	5515	4679 (-15%)	5485 (-0.5%)	4972 (-9.8%)	5448 (-0.5%)	5488 (-0.5%)	5355 (-3%)	5484 (-0.5%)

Where, A = B2 emission scenario HCS 10 percentile 2030s
B = B2 emission scenario HCS 90 percentile 2030s
C = B2 emission scenario HCS 10 percentile 2030s & increased irrigation efficiency by 20%
D = A2 emission scenario HCS 10 percentile 2030s
E = A2 emission scenario HCS 90 percentile 2030s
F = B2 emission scenario HCS 10 percentile 2080s
G = B2 emission scenario HCS 90 percentile 2080
HCS = High Climate Sensitivity

A. Key Findings

A.1. Mereb Catchment Rainfed

- The ensemble GCMs under all climate change scenarios project that future total yield of major cereals including Barley, Sorghum and Wheat under rainfed will likely to decrease from the baseline without any additional crop management practices;
- The ensemble GCMs under the B2 high SRES emission scenario project that future total yield of major cereals under rainfed will likely to decrease between 17 and 0 percent in 2030s;
- The ensemble GCMs under the A2 high SRES emission scenario project that future total yield of major cereals under rainfed will likely to decrease between 1.2 and 0.4 percent in 2030s;
- The ensemble GCMs under the B2 high SRES emission scenario project that future total yield of major cereals under rainfed will likely to decrease between 3 and 0.4 percent in 2080s; and
- Water harvesting and supplementary irrigation to rainfed would minimize the impact of future climate change on total cereal yield

A.2. Mereb Catchment Irrigation

- The ensemble GCMs under all climate change scenarios project that future total yield of Barley, Sorghum and Wheat under irrigation will likely to decrease from the baseline without any additional crop management practices other than current irrigation and efficiency in place;

- The ensemble GCMs under the B2 high SRES emission scenario project that future total yield of major cereals under irrigation will likely to decrease between 17 and 0 percent in 2030s;

- The A2 high SRES emission scenario project that future total yield of major cereals under irrigation will likely decrease between 1.5 and 0 percent in 2030s;

- The B2 high SRES emission scenario project that future total yield of major cereals under irrigation will likely to decrease between 3.3 and 3 percent in 2080s; and

- Improving irrigation efficiency would minimize the impact of climate change on total cereal yield

A.3. Gash Catchment

- Under both rainfed and irrigated farming practices, there will likely no statistically significant yield changes from the baseline under all future climate change scenarios simulated in the Gash Catchment. This could be explained in terms of suitability of soil, topography, climate, and geomorphology for crop production, on one hand and the drought and heat resilient nature of the cultivars in Eritrea, on the other hand.

A.4. Mereb-Gash Catchment:

- Under future climate change scenarios of moderate to medium climate warming and all farming conditions, major cereals will likely to continue to be heat and drought resilient and water efficient crop in Eritrea. But with increased climate change this characteristic will likely be compromised as the critical threshold would be exceeded resulting in vulnerability of the crop sub-sector in the catchment

- Under water harvesting, supplementary and improved full irrigation practices and other technologies, it would be possible to minimize the impact of climate change on cereal yield. However, it could not be possible to avoid fully the potential adverse impacts of climate change to bring about what is known as a “sustainable agricultural production” under uncertain changing climate and demographic factors

- The result is consistent with what projected by the IPCC Fourth Assessment Report (AR4) which has identified that even slight warming in seasonally dry and tropical regions reduces yield, especially sorghum, wheat, maize, barley, rice, etc. Furthermore, modeling studies that include extremes in addition to changes in mean climate show even lower crop yields than for changes in means alone

5.9.2.5.2. Potential Climate Change Impacts on Crop Evapotranspiration

With a large body of smallholders and subsistence farming households in the Mereb-Gash Catchment, there is a special concern over temperature-induced declines in crop yields as a result of increasing shortfall of evapotranspiration and hence increasing frequency of drought which will lead to increased likelihood of crop failure and livelihood impacts including sale of other assets, indebtedness, out-migration and dependency on food aid.

With this primary concern, crop evapotranspiration shortfall in the future in the catchment under different climate change scenarios under both rainfed and irrigated conditions in the scenario period (2007-2035) has been simulated and the results of the modeling are shown and summarized in Figure 5.32 and Table 5.24. In the analysis, the evapotranspiration shortfall (ET Shortfall) is defined as the difference between potential evapotranspiration and actual crop evapotranspiration which determines the crop water requirement in addition to point rainfall during the production season.

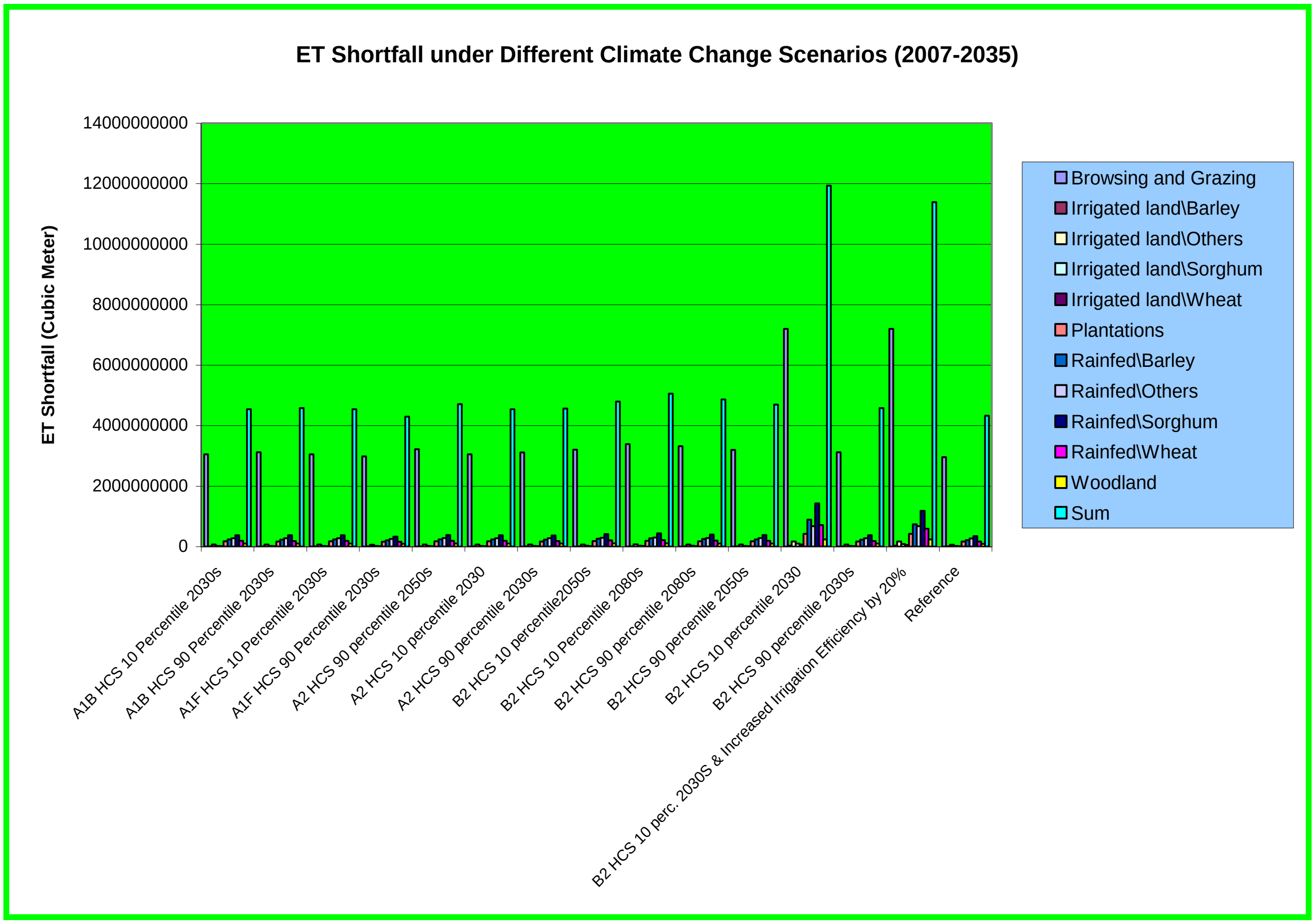


Figure 5.32: ET Shortfall from different land uses under Different Climate Change Scenarios in Mereb Catchment (2007-2035)

Table 5.24: ET Shortfall (Million m^3) and Its Change from the Baseline (%) in Major Cereal Land Uses and Under Different Climate Change Scenarios in Mereb Catchment (2007-2035): (Source: NVATWG, 2011)

	Reference	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Irrigated/ Barley	8	9 (13%)	9 (13%)	33 (300%)	9 (13%)	27 (238%)	10 (25%)	9 (13%)
Irrigated/ Sorghum	24	26 (8%)	26 (8%)	99 (313%)	26 (8%)	81(238%)	29 (13%)	27 (12%)
Irrigated/ Wheat	16	18 (13%)	17 (6%)	66 (313%)	17 (6%)	55 (244%)	19 (19%)	18 (13%)
Rainfed/ Barley	216	238 (10%)	232 (7%)	892 (313%)	234 (8%)	741(243%)	258 (19%)	241 (12%)
Rainfed/ Sorghum	345	380 (10%)	371(8%)	1426 (313%)	374 (8%)	1185 (244%)	413 (20%)	386 (12%)
Rainfed/ Wheat	173	190 (10%)	186 (8%)	713 (312%)	187 (9%)	593 (243%)	206 (19%)	193 (12%)

Where, A = A2 emission scenario HCS 10 percentile 2030s
B = A2 emission scenario HCS 90 percentile 2030s
C = B2 emission scenario HCS 10 percentile 2030s
D = B2 emission scenario HCS 90 percentile 2030s
E = B2 emission scenario HCS 10 percentile 2030s and increased irrigation efficiency by 20%
F = B2 emission scenario HCS 10 percentile 2050s
G = B2 emission scenario HCS 90 percentile 2050s

B. Key Findings

B.1. Mereb Catchment: Irrigated Cereals

- The ensemble GCMs under the A2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall would increase between 6 and 13 % from the baseline in 2030s;

- The ensemble GCMs under the B2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall would increase between 6 and 313% in 2030s which is likely the worst impact;

- The ensemble GCMs under the B2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall would increase between 12 and 25% in 2050s; and

- Water harvesting and the use of improved technology for higher irrigation efficiency would significantly minimize the impact on ET shortfall or irrigation water demand during climate change

B.2. Mereb Catchment: Rainfed

- The ensemble GCMs under the A2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall will likely to increase between 7 and 10% in 2030s;

- The B2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall will likely to increase between 8 and 313% in 2030s;

- The B2 SRES GHG emission scenario with high climate sensitivity projects that the ET shortfall will likely to increase between 12 and 20% in 2050s;

- Water harvesting and supplementary or full irrigation would significantly decrease the impact of climate change due to ET shortfall

B.3. Gash Catchment both Rainfed and Irrigation Cereals:

- The ensemble GCMs with high climate sensitivity and different SRES GHG emission scenarios projects that the ET shortfall will likely to increase during future climate change under both rainfed and irrigated farming practices. Nonetheless, the magnitude of impact would not be as much as that of the Mereb catchment.

B.4. Mereb-Gash Catchment

- The ET shortfall under both the rainfed and irrigated conditions will likely to increase in the future as a result of projected climate change without any additional crop management practices. This result is consistent with the finding of the IPCC Fourth Assessment Report which says *"Impacts of climate change on irrigation water demand requirements may be large"*. Regional studies have also found key climate change and water changes in key irrigated areas, such as North Africa (increased irrigation requirements; Abou-Hadid et al., 2003).

5.9.2.5.3. Modeling and Analysis of Potential Climate Change Impacts on Cereal Market Value

The result of the modeling of the impact of different climate change scenarios on major cereal market value in Eritrea in the model year is shown in Figure 5.33 and summarized in Table 5.25. Nonetheless, specific differences among studies depend significantly on factors such as projected population growth and food demand, as well as on trends in production technology and efficiency. For better result, all these factors have to be considered. In particular, the choice of SRES scenarios has as large an effect on projected global and regional levels of market value, food demand and supply as climate change alone (Parry et al., 2004; Ewert et al., 2005; Fischer et al., 20051; Tubiello et al., 2007a).

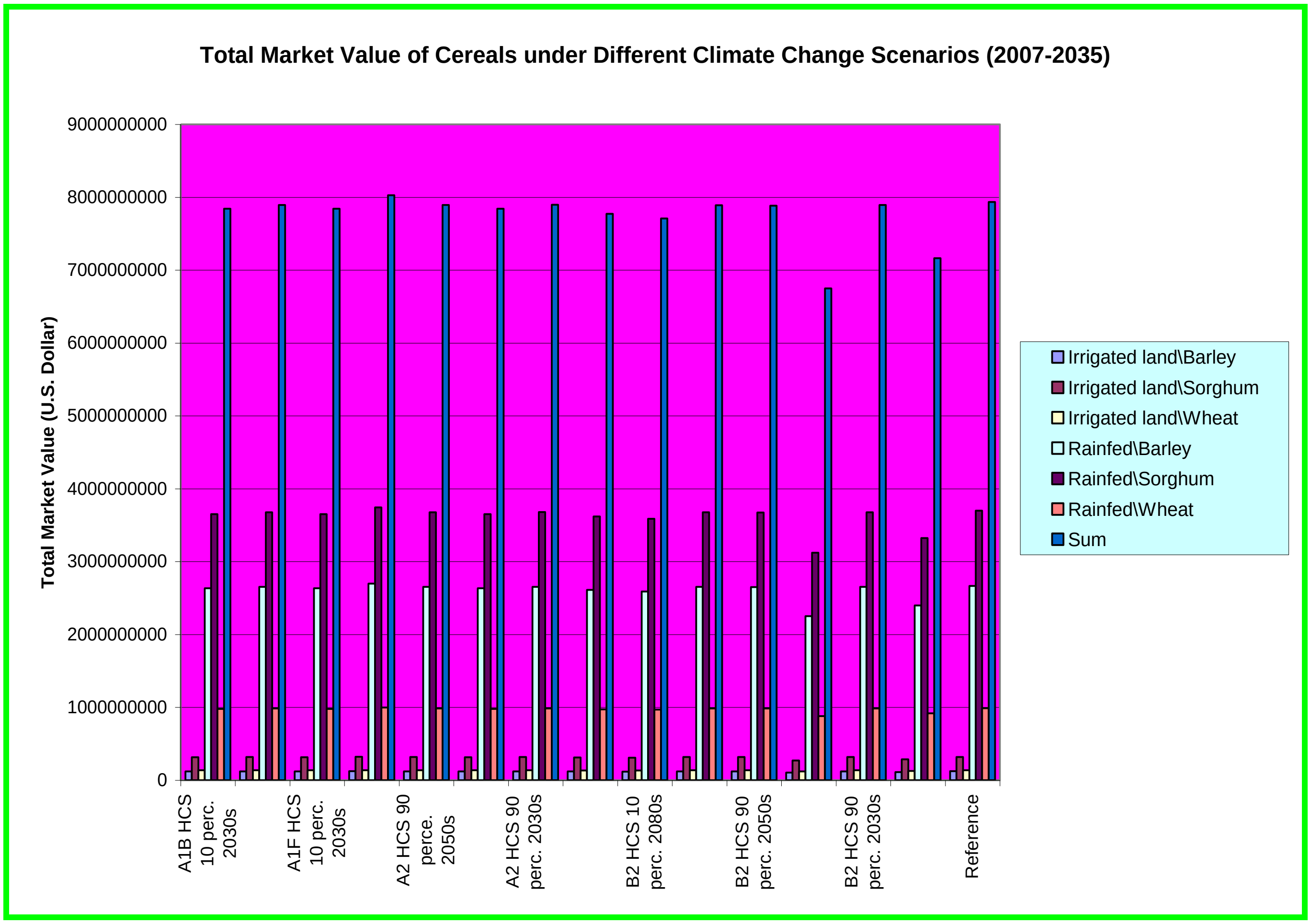


Figure 5.33: Total Market Value of Major Cereals under Different Climate Change Scenarios in Mereb Catchment

Table 5.25: Total Market Value (Million USD) of Cereals under Climate Change Scenarios- Mereb Catchment

	Reference	A	B	C	D	E	F	G
Irrigated/ Barley	123	122 (-1%)	122(-1%)	104(-15%)	122 (-1%)	111(-10%)	120 (-2.4%)	122(-1%)
Irrigated/ Sorghum	320	316 (-1.3%)	318(-0.6%)	270(-16%)	318(-0.6%)	287(-10%)	313(-2%)	318(-0.6%)
Irrigated/ Wheat	137	136(-1%)	136(-1%)	122(-11%)	136(-1%)	127(-7%)	135(-1.5%)	136(-1%)
Rainfed/	2668	2634(-1.3%)	2654(-1%)	2251(-16%)	2653(-0.5%)	2397(-10%)	2610(-2%)	2649(-0.7%)

Barley								
Rainfed/ Sorghum	3699	3653(-1.2%)	3680 (-0.5%)	3122(-16%)	3678(-0.6%)	3324(-10%)	3620(-2%)	3673(-0.7%)
Rainfed/ Wheat	989	981(-0.8%)	986(-0.3%)	879(-11%)	985(-0.4%)	918(-7%)	974(-2%)	984(-0.5%)
Sum	7936	7841(-1.2%)	7897(-1%)	6747(-15%)	7893(-1%)	7163(-10%)	7773(-2%)	7883(-0.7%)

Source: NVATWG, 2011

Where, A = A2 emission scenario HCS 10 percentile 2030s
B = A2 emission scenario HCS 90 percentile 2030s
C = B2 emission scenario HCS 10 percentile 2030s
D = B2 emission scenario HCS 90 percentile 2030s
E = B2 emission scenario HCS 10 percentile 2030s and increased irrigation efficiency by 20%
F = B2 emission scenario HCS 10 percentile 2050s
G = B2 emission scenario HCS 90 percentile 2050s

C. Key Findings

- For all climate change scenarios, the total market value has been projected based on a discount rate. The discount rate has been set at 4 percent for the scenario period;

- Under all scenarios except the B2 SRES emission scenario, the total market value, for both the rainfed and irrigated cereals, will likely be near the present value. That means there would be a decrease in cereal yield but an increase in cereal price. This may have some influence on food security and food cost in the country. This analysis is consistent with that projected by the IPCC AR4 in that crop production in low latitude developing countries would suffer more, and earlier than in mid-to-high latitude developed countries due to a combination of adverse agro-climatic, socio-economic and technological conditions (Alexandratos, 2005); and

- Under the B2 SRES emission scenario, the total market value for both rainfed and irrigated cereals in the scenario period will likely to decrease between 16 and near zero percent in 2030s and between 10 and 2 percent in 2050s. Nonetheless, the impact could be significantly minimized in the near term by supplementary and improved irrigation practices, improved crop management practices, land and water management and the use of land races that are adapted to local agro-climatic and environmental conditions.

5.9.3. Adaptation Assessment to Potential Impacts of Climate Change to Agriculture

It has been justified that existing adaptation policies and measures in agricultural sector are not effective to cope with today's climate hazards, leave alone future climate risks. Therefore, they have to be adjusted to address current vulnerability and those adjusted have to be strengthened to address future potential vulnerability. In this backdrop, many of the autonomous adaptation options identified here are largely extensions or intensifications of existing risk-management or production-enhancement activities. For cropping systems there are many potential ways to alter management to deal with projected climatic and atmospheric changes. These autonomous adaptations include:

- Wider use of technologies to harvest water;
- Conserve soil moisture (e.g., crop residue retention);
- Use water more effectively;
- Water management to prevent water logging, erosion and nutrient leaching to effectively adapt to climate change scenarios such as the B2 high SRES 90 percentile in 2030s and 2050s scenarios;
- Diversifying income by integrating other farming activities such as livestock raising;
- Altering the timing or location of cropping activities;

- Altering inputs such as varieties and / or species to those with more appropriate thermal time and vernalisation (making a seed germinate early by refrigerating it for a time) requirements and/or with increased resistance to heat shock and drought;
- Altering fertilizer rates to maintain grain or fruit quality consistent with climate;
- Altering amounts and timing of irrigation and other water management practices;
- Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management;
- Development and use of varieties and species resistant to pests and diseases;
- Maintaining or improving quarantine capabilities, and sentinel monitoring programs; and
- Using seasonal climate forecasting to reduce production risk

On the other hand, autonomous adaptations may not be fully adequate for coping with future climate change to address potential vulnerabilities, thus necessitating deliberate, planned measures to increase coping range. Many options for policy-based adaptation to climate change have been identified for agriculture and other sectors (Howden et al., 2003; Kurukulasuriya and Rosenthal, 2003; Aggarwal et al., 2004; Antle et al., 2004; Easterling et al., 2004). These can either involve adaptation activities such as developing infrastructure or building the capacity to adapt in the broader user community and institutions, often by changing the decision-making environment under which management-level, autonomous adaptation activities occur. In this backdrop, recommended effective planning and capacity building for adaptation to future climate change include:

a) Managers need to be confident that the projected changes will significantly impact on their enterprises. This could be assisted by policies that support the research, systems analysis, extension capacity, and industry and regional networks that provide this information;

b) There needs to be technical and other options available to respond to the projected climate changes. Where the existing technical options are inadequate to respond, investment in new technical or management options may be required (e.g., improved crop, forage, germplasm, including via biotechnology or old technologies revived in response to the new conditions (Bass, 2005));

c) To change their management, enterprise managers, zoba administrators, ministries, decision-makers need to be convinced that the climate changes are real and are likely to continue. This will be assisted by policies that maintain climate monitoring and communicate this information effectively. There could be a case also for targeted support of the surveillance of pests, diseases and other factors directly affected by climate;

d) Where there are major land use changes and migration, there may be a role for government to support these transitions via direct financial and material support, creating alternative livelihood options. These include reduced dependence on agriculture, supporting community partnerships in developing food and forage banks, enhancing capacity to develop social capital and share information, providing food aid and employment to the more vulnerable and developing contingency plans. Effective planning for and management of such transitions may also result in less habitat loss, less risk of carbon loss and also lower environmental costs such as soil degradation, siltation and reduced biodiversity (Stoate et al., 2001);

e) Developing new infrastructure, policies and institutions to support the new management and land use arrangements by addressing climate change in development programs; enhanced investment in irrigation infrastructure and efficient water use technologies; ensuring appropriate transport and storage infrastructure; revising land tenure arrangements, including attention to well-defined property rights (FAO, 2003a); establishment of accessible, efficiently functioning markets for products and inputs (seed, fertilizer, labour, etc) and for financial services, including insurance (Turvey, 2001); and

f) The capacity to make continuing adjustments and improvements in adaptation by understanding what is working, what is not and why, via targeted monitoring of adaptations to climate change and their costs and effects (Perez and Yohe, 2005)

After the adaptation measures have been formulated, they need to be prioritized with various methods and, subsequently, rejected, postponed, or selected for implementation. Given the range of climate change impacts and the measures to avoid or mitigate these impacts, it is unlikely that one single method can handle all possible cases. Four main methods are likely to be particularly useful for Eritrea to the prioritization process. These are: Cost-Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), Multi-Criteria Analysis (MCA) and Expert judgment.

CBA can handle optimization and prioritization; it also provides an absolute measure of desirability, albeit judged by only one criterion, i.e., economic efficiency. CBA has comparatively heavy data requirements. MCA is suitable when more criteria are thought to be relevant, and when quantification and evaluation in monetary terms is not possible. MCA is normally used for the ranking of options. But if the "do-nothing" case is included as an alternative, it can also help to clarify whether the measure is better than simply "bearing with the situation". Subjective judgment plays an important role in this method, making outcomes more arbitrary than that of CBA. CEA is a method that falls somewhere between CBA and MCA. As is the case with MCA, CEA only produces a ranking. Expert judgment is a discipline in its own right and has its own place in the domain of policy making.

Given that CBA is the more objective method and can handle optimization, it may be the most desirable option. However, this depends on the purpose and stage of the analysis. In cases where important criteria cannot be accommodated in CBA (such as sociological or cultural barriers), or when benefits cannot be quantified and valued (such as the benefits of preserving biodiversity), MCA is preferred. If desired, the outcomes of CBA can be incorporated into MCA, making the overall analysis a hybrid one.

In conclusion, it must be recognized that adaptation will ultimately be a localized phenomenon. It will be driven by the need for people to adapt to the local manifestations and impacts of climate change, which will be mediated by geography and local physical, social, economic and political environments. Individuals tend, to adapt in a reactive and often haphazard manner. At the local level, adaptation is a complex process that emerges as social systems reorganize themselves, in a largely unplanned fashion, through a series of responses to external stresses. Top-down, prescriptive strategies to undertake planned adaptations are therefore only a partial solution. The Government, community-based organizations (CBOs), non-governmental organizations (NGOs) and other bodies should address how they can enhance the capacity of systems (people) to adapt reactively and autonomously by creating enabling environments for adaptation. Such an approach must recognize that people will pursue adaptation strategies appropriate to their individual circumstances, and that adaptation may be unpredictable.

CHAPTER 6

OTHER INFORMATION

This section provides for the provision of other information considered relevant to the achievement of the objectives of the Convention. In this background and addressing climate change, this chapter covers the following issues:

- Steps taken to Integrate Climate Change into Social, Economic and Environmental Policies;
- Activities Related to Technology Transfer;
- Climate Change Research and Systematic Observation;
- Research to Adapt to and Mitigate Climate Change;
- Information on Education, Training and Public Awareness;
- Information on Capacity-Building at the National, Regional and Sub regional Levels; and
- Efforts to Promote Information Sharing

6.1. Steps taken to Integrate Climate Change into Social, Economic and Environmental Policies

Adaptive capacity depends on the availability of national resources including economic, social capital, access to ecosystem, information, technology, education, wealth. Nonetheless, the availability of these resources by itself cannot address climate change vulnerability. The resources have to be used effectively so as to realize adaptive capacity or enhance coping range to deal with current variability and change. In this backdrop, Eritrea has been devoting substantial amount of resources to promote development of its social, economic and environmental sectors along with the supporting enabling environment and has made significant progress. Some examples of these efforts and the associated challenges encountered are elaborated in the following sections.

6.1.1. Integrated Social Services

In this section, the most important social services component of the country which contribute directly or indirectly to the achievement of the objective of the Convention in terms of GHG mitigation and adaptation responses to climate change are elaborated below.

A. Energy Supply Systems

The country is dependent on consumption of fossil fuels and associated energy-intensive products (Article 4.8). Notwithstanding the real progress that has been made since 1991 in improving access to modern power supply, Eritrea still faces numerous serious challenges related to extending access to affordable power supply to its urban and rural population. Since 1991, Eritrea has been investing to modernize and expand the coverage of its power supply system and to improve the efficiency of power use in various sectors of the economy and society. As a result of investments made so far, significant progress has been made in addressing some of the major power supply issues affecting its sustainable development. Substantial investments have been made in expanding power generation, transmission and distribution. According to the new energy policy of the country, all of the steps towards improving energy efficiency and introduction of RETs across various sectors oriented towards enhancing economic efficiency, reducing dependency on fossil fuel and abating GHG emissions.

In the pursuance of increasing energy efficiency, enhancing RETs mix and abating GHG emissions it is worth mentioning some of the activities and achievements, which in practice Eritrea is making in its GHG mitigation efforts.

The new power generation facility installed recently is to consume around 170 grams of heavy fuel oil per KWh of electricity generated as compared to the average previous power supply consumption of 220 grams of diesel or light fuel oil. If we estimate the generation for 2012 to be around 300 GWh, the new generation facility will reduce CO_2 emissions by around 45,000 tones in that year. Rehabilitation of the old transmission and distribution systems in major towns has reduced power losses. The previous technical losses of 20% in transmission and distribution system have been reduced by 50%. Assuming that oil fired stations produce about 0.7 ton of CO_2/MWh generated, this reduction in technical loses implies CO_2 abatement of 21,000 tons/year. The improved stoves which have been recently introduced have around 21% efficiencies as demonstrated experimentally, while the traditional stoves are less than 10% efficient. Simple calculations made suggest that the CO_2 reduction potential per improved stove is 0.6 tons per year. A wind park to feed the Port City of Assab grid and many decentralized stand alone or wind hybrid systems in the small towns and villages in the area have been installed. Many solar PV systems have been installed in the rural areas. Around 1.6 ton of CO_2 is abated for each kW of renewable energy technologies (RETs) installed. In connection with these improvements in energy efficiency and introduction of sustainable energy supplies there is an Energy Research and Training Center which has the purpose of undertaking research activities on renewable energy resources and technologies. Moreover, the Centre is also involved in the installations, repair and maintenance of RETs, training of technicians and extension activities. These measures have already positive impacts in abating GHG emissions which is the foundation of the objective of the Convention.

B. Education

The education development plan for Eritrea has been prepared focusing on the need to develop Eritrea‘s three principal levels of education: PreK-12, Technical and Vocational Education Training (TVET) and the establishment of Institutions of Higher Education (IHEs) in an integrated manner. The new school curriculum of Eritrea has been developed and introduced recently. The Department of General Education and School Curriculum of the Ministry of Education has entrusted the Department of Environment of the Ministry of Land, Water and Environment to prepare environmental materials to be integrated into the new school curriculum. For this purpose, the Department of Environment has assigned special mandate to its Climate Change Unit to take the responsibility of preparing the environmental materials. The climate change unit has taken this opportunity to infuse climate change issues at all levels of education. Topics on climate change have been infused with all subjects that are reckoned relevant. In this context, 15 student reference books at all levels of school have been prepared.

C. Institutional Development

Eritrea has been investing substantial resources to build its institutional infrastructure covering all aspects of life. It has established and expanded a network of public, parastatal and private institutions that give its economic and social system structure and stability. However, measured against acceptable effectiveness and efficiency criteria, Eritrean public and private institutions are generally regarded weak and will need to be further developed. This is particularly the case in the delivery of basic public services whose nature, scale, quantity and timing should be further improved. The current plan focuses on the development of four core areas whose role in development is pervasive. These are the justice system, the mass media, the audit administration and the overall cross-cutting system of public service delivery. All these institutions have direct linkage with climate change response strategies. These measures could minimize some of the major barriers related to legal and institutional frameworks.

6.1.2. Economic and Environmental Policies

Eritrea has developed a number economic development plans and environmental national action plans. In doing so, directly or indirectly climate variability and change concerns have been considered and integrated to the extent national capacity is permitting. The next section elaborates polices and action plans which contribute to the achievement of the objectives of the UNFCCC Convention and at the same time promote economic and environmental sustainability.

A. National Adaptation Programme of Action (NAPA)

The National Adaptation Programme of Action (NAPA) identifies the following sectors as the most vulnerable to climate change: agriculture, water resources, forestry, coastal environments, and human health. The programme specifically seeks to develop an integrated water management and agricultural development approach to address food security through climate-sensitive technologies, thereby assisting particularly vulnerable groups, as identified by the NAPA, to enhance their resilience to climate variability and change.

B. Macro-Policy Document

The 1994 Macro-Policy Document which outlines the background for Eritrea's national economic growth strategy includes the establishment of an efficient outward-looking market economy with the government playing a proactive role to stimulate private initiatives, with irrigation-based agriculture one of four key sectors targeted for development. The Macro-Policy also addresses the potential negative environmental impact of development activities; specifically: environmental impact assessment; introducing land use practices in the implementation of agricultural projects that will avoid land degradation and loss of biodiversity; and the introduction and development of early warning systems, for example, for drought.

C. National Economic Policy Framework and Programme

The National Economic Policy Framework and Programme (NEPFP) which was intended to operationalize the framework policy statements called for the following: (i) the restoration, enhancement and preservation of Eritrea’s ecology; (ii) the prudent utilization of land, air and water resources; (iii) the establishment of sound environmental standards; and (iv) the introduction of sustainable land management practices; all of which form part of country’s adaptation strategy.

D. Food Security Strategy

Food Security Strategy emphasized that ensuring food security is one of the top national priorities and the cornerstone for sustainable economic growth and poverty reduction in Eritrea. Food security at the household level is considered to be fundamental and this goal is intended to be achieved by raising the incomes and quality of life of the poorest and most food- insecure segments of the population. It also entails assisting vulnerable groups to climate hazards increase production and establish sustainable means of livelihood to become food-secure, all of these are consistent with activities and polices related to adaptation to climate change. Nonetheless, this strategy needs update and an action plan for its effective implementation.

E. Interim Poverty Reduction Strategy Paper

The Interim Poverty Reduction Strategy Paper (I-PRSP) provides the government’s commitment to poverty reduction, and acknowledges drought as one of the major causes of poverty and food insecurity in the country. The I-PRSP proposes a number of actions that would improve the resilience of people vulnerable to climate variability and change including, inter alia, increasing water availability by harnessing seasonal water flows and improving storage capacity; improved water application techniques at the farm level; and improving productivity through *inter alia* widespread use of improved pest control and reducing post harvest losses, developing and disseminating more drought resistant, faster-maturing seed varieties, and soil conservation measures.

F. National Biodiversity Strategy Action Plan

The National Biodiversity Strategy and Action Plan (NBSAP) contains several climate change related activities and polices in that degraded terrestrial ecosystems will be rehabilitated through soil and water conservation activities, and the action plan will promote the conservation and sustainable utilization of agricultural biodiversity resources for food security, income generation and agriculture, whilst ensuring the socially fair distribution of benefits arising from the use of national agricultural biodiversity resources. Nonetheless, as this document was prepared in 2000 and its implementation has been too slow, it needs update and faster implementation.

G. National Action Plan

The National Action Plan for combating desertification and reducing the impacts of drought contains several actions to promote sustainable land management which is in support of climate change mitigation and adaptation. Nonetheless, as this document was prepared in 2002 and its implementation has been too slow, it needs update and faster implementation.

H. Integrated Water Resources Management Action Plan

The Action Plan for Integrated Water Resources Management in Eritrea (2009) contains several water resources adaptation actions mainly by adopting a catchment management approach to water resources assessment, development and protection; and water resources allocation and water use.

I. National Gender Action Plan

The National Gender Action Plan reflects a number of climate change adaptation activities and polices not only through the focus on women-headed households but also through its emphasis on empowering people and institutions; improving knowledge and addressing the concerns of vulnerable groups (women and pastoralists); reducing poverty through income-generation; and arresting land degradation and controlling desertification.

J. Overall Development Plan of Eritrea

Eritrea‘s overall development plan aims at:

- Building a society with a great sense of common and shared destiny that would sustain political commitment and dedication of the people for the continued development of a resilient nation; Fostering the development of mature community-based democratic institutions that facilitate popular participation of citizens in the process of national development;

- Creating an innovative and forward-looking society capable of adopting scientific and technological advances and making contribution to scientific and technological progress for domestic, regional and universal benefits;

- Creating a conducive operating environment for effective development planning, economic management, and efficient delivery of public services required for a modernizing, and democratic society;

- Promoting rapid, sustainable and equitable economic development in which all members of society participate, and ensuring development of a competitive and internationally integrated economy with human development, food security and poverty eradication at the core; and

- Protecting, restoring and enhancing the country‘s environment (land, water and air) by mainstreaming environmental issues including climate change in all development policies, plans, programs and projects and ensuring adherence to strict environmental standards.

All of the above mean that economic growth and development are about the people gaining access to resources, increasing their adaptive capacity to improve the quality of their lives, and acquiring the necessary institutions to influence policies and decisions which affect them. In other words, it is aimed at meeting all their human needs and, doing so without undermining the social fabric and the integrity of the ecosystem on which their future advancement depends. Hence, Eritrea's development strategy, under all circumstances, must aim at generating the social and economic conditions, institutions, and values that are necessary to achieve a rapid, just and sustainable socio-economic development.

K. Other Relevant National Policy Documents

Other National Policy Documents include the National Environmental Management Plan (NEMP-E), the National Environmental Impact Assessment Procedures and Guidelines (NEIAPG), and the draft Environmental Impact Assessment Procedures Guidelines for Agricultural Projects, etc. All contain several actions and polices related to mitigation and adaptation to climate change.

In general, Eritrea has acknowledged the importance of integrating climate change concerns into development context and ensuring this is the mandate of the Ministry of National Development, which is the institution responsible for facilitating better management and execution of the complex task of planning and co-ordination at all levels of government for a more effective use of scarce public resources, for the promotion of sustainable growth and the alleviation of poverty.

6.2. Activities Related to Technology Transfer

The negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have created a framework to promote the transfer of technologies. Technology transfer comprises five steps including technology needs and needs assessment, technology, enabling environments, capacity-building and mechanisms for technology transfer. In Eritrea, the first three steps including implementation plan have been completed while capacity-building and mechanisms for technology transfer are ongoing processes.

6.2.1. Technology Needs and Needs Assessment

Eritrea has conducted GHG mitigation and adaptation technology needs and needs assessment for priority socio-economic sectors including energy and agriculture sectors. The objective of Eritrea's Technology Needs Assessment (TNA) has been to assess and identify potential climate change mitigation and adaptation technologies to address national development objectives. The needs assessment will also contribute to the achievement of the ultimate objective of UNFCCC. In this context, the specific purpose of the TNA has been to identify and exploit local, national and international opportunities for technology transfer. The UNFCCC technical paper on the enabling environments for technology transfer (FCCC/TP/2003/2) and the IPCC special report on "Methodological and Technological Issues in Technology Transfer" have been consulted for this purpose.

6.2.1.1. Prioritized Technology Needs of Eritrea

The identified technologies in both areas of GHG mitigation and adaptation were prioritized based on country-driven criteria for mitigation and adaptation technologies. The prioritized technology needs of Eritrea under GHG mitigation and climate change adaptation are summarized in Table 6.1 below.

Table 6.1: List of Prioritized Climate Change Technologies for Eritrea

	GHG Mitigation Technologies	CC Adaptation Technologies
1	Geothermal Power	Climate-resilient crop and livestock production
2	Combined Heat and Power (CHP)	Crop & animal integrated technologies
3	Use of CFL for Lighting	Modern irrigation technologies
4	Industrial Energy Efficiency Improvement	Soil and water conservation: soil bund, stone bund and check dam construction
5	Non-motorized transport (NMT)	Improved traditional farming practices
6	Increase Vehicle Load Factor (Bus Rapid Transit (BRT))	Research and Development (RD)
7	Efficiency Improvement in Power Transmission and Distribution Systems	Drought-resistant and early-maturing crop varieties and improved seeds or alternative crop and hybrid varieties
8	Use of Compressed Natural Gas (CNG): Retrofitted in Combustion Engine	Modern water conservation technologies
9	Solar PVs and Wind Power	Conservation tillage
10	Dissemination of Improved Traditional Biomass Cooking Stove	
11	Shift from Inefficient Traditional Biomass to Modern Fuel	
12	Biofuels: Biogas & Ethanol	
13	Natural Gas Combined Cycle	
14	Landfill Methane Gas Capture for Power Generation	
15	Integrated Domestic and Commercial Hot Water Technologies	
	Waste Composting Technologies	

Source: DOE, 2011

6.3. Climate Change Research and Systematic Observation

6.3.1. Climate Change Research

A number of national research institutions in Eritrea such as Hamelmalo Agricultural College and National Agricultural Research Institute (NARI) are currently promoting climate and climate change related research on integrated climate-resilient crop and livestock production in a wide range of disciplines, including SWC, integrated crop-livestock production systems, conservation agriculture, agroforestry, rangeland management, sustainable irrigation technologies, environmental regeneration and natural resource management.

Ministry of Land, Water and Environment has conducted a number of climate change related researches which could provide data, information and tools for various activities relating to the preparation of national communication. For instance, the National Water Sector Study provided a tool as a basis for modeling of surface water and groundwater resources. It also conducted a preliminary study on the situation of nation's water resources which has useful data and information as input to the preparation of national communication. Department of Environment conducted Initial and Second National Communications, NAPA, National Capacity Self Assessment (NCSA), and Modeling of Climate and Climate Change Scenarios and other useful documents important for informed decision making as related to sustainable development. Ministry of Energy and Mines (MOEM) has Energy Research and Training Center with the purpose to undertake research activities on RETs, conservation of energy and training of technicians. For this purpose it has a number of wind and solar stations installed across the country. The country has ratified a number of Multilateral Environmental Agreements (MEAs) and fulfills its reporting commitments under the respective Conventions. Nonetheless, State of Environment Report and monitoring and reporting on natural resources are largely absent. As a result, the level of environmental sustainability is not clear.

6.3.2. Systematic Observation

Systematic climate data collection and documentation activities are shared among different institutions such as MOLWE, MOTC (Asmara International Air Port), MOA, MOEM, MOH, MOPW and the local government. The roles and responsibilities of these ministries are not clearly identified. There are a number of overlapping activities. Each established many of meteorological stations at selected sites. These stations were put in place to generate data needed for the respective institutions. Most of the attributes such as the location, distribution, and type of instruments used in each of these stations do not satisfy the requirements for a national observation network and WMO standards. The coverage and quality of data is not complete. For instance, there is no adequate upper-air and oceanographic observations and the existing data need to be improved in terms of standardization and exchange of data.

Currently, Eritrea's seasonal forecasts are developed by Asmara International Airport, with support from the IGAD Climate Prediction and Applications Centre (ICPAC) based in Nairobi, as is the case with all the ICPAC countries. The regional centre is well staffed and equipped, and supported by international organizations. It has also undertaken human resources development targeting the ICPAC countries. Nonetheless, participation in the global research and observation systems such as WMO and GCOS is not satisfactory. To address this capacity building gap, there is an urgent need to develop and implement national systematic observation plan. The role of the IPCC/WMO focal Point, which is the MOTC, is not clear and coordination with the focal point of UNFCCC which is MOLWE is too weak.

Hence, the establishment of an efficient observation system and development of human capacity resources in technical, scientific and managerial aspects, introduction of the state-of-the-art communication and information technology and investment to satisfactory levels of capital to support these actions are urgently needed since these elements are prerequisite for effective climate change research and systematic observation.

6.4. Information on Research Programme

Research programme, on specific aspects of climate change such as mitigation, development of country specific emission factors and activity data particularly for key source categories, and Clean Development Mechanisms (CDM) for funding are far from satisfactory. The country's involvement in such research activities with other bilateral and multilateral institutions is not adequate. There is an urgent need for an action plan in this area to fill the gap.

6.5. Information on Education, Training and Public Awareness

The implementation of Article 6 of the convention is identified by the NCSA as one of the priority area of interventions. In this backdrop, a project profile has been prepared for implementation. The implementation strategy is to establish institutional framework as the Department of Environment (DOE) the central coordinating body. DOE shall prepare periodic awareness materials and translating them into local languages. The DOE (MOWLE) would collaborate with key actors and stakeholders to produce the material. It will organize periodic sensitization and training workshop for targeted audiences, and organize mass media programmes.

In addition, MOLWE will collaborate with the Curriculum Development of the MOE, MOND, higher institutions and other training institutions to review curricula and training modules. The training institutions would then integrate climate change issues into their training programmes and train manpower to strengthen human resources to implement climate change issues. In the local administration, the local environment committee would spearhead awareness and training of zonal and local actors on climate change and other related MEAs such as UNCCD and UNCBD implementation at that level, in collaboration with other local actors such as the local administration, NGOs, CBOs and the private sector. The NCSA has recommended that capacity-building activities should be undertaken in effective, efficient and programmatic manner.

6.6. Capacity Building

Capacity building should assist Eritrea to build, develop, strengthen, enhance, and improve its capability to contribute to the achievement of the objective of the Convention through the implementation of the provisions of the Convention and the preparation for its effective participation in the Kyoto Protocol process. In this background, the progress so far made and the identified capacity needs and gaps are elaborated underneath.

6.6.1. Specific Needs, Options and Priorities for Capacity-Building

The major synergistic constraints and opportunities for capacity building have been identified during the national Capacity Self Assessment (NCSA) process. Overall the capacities for environmental management in general and climate change response in particular at local and regional levels were found to be weaker than at national level, although the level of environmental awareness is relatively high. Hence the regional governance structures in particular need institutional and individual capacity building to better address environmental and climate change concerns to cope with current climate variability and change. The need to retain a local and regional implementation focus was highlighted throughout all assessment components of the NCSA; this need has been translated into key objective in the NCSA action plan.

Specific needs, options and priorities in the climate change and related thematic areas include the following:

- Establishing national climate change secretariats to enable the effective implementation of the Convention and effective participation in the Kyoto Protocol process, including preparation of national communications;
- Developing an integrated implementation programme which takes into account the role of research and training in capacity building;
- Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessments into sustainable development programmes and ***implement*** national adaptation programmes of action;
- Strengthening existing national research (such as NARI, Hamelmalo Agricultural College & National Energy Research & Training Centre) and training institutions in order to ensure the sustainability of the capacity-building programmes;
- Strengthening the capacity of meteorological and hydrological services to collect, analyze, interpret and disseminate weather and climate information to support implementation of national adaptation programmes of action, mitigation and adaptation strategies formulated from national communications;
- Enhancing public awareness (level of understanding and human capacity development);
- Eritrea's participation in Kyoto protocol process is ineffective. To date, no single effective CDM project has been prepared by Eritrea and approved by CDM mechanism due to weak technical, institutional and managerial capacity. Hence, capacity building in these areas is critical;
- Existing national institutions have weak capacity to incorporate traditional skills, knowledge and practices, to provide appropriate services and facilitate information sharing to the level required. As a priority, therefore, capacity building in Eritrea should mobilize these existing national, sub regional and regional institutions building on existing processes and endogenous capacities;
- Lack of early warning systems for natural disaster management could reduce the coping range of the country and individuals in the face of climate hazards. This area is one of the priorities of the country for capacity building;

- Land degradation and desertification are key environmental concerns and may compromise the country's adaptive capacity in current and future climate risks. NAP of UNCCD had proposed 23 Project Profiles (PPs) ten years ago. Nonetheless, to date those identified PPs have not been implemented to the required level. The same line of discussion holds true for implementation of NAPA, NBSAP, NCSA itself and NC follow up. Mobilizing financial resources and political buy-in are critical elements

6.6.2. South-South Cooperation

This area of capacity-building has not been exploited and / or targeted the right people to the required level to date mainly due to lack of commitment, negligence and low awareness as to the impact of such cooperation.

6.6.3. Promotion and Level of Involvement of Stakeholders

Eritrea has developed country specific guidelines for effective engagement of stakeholders in various climate change activities and projects. The level of involvement of stakeholders is to the extent that stakeholder participation is a cross-cutting issue across all components and activities of climate change.

In Eritrean version, stakeholders are individuals or groups who have the current and past experience of coping with, and adapting to, climate variability and extremes. The principle resource for responding to climate change impacts is the people themselves, and their knowledge and expertise. Through an ongoing process of negotiation and policy dialogue, they can 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.

6.6.4. 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 urgent.

6.6.5. Dissemination and Sharing of Information on Capacity-Building

Both at the secretariat and national focal point levels, improved decision-making, including effective and efficient assistance for participation in regional and international negotiations and capacity-building training workshops targeting those directly working in climate change issues is critical. Participation should be driven more by technical relevancy not exclusively by political criteria and/or financial benefit which have long been proved to be inefficient, particularly in LDCs, as a sequel to this several negotiations and capacity-building outcomes are not effectively disseminated, shared and translated into action at national, sub-regional and regional levels. Thus, there is an urgent need to assess the ongoing Convention negotiation and workshop processes based on the following questions: Who is who? Who is working? Who is not working? Why? There is also a need to look for a mechanism to communicate directly to those national experts who are the holders of the expertise and practical skills in the field.

6.6.6. Capacity-Building Activities

Capacity-building activities aimed at integrating adaptation to climate change into medium- and long-term planning are mainly those capacity-building activities conducted under the implementation of NAPA and National Communication. NAPA has a short to medium term objective of integrating adaptation while NCs and NCSA have medium to long term objectives. Eritrea has conducted a number of capacity building activities to implement these projects across all components. These capacity building activities engaged all relevant stakeholders to enhance national capacity. As learning by doing, a number of short-term concrete projects for implementation have been prepared targeting different UNFCCC funding sources such as LDCF, AF, GEF trust fund, RAF+, etc. In this context, preparation of Project Identification Forms (PIFs) and Project Documents is an ongoing commitment in the country.

6.7. Information and Networking

6.7.1. Efforts to Promote Sharing Among and Within Countries and Regions

In this area, the secretariat needs to establish regional mechanisms to share information on a continuous basis. The strategy is to create regional platforms for countries to share information created by themselves in stead 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 his/her 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.

6.7.2. Participation in and Contribution to Information Networks

Eritrea has been participating in and contributed to information networks of regional and international initiatives such as AfricaAdapt knowledge sharing platform, Global Climate Change Adaptation Network (GAN), NCSP, WEAP, SimCLIM, ICPAC, AGRHYMET, PRECIS, ACMAD, DMC, WeADAPT, ENDA, FAO, IDS, WMO, START, UNEP (Global Change, GAN), UNDP (APF, ALM)), SEI, UNITAR,CSAG, NWP, FNR_Rio , etc.

6.7.3. Access to, and Use of, Information Technologies

Fast, accessible, affordable and reliable communications system is critical for development. In recognition of this, Eritrea has invested substantially in the development of its telecommunications and postal services. Today, Eritrea is reasonably well connected domestically and internationally by both telecommunications and postal services. Almost all major cities can be accessed through postal and telephone services and efforts are currently underway to provide access to telephone services to parts of the country that are not being served. The recent expansion of internet services and the installation of GSM-900 with a capacity of 400,000 have improved access to telecommunication services. The completion by 2009 of the CDMA-WLL fixed network with a capacity of 200,000 has further enhanced access and reliability. However, in spite of these accomplishments, the transmission of large volume text, voice and video data is limited by the absence or inadequacy of broadband fiber optic infrastructure system. In regards to SNC preparation, the use of this opportunity enables access to information systems which has been common across GHG inventories, GHG mitigation analysis, TNA, and vulnerability and adaptation assessments.

CHAPTER 7

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

7.1. Introduction

The extent to which Eritrea will effectively implement its commitment to communicate information will depend on the implementation by developed country Parties of their commitments under the Convention relating to financial resources and the transfer of technology. The developed country Parties and other developed Parties included in Annex II shall provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations under the Article 12, paragraph 1. They shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of Article 4 and that are agreed between a developing country Party and the international entity or entities referred to in Article 11. In this backdrop, this section includes information on the constraints and gaps and the related financial, technical and capacity needs.

7.2. Financial, Technical and Capacity Needs

7.2.1. Financial Needs

Eritrea has encountered a number of financial difficulties in the course of implementing its reporting commitment under the Convention. The main difficulty was the inadequacy of the SNC fund to cover priority areas identified under the components of the national communication. Eritrea has opted to conduct TNA as part of the SNC preparation process including its detailed project document since effective implementation of party's commitment without technology transfer would not be realized. The other justification to do so was the project team found it cost-effective to synergize and make use of the demanding consultation processes which have been conducted for the preparation of SNC. Therefore, due to this option certain priority areas have been compromised. Therefore, there is a need to enhance the fund for the preparation of national communications if meaningful preparation and improvement of national communications on a continuous basis is required.

Eritrea has also prepared and submitted its NAPA to the COP of the Convention in 2007. However, most of the urgent and immediate adaptation needs identified by NAPA have not yet been implemented to date due to financial constraint faced by the LDCF. Eritrea's various expectations from the climate change negotiation have not also yet been materialized obstructing the country's progress in complying with its commitment under the Convention.

7.2.2. Technical Needs

Technical needs cut across all activities of the country's commitment under the Convention. Technical needs span from scientific knowledge of climate change to skills of climate and impact modeling 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. In general, these technical needs are impeding the country from maximizing the benefits which can be tapped from the Convention resources.

7.2.3. Capacity Needs

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, notwithstanding 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. Given its past land use practices as well as its location, physical features, and arid climate, Eritrea has an area liable to drought and desertification, fragile eco-system including mountainous ecosystem and low-lying coastal area and the country is dependent on consumption of fossil fuels and associated energy-intensive products. In this backdrop, Eritrea needs capacity development in the following priority areas that can enhance the realization of its adaptive capacity to cope with current and potential future climate risks and at the same time to contribute to the achievement of the objective of the Convention.

- Develop comprehensive national baseline data on the environment (land, water & atmospheric components);
- Strengthening the capacity of meteorological and hydrological services;
- Strengthening existing national research and training institutions;
- Alternative renewable energy sources, such as wind and solar, shall be harnessed and developed to substitute for the use of fuel wood and petroleum products for food preparation and general heating;
- Non-wood construction materials and farm implements shall be continuously developed to prevent further depletion of the country‘s forest resources;
- Measures shall be taken to establish appropriate vehicle emission standards, inspection procedures, and to develop adequate capacities to enforce them;
- Review of the adequacy of existing and new legal and policy provisions pertaining to the protection and restoration and management of natural resources and the environment with mainstreaming of climate change concerns at the core of the agenda;
- Land use classification and development of land use maps to promote sound land use management, including afforestation, intensification of agriculture, and retirement of marginal lands;
- Integrated Coastal Area Management (ICAM) Proclamation, a proclamation to establish the Eritrean Coastal Authority, and an Integrated Coastal Area Management; and
- 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

7.3. The GEF, Annex II Parties, Multilateral/Bilateral Contributions

Eritrea has made significant support to the implementation of a number of projects funded by the GEF to comply with its commitment under the Convention. Most of the contribution was in kind including providing office, computers, office furniture, and workshop venues and some of these contributions were in cash. The internet, telephone, staff resources and associated costs were captured which was about USD 20,000.00.

The majority of the fund was obtained from the GEF trust fund. Overall, the trust fund has supported for preparation INC and SNC which amounted to USD 740,000.00. The LDCF provided for the preparation of NAPA USD 200,000.00. The LDCF also funded one Large Scale- NAPA follow-up adaptation project amounting to USD 3,000,000.00 and UNDP CO also co-financed this project. The Adaptation Fund (AF) provided about USD 4,000,000.00 for the implementation of one concrete adaptation programme where UNDP CO and others contributed about USD 2,000,000.00. Despite it has not been captured, the UNFCCC ; secretariat has been supporting full costs for participation of three delegates of the focal point in climate change negotiation processes each year. Funds which have not been utilized so far include CDM, SCCF, and SPA. Eritrea has not yet received any financial and technical assistance from bilateral programmes and activities. Therefore, capacity development has to be put forward to utilize effectively these funds, in particular and the broad Convention resources, in general.

7.4. Information on Implementation of Adaptation Measures

In the implementation of adaptation measures both barriers and opportunities exist. Operationally, the formulation of an adaptation strategy can pose a big challenge. It means situating the climate change issue in a policy world that is full of competing priorities, interest groups, short attention spans and a host of potential unpredictable events. On the other end, the various national developments plans and polices discussed elsewhere open up the possibility for effective mainstreaming of adaptation / appropriate GHG mitigation concerns. Besides, significant momentum has also occurred through international participation in multilateral environmental agreements (MEAs) that could be effectively leveraged. Although these efforts, both national and international, were not directly motivated by climate change adaptation, their objectives overlap. The adaptation strategy development process should build on such experience.

Eritrea is currently implementing a small number of pilot adaptation projects which is an opportunity to learn by doing. However, developed parties are required to enhance their support to Eritrea to meet its specific needs and concerns relating to vulnerability and adaptation to climate change in line with their obligation under the Convention. The priority intervention areas for support would include development and enhancement of capacities, technology transfer based on Eritrea's technology needs assessment and know-how.

7.5. Uncertainties

The GCMs used capture large scale dynamical response of atmosphere and grid resolution data is not robust and too coarse to capture local effects of mountains and lakes. Moreover, historical trends or recent changes in climate are complicated by data availability, gaps and quality. Specifically, time series data availability and climate variability data at all temporal scales is limiting the quality of the V&A assessment. For instance, Agriculture requires small scales e.g., daily agromet station data. Therefore, downscaled future either RCM or statistical downscaling method which provides high resolution version of future based on GCM dynamic change is required for subsequent assessments.

REFERENCES

Alcamo, J., M. Flörke and M. Marker, 2007: Future long-term changes in global water resources driven by socio-economic and climatic change. Hydrol. Sci. J., 52, 247-275

An Adaptation Policy Framework: Capacity Building for Stage II Adaptation (UNDP-GEF, 2000) http://www.undp.org/cc/apf.htm

Annotated guidelines for the preparation of national adaptation programmes of action http://unfccc.int/text/program/sd/ldc/documents/annguide.pdf

Bates, B.C., Z.W. Kundzewicz, S.Wu and J.P.Palutikof, EDs**.,** 2008: *Climate Change and Water*. *Technical Paper of the IPCC, IPCC Secretariat*, Geneva, 210pp

Bokrezion Habte, 2008, National Greenhouse Gas Inventory for Crop Sub-sector, Ministry of Agriculture, Asmara, Eritrea

Climate Change Secretariat (UNFCCC), 2004, Reporting on Climate Change: User Manual for the Guidelines on National Communications from non-Annex I Parties, Bonn, Germany

CLIMsystems Ltd, 2010, SimCLIM Essentials, Hamilton, New Zealand

DoE**,** 1999. *Eritrea Biodiversity Stocktaking Assessment Report*. Department of Environment, Ministry of Land Water and Environment. Asmara, Eritrea.

DÖll. P. 2002: Impact of climate change and vulnerability on irrigation requirements: a global perspective. *Climate Change*, 54, 269-293

DÖll. P. and M. FlÖrke, 2005: Global-scale estimation of diffuse groundwater recharge. *Frankfurt Hydrology Paper 03*, Institute of Physical Geography, Frankfurt University, Frankfurt

Downing. T.E., R.E. Butterfield , B. Edmonds, J.W. Knox. S. Moss, B.S. Piper. E.K. Weatherhead and the CCDeW Project Team, 2003: *Climate Change and the demand for water, Research Report*, Stockholm Environment Institute, Oxford Office, Oxford

Eakin. H. and M.C. Lemos, 2006: Adaptation and the state: Latin America and the challenge of capacity-building under globalization. Global Environ. Change., **16,** 7**-**18

Energy and Power Evaluation Program (ENPEP) (http://www.dis.anl.gov/CEEESA/ENPEPwin.html)

Mr. Girmay Abraha, 2008, National Greenhouse Gas Inventory in the Livestock Sector, Ministry of Agriculture, Asmara, Eritrea

Guidelines for the preparation of national adaptation programmes of action http://unfccc.int/text/program/sd/ldc/documents/13a04p7.pdf

Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment, Carter, T.R., Parry, M. L., Harasawa, H., Nishioka, S. 1999

Halcrow, 1997, Feasibility Study of the Eastern Lowlands Development, Asmara, Eritrea

HDI Report http://www.undp.org/hdr2003/

Integrated modeling system for climate change impact and adaptation assessment (IGCI) http://www.waikato.ac.nz/igci/modelling/modelling1.html

IPCC, Climate Change 2001, The scientific Basis. Contributions of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

IPCC, Climate Change 2007**,** Impacts, Adaptation & Vulnerability. Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

IPCC-TGCIA, 1999: Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment, Version 1

Jones, R.G., Noguer, M., Hassell, D.C., Hudson, D., Wilson, S.S., Jenkins, G.J. and Mitchell, J.F.B. (2004) *Generating high resolution climate change scenarios using PRECIS*, Met Office Hadley Centre, Exeter, UK, 40pp April 2004

Long-range Energy Alternatives Planning System (LEAP) (http://forums.seib.org/leap/)

Lu, X. (2006), Guidance on the Development of Regional Climate Scenarios for Application on Climate Change Vulnerability and Adaptation Assessments

Meahrteab Micheal, 2008, National Greenhouse gas Inventory in the Municipality Solid Waste System, Department of Environment, Asmara, Eritrea

Methodological Guidelines, Main Reports: Economics of Greenhouse Gas Limitations", UNEP-Risø, 1999. (http://uneprisoe.org/EconomicsGHG/MethGuidelines.pdf)

Methodologies and Tools to Evaluate Strategies for Adaptation to Climate Change (UNFCCC, 2000) http://unfccc.int/program/mis/meth/compendium.pdf

Miller, K.A. and D.Yates, 2006: Climate Change and Water Resources: A Primer for Municipal Water Providers. AWWA Research Foundation, Denver, CO, 83 pp.

Miller. K.A., S.L. Rhodes and L.J. MacDonnell, 1997: Water allocation in a changing climate: Institutions and adaptation, Climatic Change, **35**, 157-177

MLW&E**,** 2000. National Biodiversity Strategy and Action Plan. Ministry of Land, Water and Environment. Asmara, Eritrea.

MLW&E, 2001. Eritrea's Initial National Communication. Under the United Nations Framework Convention on Climate Change. Asmara, Eritrea.

MOA, 2002, The National Action Program for Eritrea to Combat Desertification and Mitigate the Effects of Drought, Asmara, Eritrea.

MoH, 2004, National Demographic Health Survey, Asmara, Eritrea.

NRCE, 1996, Eastern Slope Agricultural Development Potential Study, Asmara, Eritrea

Seid Abdu et al, 2001, Status of Weather Stations in Eritrea, Department of Environment, Asmara, Eritrea

Seid Abdu, 2004, Status of Ozone Depleting Substances and Related Equipment in Eritrea, Department of Environment, Asmara, Eritrea

Seid Abdu et al, 2010, Comprehensive Climate Change Scenarios for Eritrea, Department of Environment, Asmara, Eritrea

Seid Abdu et al, 2009, Current Knowledge on Impacts, Adaptation and Vulnerability in Key Natural And Human Systems in Eritrea, Department of Environment, Asmara, Eritrea

Seid Abdu et al, 2011, Impact, Adaptation and Vulnerability Assessment on Water Resources to Climate Change in Mereb-Gash Basin, Department of Environment Asmara, Eritrea

Seid Abdu et al, 2011, Impact, Adaptation and Vulnerability Assessment on Major Cereals to Climate Change in Mereb-Gash Basin, Department of Environment Asmara, Eritrea

Stakhiv, E.Z., 1998: Policy implications of climate change impacts on water resources management. *Water Policy*, 1, 159-175

State of Eritrea, MOLWE, 2007, National Adaptation Programmes of Action, Asmara, Eritrea

State of Eritrea, MOLWE, 2007, National Capacity Needs Self Assessment, Asmara, Eritrea

State of Eritrea, MOLWE, 2011, Technology Needs Assessment, Asmara, Eritrea

Simonovic. S.P. and L.H. Li, 2003: Methodology for assessment of climate change impacts on large-scale flood protection system. J. Water Res. Pl.-ASCE, 129 (5), 361-371

Technical Support Unit (TSU) for IPCC National Greenhouse Gas Inventories Programme (NGGIP) http://www.ipcc-nggip.iges.or.jp/tsu/tsustaff.htm

"Technologies, Policies and Measures for Mitigating Climate Change". IPCC Technical Paper I, 1996 (http://www.ipcc.ch/pub/techrep.htm)

Tesfaye Geberhiowiet et al, 2009, National Greenhouse Gas Inventory in Energy Sector, Department of Environment, Asmara, Eritrea

Tesfai Ghebrehiwot et al, 2009, Greenhouse Gas Mitigation Assessment and Analysis, Department of Energy, Asmara, Eritrea

The UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, Feenstra, J.F., I. Burton, J.B. Smith, R.S.J. Tol, 1998

Toolkit for Vulnerability and Adaptation Assessment (T. Downing) http://www.aiaccproject.org/resources/ele_lib_docs/Toolkit_VAA.pdf

User Guide for WEAP 21, 2007, Stockholm Environment Institute, U.S.Center

WRD, 1998, Sector Study on National Water Resources and Irrigation Potential, Vol. 2a & 2b, Asmara, Eritrea.

ANNEXES

ANNEX I: Members of the Greenhouse Gas Inventory Thematic Working Group

Source Team	Name of Expert	Institution	Responsibility
Energy	Dr. Semere Habtetsion	Department of Energy	Energy Team Leader
	Mr.Tesfai Ghebrehiwot	Department of Energy	Energy Inventory Assistant
	Mr.Gebreselse Meberhatu	National Statistics & Evaluation Office	Energy & all sectors Statistics Provider
Agriculture	Mr. Girmay Abraha	Agriculture, Livestock MoA	Agriculture Team Leader
	Mr. Bokretseion Habte	Agriculture, crop production MoA	Compiler in crop production
LULUCF	Mr. Fekreyesus Gilay	MoA	Data Provider
Industry	Mr. Solomon T/Mariam	MoTI	Data Provider

ANNEX II: Members of the GHG Mitigation Assessment and Analysis Thematic Working Group

No.	IPCC GHG Category	Name of Technical Expert	Institutions
1	Energy	Dr. Semere Habtetsion	Ministry of Energy & Mines
		Mr. Tesfaye Geberhiowiet	Ministry of Energy & Mines
		Mr. Tewolde Zerie	Ministry of Transport & Communication
		Mr. Gebreselse Meberhatu	National Statistics & Evaluation Office
		Mr. Seid Abdu Salih	Ministry Land, Water & Environment
2	Agriculture	Mr. Daniel Yenabie	Ministry of Agriculture
		Mr. Girmay Abraha	Ministry of Agriculture
		Mr. Berehanu Habte	Ministry of Agriculture

ANNEX III: Members of the V& A Assessment Thematic Working Group, also working in the rest of the Thematic Working Groups not mentioned in Annexes

No	Sectors Covered	Name of Technical Expert	Institutions
1	Water Resources	Mr. Tesfu Andemariam	Water Resources Department
		Mr. Seid Abdu Salih	Department of Environment
2	Agriculture	Mr. Daniel Yenabie	Ministry of Agriculture
		Mr. Berehanu Habte	Ministry of Agriculture
		Mr. Seid Abdu Salih	Department of Environment
		Mr. Isaac Fesseha	Asmara International Airport

Annex IV: Default IPCC Carbon Emission Factors used in Emissions Calculations

Fuel Type	**Carbon Emission Factor (TC/TJ)**
LPG	17.2
Gasoline	18.9
Jet-Kerosene	19.5
Other Kerosene	19.6
Diesel Oil	20.2
Fuel Oil	21.1
Lubricants	20.0