Republic of Botswana

Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC)

DECEMBER 2011

Ministry of Environment, Wildlife and Tourism

Pictures on cover page:

Channel in Okavango Delta

Morupule Power Station

Stakeholder workshop in Okavango Delta area

Veld fire at Pandamatenga farming area

- Image courtesy of Florian Fritzsche -

REPUBLIC OF BOTSWANA

MINISTRY OF ENVIRONMENT WILDLIFE AND TOURISM

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

Co-ordinated by:
Dorcas N. Masisi – Team Leader/Project Manager
Chandapiwa P. Sebeela – Assistant Project Manager

Lead Author:
Dorcas Ntiki Masisi

Contributing Authors:
Omphile UJ, Nsoso SJ, Aganga AA, Malope P, Aganga AO, Gopolang P, Mmolotsi R, Kgosikoma K, Akanyang L, Walker KP, Batisani N, Machacha D, Makhwaje E, Patrick C, Moji B, Semetsa S, Odirile PT, Tsheko R, Moalafhi DB, Atlhopheng JR, Masike S, Khupe JSN, Sebeela CP, Mmopi K, Lesolle PM, Mothupi RC, Gopolang BJ, Nkago T, Lesolle DM, Moalosi M, Maganu E, Ndzinge IT, Mmolotsi O, Ntshwarisang L.

Review Editors:
UNDP National Communications Support Unit

Copy Editor:
Florian Fritzsche

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Foreword

Recognizing the problems posed by climate change and the importance of taking the necessary action to mitigate climate change impacts, the Government of Botswana ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 27 January, 1994 which came into force on 27 April, 1994. Though Botswana is a minor emitter of greenhouse gases (GHG), the country is negatively impacted by climate change. Water is a scarce commodity in the country and the situation is going to be aggravated by the impacts of climate change. Other economic sectors that are impacted by climate change include tourism, health, energy, agriculture – both crops and livestock, rangelands and forestry upon which livelihoods depend.

The Second National Communication (SNC) is the second assessment of Botswana's situation with regard to position, national circumstances and responses to climate change. This follows the Initial National Communication that was prepared and submitted to the UNFCCC in 2001. The SNC serves as the basis for future action in research and offers opportunities for policy development and refinement. The report goes beyond the reporting commitment of a non-Annex I Party under the existing guidelines for the preparation of the National Communications to the UNFCCC. Therefore the document serves as a useful tool upon which to base decisions concerning climate change and future national development.

Despite many challenges encountered during the preparation of this report, valuable experience was gained, national capacity on climate change issues was further developed and many lessons were learnt. A foundation has been laid for sustainability in preparing successive national communications.

On behalf of the Government of Botswana, I would like to express my sincere appreciation to the Global Environment Facility (GEF), UNDP as its implementing agency, the National Communication Support Program and the UNFCCC Secretariat for their support throughout the preparation of this SNC.

I have the pleasure and singular honour of presenting to you, Botswana's Second National Communication which represents the commitment of the Government of Botswana and its people to address global warming and climate change. The report contains the greenhouse gas inventory for Botswana as well as the main findings of studies which assessed the possible impact of climate change and vulnerability of various economic sectors. The report also contains an analysis of potential measures to abate the increase of greenhouse gas emissions as well as possible adaptation options to address the adverse impacts of climate change across the various sectors.

Honourable Tshekedi Khama
Minister of Environment, Wildlife and Tourism, Botswana

ACKNOWLEDGEMENTS

The funding for the SNC preparation was provided by the Global Environment Facility (GEF) under the climate change focal area the project being "Enabling Botswana to prepare its Second National Communication to the UNFCCC". The preparation of the Botswana's Second National Communication to the UNFCCC has been jointly undertaken by the following and the Ministry of Environment, Wildlife and Tourism wishes to appreciate the effort and time spent by the various teams to produce the SNC:

- The Department of Meteorological Services under the Ministry of Environment, Wildlife and Tourism as the Climate Change focal point.
- The report was prepared under the directorship of Mr. Phetolo Phage, at that time Director of the Department of Meteorological Services and National Climate Change Focal Point. The National Committee on Climate Change (NCCC) endorsed all the activities of the SNC. The Climate Change Focal Point appreciates the effort of the academia, line ministries and other non-governmental organizations who took part in the preparation and review of the SNC.

The Climate Change Focal Point gratefully acknowledge the important contribution of Yamil Bonduki of UNDP National Communications Support Unit for both coordinating the peer review of the technical chapters of the SNC report and for personally reviewing the GHG Abatement Analysis and the Vulnerability and Adaptation chapters.

Furthermore, sincere gratitude goes to the NCCC members who represent line ministries and other governmental organizations, research institutions and related NGOs.

Special appreciation also goes to the invaluable contribution of the UNDP country office especially to Mr. Leonard Dikobe, Programme Specialist (Energy and Environment), the UNDP Resident Representative and the Assistant UN Resident Representative, for their support throughout the report preparation.

Thabang L. Botshoma

Director of Meteorological Services and National Climate Change Focal Point

TABLE OF CONTENTS

Foreword v

Acknowledgements vii

Table of Contents ix

List of Figures xiii

List of Tables xv

List of Acronyms xvii

0 Executive Summary 1

0.1 Introduction 1

0.2 National Circumstances 1

0.3 Greenhouse Gas (GHG) Inventory 3

0.3.1 Programs containing measures to facilitate adequate adaptation to climate change 5

0.3.2 Assessments of climate change 5

0.4 Mitigation Analysis 8

0.4.1 Projected Energy Demand 8

0.5 Other information considered relevant to the achievement of the objective of the Convention 9

0.5.1 Education training and public awareness 9

0.5.2 Research and systematic observation 9

0.5.3 Technology transfer 10

0.5.4 Capacity building 10

0.6 Constraints and gaps, and related financial, technical and capacity needs 10

0.6.1 Constraints and gaps 10

0.6.2 Technical and capacity needs 11

0.6.3 Financial needs 11

1 National Circumstances 13

1.1 Geographic and geological profile 13

1.2 Climate profile 14

1.3 Natural resources: 16

1.3.1 Water resources 16

1.3.2 Forests 18

1.3.3 Land use 19

1.4 Economic profile 20
1.5 Agriculture 22
1.5.1 Livestock 22
1.5.2 Crops 23
1.6 Energy 24
1.7 Mining 25
1.8 Transport and telecommunications 26
1.8.1 Railways and roads and airport networks 27
1.8.2 Telecommunications 28
1.9 Tourism 28
1.10 Population 28
1.11 Public health 30
1.12 Education 30
2 Greenhouse Gas Inventory 31
2.1 Introduction 31
2.1.1 Methodology 31
2.1.2 Data sources 31
2.2 Sources of GHG emissions 33
2.2.1 Energy 35
2.3 Carbon dioxide emissions 36
2.3.1 Residential 36
2.3.2 Industry and transformation 36
2.3.3 Transport 36
2.3.4 Government 37
2.3.5 Agriculture 37
2.3.6 Industrial processes 37
2.3.7 Emissions from land use change and forestry 37
2.4 Methane emissions 37
2.4.1 Methodology 38
2.4.2 Emission from the agricultural sector 39
2.4.3 GHG Emissions from waste 39
3 Programs containing measures to facilitate adequate adaptation to climate change 40
3.1 Assessments of climate change 40
3.1.1 Assessment using downscaling 40

3.1.2 Results obtained under downscaling 40
3.1.3 Characterisation of climate variability and associated extreme events 45
3.1.4 Future drought analysis using SPI 47
3.1.5 Future drought analysis using PDSI 49
3.1.6 Assessments using MAGICC/SCENGEN 50
3.1.7 Rainfall trends 50
3.2 Vulnerability and adaptation assessments of key sectors 52
3.2.1 Water resources 52
3.2.2 Health 58
3.2.3 Crops 61
3.2.4 Grasslands and livestock 64
3.2.5 Forestry 67
4 Programs containing measures to facilitate adequate mitigation to climate change 71
4.1 Mitigation Analysis 71
4.1.1 Introduction. 71
4.2 Energy 72
4.2.1 Methodology. 72
4.2.2 Creation of the structure of the energy sector (Current accounts) 72
4.2.3 Mitigation options 74
4.2.4 Demand side management strategies 74
4.2.5 Projected Energy Demand 77
5 Other information considered relevant to the achievement of the objective of the Convention 78
5.1 Education, training and public awareness 78
5.2 Research and systematic observation 78
5.3 Technology transfer 79
5.4 Capacity building 80
6 Constraints and gaps, and related financial, technical and capacity needs 81
6.1 Constraints and gaps 81
6.2 Technical and capacity needs 81
6.3 Financial needs 82
6.4 Adaptation measures/projects and barriers 83
7 References 85
8 ANNEXES 87

LIST OF FIGURES

Figure 0.1: Allocation of GDP by sector, Botswana (World Bank, 2000) 2

Figure 0.2: Comparison of the INC Inventory and SNC Inventory 5

Figure 0.3: Projected energy demand of Botswana 8

Figure1.1: Topography map of Botswana 13

Figure 1.2: Rainfall map of Botswana 16

Figure 1.3: Okavango Delta 17

Figure 1.4: Primary energy supply for the year 2008 25

Figure 1.5: Commercial energy demand (excluding fuelwood) for the year 2008 25

Figure 2.1: Distribution of greenhouse gas emissions by gases for the year 2000 33

Figure 2.2: Distribution of greenhouse gas emissions by sectors for the year 2000 35

Figure 2.3: Major sources of CO_2 35

Figure 2.4: Comparison of Methane emissions (Gg CH_4) 1994 and 2000 from different subsectors.. 38

Figure 3.1: Observed distribution of rainfall indices in Botswana 42

Figure 3.2: Projected distribution of rainfall indices in Botswana, 2046-2065 43

Figure 3.3: Historical annual Climate Moisture Index (CMI), 1961-1990 45

Figure 3.4: Comparison of Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI) 46

Figure 3.5: Percentage changes in SPI5 and SPI12 48

Figure 3.6: Percentage change in PDSI 49

Figure 3.7: Coefficient of variation of seasonal rainfall (October-March) 51

Figure 3.8: Map of t-test statistics as a quality measure to identify trends for total rainfall in December/January/February (DJF) 51

Figure 3.9: Annual mean number of days with rainfall exceeding 5 mm 52

Figure 3.10: Change in Gumbel 24-hour runoff due to predicted climate change in Botswana, Echam5 GCM, A1b emissions scenario, 2046-2060 55

Figure 3.11: Change in Gumbel 24-hour runoff due to predicted climate change in Botswana, Echam5 GCM, A1b emissions scenario, 2080-2100 56

Figure 3.12: Malaria deaths in different areas Botswana 2004-2009 59

Figure 3.13: Relationship of rainfall and malaria occurrence in Botswana, 1997 to 2008 60

Figure 3.14: Diarrhoea cases for 2004, 2005 and 2006 - showing significant increase in years with high rainfall 60

Figure 3.15: Changes in relative abundance of species groups in different range condition classes . 64

Figure 3.16: General range succession model with precipitation, grazing pressure, temperature, wind velocity and vapour pressure 66

Figure 3.17: Layout of quadrates in a sample point 68

Figure 3.18: Total woody biomass (kg/ha) of all trees species as per area/zone 68

Figure 4.1: Comparison of the INC inventory and SNC inventory 71

Figure 4.2: Historical and projected energy demand (baseline scenario) 77

Figure 4.3: Base year and final energy demand (baseline scenario) 77

List of Tables

Table 0.1: Greenhouse Gas (GHG) of Botswana Inventory for 2000 4

Table 0.2: Sectoral impacts and adaptation measures 7

Table 0.3: Potential mitigation options in key sectors 9

Table 1.1: Land tenure 20

Table 1.2: Livestock population ('000) from 1979 to 2003 (CSO, 2004) 22

Table 1.3: Total production by crop in metric tons (CSO, 2004) 23

Table 1.4: Population by sex and census districts (CSO, 1991 and 2001) 29

Table 1.5: Selected notifiable diseases - cases and deaths, 1998 – 2003 (CSO, 2004) 30

Table 2.1: Global warming potential for various gases (time horizon 100 years) 33

Table 2.2: Emissions of individual GHG by sector for the years 2000 in Gg 33

Table 2.3: Total GHG emissions by sector for the year 2000 34

Table 3.1: Values of mean, standard deviation (sd) and autocorrelation coefficient (ac) of various rainfall indices for 18 stations of Botswana 44

Table 3.2: Impacts of climate change as depicted by MAGICC/SCENGEN model 50

Table 3.3: Impacts of climate change on water resources by WEAP model 54

Table 3.4: Impacts of climate change as depicted by STELLA model 54

Table 3.5: Adaptation measures in water sector 57

Table 3.6: Adaptation measures in health sector and methods of implementation 61

Table 3.7: Length of growth development stages for sorghum for MAGICC SCENGEN climate change scenarios for four regions of Botswana 62

Table 3.8: Change in length of plant growth with 2 ^{o}C increase in temperature (scenarios for four regions of Botswana) 62

Table 3.9: Adaptation measures in the agricultural sector 63

Table 3.10: Forest products harvested by gender 69

Table 3.11: Coping strategies for changes in the availability of forest resources 70

Table 4.1: GDP growth in Botswana for 2001-2015 73

Table 4.2: 2000 quarterly gross domestic product (GDP) by type of economic activity at current prices (millions of Pula) 74

Table 4.3: Assumptions for the baseline scenarios in the energy sector and suggested mitigation measures 75

Table 4.4: Mitigation options in key sectors 76

Table 5.1: Key technology needs for Botswana 80

Table 6.1 Financial support received 82

Table 6.2: Project proposals related to climate change, technologies to be used and equipment required 83

Table 6.3: Barriers to adaptation measures 84

Table A1: 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 87

Table A2: Sheets 1 of 3 of the calculation of carbon dioxide emissions from the energy sector (Reference approach) 89

Table A3: Emissions from coal mining (figures for the year 2000) 92

Table A4: Emissions from alcoholic beverages 93

Table A5: Summary of GHG emissions from the agriculture sector 94

Table A6 Estimated changes of biomass for the different types of forest in Botswana 96

Table A7: Total amount of carbon absorbed by the different types of forests during the year 2000 100

TableA8: Estimated methane emissions from solid waste disposal 101

Table A9: Total annual MSW disposed to SWDSs (Gg MSW) 102

Table A10: Emissions from solid waste disposal 103

Table A11 Emissions from liquid waste disposal 104

Table A12: Emission Factor for domestic/commercial wastewater 105

Table A13: Total emissions from waste water 106

LIST OF ACRONYMS

BAU	Business as Usual
CDM	Clean Development Mechanism
CH_4	Methane
CMI	Climate Moisture Index
CO_2	Carbon dioxide
CO_2e/CO_2eq	Carbon dioxide equivalent
COP	Conference of Parties
CSO	Central Statistics Office
EE	Energy Efficiency
EEC	Energy Efficiency and Conservation
GCM	Global Climate Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GWP	Global Warming Potential
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
ISPAAD	Integrated Support Programme for Arable Agriculture Development
IWRM	International Water Resource Management
LEAP	Long Range Energy Alternative Planning
LIMID	Livestock Management and Infrastructure Development
LULUCF	Land Use, Land Use Change and Forestry
NA1	Non Annex 1 (Developing country parties to the UNFCCC)
SNC	Second National Communication
NCSA	National Capacity Self Assessment
PDSI	Palmer Drought Severity Index
PV	Photovoltaic
R & D	Research and Development
RE	Renewable Energy
SPI	Standard Precipitation Index
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	US-Dollars
V&A	Vulnerability and Adaptation

0 EXECUTIVE SUMMARY

0.1 Introduction

The Second National Communication (SNC) of the Republic of Botswana is prepared in accordance to Articles 4.1 and 12.1 of the United Nations Framework Convention on Climate Change (UNFCCC) and the guidelines for national communications of non-Annex I Parties to the Convention (UNFCCC 2003).

0.2 National Circumstances

Botswana lies between 20.0°-29.4˚ E and 17.8°-26.8˚ S. Botswana occupies an area of 600,370 km^2, of with a land area 581,730 km^2 (INC, 2001) and Okavango swamps covers 18,640 km^2. It is a landlocked country located in Southern Africa, dominated in geographical terms by the Kalahari Desert - a sand-filled basin averaging 1,100 meters above sea level. Botswana is bordered by Zambia and Zimbabwe to the northeast, Namibia to the north and west, and South Africa to the south and southeast. At Kazungula, four countries - Botswana, Zimbabwe, Zambia and Namibia - meet at a single point mid-stream in the Zambezi River.

The country is arid to semi-arid with warm winters and hot summers and highly erratic rainfall. The mean annual rainfall ranges from over 650 mm in the north-east to less than 250 mm in the south west. The national average rainfall is 475 mm per year. Most rain occurs in summer during the months from October to April.

The population at the time of the (2001) national census was 1,680,863, with a growth rate of 2.5% from the 1991 census. Most of the population is concentrated along the railway line in the east of the country at about 3 people per square kilometer. The population distribution is related to both historical factors, and to the availability of water and arable soils.

In 2000, the GDP and the GNP amounted to about 5.8 billion USD and 5.1 billion USD respectively. Botswana is categorized as a lower middle income country, with its GNP per capita being 3,166 USD in 2002. The average yearly economic growth rate for the 2000 was 5.9%.

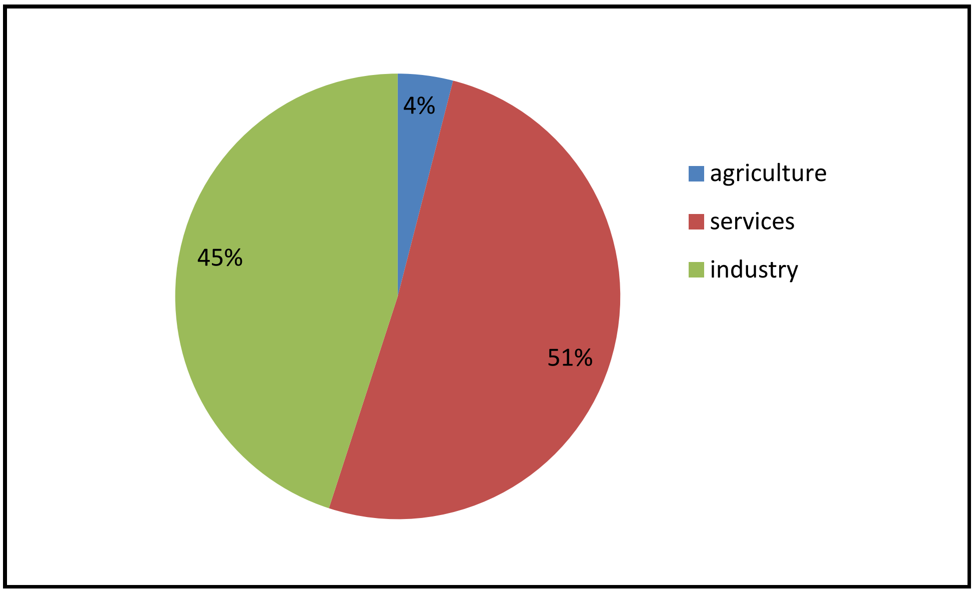


Figure 0.1: Allocation of GDP by sector, Botswana (World Bank, 2000).

Botswana is generally an arid country, with little surface water except in the far north. Surface water resources are the main source of water supply for urban areas. Groundwater is the main source of portable water supply in Botswana. Much of the country (about 66 percent) depends entirely on groundwater. The growing pressure on water resources is a result of the increases in population, rapid urbanization and development. With more people moving into the cities and major settlements, the demand on water resources has increased, presenting a serious problem to the country which is drought prone.

Botswana vegetation types are closely related with climate. The hardwood forests of the north of the country represent a valuable resource. Over 60% of Botswana land area is covered by sparse savannah woodland and scrub formations. Forests in Botswana are still a versatile renewable resource, providing simultaneously a wide range of economic, social, and environmental benefits and services. Derivation of products from forest resources continues to be under great pressure due to human activities particularly wood, which has major contribution of fuel energy used in the country.

The energy sector, particularly the electricity and petroleum sectors, contribute significantly to the national GDP and national employment, and are therefore significant components of the national economy. Coal, petroleum products and biomass dominate Botswana's primary energy supply. In 2000 coal accounted for 34% of the primary energy supply followed by petroleum product and fuelwood at 32% and 30% respectively (EAD 2000). Most of the coal is used for power generation. The major energy consumers are the residential (mainly fuelwood), transport, and industry at 42, 27 and 23% respectively.

Botswana has seen the growth in car ownership across the country has created congestion in cities that substantially reduces the efficiency and increases the operating costs of busses, the motor vehicle population growth rate was 1% for Botswana in 2000. Freight transport demand has also grown rapidly particularly by road.

The agriculture sector in Botswana, like in many countries, plays an important role in providing food, income, employment and investment opportunities for majority of people, particularly the rural community. Agriculture meets only a small portion of food needs and contributes just 2.8% to GDP primarily through beef exports. Only about 0.7% of total land area is arable. Crop production is hampered by physical constraints such as poor soils, inadequate economic infrastructure, scarce water resources and recurrent drought. The principal crops for domestic use are sorghum, corn, and millet. Sorghum and corn production in 2004 were 32,000 tons and 10,000 tons, respectively. The sorghum and corn harvests comprise less than 10% of the annual requirement of 250,000 tons. In 2004, Botswana's agricultural imports (primarily cereals) exceeded agricultural exports by USD 102.5 million. The agriculture sector also remains of strategic importance to the country's economy because of; among others the livestock sub sector significant contribution to the economy through foreign earnings.

0.3 Greenhouse Gas (GHG) Inventory

The national GHG inventory anthropogenic emissions and removals for the year 2000 were calculated for the following five sectors: Energy; Industrial Processes;

Agriculture; Land Use, Land Use Change and Forestry; and Waste. The Revised IPCC 1996 Guidelines were used in line with Decision 17/CP.8 of UNFCCC Conference of Parties (COP) 8. The three main GHGs considered are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). As these gases have different global warming potentials (GWP), they have been converted to equivalence in carbon dioxide emissions. Data to prepare the inventory were acquired from national and international statistics. IPCC's default emissions factors were applied.

Botswana's GHG emission was 7,168.7Gg CO_2 eq in 2000 and removal was 42,941 Gg CO_2 eq. The net emission after accounting for the removal was -35,506.777 Gg CO_2 eq, thus indicating that Botswana was a net sink in 2000.

Table 0.1: Greenhouse Gas (GHG) Inventory of Botswana for 2000.

Sectors	Emissions CO_2 eq (Gg)	Sink CO_2 eq (Gg)
Energy	5,537.923	
Agriculture	1785	
Waste	111.3	
Land-use change and Forestry		-42,941
Total emissions	7434.223	
Net Total (after subtracting sink)	-35506.777	

From the 1994 and 2000 aggregated emissions carbon dioxide emissions have increased by about 74% and CH_4 emissions have declined by 49% and those of N_2O have also declined by 100%. The increase is attributed to the use of biomass by households for cooking, in 1994 households only contributed about 2% of CO_2 but in 2000 households contributed 46% of CO_2 emissions. The decrease of CH_4 and N_2O were due to the fact that emissions from savannah burning were not included in the GHG Inventory calculations for Botswana. Savannah burning contributed to 37% and 80% of the CH_4 and N_2O respectively.

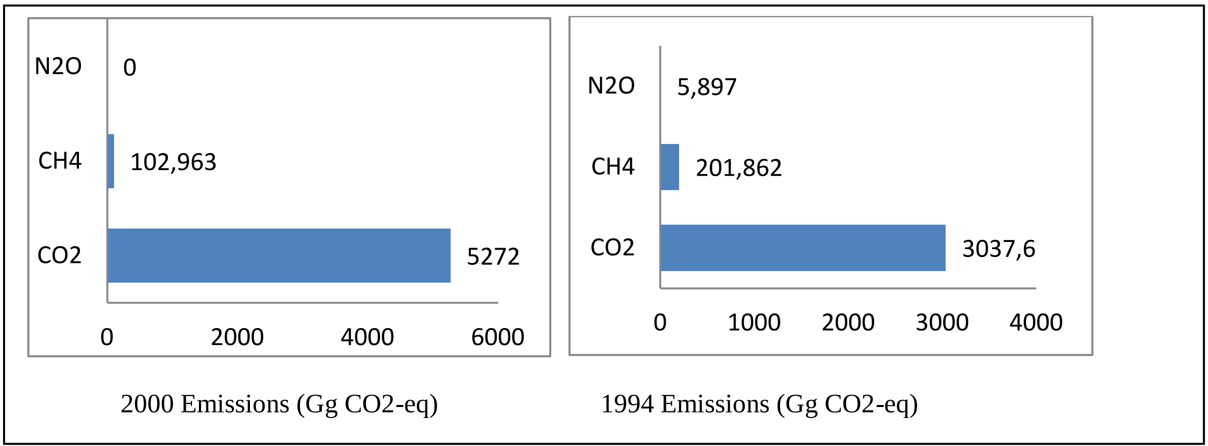


Figure 0.2: Comparison of the INC Inventory and SNC Inventory.

0.3.1 Programs containing measures to facilitate adequate adaptation to climate change

The V&A assessment carried under NC2 updated the INC assessment in identifying potential impacts across seven sectors: Water Resources, Grasslands and Livestock, Crops, Forestry, and Public Health

0.3.2 Assessments of climate change

To investigate climate change in Botswana conclusions from the SNC studies and other climate change studies we used.

The trends of change in the mean annual air temperature, the mean annual precipitation, and the moisture, were estimated for 1960 – 1990, 1961 - 2000 and future 2046-2065 time periods. To evaluate historical climate variability the climate moisture index (CMI) was used and statistical tests of significance of differences were also carried out. Future climate change in Botswana was assessed using downscaling of global circulation model simulations (GCM) and also using the MAGICC/SCENGEN.

Results from the GCMs indicate that rainfall has been highly variable, spatially, inter and intra annual (CMI; 1960-1990), and that droughts in terms of rainfall deficits Standardized Precipitation Index (SPI) are most common in northern Botswana, indicating that this area may be most affected by on-going climate change. Extreme droughts based on low rainfall and soil conditions are most common in south western Botswana Palmer Drought Severity index (PDSI) and high rainfall events with risks of floods are most likely in north eastern Botswana. Several large dams are located in this area. Droughts are expected to increase in frequency and severity, particularly in the period 2080-2100, the changes are largest in western and northern Botswana. The SPI and PDSI results show similar patterns but differ on details.

Downscaling of global circulation model simulations (GCM) – there is indication of an increase in total annual rainfall in the south of the country, and a decrease in total annual rainfall in the north and the east of the country.

MAGICC/SCENGEN results indicate an increase in temperature of 2^{o}C on average all areas of Botswana in 2030, temperature is increasing from 0.5 degrees to over 2 degrees Celsius. Warming is most pronounced over existing desert regions of the Kalahari. The projections also indicate a decrease in river flows of about 0.8% also indicates a reduction in rainfall of about 3 to -9% and a 13 % decrease in river flows and 19 % decline in cereal production.

Table 0.2: Sectoral impacts and adaptation measures.

Sector	Impacts	Adaptation	Adaptation	Adaptation	Adaptation	Barriers
Crops	Changes in growing season length	Development of heat tolerant and drought resistance crops	Intensify irrigation systems	Changes in ploughing methods	Develop agricultural infrastructure	Lack of resources Lack of technology Lack of capacity
	Changes in crop productivity	Seed and fertilizer provision	Early warning systems	Use of greenhouse/nets	Drought mitigation	
Health	Shift in malaria band	Malaria Control Programme				
	morbidity and mortality children under five (5) years of age	Control of Diarrhoeal Diseases Programme (CDDP)	Integrated management of Childhood Infections (IMCI)			
Water	Decrease in annual dam yields	Water Recycling	Rainwater Harvesting	Desalination of groundwater	Incorporate water demand in all national development plans	
	Average increase in unmet water	Need to increase investments in water infrastructure, (e.g. additional storage volume)	improve efficiency, and review existing national and sectoral policies			
Grassland and Livestock	Preferred plant species changing composition to undesirable plants	Provision of Feeds	Diversification of farm produce			
Forestry	Thorn and shrub savannas are predicted to expand at the expense of grasslands and moister forests and woodlands.	Planting trees	Use alternatives to trees	Enforcement of conservation policies		

0.4 Mitigation Analysis

To estimate future trends of GHG emissions under different mitigation policies, the software LEAP (Long-range Energy Alternatives Planning system) was used.

0.4.1 Projected Energy Demand

Figure ES 3: shows the final and estimated final energy demand by sector in Botswana, The annual growth rate is projected to grow at 2% from 2000 to 2035 in the business as usual scenario. During this period the agricultural sector final energy demand is expected to increase at an average annual growth rate of 6% while the transport sector's final energy demand is projected to increase at an average annual rate of 2.4%.

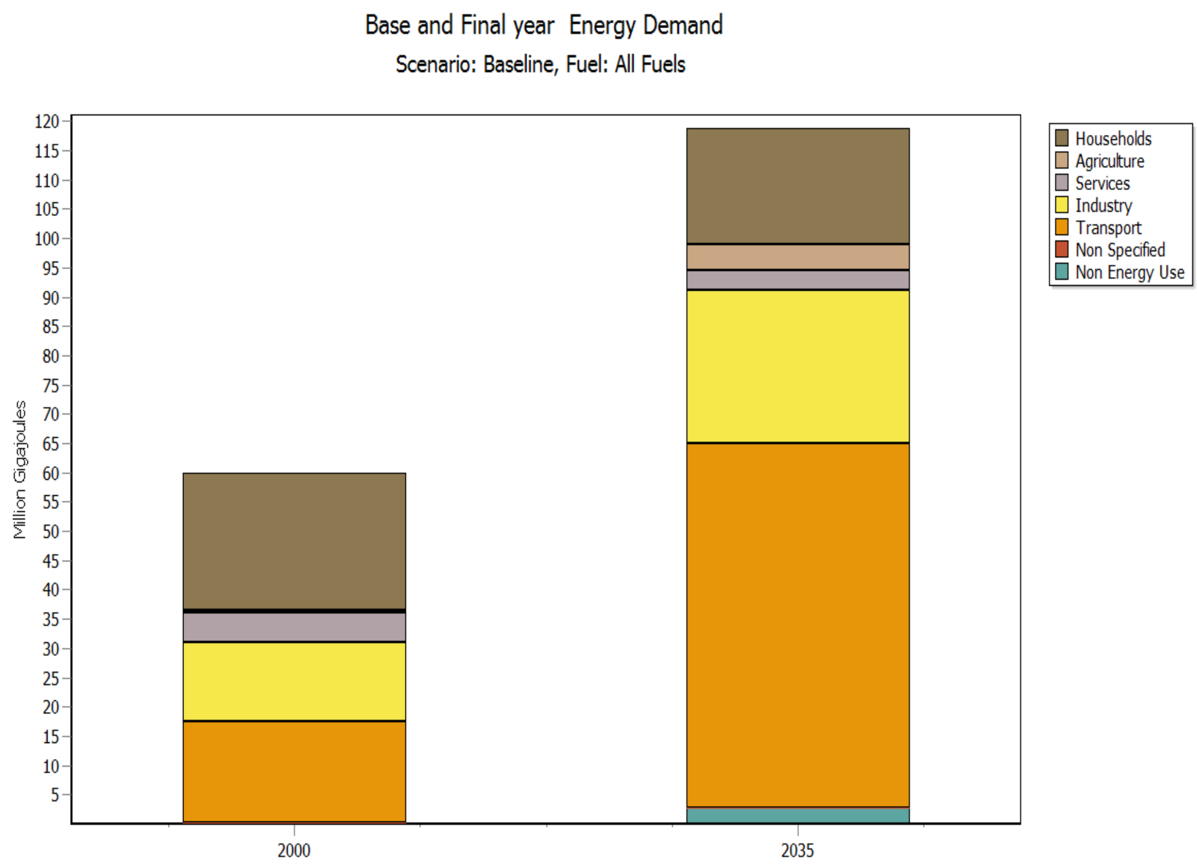


Figure 0.3: Projected energy demand of Botswana.

Industry is projected to increase at an average annual growth rate of 6.5% and non energy use to increase at an average annual rate of 2% but final energy demand for households is expected to decrease at an annual rate of 0.5%.

Table 0.3: Potential mitigation options in key sectors

Sector	Mitigation options
Energy	Energy efficiency in Residential (efficient bulbs, efficient refrigerators, smart meters) Replacing fuel wood with use of LPG and biogas Building insulation PV electricity
Waste	Landfill gas recovery
Agriculture	Livestock waste management through • Aerobic manure composting • Biogas capture (for rural households)
LULUCF	Reforestation
Industrial Process	Energy efficiency (electric furnace, *space heating, general lighting purposes and* motors) Energy audits
Transport	Modal shift Fuel economy CNG/biodiesel buses

0.5 Other information considered relevant to the achievement of the objective of the Convention

0.5.1 Education training and public awareness

The university of Botswana Environmental Science Department provides training on environmental issues. During the preparation of this report awareness activities were carried out in the form of workshops for environmental school teachers, farmers, communities and school assembly addresses for students.

0.5.2 Research and systematic observation

A large part of the ongoing research is contributed by individual research efforts at the University of Botswana and other tertiary education centres. Recent studies have looked at vulnerability, impacts and adaptation in the whole of the Botswana Limpopo Basin. The research looked at the various sectors of agriculture, water resources, wildlife, natural products and potential adaptation strategies. Some of the simulations studies highlighted above are part of the follow up work, and there are other studies in the planning that arise from the main study.

0.5.3 Technology transfer

Technology needs assessment report was prepared in 2004, in this report technologies for mitigation and adaptation were identified and prioritized, the report singled out policy improvement that could lead to more enabling environments, demonstrated how the capacity of local institutions and experts could be increased, and showed how public awareness of climate change issues could be enhanced.

0.5.4 Capacity building

The UNDP/Government of Botswana Environmental Support Programme project built capacity of officers from different institutions on climate mitigation and vulnerability and adaptation assessments. Also funding under the SNC was also used to build capacity on mitigation and vulnerability assessments. Capacity was also built through attending domestic and regional workshops on key areas and also through hands on involvement in the preparation of this report.

0.6 Constraints and gaps, and related financial, technical and capacity needs

0.6.1 Constraints and gaps

The main constraints are related to lack of activity data and information, and the lack of expertise in the respective sectors. Due to the unavailability of relevant data, assumptions were made and data obtained from secondary sources. Climate change is not yet a priority for the country even though there is a Parliamentary Committee on Climate Change and therefore the integration of climate change issues in development programmes and projects still remains a challenge. As a result there are no national climate change plans and absence of policy and legal framework to implement convention. Climate Change is weakly infused in social, economic and environmental policies.

Some of the capacity constrains identified under the National Capacity Self Assessment report were inappropriate institutional structure, inadequate manpower and inadequate policy framework.

0.6.2 Technical and capacity needs

Technical and financial support is urgently needed for capacity building and to establish research programs within universities and research institutes. In this respect, support is needed for;

0.6.3 Financial needs

Funding is needed for the country to cope with the adverse impact of climate change and the funding needs are expressed in the relevant chapters of this report.

Cooperation with Annex 1 Parties and other international Institutions: Botswana has received support from developed countries through various programmes. There were some projects financed in the field of climate change through international organizations such as the World Bank. Botswana received the following support for institutional strengthening of the Designated National Authority for Clean Development Mechanism projects.

1 National Circumstances

1.1 Geographic and geological profile

Botswana is a landlocked country located in Southern Africa, north of South Africa that neighbours Zimbabwe, South Africa, Namibia and Zambia. Botswana has land boundaries of combined length 4,013 km, of which the constituent boundaries are shared with Namibia, for 1,360 km; South Africa 1,840 km; Zimbabwe, 813 km and Zambia, less than 1 km. It lies between 20 and 29.4˚ E and 17.8 and 26.8˚S. Botswana occupies an area of 600,370 km², of which 581,730 km² are land.

Figure1.1: Topography map of Botswana.

Botswana lies entirely within the shallow basin formed by the high-lying interior plateau of southern Africa. Three-quarters of the land surface is covered by the Kalahari sands, which fill the basin to a depth of up to several hundred meters. The land surface is nearly flat, with a mean altitude of 1 000 m above sea level. The lowest point in Botswana is at the confluence of the Limpopo and Shashe rivers at an altitude of 537 m. The highest point is found at the Otse Hill in the south east, at 1491 m.

Botswana is underlain by basement granites, which in turn are covered by the Karroo sedimentary layer within which the Ecca shales are found. These sediments host Botswana's coal deposits. The diamond-bearing ores are found in volcanic intrusions known as kimberlite dykes at Orapa, Letlhakane and Jwaneng.

The Okavango Delta, the world's largest inland delta, is in the northwest and the Makgadikgadi Pans, a large salt pan lies in the north-central area. The country is divided into four drainage regions:

The Chobe River on the border with the Caprivi Strip of Namibia together with a small adjacent swampy area is part of the Zambezi basin; most of the north and central region of the country is part of the Okavango inland drainage basin;

The easternmost part of the country falls into the Limpopo drainage basin;

The southern and southwestern regions, which are the driest of all, are drained by the Molopo river along the South African border

The Nossob river through the Kalahari Gemsbok National Park, and are technically part of the basin of the Orange river.

1.2 Climate profile

The country is arid to semi-arid with highly erratic rainfall. The mean annual rainfall ranges from over 650 mm in the north-east to less than 250 mm in the south west. The national average rainfall is 475 mm per year. Most rain occurs in the months from October to April, and falls as localised showers and thunderstorms. The main features of the climate are determined by Botswana's inland location, astride the subtropical high-pressure belt. During the summer months, the Inter-Tropical Convergence Zone (ITCZ) moves southward to about 20° S to bring moisture to the northern parts of the country. The rest of the subcontinent is influenced by a thermal low pressure cell. Moist air associated with the ITCZ, and the moist air which is fed in to the eastern parts of the country from the Indian Ocean, is warmed by the intense sunshine, leading to convective storms. The air becomes progressively drier westwards as most of the moisture is shed over the eastern and northern parts of the country. Between May and September the stable high pressure cell displaces the ITCZ and its associated thermal lows to the north, resulting in drier conditions in winter. Once every few weeks during the dry season, westerly waves displace the cell northward, drawing in cold air from the south and causing light frontal clouds.

The daytime air temperatures are generally warm to hot due to the high insolation, but because of the low humidity night-time minimum temperatures regularly drop to near freezing in winter. The mean monthly maximum temperature ranges from 29.5 to 35˚C in summer, and 19.8 to 28.9˚C in winter. Mean monthly minimum temperatures range from 14.6 to 20.8˚C in summer, and 2.9 to 11.6˚C in winter. The high solar radiation, low humidity and high temperatures lead to very high evaporation rates, ranging from 1.8 to 2.2 m annually for surface water. The sparse and highly variable rainfall, the high evaporation rate and the virtual absence of permanent surface water over large parts of the country combine to ensure that water is a scarce resource in Botswana.

Botswana is highly vulnerable to climate change effects because of the variable nature of the country's rainfall frequency and magnitude. Botswana is also susceptible to variations in climate induced by global sea-surface temperature (SST) anomalies. In particular, El Niño events in the East Tropical Pacific lead to negative departures from the normal in respect of rainfall over arable land in the country, while La Niña events tend to enhance rainfall amounts. Rainfall in Botswana is highly correlated with the global El Niño-Southern Oscillation (ENSO) phenomenon. During strong 'El Niño' years, the rainfall over most of Botswana is severely depressed. These conditions may persist for several years in succession. The persistence of drought always bring a host of social problems like famine, diseases etc.: for instance, the combination of drought and rinderpest in 1896/97 nearly wiped out the cattle population in Botswana. Conversely during 'La Niña' years, flooding can be experienced in the east. Floods lead to water logging of soils, leaching of soil nutrition and the proliferation of pests. During the 1999/2000 rainfall season the outbreak of pest (in particular quelea birds) and diseases caused a 50% reduction in crop yields.

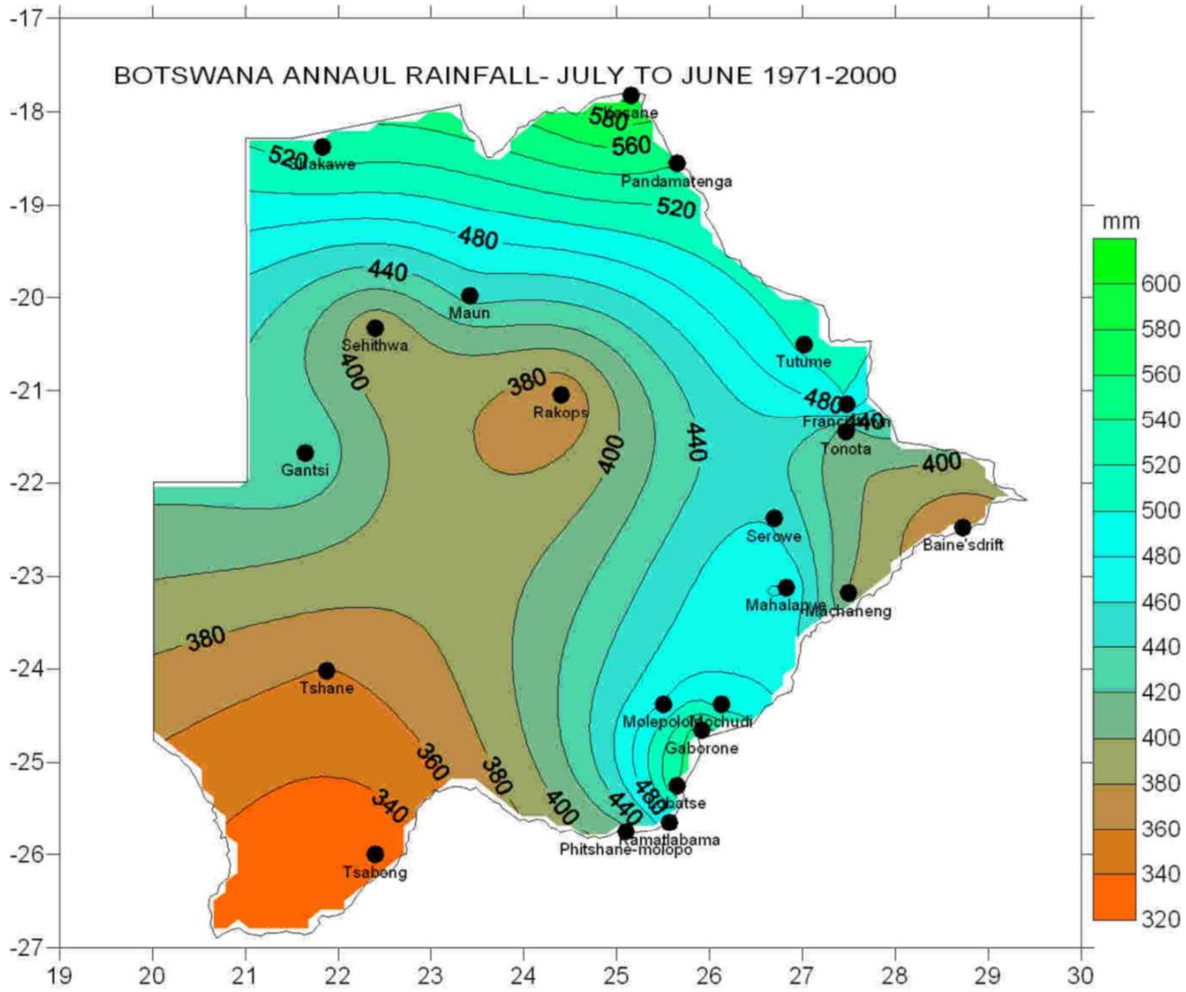


Figure 1.2: Rainfall map of Botswana (Source: Department of Meteorological Services).

1.3 Natural resources:

1.3.1 Water resources

Water is the scarcest resource in Botswana, affecting many aspects of the nation's development. Increasing demands for consumptive water uses such as domestic, mining, industrial, commercial and agricultural water demands makes water a very valuable commodity that requires careful planning for its sustainable utilization and conservation. Groundwater is the main source of potable water supply in the country. Except for the urban centers and a few major villages, most villages depend on groundwater for their water needs. Groundwater recharge is very limited, making the resource finite and non-renewable. Surface water resources are the main source of water supply for urban areas.

Figure 1.3 Okavango Delta.

In 1994, over 93% of Batswana had access to safe drinking water (piped) and at least 90% of people were within 2.5 km of a source of drinking water. In 1990, surface water comprised 36% (41.9 million cubic meters) and groundwater 64% (75.7 million cubic meters) of the consumed water resources in Botswana. The groundwater resources are mostly of fossil type, so their exploitation must be carefully managed if the wellfields are not to be exhausted. Supply from surface water is expected to rise to 57% of consumption in 2020. The Limpopo and Zambezi Rivers are viewed as potential sources to meet future water needs. Waste water is recognised as an important water resource that could be used more extensively. The ephemeral nature of the surface water supplies, and Botswana's increasing dependence on these sources, increases the country's vulnerability to drought and to climate change.

The main threats to the water resources are over-exploitation and pollution. The main sources of pollution are industrial and domestic effluent from settlements, human waste from pit latrines and waste disposal on the dam catchment areas and shallow aquifers. Water sources are monitored on a regular basis to assess the deterioration in the quality. Effluent quality is also monitored at source to ensure that it is compliant with the effluent quality standards. (State of the Environment Review Report 2002).

1.3.2 Forests

Forestry is the responsibility of the Department of Crop Production and Forestry within the Ministry of Agriculture. Commercial forestry is thus included within the agricultural sector although estimates of timber production or contribution to the GDP are not distinguished from the rest of the agricultural sector. Wood resources in the forest reserves are only exploited when Government issues permits to do so. The main timber species are *Baikiaea plurijuga* Harms and *Pterocarpus angolensis* DC. Harvesting from the Chobe Forest Reserve was suspended in 1993 due to fears that the resource was not being sustainably harvested (INC, 2001).

Forests in Botswana as in most of the developing countries are still a versatile renewable resource, providing simultaneously a wide range of economic, social, and environmental benefits and services. The sustainability of the goods and services derived from the forests depends on a number of factors. In the context of Botswana these include, among others: population growth, socio-economic and political changes, agricultural production, energy needs and consumption patterns, development patterns, institutional frameworks (policies, legislations, land tenure systems), and public education on environmental issues. Botswana forests/woodlands are found on state-land, freehold and tribal land.

The stocking situation on state-land in particular forest reserves is estimated at 10 million m^3 The total growing stock of all woodlands in the country has been estimated at 1,277,400 metric tonnes and the mean annual increment at 40.8million tones per annum. (CSO Environ. Statistic, 2000).

At present the land under plantations and woodlots stands at 1200 ha and it is expected to increase due to new afforestation programs funded by both government and donors to offset fuel-wood shortages and other wood materials particularly around peri-urban and urban areas. National Tree Planting program that is an annual event has also raised the level of awareness about the importance of tree planting and is envisaged to continue to play a major role in sensitizing and increasing our woody vegetation.

Forest fires contribute a lot to the destruction of the natural forest resource. Fire is also a significant factor in forest reserve management, and impact on the only commercially exploitable timber trees. As far back as 1935 foresters in Chobe noted that, "There is ample proof throughout the concession area of the damage caused by man and animals, by insects, drought, frost and wind, but the combined damage from these causes is insignificant compared with the disastrous effects of fire." Nothing has changed today. "Fire has been and is still one of the worst threats to the forests of Botswana" (Gombalume and Manthe, 1995).

1.3.3 Land use

Botswana land tenure is categorized into three main systems: State land (which includes national parks, some game reserves and wildlife management areas, and all the forest reserves) covers 41.8% of Botswana’s total land area, freehold land make up 3.4% while the balance of 54.8% is communal or tribal land (Environmental Statistics, 2006). The table below show how the land is used.

Table 1.1: Land tenure.

Use/Tenure	Land, square kilometres
Communal Land	
Pasturer, Arable and Residential areas	253 223
Tribal Grazing Land Policy Ranches	24 292
Lease ranches	13 090
NADP (fencing component)	28 392
Sub-total	**318,997 (54.8%)**
Freehold Land	
Freehold farms	19 109
Arable blocks	320
Sub-total	**19 429 (3.4%)**
State Land	
National Parks	45 900
Game Reserves	60 558
Forest Reserves	4 555
Wildlife Management Areas	128 574
Quarantine and Botswana Livestock Development Corporation ranches	3 717
243,304 41.8	
Sub-total	**243 304 (41.8%)**
Total land	581 730 (100%)

(Environmental Statistics, 2006)

1.4 Economic profile

Since the 1970's, the main economic activity has shifted from agriculture (specifically, beef production) to mining. Increased mineral production stimulated infrastructural development and the expansion of Government services. Sustainable economic diversification is a priority in the current development plan, and there are some indications that it is already occurring. For instance, in the mid 1980's the mining sector constituted 50% of the GDP, whereas in 1994 it contributed 36%. Recurrent and prolonged droughts have had negative impacts on the agricultural sector, which was the dominant sector prior to independence.

Unemployment was reported to be 21% in 1994. The private sector is the largest formal sector employer (57.0%) followed by Government (37.1%) and the parastatals (5.9%). Agriculture is responsible for a significant proportion of informal sector employment. The development priorities of Botswana are focused on diversifying the economy, creating employment, reducing poverty, providing infrastructure and recovering its cost, developing human resources, rural development, improving environment and land use policy, and policy reform in the public sector. The real growth rate of GDP during the 1999/2000 national accounts year is forecast to be around 10%, which would be more than double the growth rate estimated for 1998/99. The primary reason for this expected acceleration is a substantial growth of around 15% in GDP from the mining sector, due in turn to the doubling of production at the Orapa mine following the completion of the expansion project. The fall in the growth rate in 1998/99, from 8.0% of the preceding year to 4.5%, was also due mainly to a contraction in the mining sector GDP by over 4%. This shows that despite the economic diversification taking place in the economy, the overall growth and prosperity of the country are still crucially dependent on the fortunes of the mining sector, which contributes around a third of the country’s GDP. While the growth rate of the mining sector is thus likely to go through some oscillations, the growth rates of other major sectors such as Manufacturing, Construction, Trade, Finance and Services are likely to continue at an average rate in the range of 6 to 7%.

Botswana seeks to further diversify its economy away from minerals, which account for over 40% of GDP. Foreign investment and management are welcomed in Botswana. Botswana abolished foreign exchange controls in 1999, has a low corporate tax rate (15%), and no prohibitions on foreign ownership of companies. The country's inflation rate had remained stable and comparatively low over the 10 years preceding 2005. However, rising fuel and utility prices along with the government's 12.5% devaluation of the Pula in May 2005 resulted in a spike in inflation to 11.4% as of December 2005, which fell well outside the Bank of Botswana's target rate of between 4%-7%. Inflation as of November 2007 was 7.7%. The Government of Botswana was considering additional policies to enhance competitiveness, including a new Foreign Direct Investment Strategy and National Export Development Strategy. Botswana's parliament adopted both a Privatization Master Plan and a new Competition Policy that were aimed at fostering economic diversification.

1.5 Agriculture

1.5.1 Livestock

More than one-half of the population lives in rural areas and is largely dependent on subsistence crop and livestock farming. Agriculture meets only a small portion of food needs and contributes a very small amount to GDP--primarily through beef exports--but it remains a social and cultural touchstone. Cattle raising in particular dominated Botswana's social and economic life before independence. The national herd is estimated between 2 and 3 million head, but the cattle industry is experiencing a protracted decline. The table below shows the statistics for livestock population between 1979 and 2003.

Table 1.2 Livestock population ('000) from 1979 to 2003 (CSO, 2004).

Year	Cattle	Goats	Sheep	Donkeys	Horses	Chickens	Pigs
1979	2,840	616	152	127	18	740	6
1980	2,911	638	149	130	22	833	6
1981	2,967	621	140	127	24	1,046	5
1982	2,979	636	140	138	24	1,146	5
1983	2,818	783	165	142	23	961	5
1984	2,685	889	167	139	23	714	7
1985	2,459	1,138	200	146	23	1,020	9
1986	2,332	1,332	229	142	24	1,179	11
1987	2,264	1,470	240	147	24	1,283	11
1988	2,408	1,691	259	150	28	1,810	13
1989	2,543	1,897	286	151	32	2,013	15
1990	2,696	2,092	317	158	34	2,126	16
1993	1,821	1,838	250	231	31	1,077	4
1995	2,530	2,624	337	303	35	3,157	1
1996	2,249	2,205	349	336	5	1,355	3
1997	2,212	2,615	409	404	7	1,191	2
1998	2,345	2,199	393	400	8	776	4
1999	2,581	1,916	369	373	5	874	4
2001	2,468	1,887	306	409	5	928	5
2002	3,060	1,683	273	405	6	866	2
2003	2,028	1,355	220	493	7	650	4

The cattle population increased by 13.0 percent between the 1993 and 2004 agricultural censuses. However cattle birth rate, death rate and off-take rate decreased by 6.1, 58.6 and 10.8 percent respectively. Goats and sheep population decreased by

19.6 and 9.8 percent respectively, with decreases in their birth, death and off take rates by 3.3, 43.1 and 27.1 percent respectively during the same period. (CSO, 2004)

1.5.2 Crops

Crop production is hampered by traditional farming methods, recurrent drought, erosion, and disease. Most of the land under cultivation is in the eastern region. The principal crops for domestic use are sorghum, corn, and millet. Sorghum and corn production in 2004 were 32,000 tons and 10,000 tons, respectively. Smaller quantities of cowpeas, beans, and other pulses are also grown. The 2004 output of all these crops was about 20,000 tons; in addition, 16,000 tons of vegetables and 10,000 tons of fruit were grown. (CSO, 2004). The table below shows total production by crop in metric tons between 1979 and 2003.

Table 1.3 Total production by crop in metric tons (CSO, 2004).

Year	Sorghum	Maize	Millet	Beans & Pulses	Sunflower	Ground-nuts	Other Crops	Total
1979	5,000	3,000	1,000	1,000	900	200	11,100	22,200
1980	29,000	12,000	3,000	2,000	1,400	1,400	48,800	97,600
1981	28,000	22,000	2,000	3,000	1,200	2,000	58,200	116,400
1982	4,000	13,000	500	500	7,000	300	19,000	44,300
1983	5,000	9,000	500	300	200	800	15,800	31,600
1984	6,000	500	700	400	400	600	8,600	17,200
1985	15,000	1,500	1,800	400	500	800	20,000	40,000
1986	16,000	3,600	1,300	600	200	200	21,900	43,800
1987	18,000	3,300	400	100	100	100	22,000	44,000
1988	94,000	7,300	3,700	2,300	200	200	107,700	215,400
1989	53,000	20,000	2,000	2,500	200	500	78,200	156,400
1990	38,200	12,000	1,700	2,000	240	540	54,680	109,360
1993	10,797	2,976	1,624	530	113	126	423	16,589
1995	113,547	18,953	19,390	10,181	962	951	12,061	176,045
1996	59,048	24,629	2,508	3,914	39*	551	8,376	99,217
1997	13,450	22,647	1,357	4,467	444	1,040	10,133	53,538
1998	3,743	2,344	507	1,198	1,267	121	7,324	16,504
1999	6,658	3,796	860	1,348	2,829	217	8,287	23,995
2001	1,583	4,976	472	1,280	150	147	8,962	17,570
2002	15,805	16,447	54	1,907	2,250	137	7,694	44,294
2003	23,501	1,633	91	460	960	15	15,384	42,044

1.6 Energy

The energy sector, particularly the electricity and petroleum sectors, contribute significantly to the national GDP and national employment, and are therefore significant components of the national economy. The profile of Botswana's energy supply is similar to most developing countries, particularly the Southern African Development Community (SADC) countries, and is dominated by fuelwood which contributes 58% to the total primary energy supplied. The fuelwood is mainly collected by hand, by individual households, resulting in local depletion. At a national scale, the supply due to tree growth is greater than the harvest. Fuelwood is used in the residential sector, government institutions and in small to medium commercial enterprises, especially in rural areas. Annual national wood demand is estimated to be 1.8 million tons. Liquid petroleum gas (LPG) and electricity are used in medium and high-income households. LPG is steadily gaining in popularity in the low-income households because of convenience, and because of localised fuelwood scarcity.The water and electricity supply sectors together contributed 2.2% to the 1994 GDP. The Botswana Power Corporation (BPC), a parastatal (a statutory corporation), uses coal mined at Morupule to generate electricity at the Morupule power station. The installed capacity is 132 MW. A coal-fired power station at Selibe Phikwe was decommissioned in 1995/6. Botswana Ash generates 20 MW for its own use. In the rest of the country diesel generators are estimated to supply over 20 MW of energy to villages, rural schools, hospitals, police stations and prisons. Solar photovoltaic and wind-generated electricity contribute a fraction of one percent to the total energy supply, but occupy an important niche in satisfying needs in remote areas, and are promoted by the national energy policy. Solar and photovoltaic technologies are used in schools, for rural street lighting, and in some homes and government buildings. In 1994, 75.1% of the electricity supply in Botswana was generated in the country, and 24.9% was imported from the Southern African Power Pool (CSO, 2000). Nearly 100% of the petrol, diesel and paraffin fuel marketed in Botswana (except for small amounts from Namibia for the Ghanzi district) is imported by the five multinational oil companies (BP, Shell, Caltex, Total and Engen) from South

Africa. The transport sector is the main consumer of petrol and diesel. A combined total of 435 million liters of petrol and diesel was consumed in 1994.

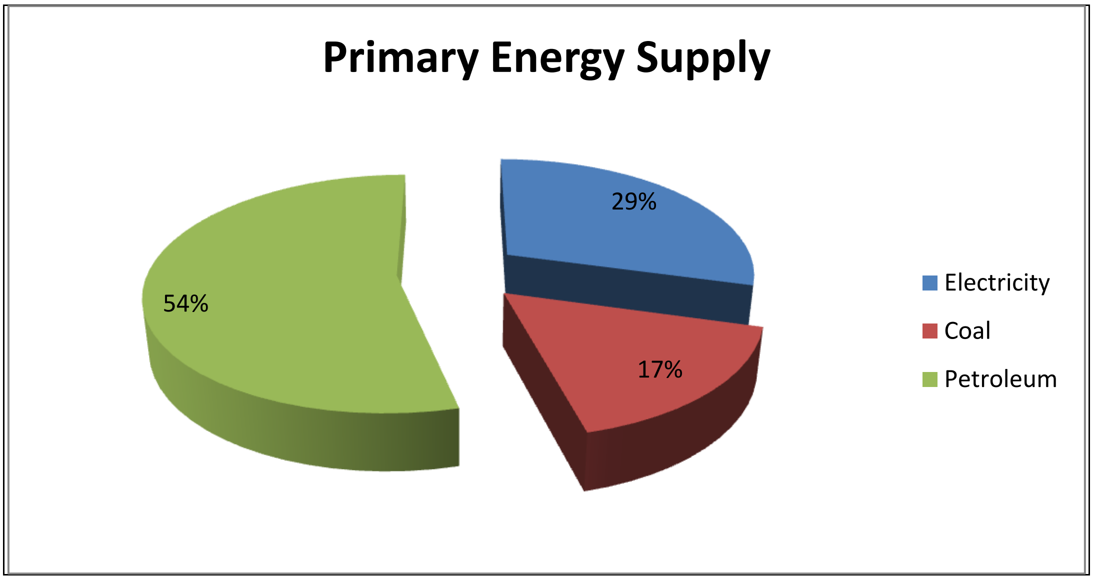


Figure 1.4: Primary energy supply for the year 2008.

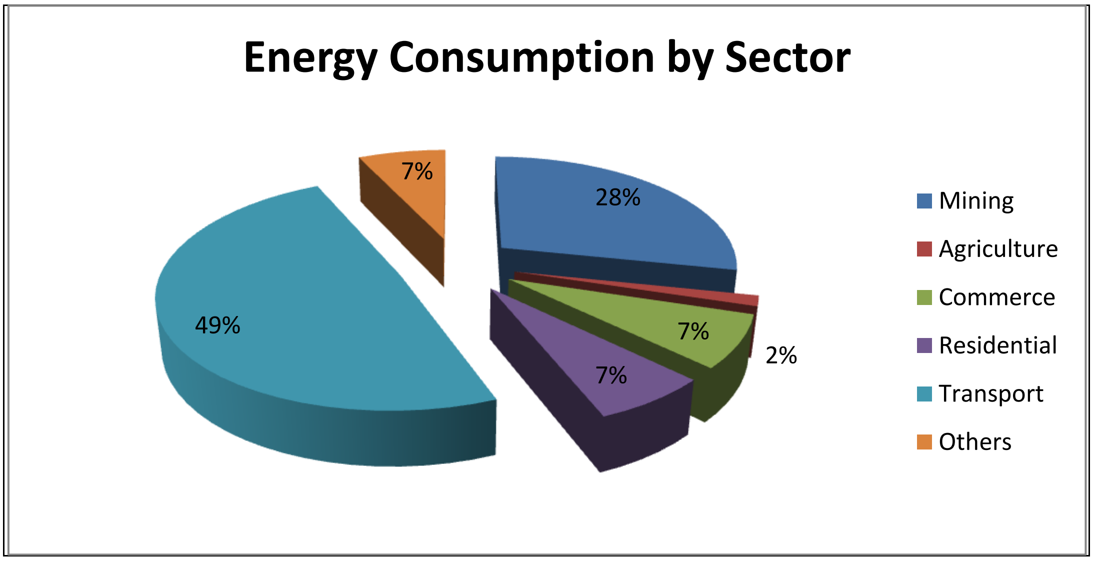


Figure 1.5: Commercial energy demand (excluding fuelwood) for the year 2008 (Source Draft Energy Policy).

1.7 Mining

Botswana has several important mineral deposits. Diamonds were first discovered in Botswana in 1967 and are currently mined at Orapa, Letlhakane, Damtshaa and

Jwaneng. The output in 1996 was 17.7 million carats. The diamond mining industry was a key factor in the rapid economic and social development of the country. In the period between 1980 and 1995, diamond exports contributed 50% - 70% of foreign exchange earnings. Copper-nickel reserves have been exploited at Selibe Pikwe since 1973. Since 1984 production has been relatively constant at 49 000 tons of matte. Sale of copper-nickel contributed between 5% to 9% of total exports. Coal has been mined at Morupule since 1976, with 900 778 tons extracted in 1994. Coal reserves in Botswana are estimated to amount to 212.8 billion tons. Extensive reserves of salt and soda ash are found at Sowa Pan; production in 1995 was 208 and 211 thousand tons of each. Other minerals are known to occur, including gold, manganese and semiprecious stones, but are not mined in significant quantities. Crushed stone, sand and clay are quarried for construction purposes; the level of production depends on the building industry and large infrastructure projects. The mining sector dominated the economy in 1994 (36% of the GDP) and continues to do so at present.

In 2007, diamonds accounted for 67% of total exports (down from a high of 84% in 2003/2004) and 28% of GDP. The current economic slowdown has greatly impact Botswana's diamond mining industry.

BCL operates a copper-nickel mine at Selebi-Phikwe, other copper-nickel mines include Tati Nickel near Francistown. Botash, the sole producer of soda ash in the region and supported by substantial government investment, produced 265,000 tons of soda ash in 2005.

Coal-bed methane gas has been discovered in the northeastern part of the country, estimated by the developers at a commercially viable quantity of 12 trillion cubic feet. Development of the gas fields has been slow. Other minerals found in Botswana include potash, coal, iron ore and silver.

1.8 Transport and telecommunications

A highway connecting all major towns and district capitals is completely paved, and the all-weather Trans-Kalahari Highway connects the country to Walvis Bay in

Namibia. A fiber-optic telecommunications network has been completed in Botswana connecting all major population centers.

In addition to the government-owned newspaper and national radio network, there is an active, independent press (one daily and seven weekly newspapers). Two privately owned radio stations began operations in 1999, and a third began operations in 2008. In 2000, the government-owned Botswana Television (BTV) was launched, which was Botswana's first national television station. GBC is a commercially owned television station that broadcast programs to the Gaborone area only. Foreign publications are sold without restriction in Botswana, and there are 22 commercial Internet service providers. Three cellular phone providers cover most of the country.

1.8.1 Railways and roads and airport networks

The route length of the railways is nearly 900 kilometres comprising 650 kilometres of main line between Ramatlabama in the south and Ramokgwabwe in the north, and 250 kilometres of branch lines serving copper and nickel mines in Selebi Phikwe area, coal mines in Morupule and soda plant at Sua. At the end of 1992 Botswana had 18,327 kilometers of roads of which 8,766 kilometres are maintained by the Department of Roads and 9,566 kilometres by the district councils. This road network links all settlements with a population of over 100 people, which represents over 90% of the national population. This does not include internal roads in cities, towns or villages which are public roads maintained by Local Government. The total road network maintained by the Central Government in 2006 was 8,916 km of which 6,396 km was bitumen, 1,221 km gravel and 1,299 km was sand. In the Northern part of Botswana, traffic volume stood at 46, 283 in 2007 while in the Southern and Western part of the country the number of vehicles on the roads were counted to be 65,428 and 2,980 respectively. By the beginning of 1990s there were 27 government owned airfields of which four were paved major airports, namely Sir Seretse Khama Airport in Gaborone, Maun Airport, Francistown Airport and Selebi-Phikwe Airport. Total aircraft movements slightly went up by 0.02 percent from 76,390 in 2006 to 76,407 in 2007. Maun airport was the busiest as it accounted for 54.7 percent of all aircraft movements which occurred in 2007. Gantsi airport had the least number of aircraft movements. Air passenger movement increased by 7.5 percent, from 567,058 in 2006 to 609,715 passengers in 2007 (Figure 5). In terms of passenger movement, Gaborone airport was the busiest accounting for 51.6 percent of all movements. (CSO, 2007).

1.8.2 Telecommunications

Botswana Telecommunications Corporation (BTC) was established as a parastatal in 1980. The BTC has implemented an almost 100% digital telephone network throughout the country. BTC has implemented a countrywide digital telephone network with several thousand kilometers of fiber optic cable and a complete countrywide microwave network. Other services offered by the BTC include countrywide paging and a digital data network (ISDN and X.25) as well as high-speed Internet access.

Other telecommunications services available privately are mobile telecommunications from two private GSM digital mobile networks.

1.9 Tourism

Tourism is an increasingly important industry in Botswana, accounting for approximately 10% of GDP in 2006. One of the world's unique ecosystems, the Okavango Delta, is located in Botswana. The country offers excellent game viewing and birding both in the Delta and in the Chobe Game Reserve--home to one of the largest herds of free-ranging elephants in the world. Botswana's Central Kalahari Game Reserve also offers good game viewing and some of the most remote and unspoiled wilderness in southern Africa.

1.10 Population

The population at the time of the most recent national census (2001) was 1,680,863, a growth rate of 2.5% from the 1991 census. Most of the population is concentrated along the railway line in the east of the country at about 3 persons per km². The population distribution is related to both historical factors, and to the availability of water and arable soils. The population is young: about 43% of the people are less than 15 years of age (1991 data). In the 1980's population growth was estimated to be 3.5%, but has been recently revised to 2.5% (National Development Plan 8). The population is becoming increasingly urbanized. Currently, 52% of the people live in urban settlements, and the annual rate of urbanization is 8%.

Table 1.4: Population by sex and census districts (CSO 1991 and 2001).

District	1991 Census Population	2001 Census			
		Households	**Male**	**Female**	**Total**
Gaborone	133,468	58,476	91,823	94,184	186,007
Francistown	65,244	23,124	40,134	42,889	83,023
Lobatse	26,052	8,523	14,202	15,487	29,689
Selibe Phikwe	39,772	15,258	24,334	25,515	49,849
Orapa	8,827	2,578	4,837	4,314	9,151
Jwaneng	11,188	4,681	7,613	7,566	15,179
Sowa	2,228	979	1,570	1,309	2,879
Southern	128,989	24,463	53,810	59,894	113,704
Barolong	18,400	10,348	23,397	24,080	47,477
Ngawketse West		2,391	5,159	5,312	10,471
South East	43,584	14,780	29,125	31,498	60,623
Kweneng East	170,437	43,812	91,045	98,728	189,773
Kweneng West		8,766	20,474	20,088	40,562
Kgatleng	57,770	17,054	35,725	37,782	73,507
Central Serowe/Palapye	128,471	33,969	73,282	79,753	153,035
Central Mahalapye	95,433	23,730	53,318	56,493	109,811
Central Bobonong	53,558	15,057	32,064	34,900	66,964
Central Boteti	35,459	10,363	23,478	24,579	48,057
Central Tutume	100,049	27,168	57,821	65,693	123,514
North East	43,354	10,834	23,164	26,235	49,399
Ngamiland East	55,469	15,615	35,269	37,113	72,382
Ngamiland West	36,723	10,184	23,030	26,612	49,642
Chobe	14,126	4,600	9,395	8,863	18,258
Delta	2,342	514	1,355	1,333	2,688
Ghanzi	23,725	7,666	16,564	15,917	32,481
CKGR	994	110	352	337	689
Kgalagadi South	19,794	5,679	13,037	12,901	25,938
Kgalagadi North	11,340	3,984	8,111	8,000	16,111
Total	**1,326,796**	**404,706**	**813,488**	**867,375**	**1,680,863**

1.11 Public health

There has been a minimal increase in the number of health facilities from 1998 to 2003. Over this period, the number of clinics increased from 225 in 1998 to 257 in 2003 and health posts from 323 in 1998 to 336 in 2003, which is an increase of 14.2% and 4.0%, respectively. Mobile stops increased from 740 in 1998 to 761 in 2003.

The notifiable disease surveillance system is aimed at effectively monitoring and controlling outbreaks and spread of diseases of epidemic and contagious nature. Fourteen of these diseases are reported on weekly basis. The table below gives the five most significant diseases, mainly Malaria (confirmed), Measles, Rabies (exposure), Viral Hepatitis and Diarrhoea. (CSO, 2004)

Table 1.5: Selected notifiable diseases - cases and deaths, 1998–2003 (CSO, 2004).

	1998	1999	2000	2001	2002	2003
Cases						
Malaria Confirmed	5,027	12,443	7,758	4,720	1,284	1,886
Measles	707	439	2,672	292	111	64
Rabies Exposure	1,573	1,199	1,425	1,497	1,484	1,331
Viral Hepatitis	264	315	318	327	258	168
Diarrhoea under 5 years	69,042	63,298	64,375	64,591	58,085	57,550
Diarrhoea over 5 years	61,992	54,712	55,965	57,153	51,381	51,174
Deaths						
Malaria confirmed	11	40	20	31	4	11
Measles	1	-	-	-	-	-
Rabies exposure	-	2	-	-	-	-
Viral hepatitis	1	1	4	7	7	4
Diarrhoea under 5 years	24	51	74	79	93	146
Diarrhoea over 5 years	18	28	29	63	85	136

1.12 Education

In 1994 a national policy on education, the Revised National Policy on Education (RNPE) was revised with the emphasis of improving access to education and ensuring that the quality of education is relevant to the children and their communities.

2 Greenhouse Gas Inventory

2.1 Introduction

Information presented in this chapter is of anthropogenic emissions and removals of greenhouse gases (GHG). The information is presented as requirement under Article 4.1(a) of the Convention. Article 4 of the UNFCCC, requires Parties to develop, periodically update, publish and make available to the Conference of the Parties national inventories of anthropogenic emissions. According to the Guidelines (2003) for preparation of national communications of non-Annex I Parties, the year 2000 is selected as the baseline year for GHG inventory.

2.1.1 Methodology

Botswana's Initial GHG inventory considered five main modules such as energy, industrial processes, agriculture, waste and LUCF, as guided by revised IPCC of 1996. Botswana's second national GHG inventory covers the major sources and sinks as well as most gases mandated by 17/CP8. The National GHG Inventory was prepared based on the Revised 1996 IPCC Guidelines for National GHG Inventories, Good Practice Guidance and Uncertainty Management in National GHG Inventories (IPCC 2000), and Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003). The default emissions factors and IPCC Tier 1 methodology were used in line with Decision 17/CP.8 of UNFCCC Conference of Parties (COP) 8. Estimates in this inventory were made for the base year 2000. The national inventory has considered three direct GHGs such as CO_2, CH_4 and N_2O. Aggregated GHG emissions and removals expressed in CO_2 equivalent have been provided too. The calculation of National GHG Inventory was done using the software for Non-Annex 1 Countries to the UNFCCC (UNFCCC-NAI Software).

2.1.2 Data sources

Data sources for the inventory were the Department of Energy Affairs who provided the energy balance. Other sources were the Central Statistics Office who provided the agricultural census covering the year 2000, Department of Forestry and Range

Resources, Food and Agricultural Organisation (FAO) and different data bases, surveys and studies prepared by international organizations such as UNEP/RISØ.

Emission estimates for petroleum combustion were made using the emission factors contained in Emission Factor Data Base. Local classification of forests was used in the estimation of gases form the Land Use Change and Forestry Sector. The data used for the waste sector (population) was estimated using the average between the 1991 and 2001 census since there was no census in 2000.

During the preparation of the GHG Inventory, inventory of gases with direct greenhouse effect - CO_2, CH_4 and N_2O, from key sources were prioritized. The inventory of gases with indirect greenhouse effect - CO, NO_x, SO_2, and the emissions of HFCs, PFCs, SF_6 compounds were not identified. The inventory of gases with indirect greenhouse effect - CO, NOx, SO_2, and the emissions of HFCs, PFCs, SF_6 - were not identified. The estimation of gases such as CO, NO_x, SO_2 from direct fuel combustion require detailed process information such as combustion conditions of the different types of fuels, size and age of the different engine types and the engine maintenance and operational practices which are currently not available. The estimation of other gases such as HFCs, PFCs, SF_6 was not possible due to unavailability of activity data.

The national GHG inventory was calculated for the following sectors:

- Energy
- Industrial processes
- Agriculture
- Land Use Change and Forestry
- Waste

The GHG data reported here contain estimates for direct greenhouse gases,

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

Table 2.1: Global warming potential for various gases (time horizon 100 years).

Gas	GWP
CO2	1
CH4	21
N2O	310

Botswana's total GHG inventory for the year 2000 is presented by GHG type and also by sector Sectors, and sources of GHG emissions, are categorized according to their percentage share in the national GHG inventory.

2.2 Sources of GHG emissions

Botswana's GHG emissions were 7,434.2 Gg CO_2 eq in 2000 and removals were 42,941.0 Gg CO_2 eq. The net emission after accounting for the removal was -35,506.8 Gg CO_2 eq, thus indicating that Botswana was a net sink in 2000.

Table 2.2: Emissions of individual GHG by sector for the years 2000 in Gg.

Sector	CO_2	CH_4	N2O	CO_2 eq (Gg)
Energy	**5,272.0**	**12.7**	**0.00**	**5,537.9**
Agriculture	**0.0**	**84.7**	**0.00**	**1,785.0**
Waste	**0.0**	**5. 3**	**0.00**	**111.3**
Land-use change and Forestry	**-42,941.0**	**0.0**	**0.00**	**-42,941.0**
TOTAL	**-37,587.0**	**102.7**	**0.00**	**-35,506.8**

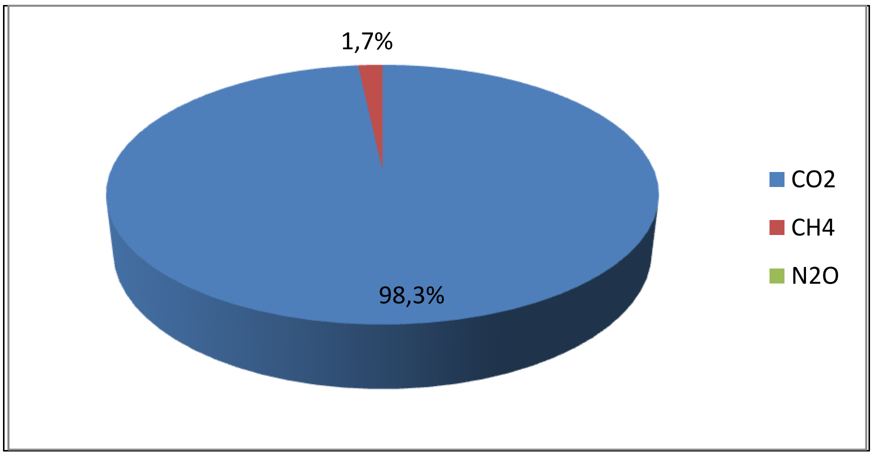


Figure 2.1: Distribution of greenhouse gas emissions by gases for the year 2000.

Carbon dioxide constitutes 98.3% of the greenhouse gases and methane 1.7% (figure 2.2). The distribution of emissions by key sectors is as follows: "Energy" 74.5%, "Agriculture" 24.0%, and "Waste" 1.5%. (Figure 2-3). The distribution of emissions excludes CO_2 removals in the Land Use Change and Forestry sector.

Table 2.3 Total GHG emissions by sector for the year 2000

Sectors	CO_2 eq (Gg)	Share of sector in total emission (%)
Energy	**5,537.9**	**74.5**
Agriculture	**1785.0**	**24.0**
Waste	**111.3**	**1.5**
Total emissions	**7434.2**	
Land-use Change and Forestry	**-42,941.0**	
Total	**-35,506.8**	

The comparison between the 1994 and 2000 inventory show that there is a decrease of about 18.7%. The total emissions in 1994 were **9,142.9 Gg CO_2 eq** compared to **7,434.2 Gg CO_2 eq** in 2000. The reduction is due to the fact that emissions from savannah burning were not included in the GHG Inventory calculations for Botswana. The removal of emissions by sinks from the LULUCF sector have increased from **38,733.6 Gg CO_2 eq** in 1994 to **42,941.0 Gg CO_2 eq** in 2000. The increase can be attributed to the fact that there was no data for forest and grassland conversion, abandonment of managed land, on-site burning, and emissions and removals from soil were also not estimated due to lack of data. Also that government has introduced activities like community woodlots which encourages tree planting and tree planting day is commemorated every year. 2000 GHG Inventory calculations only considered data from forests. There is uncertainty in the Land-use change and Forestry attributed to the main sources.

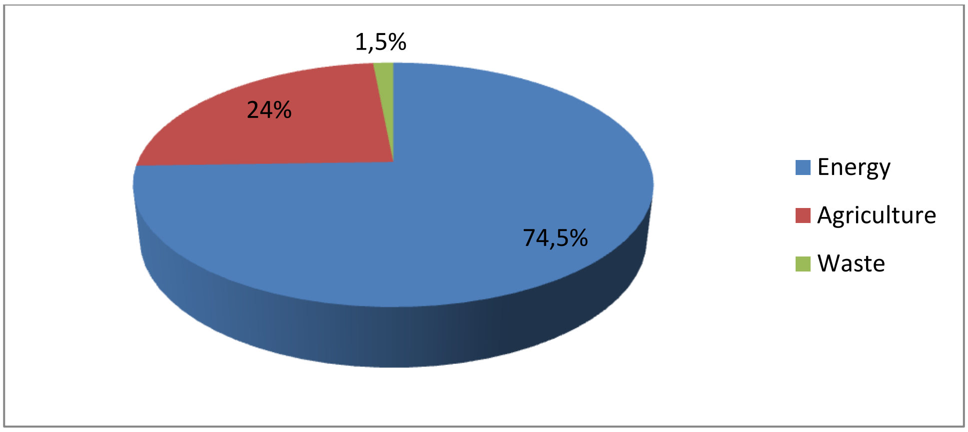


Figure 2.2: Distribution of greenhouse gas emissions by sectors for the year 2000.

2.2.1 Energy

In 2000 a total of 5,537.9 Gg CO_2 eq were emitted by the energy sector which is the main source of CO_2 emissions. Emissions from residential were the highest at 2,447 Gg CO_2 (46%) followed by emissions from industry (37%), Transport was the third with (9%) government with 7% and Agriculture with 1% as shown in Figure 2.5.

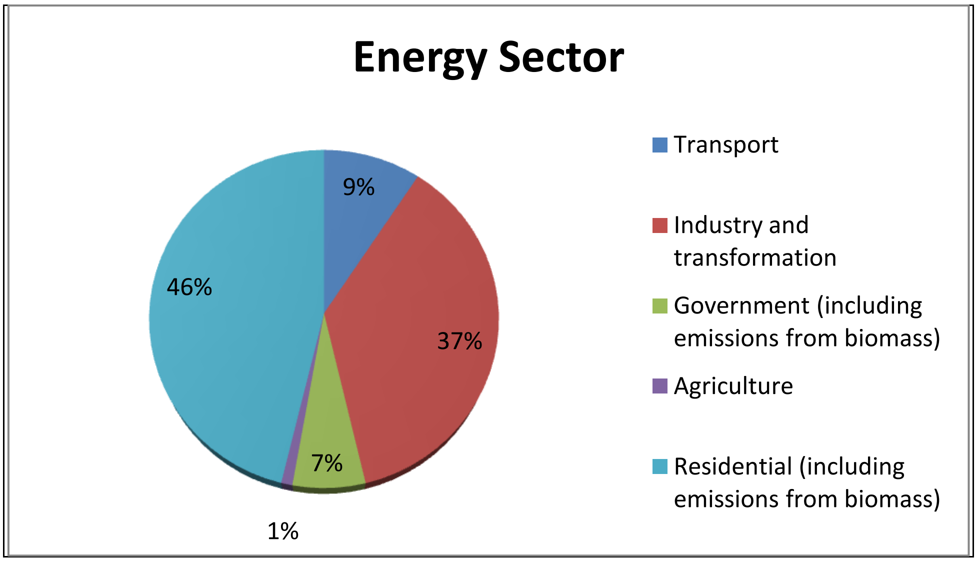


Figure 2.3: Major sources of CO_2.

2.2.1.1 Methodology

The energy balance from the Department of Energy Affairs provides the data in units of energy (Terra joules). Emission estimates for both traditional and conventional energy sources combustion were made using the emission factors contained Emission Factor Data Base. Using the UNFCCC software for Non-Annex 1 Countries the following were determined by using both the reference and the sectoral approach:

- Carbon dioxide (CO_2) emissions from liquid fossil fuels.
- CO_2 emissions from solid fossil fuels.
- CO_2 emissions from biomass used in energy.
- Total CO_2 emissions for the country from the energy sector.

2.2.1.2 Activity data

All raw energy data used in the estimation of GHG emissions were obtained from local sources from the Department of Energy Affairs and the Central Statistics Office.

2.3 Carbon dioxide emissions

2.3.1 Residential

The residential is characterized by fuel consumption mainly for cooking and lighting. The main source of CO_2 emissions in this subsector is from biomass burning even though biomass is regarded as carbon-neutral fuel; though small quantities of coal, paraffin, candle and LPG gas were also consumed. In 2000, 2,447 Gg CO_2 eq were emitted into the atmosphere from biomass burning in Botswana, comprising 46% of CO2 emissions from the energy sector, and 32.9% of total national GHG emissions.

2.3.2 Industry and transformation

In 2000, 1,950.64 Gg CO_2 eq were emitted into the atmosphere from electric energy and heat production in Botswana, comprising 37% of CO_2 emissions from the energy sector, and 26.2% of total national GHG emissions. Emissions from industry and transformation are mainly due to the fuel combustion, used for electricity generation at thermal power plant.

2.3.3 Transport

In this sub sector 474.48 Gg CO_2 eq were emitted into the atmosphere from the consumption of petroleum products in Botswana, comprising 9% of CO_2 emissions from the energy sector, and 6.4% of total national GHG emissions in 2000. The main sources of emissions from this sub sector are road transport.

2.3.4 Government

Sources of emissions from this subsector were from lighting and biomass burning as some of the government institutions like schools use wood fuel for cooking. 369.04 Gg CO_2 eq were emitted into the atmosphere. The emissions comprised of 7% of CO_2 emissions from the energy sector, and 5% of total national GHG emissions in 2000.

2.3.5 Agriculture

Carbon dioxide emissions from agriculture were mainly produced by fuel combustion in agricultural machinery (tractors, etc.). In 2000, CO_2 emissions from agriculture amounted to 52.72 Gg CO_2 eq, comprising only 1% of CO_2 emissions from the energy sector, and 0.7% of national GHG emissions.

2.3.6 Industrial processes

Industrial processes in the country are minimal and therefore the only emissions calculated in this sector are from alcoholic beverage production. The emissions are very negligible, amounting to only 0.039 Gg CO_2.

2.3.7 Emissions from land use change and forestry

Forests are beneficial to the society since they provide wood and non-wood products, food and medicine; they offer protection to the environment (conservation of soils) and provide habit for wildlife. Conservation efforts of the Government of Botswana are focused on forestry and forestry resources as they add value to the quality of wilderness in the country. They also contribute to the protection of biodiversity.

2.4 Methane emissions

In 2000, methane was emitted from the energy sector (subsectors: fuel combustion and fugitive emissions), agricultural sector (subsectors: enteric fermentation, manure management) and waste sector (solid waste disposal and wastewater treatment).

Total CH_4 emissions from the Botswana amounted to 2,162.223 Gg CO_2-eq, this accounts to 29.1% of the national greenhouse gas emissions. The energy sector's contribution to methane emissions accounted to only 12.3% of the total. The agricultural and waste sectors contributed 82.6% and 5.1% respectively. In comparison with the 1994 level (201.862 Gg CH_4), methane emissions decreased by 49.0%. Within this decrease, CH_4 emissions from the energy sector were reduced only by 49.9%, while the emissions from the agricultural and waste sectors were reduced by 49.6% and 33.2% respectively.

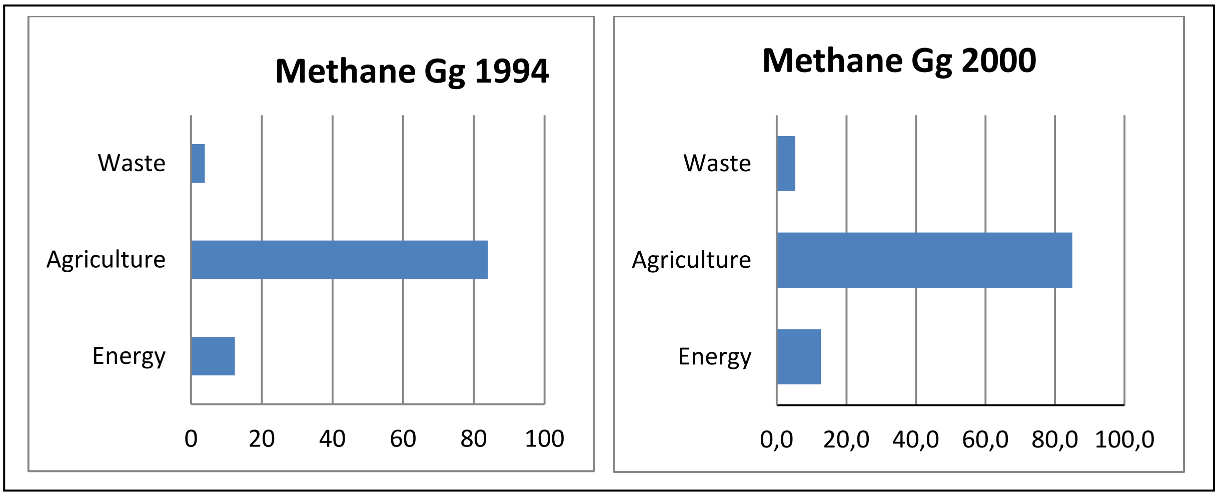


Figure 2.4: Comparison of methane emissions (Gg CH_4) 1994 and 2000 from different subsectors.

Since the 1970s, the main economic activity has shifted from agriculture (specifically, beef production) to mining. Emissions from coal mining were calculated and these amounted to 12.663 Gg CH_4 per annum.

2.4.1 Methodology

Calculations of methane from coal mining could not be calculated using the UNFCCC Software for NA1 Countries, the formula for calculation was obtained from the GHG manual. The calculations for NMVOC from alcoholic beverages were calculated using the UNFCCC Software for NA1 Countries. Emission factors are default values from the IPCC. The value for these emissions was very small (about 0.04 Gg CH_4 per annum) and it could not be reflected in the summary tables.

2.4.2 Emission from the agricultural sector

Of domestic animals, ruminant animals (cattle, camels, donkeys, sheep and goats) are the major source of methane emissions with cattle being the most important source in Botswana and globally. Methane is produced as part of the normal fermentative digestive process of animals. The methane is exhaled by the animal.

Methane emissions were calculated for livestock enteric fermentation and livestock manure management. The use of fertilizers is low and therefore N_2O emissions from this source are not significant. Most of the crop residues in Botswana are used as cattle feed and the emissions from this area are minimal.

2.4.2.1 Methodology:

The UNFCCC Software for NA1 countries was used to calculate the emissions within the agriculture sector for both enteric fermentation and manure management. The combined emissions from domestic livestock, (cattle, goats, horses, donkeys and sheep) amounted to 84.69 Gg CH_4 per annum from enteric fermentation and the emissions from manure management are 3.32 Gg CH_4 per annum.

2.4.3 GHG Emissions from waste

Liquid waste disposal in the country has sewer lines and septic tanks. The use of pit latrines is common in both rural and urban areas.

2.4.3.1 Methodology

Most of the waste at dumping sites in Botswana is not managed; therefore the methane content from dumping sites is low. The UNFCCC software for NA1 countries was used to estimate the methane content from solid waste as well as from waste water treatment plants.

The total emissions from the solid waste disposal are 4.79 Gg CH_4 annually. Currently no methane is recovered from any of the solid waste disposal sites. The total emission from waste water was found to be 0.74 Gg CH_4 per year. The total emissions from this sector are 4.79 Gg CH_4 from solid waste and 0.74 Gg CH_4 from liquid waste.

3 PROGRAMS CONTAINING MEASURES TO FACILITATE ADEQUATE ADAPTATION TO CLIMATE CHANGE

3.1 Assessments of climate change

To investigate climate change in Botswana conclusions from the SNC studies and other climate change studies we used.

The trends of change in the mean annual air temperature, the mean annual precipitation, and the moisture, were estimated for 1960–1990, 1961-2000 and future 2046-2065 time periods. To evaluate historical climate variability the climate moisture index (CMI) was used and statistical tests of significance of differences were also carried out. Future climate change in Botswana was assessed using downscaling of global circulation model simulations (GCM) and also using the MAGICC/SCENGEN.

3.1.1 Assessment using downscaling

Analyses for downscaling are carried out for ten GCMs' runs for the 20th and 21st century under observed CO_2 concentrations and the SRES A2 greenhouse gas emission scenario respectively (Wolski et al. 2010). Downscaling was done using statistical SOM-based method (Hewitson and Crane, 2006) Changes in rainfall were assessed using the following indices - total annual rainfall, number of rain days with > 2mm rainfall, median daily rainfall (for days with rainfall > 0 mm), maximum daily rainfall, onset of rainy season and end of rainy season.

3.1.2 Results obtained under downscaling

Observed characteristics of Botswana rainfall

Annual rainfall

Mean annual rainfall varies between 320 mm/year (Tsabong) and 585 mm/year (Kasane), with higher values recorded in the northern and eastern fringes, and lower rainfall in the interior and in the southern part of the country (Figures.3.1&3.2 and Table 3.1). Standard deviation of annual rainfall falls within the 90-205 mm/year range, giving coefficient of variation (CV) of 0.2-0.4, with spatial pattern similar to that for mean annual rainfall. 1-year lag autocorrelations for annual rainfall are predominantly negative (i.e. a higher rainfall year is likely to be followed by a lower rainfall year) apart from the north-west of the country where autocorrelations are positive (i.e. a higher rainfall year is likely to be followed by another high rainfall year).

Number of rain days

Number of rain days (with rainfall > 2 mm/day) falls within a 20-40 range with standard deviations 3.5-11.5 days and resulting CV of 0.15-0.25. Autocorrelations are mostly positive, but fall within -0.22–0.42 range, with spatial pattern similar to that of autocorrelations of mean annual rainfall (Figures.3.1&3.2 and Table 3.1).

Median and maximum daily rainfall

Median daily rainfall varies between 4.6 (Tsabong) and 13.2 mm/day (Letlhakane), while maximum daily rainfall between 49 (Tsabong) and 68 mm/day (Mahalapye) (Figures.3.1 & 3.2 and Table 3.1). Values of standard deviation are 1.8-6.0 mm/day and 15.2-27.4 mm/day respectively. The CV for maximum daily rainfall is slightly higher (median value of 0.4) than that for median daily rainfall (median of 0.35). Autocorrelations for both indices are mostly negative. The spatial pattern of median daily rainfall is similar to that of mean annual rainfall, with higher values to the south-east and north of the country and lower values in the interior and west of the country.

Onset and end of rainy season

The index of the beginning of the rainy season varies between 83 (Good Hope) and 107 (Gumare) days, which corresponds to 21 September and 15 October respectively (Figures.3.1&3.2 and Table 3.1). The index of the end of the rainy season varies between 221 (Selebi-Phikwe) and 256 days (Tsabong), which corresponds to 6 February and 13 March respectively. Standard deviation of the onset of rainy season falls within 12-24 days with median of 16 days and these values are smaller than standard deviations for the end of rainy season (15-33 days with median of 21 days).

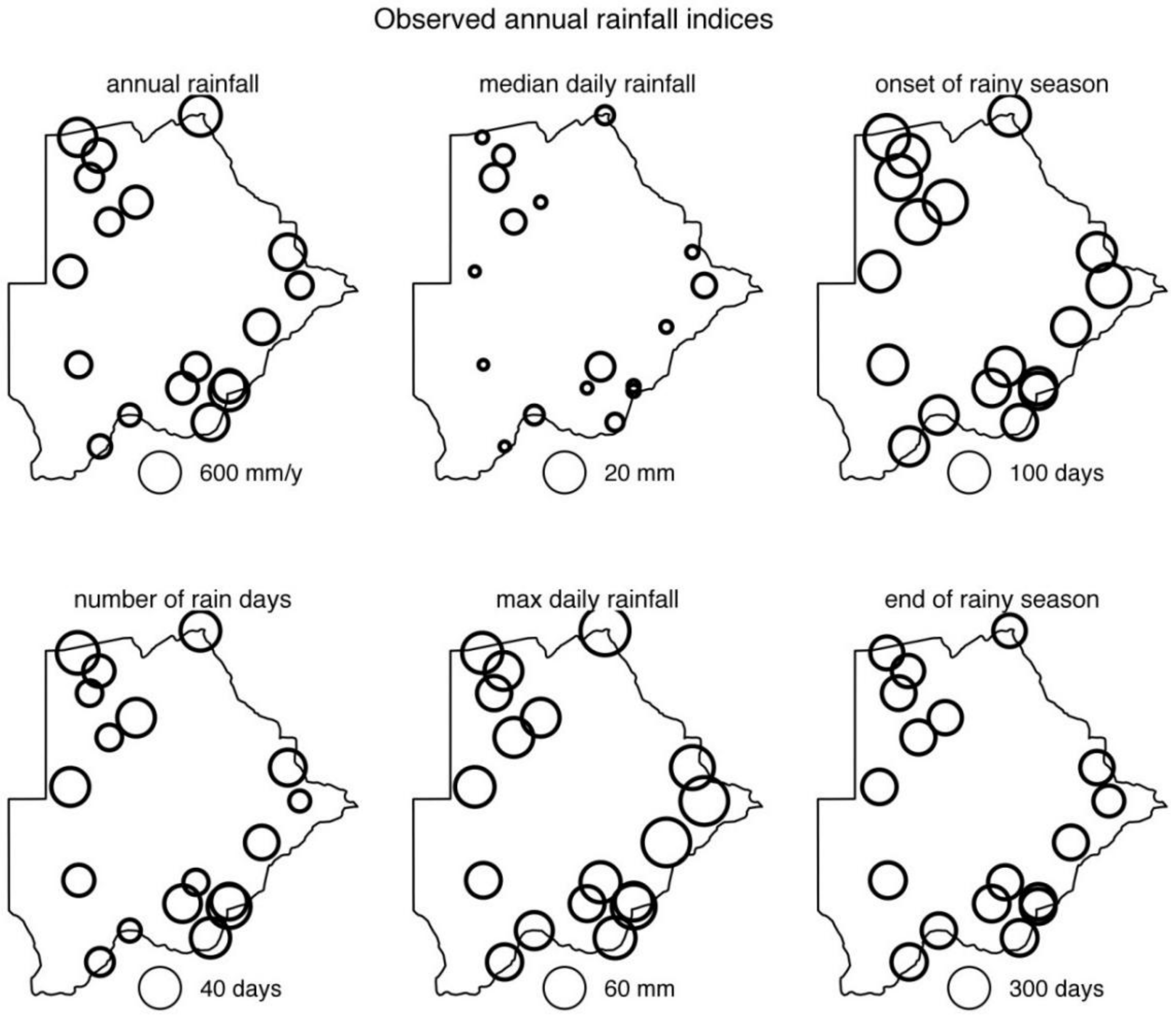


Figure 3.1: Observed distribution of rainfall indices in Botswana.

The downscaling results indicate for the period 2046-2065:

- an increase in total annual rainfall in the south of the country, and a decrease in total annual rainfall in the north and the east of the country
- an increase in mean number of rain days throughout the country
- a decrease in median daily rainfall and a decrease in its variance, throughout the country
- a decrease in maximum daily rainfall and a decrease in its variance throughout the country
- an earlier beginning of rainy season in the south but a later beginning of rainy season in the north and the east of the country
- a later end of rainy season throughout the country.

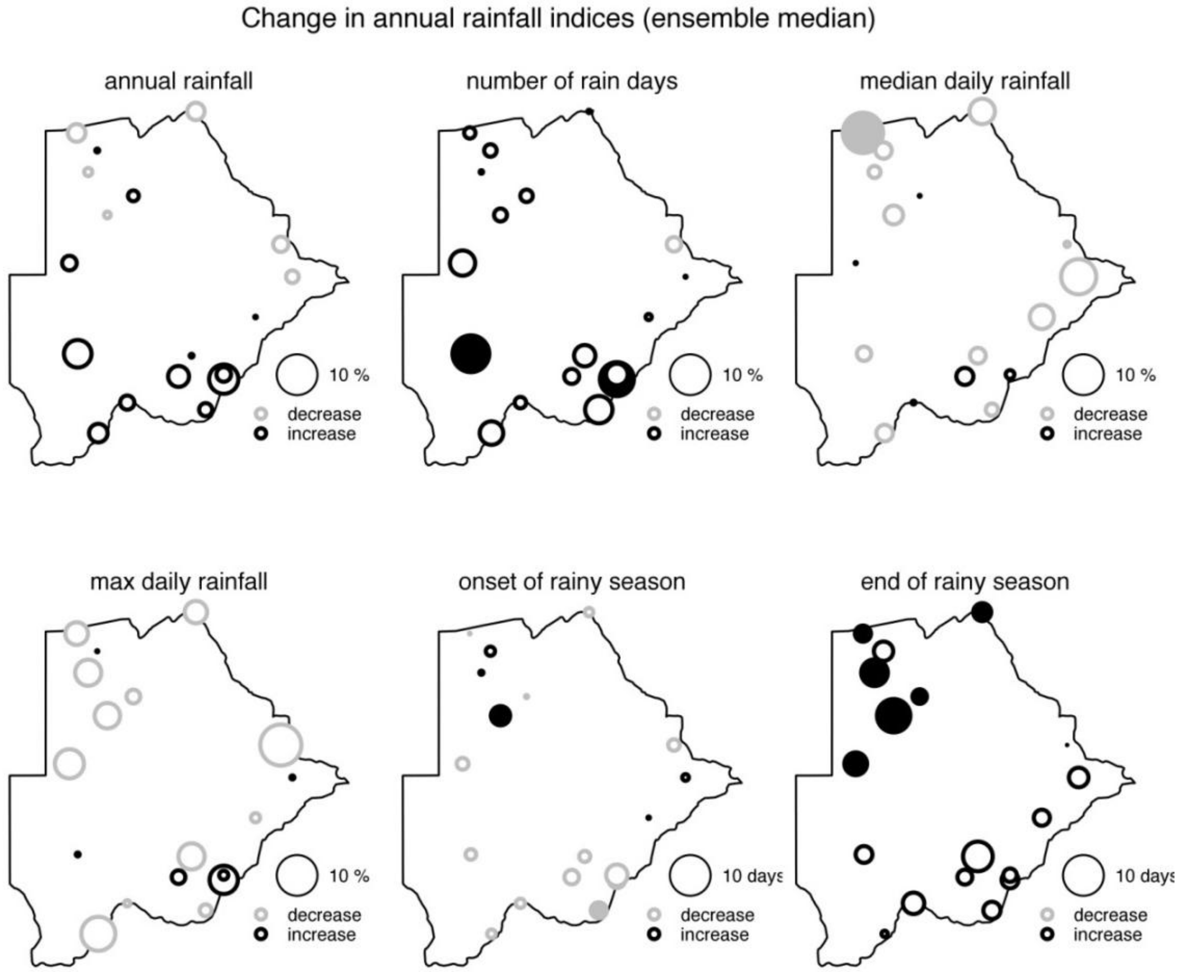


Figure 3.2: Projected distribution of rainfall indices in Botswana, 2046-2065.

Table 3.1: Values of mean, standard deviation (sd) and autocorrelation coefficient (ac) of various rainfall indices for 18 stations of Botswana.

	Annual rainfall (mm/year)			Number of rain days (days)			Median daily rainfall (mm/day)			Maximum daily rainfall (mm/day)			Onset of rainy season (days)			End of rainy season (days)		
	mean	sd	ac (-)	Mean	sd	ac (-)	mean	sd	ac (-)	mean	sd	ac (-)	mean	sd	ac (-)	mean	sd	ac (-)
033-Francistown	505	204	-0.03	34.2	10.5	0	5.9	2.3	0.25	61.4	22	0.06	91	17	-0.17	239	26	-0.17
037-Gaborone	556	188	0.29	41.0	10.5	0.38	5.8	2.1	0.48	62.8	27.1	-0.19	87	15	-0.45	250	21	0.09
039-Gantsi	446	180	-0.16	36.1	10.1	-0.02	4.8	1.4	-0.08	56.5	27.4	-0.09	95	18	-0.28	247	21	-0.03
064-Kasane	585	149	-0.18	37.9	11.4	0.12	8.6	6.0	0.61	70.0	25.6	0.27	97	17	-0.08	233	16	0.06
106-Mahalapye	490	158	0	32.1	7.3	-0.01	5.6	1.5	0.16	68.1	25.4	-0.02	90	17	-0.36	243	22	-0.32
130-Maun	445	166	-0.15	35.9	10.3	-0.03	5.4	2.1	-0.09	54.1	25.9	0.03	103	17	0.1	239	20	-0.01
223-Shakawe	534	205	-0.26	39.7	11.1	-0.06	5.6	1.8	0.25	57.5	19.8	-0.23	106	15	-0.08	236	15	0.01
244-Tsabong	320	144	0.12	26.5	9.2	0.16	4.8	1.7	0.01	50.3	22.8	-0.13	91	17	-0.18	253	22	0.09
251-Tshane	359	148	0	29.7	8.0	0.21	4.6	1.2	0.09	49.6	22.7	-0.46	92	24	0.08	256	24	-0.14
000-Gumare	394	179	-0.19	24.4	8.9	-0.22	12.8	6.3	0.19	49.1	23.2	0.08	107	18	0.19	242	18	0.04
035-SSKA	465	123	-0.04	34.2	6.4	0.23	5.7	1.8	0.12	54.0	15.2	-0.02	87	16	-0.28	252	16	0.05
041-Goodhope	513	167	0.2	37.5	9.1	0.21	8.2	3.1	0.65	58.6	24.9	0.4	83	12	-0.41	256	21	0.22
053-Jwaneng	441	142	0.19	34.9	9.4	0.42	5.2	1.8	0.53	50.0	20.7	-0.24	87	19	0.12	255	26	-0.14
094-Letlhakane	398	173	0.09	24.1	10.1	0.21	13.2	4.4	0.16	57.4	21.4	0.1	91	17	-0.1	244	25	0.11
211-Sehithwa	385	150	-0.06	24.4	8.3	0.18	11.1	5.0	0.32	55.6	23.8	-0.16	104	15	0.21	244	23	-0.08
213-Selibe-Phikwe	372	90	-0.55	20.0	3.4	-0.17	11.2	3.5	0.01	68.2	23.4	-0.3	102	16	-0.08	221	33	-0.68
219-Seronga	464	171	0.04	29.9	7.7	0.13	9.9	4.0	0.40	54.2	16.7	-0.24	99	22	0.21	231	20	-0.22
259-Werda	306	127	-0.06	21.1	6.7	-0.21	9.0	3.3	0.21	53.0	21.2	0.11	90	15	0.04	246	24	0.07

3.1.3 Characterisation of climate variability and associated extreme events

The following indicators were employed to characterize climate variability and associated extreme events like droughts and floods (World Bank 2010):

- Climate moisture index (CMI)
- Standard Precipitation Index (PSI)
- Palmer Drought Severity Index (PDSI)
- Peak flood analysis
- Monthly data analysis.

To evaluate historic climate variability in Botswana the *Climate Moisture Index* (CMI) was used. Twenty-two GCM model scenarios from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) and the historical scenarios were analyzed based on their CMI to identify the dry and wet scenarios for Botswana. A wet scenario is indicated by the largest positive change in CMI and a dry scenario is indicated by the largest negative change in CMI

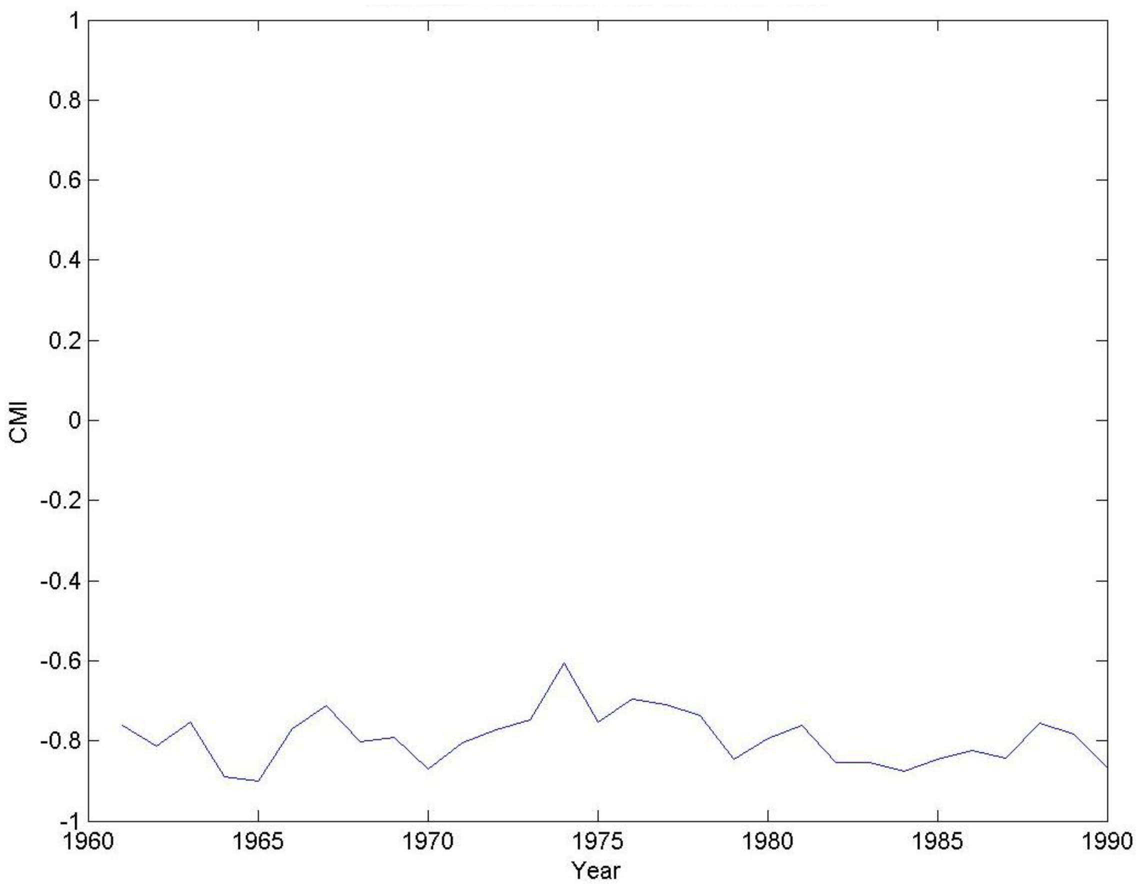
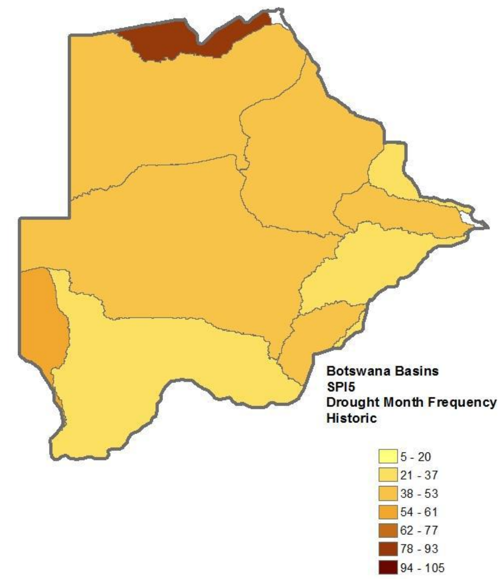
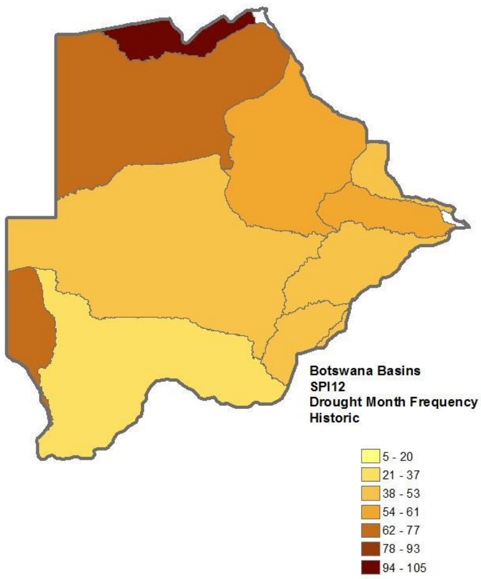


Figure 3.3: Historical annual Climate Moisture Index (CMI), 1961-1990.

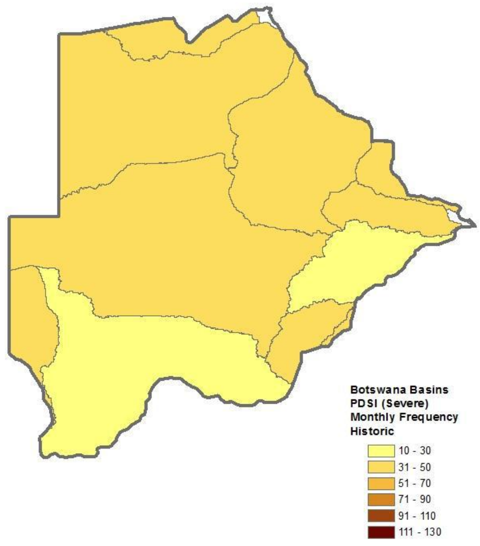
To analyse historical droughts two drought indices were used the *Standardized Precipitation Index* (SPI), and the *Palmer Drought Severity index* (PDSI).



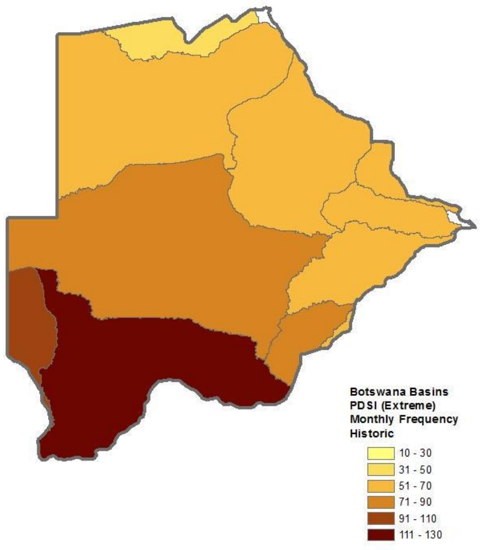
5 Month Standardized Precipitation Index (SPI), Botswana 1961-1990 rainfall record (360 months); Mitchel and Jones 2005)



12 Month Standardized Precipitation Index (SPI), Botswana 1961-1990 rainfall record (360 months); (Mitchel and Jones 2005)



PDSI Severe Monthly Frequency, Historic (1960-1990 or 360 months).



PDSI Extreme Monthly Frequency, Historic (1960-1990 or 360 months).

Figure 3.4: Comparison of Standard Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI).

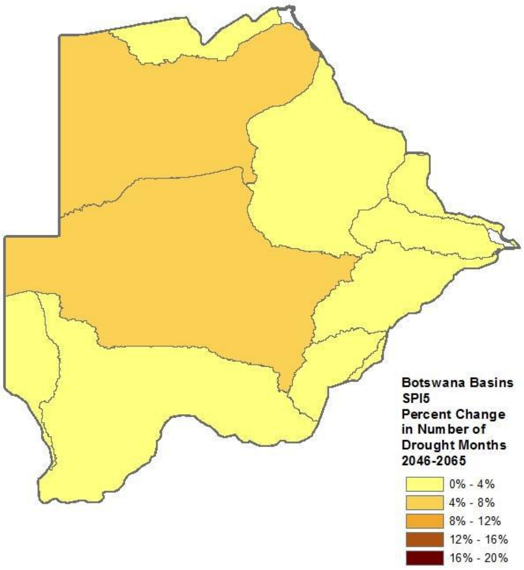
Comparing SPI and PDSI suggests that the drought in the north is more severe but shorter (generally less than 5 months), while the drought in the south generally lasts longer (at least 5 months), but is less severe. Also, SPI is better used as a "change" in expected drought, rather than showing historical results, because it detects the deviation from the median precipitation of each basin.

The CMI confirms that Botswana is arid or semi-arid. Droughts in terms of rainfall deficits (SPI) are most common in northern Botswana, indicating that this area may be most affected by on-going climate change. Extreme droughts based on low rainfall and soil conditions are most common in south western Botswana (PDSI). High rainfall events with risks of floods are most likely in north eastern Botswana. Several large dams are located in this area. Overall, droughts have been more common than floods.

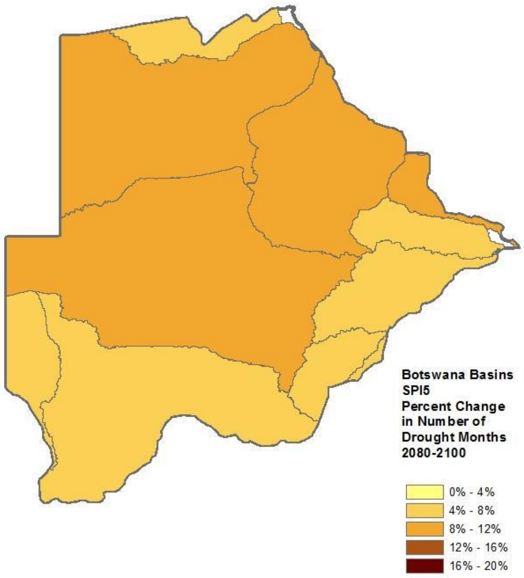
3.1.4 Future drought analysis using SPI

SPI was used to estimate future drought conditions using the “gfdlcm21-A1b” GCM-sres projection. This GCM-sres projection was chosen because it presents the worst (on average) drought scenario according to the SPI calculation. Moreover, an additional GCM scenario was evaluated as described below to compare with the PDSI drought indicator.

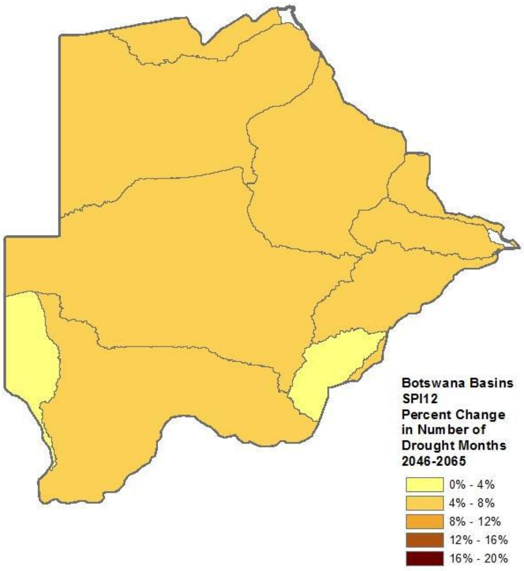
Data from this GCM-sres was taken for two time periods, 2041-2060 and 2081-2100. The SPI drought index is used to estimate the change in future expected drought frequency from the historic record. The map in Figure 3.5 shows significant increases in the 5 month drought duration during the period of 2046 to 2065. However, more dramatic negative impacts are seen for the A1b scenario for the 2081-2100 time period especially for the SPI-12.



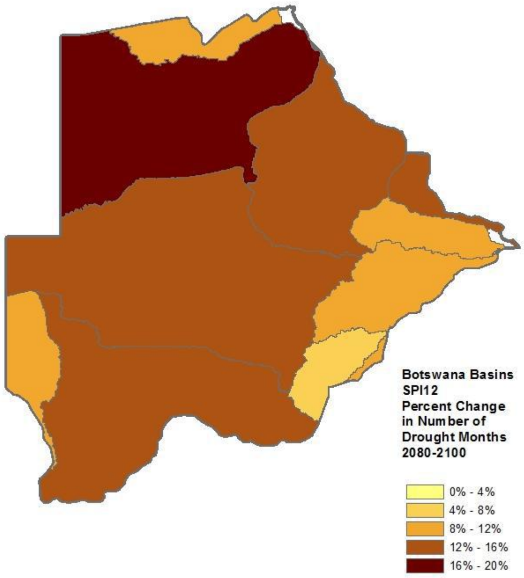
Percentage change in the frequency of the 5-Month Standardized Precipitation Index (SPI5) due to predicted Climate Change in Botswana, gfdlcm21, A1b emissions scenario, 2046-2065,.



Percentage change in the frequency of the 5-Month Standardized Precipitation Index (SPI5) due to predicted Climate Change in Botswana, gfdlcm21, A1b emissions scenario, 2080-2100.



Percentage change in the frequency of the 12-Month Standardized Precipitation Index (SPI12) due to predicted Climate Change in Botswana, gfdlcm21, A1b emissions scenario, 2046-2065.



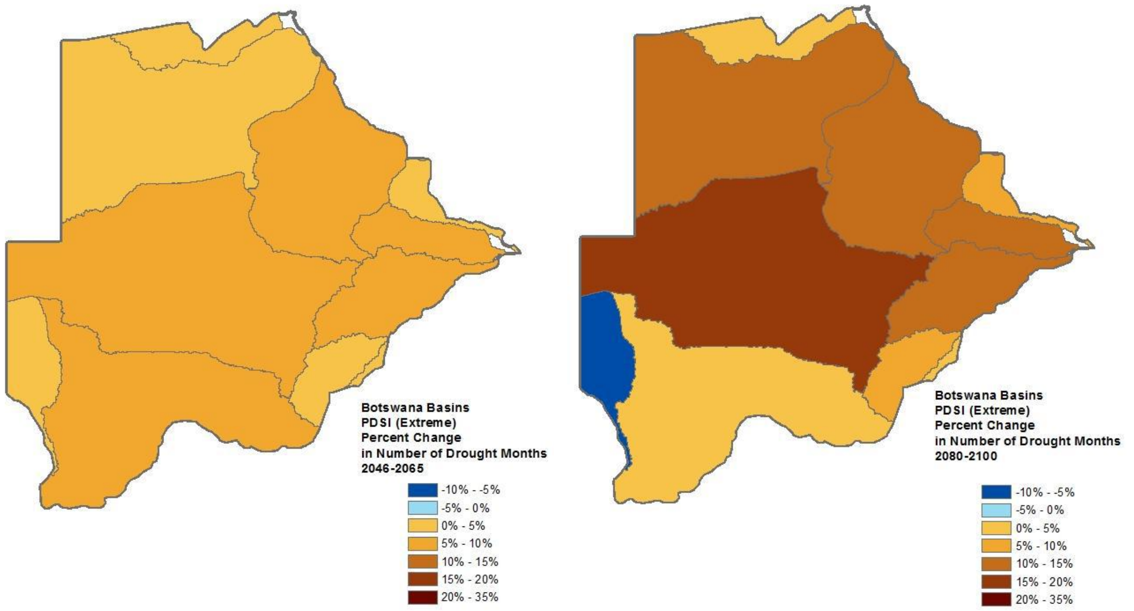
Percentage change in the frequency of the 12-Month Standardized Precipitation Index (SPI12) due to predicted Climate Change in Botswana, gfdlcm21, A1b emissions scenario, 2080-2100

Figure 3.5: Percentage changes in SPI5 and SPI12.

Results show that durations of droughts indicated in this GCM simulation are expected to increase over time, especially for Northern and Central Botswana

3.1.5 Future drought analysis using PDSI

PDSI was used to estimate future drought conditions under the “inmcm30_sresA2” GCM-sres projection. This GCM-sres projection was chosen because it presents the worst (on average) drought scenario according to the PDSI calculation, i.e. the GCM that produced the worst droughts based on the SPI described above did not produce the worst droughts based on the PDSI. Data from this GCM was taken for the same two time periods, 2041-2060 and 2081-2100. An additional GCM scenario was evaluated as described below to compare results with the SPI drought indicator



Percentage change in the frequency of the Palmer Drought Severity Index for extreme drought levels, due to predicted Climate Change in Botswana, GCM inmcm30, A2 emissions scenario, 2046-2065.

Percentage change in the frequency of the Palmer Drought Severity Index for extreme drought levels, due to predicted Climate Change in Botswana, GCM inmcm30, A2 emissions scenario, 2081-2100.

Figure 3.6: Percentage change in PDSI.

The results show that droughts indicated in this GCM simulation are expected to worsen with time, especially in the Western and South Western part of the country.

3.1.6 Assessments using MAGICC/SCENGEN

From studies, it appears that that the temperature will increase by 2.5° and precipitation will decrease by 5% in 2050.

Table 3.2: Impacts of climate change as depicted by MAGICC/SCENGEN model.

Year	Impact
up to 2050	• Increased temperature: 2°C on average ○ 0.8 % decrease in river flows • Reduced rainfall: by-3 to -9% ○ 13 % decrease in river flows ○ 19 % decline in cereal production
up to 2050	
Pre-model assessments **• Coefficients of variability (CVs) for rainfall for the country are increasing. So rainfall prediction will become more uncertain as rainfall will become more erratic.** **• Rainfall intensities have been increasing and yet annual rainfall quantities are decreasing (0.872/annum).** **• Increase in frequency and duration of dry spells are also a common feature of our changing climate.** **• There are borehole water (groundwater) declines of 1-4m, and the eastern side is the most affected e.g. Molepolole, Serowe, Palapye and Thamaga.** **• Late onset of rains is a concern e.g. first rains coming 3-4 months late.**	

3.1.7 Rainfall trends

Mean annual rainfall covers a range from 620mm in the northern Kasane area to 300mm in the southwestern Tsabong area. Low amounts of total rainfall and large interannual variability of rainfall with coefficients of variation from 25-50%, as depicted in Fig. 3.7 for the main rainy season generally obscure trends and complicate any analysis. In general, time series indicate a trend of declining rainfall in most parts of the country, which may be a result of climate change. Significant negative trends of total annual rainfall at a 90% confidence level were only observed for the stations of Ramatlabama and Maun, and at 85% confidence level for Kasane, all of which are located in areas with comparably high annual rainfall. Agronomically, the distribution of rainfall among individual events (Fig. 3.9), as well as the prevalence and length of dry spells are of particular importance. However, further studies involving larger data sets are necessary to identify trends in annual rainfall and its timing, as well as possible links to climate change.

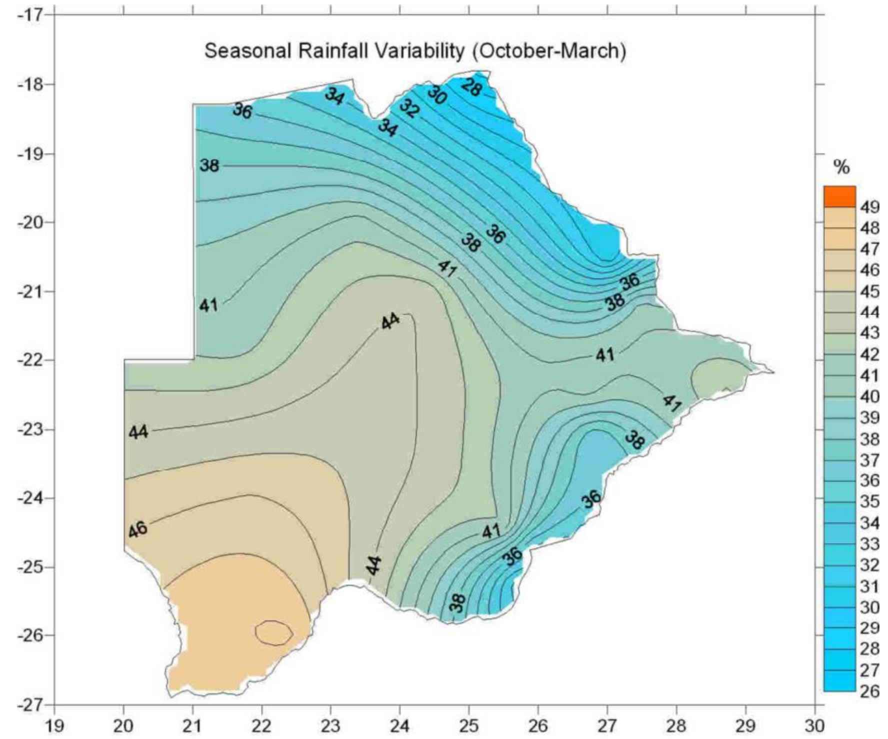


Figure 3.7: Coefficient of variation of seasonal rainfall (October-March).

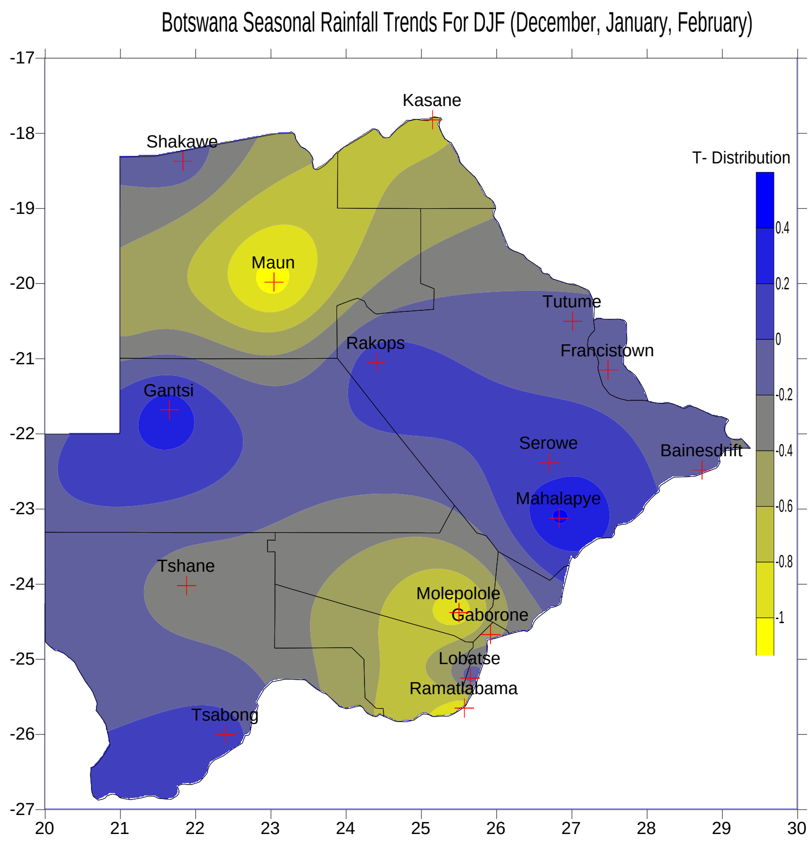


Figure 3.8: Map of t-test statistics as a quality measure to identify trends for total rainfall in December/January/February (DJF).

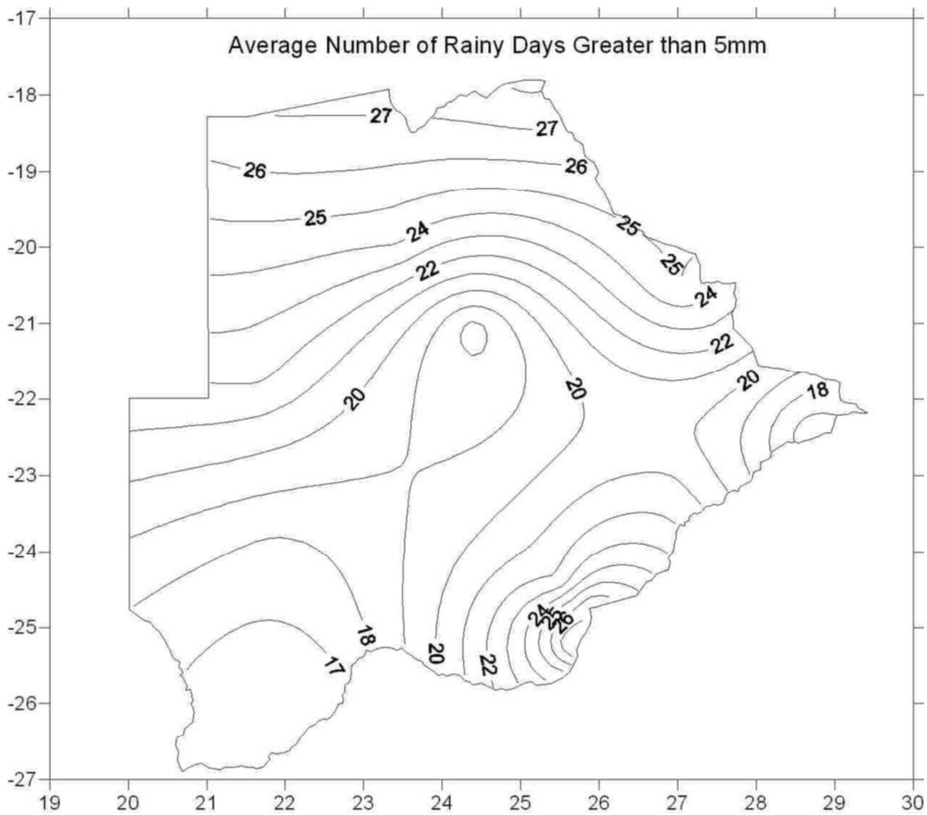


Figure 3.9: Annual mean number of days with rainfall exceeding 5mm.

3.2 Vulnerability and adaptation assessments of key sectors

In this chapter climate change impact and vulnerability were assessed for the following sectors, Water Resources, Agriculture, Grasslands and livestock, Forestry, Crops and Public health. Detailed analysis of adaptation policy and measures has been carried out. Vulnerabilities, socioeconomic implications and suggested adaptation policies and measures for each sector are outlined.

3.2.1 Water resources

Water is a scarce resource in Botswana and in addition to scarcity, rainfall is already highly variable. The growing population and industrialization coupled with water demand for agriculture and mining place a heavy demand on the already dwindling resource. The National Water Master Plan Review (NWMPR) of 2006 recommended major institutional reforms in the water sector.

Vulnerability of the water resources to climate change have been studied under the SNC and also (World Bank 2010). The vulnerability of the water sector was assessed using the MAGICC-SCENGEN to generate climate change scenarios and WEAP for integrated water resources planning and SYSTEM DYNAMIC MODEL (STELLA). Runoff Analysis – Peak Runoff was estimated using The US Department of Agriculture Natural Resources Conservation Service (NRCS) runoff procedure commonly called the "SCS" method.

From the vulnerability and assessment study of the water sector it is evident that Botswana's limited water resources are threatened by the impacts of climate change. Generally, dam yields are likely to be reduced by between 10 and 14% by the year 2050, with up to 19 % decline in cereal production if nothing is done to cushion for these impacts. Centers supplied by either or both surface and ground waters will feel the impacts especially from the year 2020 when alternative water sources will need to be sought elsewhere to augment the already strained supply. The Kgalagadi district, which mostly depends on ground water, will experience the highest increase in unmet water demand (97 %) while the South east district will be the hardest hit (81 %) from the areas supplied by surface waters by the year 2050. Frequency and duration of dry spells will increase with return periods of rainfall quartiles increasing and becoming very uncertain.

In another study by Parida et al (2006) on the Notwane river basin which drains into Gaborone dam, it was found out that climatic variables contribute 48 % to changes in annual yields for the dam. The variables considered in the study were rainfall, temperature and evaporation. The study concluded that a decline in rainfall of (0.942/annum) will contribute to 20 % decline in annual yields, an increase in temperature of (0.132 °C per annum) will contribute to 11 % decrease in annual yields, and an increase in evaporation will contribute to 16 % reduction in annual yields.

3.2.1.1 Projected Results

Table 3.3: Impacts of climate change on water resources by WEAP model.

WEAP MODEL	
Year	Impact
2030 (district level)	• Average increase in unmet water demand in districts: 42-97%. The least impacted (lowest levels) being 11% in Kweneng East and Ngamiland East Districts. The most vulnerable districts are: the dry Kgalagadi (97%) and the heavily populated eastern region (e.g. South East district with 81%). • The impact is on groundwater in most cases (districts), whereas in the east it is surface water mainly. • There are groundwater declines in several zones.
2030 (Gaborone, Francistown, Selibe Phikwe, Serowe, Mahalapye, Bobonong)	Reduction in water supply: 11-12%

Table 3.4: Impacts of climate change as depicted by STELLA model.

STELLA MODEL	
Year	Impact
2030	• Decrease in annual yields in dams: 8%
2050	• Decrease in annual yields in dams: 10%. • Evaporation increases: 20%. • Annual rainfall declines: 10%. • Intensity of droughts increase: 10%.

3.2.1.2 Peak flow results

It is apparent from Figure 3.10 and Figure 3.11 that overall, peak runoff rates are increasing over time for this GCM and SRES scenario (2046-2065 compared to 2081-2100) and exhibit some spatial variance: storm risks move to West and North from North East. It is also notable that the extreme Southwest portion of Botswana in the Kalahari Desert shows some of the more significant impacts. Frequency of storms will increase in western and northern Botswana. The monthly data analysis shows that aridity will increase (declining CMI) and that PET will increase by around 5%. In south-mid eastern Botswana (part of Limpopo basin), precipitation is likely to decrease but there is a likely increase in flooding; there is a definite bias towards increased droughts and groundwater recharge is likely to decline.

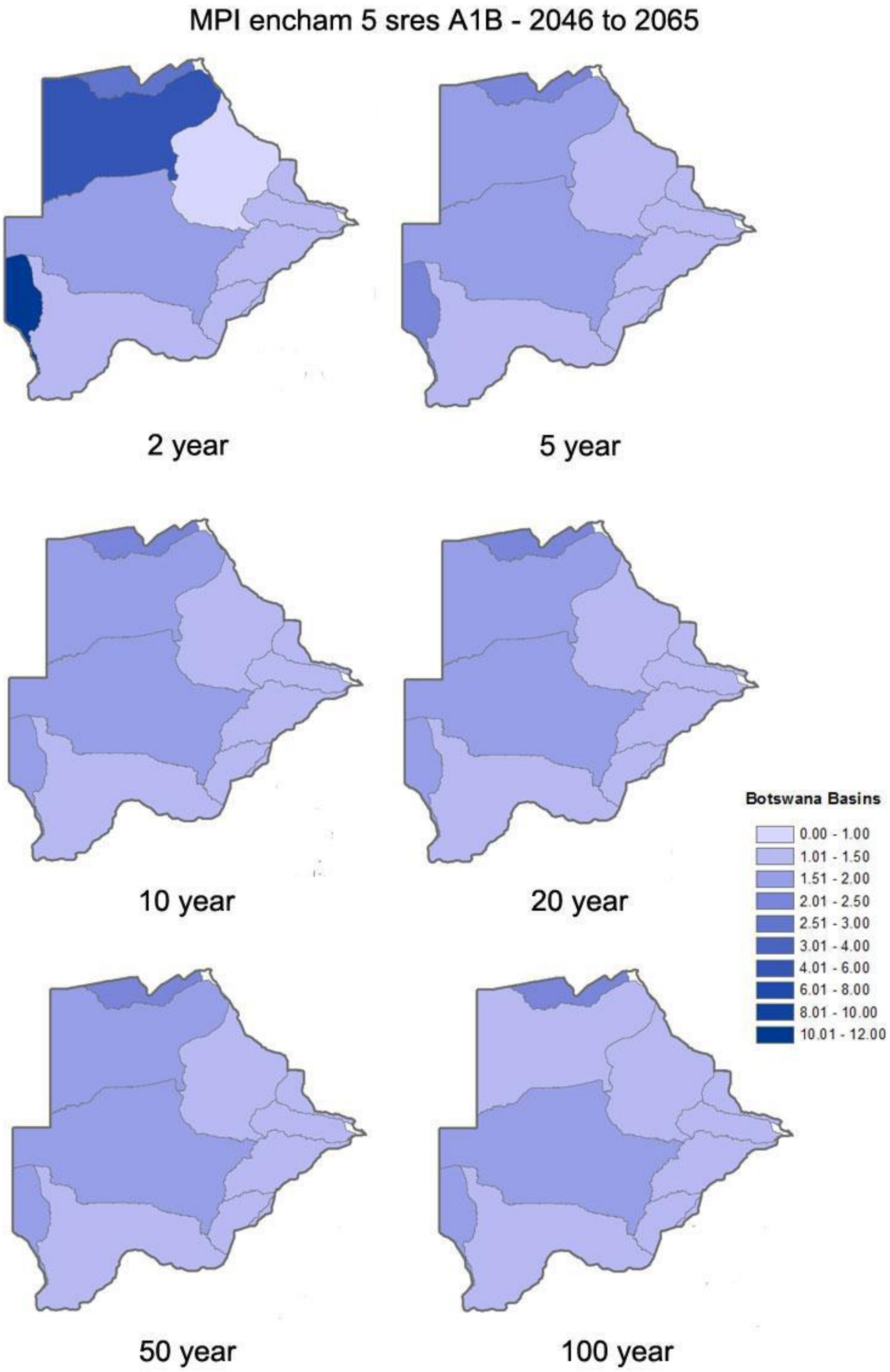


Figure 3.10: Change in Gumbel 24-hour runoff due to predicted climate change in Botswana, Echam5 GCM, A1b emissions scenario, 2046-2060 (World Bank 2010).

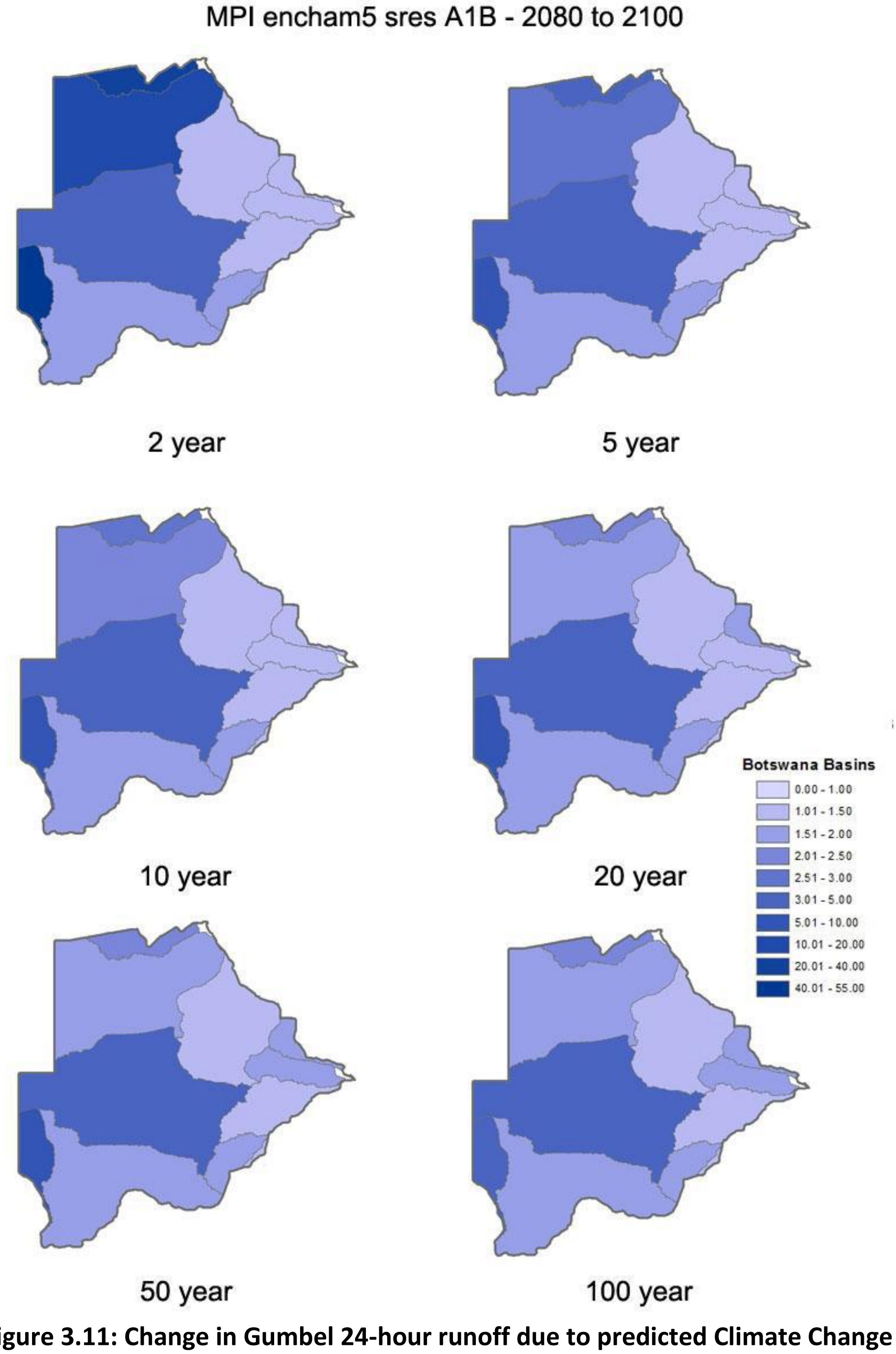


Figure 3.11: Change in Gumbel 24-hour runoff due to predicted Climate Change in Botswana, Echam5 GCM, A1b emissions scenario, 2080-2100 (World Bank 2010).

3.2.1.3 Adaptation measures

Some adaptation measures are already in place in the country particularly water transfers from an area with surplus to less endowed areas (for instance the North South Carrier Water Transfer Scheme), water purchase from neighbouring countries. The water utilities Corporation Has incorporated the IWRM into the national water strategies. These measures were introduced as longterm measures to relieve the water shortage situation.

Table 3.5: Adaptation measures in water sector.

Temporal Scale	Impacts and/or Constraints	Adaptation
Seasonal	Increased water demand due to temperature increase –winter average temperatures will increase with increasing temperatures (due to climate change) thus water demand will increase in winter too. Water demand felt across all sectors	Water conservation measures and awareness campaigns ○ Water pricing used as a tool ○ Water accounts studies and implementations ○ Water cuts and/or restrictions ○ More use of rainwater catchment systems ○ Desalination for hard water.
Yearly	The increasing GDP, population and Temperatures will cause annual increments on water demand, hence create shortages.	○ Same approaches as above. ○ Short, medium to long term forecasting.
Decadal	Increasing demand versus declining water resources	Need to plan along policy lines e.g. water conservation strategy to reduce the impacts of increasing demand versus declining water resources
Long term	Indications are that by 2030 (WEAP model) and beyond (STELLA model) there will be serious water shortages. Reducing rainfall, population increase, increasing costs of providing water and limitations in benefits; as well as rising GDP, and Temperature with subsequent escalation in water demand.	Forecasting studies like modelling ○ Water resources inventories to check areas that need improvements Robust adaptation steps need to be taken.

Table 3.5 (continued): Adaptation measures in water sector.

Spatial scale	Impacts and/or Constraints	Adaptations
Towns (urban)	Increasing water demand for domestic and industrial–Based on 1960-1990 record, inflows into dams have a high failure rate probability of 0.79	Need to protect the most vulnerable (poor) as water becomes an expensive commodity.
		○ -Diversify/increase water resources for rural areas (provide safer water resources). They have less water, mostly poor quality water
Districts (zone)	Groundwater levels decline (all model assessments). All centres experience heightened water demand.	Need to increase data availability/access and documentation ○ Intensify awareness ○ • Adopt indigenous methods of water use
Country average	Botswana, will as early as 2020/2030 have to seek alternative water sources due to impacts of climate change, Botswana, being in a semi-arid location, is likely to have serious water shortage in the near future. Water levels in most of wellfields are declining.	IWRM strategies needs to be implemented (e.g. loss reductions, water recycling rainwater harvesting, water pricing, water restrictions, and IWRM efficiency plans).

3.2.2 Health

The study focused on vector borne diseases such as malaria and diahorrea and the assessment was conducted in the context of generalizing health outcomes from one setting to another on diseases such as malaria having important local transmission dynamics that cannot be easily represented in multiple relationships. The assessment of the potential future health impacts of climate change is conducted in the context of and is limited by looking at inclusion of different development scenarios in health projections and limited understanding of the extent, rate, limiting forces and major drivers of adaptation of human populations to changing climate.

3.2.2.1 Malaria

About 30% of the population of Botswana is exposed to some risks of malaria infection every year, and cases are reported yearly mainly in the Northern Districts.

Malaria infection is unstable and occurs in epidemics relative to the level of rainfall. During years of heavy rainfall, the risk of malaria shifts westwards and southwards Malaria occurs yearly in peaks or infrequently in the hypo-endemic areas. The peaks occur towards the end of the rainy season. There is no transmission between May and September because the dry and cold environment during those months is not conducive to mosquito breeding and development of the parasite. One finding is that for the past ten (10) years there has been a downwards trend in malaria cases in the endemic areas even in years of heavy rainfalls such as 2006. While Bobirwa, Tutume, Serowe/Palapye and Boteti are in the transition zone for malaria, fatalities indicate persistence, indicating a widening of the malaria belt.

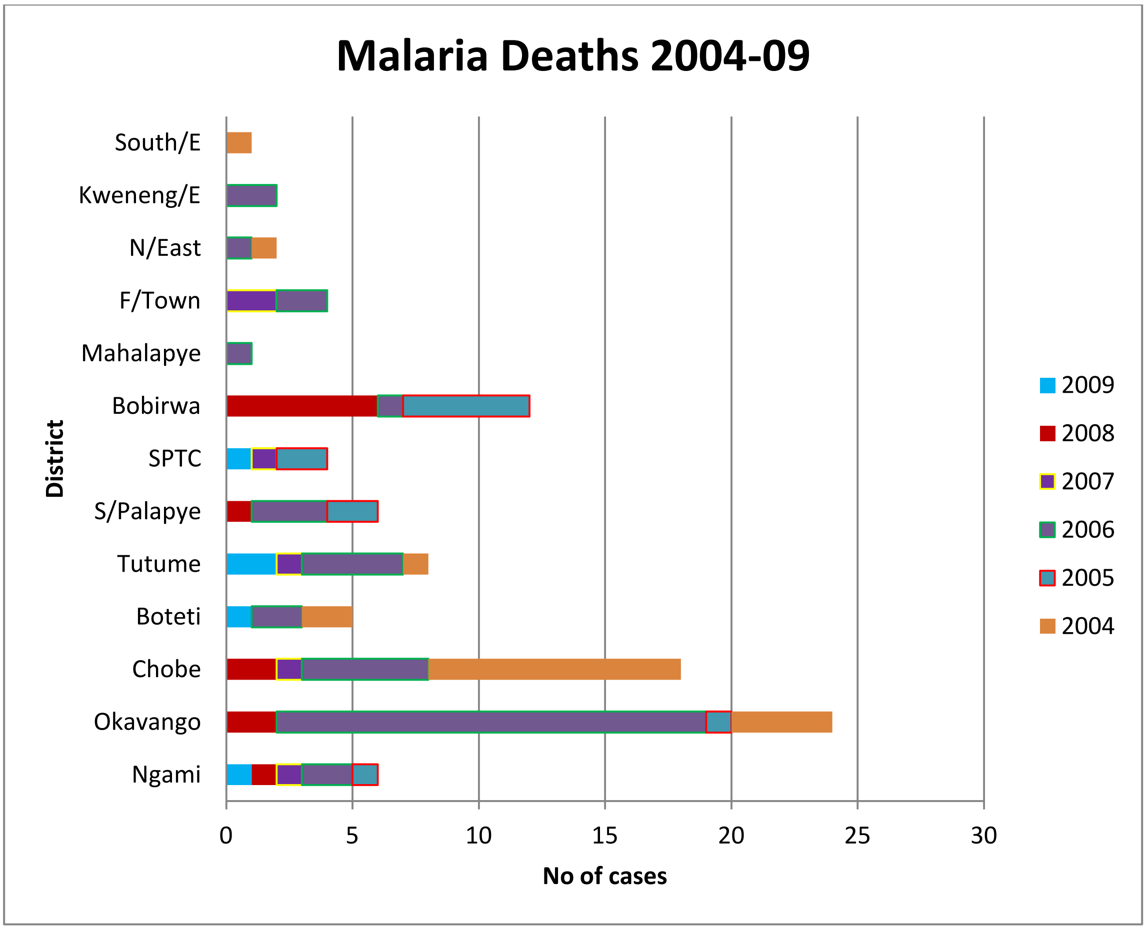


Figure 3.12: Malaria deaths in different areas Botswana 2004-2009.

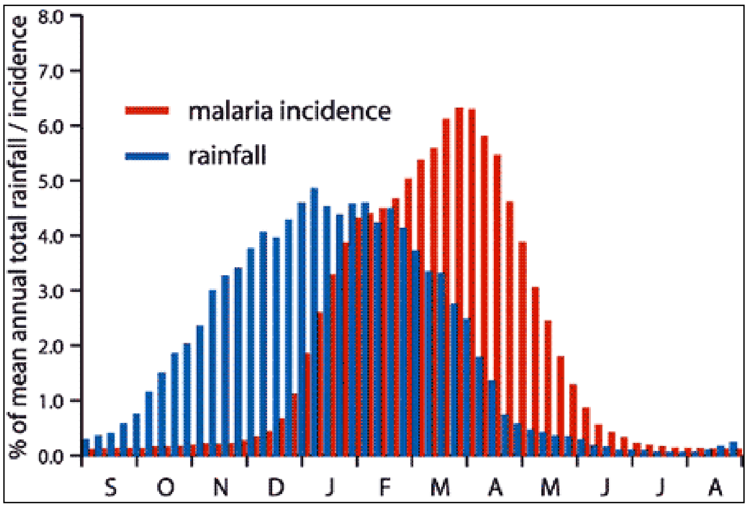


Figure 3.13: Relationship of rainfall and malaria occurrence in Botswana, 1997 to 2008 (Source: *Roll Back Malaria* project data on Botswana).

3.2.2.2 Diarrhoea

In Botswana diarrhoeal disease may be exacerbated by climate variability and change as variable rainfall patterns are likely to compromise the supply of fresh and clean water. Water is essential for hygiene and both water scarcity and excess water such as torrential rains increase the burden of diarrhoeal illnesses, which are spread through contaminated water. The study has concluded that diarrhoea is also a major cause of morbidity and mortality in Botswana, especially in children under five (5) years of age. Occurrence of diarrhoea is fairly steady from year to year, but outbreaks do occur, some of them very serious such as the 2006 outbreak. The outbreaks occurred in a year with above normal rainfall implying that this brings with it a higher risk of diarrhoea due to contamination of water as depicted by Fig. 3.14.

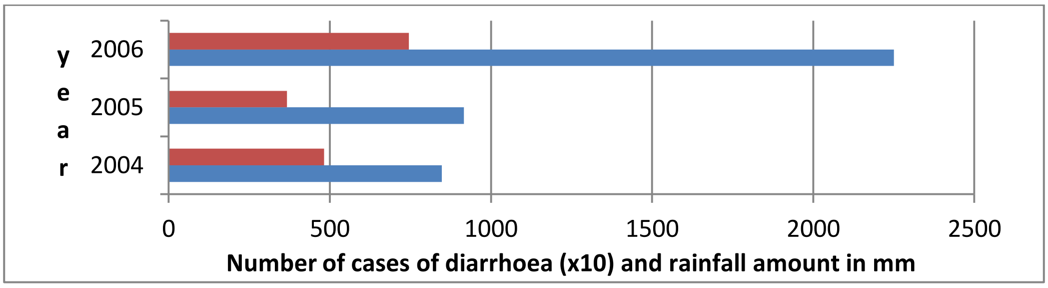


Figure 3.14: Diarrhoea cases (red bars) for 2004, 2005 and 2006 - showing significant increase in years with high rainfall (blue bars).

3.2.2.3 Adaptation measures in health sector

Table 3.6: Adaptation measures in health sector and methods of implementation.

Adaptation Measure	Action/Implementation
I. Malaria Control Programme	Vector Control Interventions including Insecticide Treated bed Nets (ITN) and Indoor Residual Spraying (IRS)
	Case Management
	Surveillance Monitoring and Evaluation
	Programme Management and application of control measures.
	Public Education and malaria campaign through print, electronic media and radio
II Control of Diarrhoeal Diseases Programme (CDDP) Integrated management of Childhood Infections (IMCI)	Adequate Public Education
	Surveillance, Reporting and Monitoring
	Infrastructure Development including water treatment plants and boreholes.
	Access to Safe/Potable Water and Improved Sanitation
	Technological/Engineering Interventions such as clean water technologies and bio-latrines and other.
	Medical Intervention
III Socio-economic development as a component of adaptation	Intervention studies
	Appropriate Action targeting improving resilience of vulnerable grpus by providing social safety nets (food basket, fortified foods, public works programme) in Health sector and related sectors.

3.2.3 Crops

The methodology adopted looked at the suitability of soil for crop production and administered a questionnaire to look at farmers perceptions on climate change, the study looked at the impact of increased temperature on the duration of crop stages that is on the duration of initial development and mid season of sorghum crop growth stages for four locations in Botswana (Kasane, Mahalapye, Ghazi, Tshane).

From the table the range of projections from MAGICC SCENGEN for the growth stages for sorghum is very narrow, the greatest change is in the total growing period 14 days less than the present growing period projected for Mahalapye.

Table 3.7: Length of growth development stages for sorghum for MAGICC SCENGEN climate change scenarios for four regions of Botswana.

Growth stages (days)	original	Kc		Kasane	Mahalapye	Ghanzi	Tshane
Dini	20	Kcini	.30	18	18	18	18
Ddev	35	Kcdev		32	31	32	31
Dmid	45	Kcmid	1.05	41	40	40	40
Dend	30	Kcend	.50	27	27	27	27
Total	130			118	116	117	117

Kc: Crop coefficient; ini: Initial stage; dev: Development stage; mid: Mid-season stage; end: Late-season stage.

Studies have shown that the projected increases in temperature will reduce the growing period of sorghum by about 11%, and other studies Chipanshi (2003) that the will be a 30% reduction in yield. Parida et al (2006) projections indicate reduction in cereal production by 10% in 2030 and 19% in 2050.

Table 3.8: Change in length of plant growth with 2^{o} C increase in temperature (scenarios for four regions of Botswana).

Growth stages	original	Kc		Kasane	Mahalapye	Ghanzi	Tshane
Dini	20	Kcini	.30	2	2	2	2
Ddev	35	Kcdev		3	4	3	4
Dmid	45	Kcmid	1.05	4	5	5	5
Dend	30	Kcend	.50	3	3	3	3
Total	130			12	14	13	13

Kc: Crop coefficient; ini: Initial stage; dev: Development stage; mid: Mid-season stage; end: Late-season stage.

Table 3.9: Adaptation measures in the agricultural sector.

Adaptation/ Technologies	
Irrigation	Since Botswana is a water-scarce country will have to rely more on the use of water either generated through desalination, use of soil-water-crop management strategies, harvesting of rainwater and treated waste water. This will contribute to intensification of irrigation systems which is still not well developed.
Conservation systems	Zero tillage which could result in better soil structure increased soil water infiltration due to the protection of soil surface structure by residues
Crop diversification	This provide a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lessen risk.
Improved crop varieties	disease-tolerant varieties and early-maturing varieties to increase the productivity of the crops, this could include development of heat tolerant and drought resistance crops.
Seed and fertilizer provision	Provision of seeds and fertiliser will help increase productivity of the crops. The Botswana Government in 2008 introduced an Agricultural Support Scheme called Integrated Support Programme for Arable Agriculture Development **(ISPAAD)** to address challenges in the arable sub-sector, of poor technology adoption by farmers and low productivity of the sub-sector. The scheme provides Seeds and Fertilizers to farmers.
Use of greenhouse/nets	For providing favourable growing conditions
Early warning systems	Early warning coordination, emergency and response plans need to be improved.
Drought mitigation	Some of the schemes that the government has introduced over the years help to facilitate access to farm inputs and credit and improve agricultural extension outreach. These schemes also serve as a basis for drought mitigation measures
Infrastructure	The government has a scheme for the construction of dams, wells, irrigation schemes and maintains agricultural implements. Costs for this scheme are • Dams for syndicates are 80% government subsidy. • Dams for individuals are fully paid for by owners. · Irrigation schemes designs, farm implements diagnosis of problems and well casing are free

3.2.4 Grasslands and livestock

The study focused on vulnerability and impact of climate change on the livestock sector. Assessment was based on indicators such as livestock population parameters, birth and mortality rates, offtake, deaths due to various illnesses, changes in the breeding strategies due to policy, nutritional constraints, social and economic wellbeing of farmers. Vulnerability and impacts of the rangeland and livestock to climate change was assessed based on range condition scores in the communal cattle post areas, ranches and in the protected areas. Effects of policy (past and present) on both livestock and rangelands was assessed on the basis of secondary data as well as information that was gathered during the survey study and plant and water composition analyses. This study was built on earlier work already done during the INC.

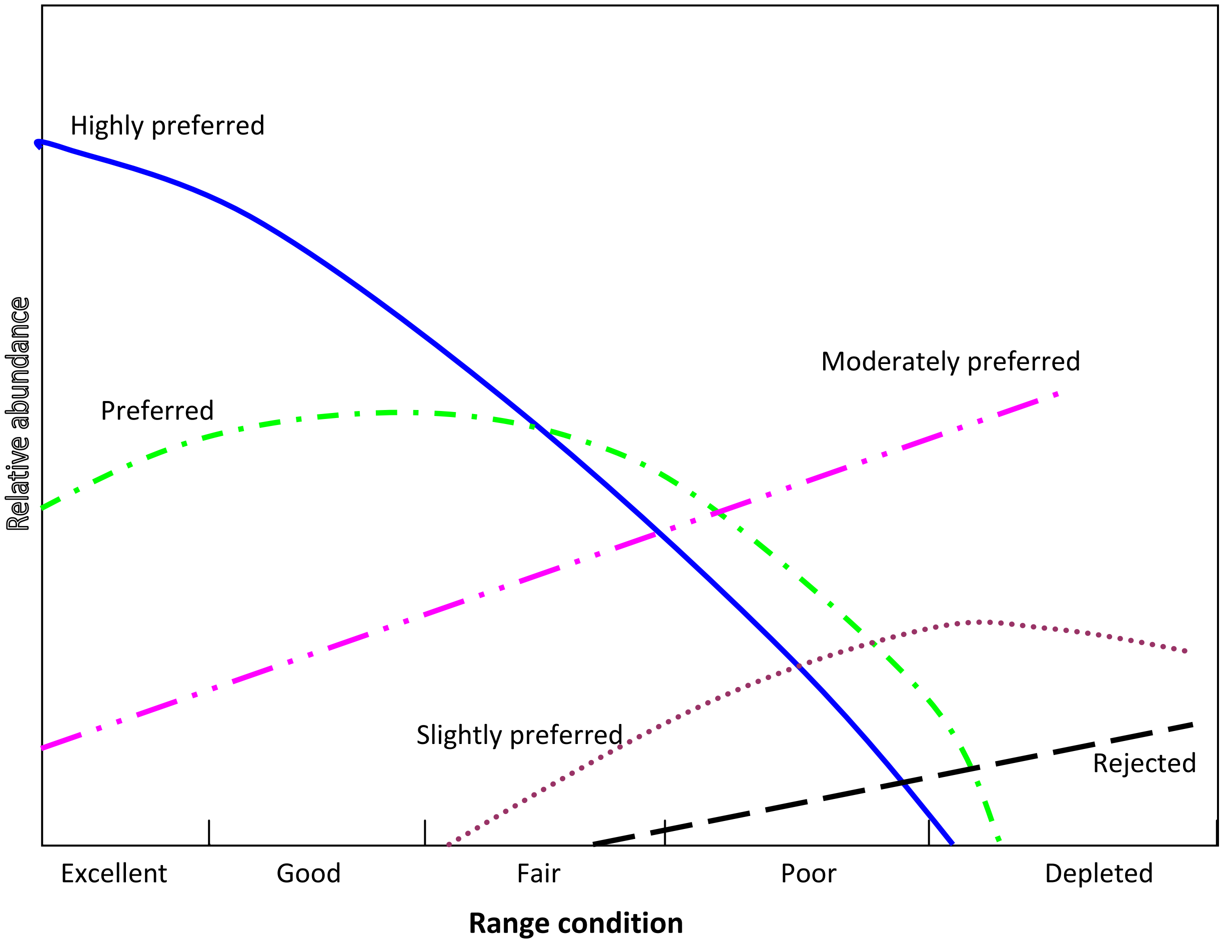


Figure 3.15: Changes in relative abundance of species groups in different range condition classes.

Documentation in most cases relate to change only and not the mechanism of change. It is likely that a combination of factors is responsible for these dramatic shifts.

The preferred plants are those that decrease as the grazing pressure becomes excessive. They are the most desirable plants to have on the range and those that animals like most. Most of the tall growing, palatable grasses fall within this group of plants. If preferred plants are plentiful on the range, the indication is that the grazing programme is going on well, the climatic conditions are close to ideal for the area and that the range is being maintained in good condition.

The slightly preferred plants, on the other hand, are those plants that increase as the grazing pressure increases and the climatic conditions are sub-optimal for plant growth. These are native plants that occur in the climax range, but are less attractive to the grazing animals. They tend to escape grazing because they are either shorter, less palatable or have protective appendages. These plants replace the highly preferred ones when long-term grazing pressure and the level of dryness increase.

The rejected species are usually annuals, weeds, or unpalatable shrubs that invade the range as the preferred and the slightly preferred species are weakened by constant heavy grazing pressure or frequent and prolonged drought periods. While some of these plants may come from other areas, they are usually present on small areas within the ranges that have been disturbed. They are poor producers and do not protect the soil as well as the other groups do.

The driving forces in succession are moisture (rainfall) and temperature. In the more humid range types (which are not common in Botswana) recovery after retrogression is both rapid and predictable. The climax plants will usually dominate the site within a few years if severe soil erosion has not occurred. In the drier range types such as we have in Botswana, the palatable plants tend to be less resistant to grazing (Field 1978). Here retrogression can occur within just a few years under heavy grazing, but recovery is a slow process often requiring many years under complete absence of grazing.

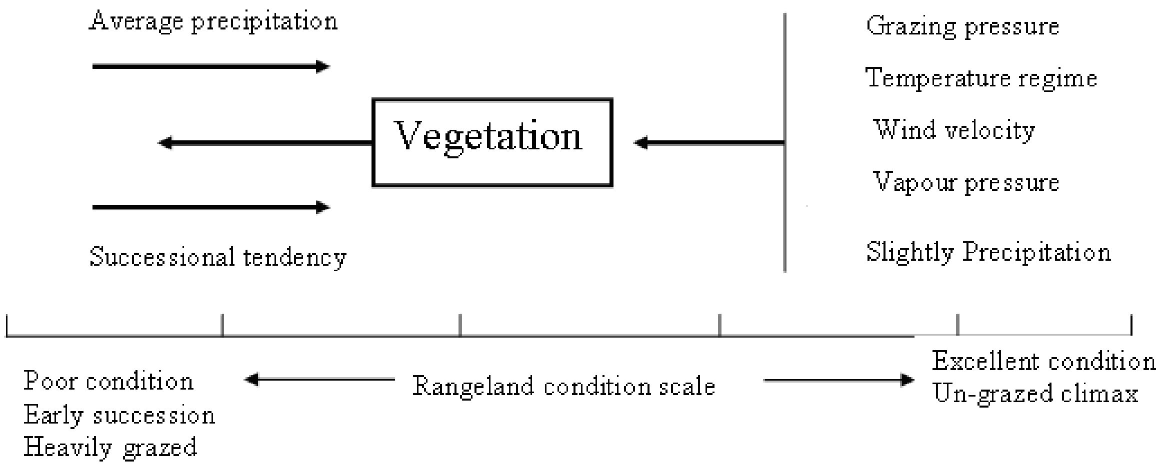


Figure 3.16: General range succession model with precipitation, grazing pressure, temperature, wind velocity and vapour pressure.

3.2.4.1 Survey areas

The study was conducted in selected sites in five agricultural regions:

- Southern Region – Mmathethe (hard veldt) and Letlhakeng (sand veldt)
- Western – Tshane (sand veldt) and Gantsi (sand veldt, commercial farmers)
- Central – Bobonong – (hard veldt and prone to drought and recent outbreak of foot and mouth diseases) and (Shoshong (sand veldt)
- Francistown – Tati Block Farms (hard veldt) and Matsiloje (outbreak of FMD)
- Ngamiland (wetland and an outbreak of CBBP) and Sehithwa.

3.2.4.2 Parameters measured

A structured survey instrument was developed and face to face interviews conducted for 100 farmers in the selected areas. In each study area 20 farmers (10 male and 10 female) were randomly selected and interviewed. Visual appraisals of livestock breeds and rangeland conditions were conducted in each area

The result of the survey the majority (72%) of the livestock farmers keep their animals in communal areas, with only 28% keeping their livestock in the fenced commercial areas. It is important to note that keeping livestock in communal areas has important implications for range conservation. This is because where livestock are kept in the open range it is difficult for individual herders to control grazing because they cannot limit stock numbers in a particular area. The major sources of income for the interviewed livestock farmers were livestock sales (38%), followed by sale of crops (19%); formal employment (17%), rental income (10%) old age pension and remittances, both at 8%.

It is important to note that not all livestock farmers are the same in terms of vulnerability, some are more vulnerable than others. For instance, commercial farmers may have a better ability to cope and resist a drought episode and hence less vulnerable than communal farmers who might experience difficulties trying to cope with a drought situation. This partly explains the fact that cattle ownership has become more and more skewed with fewer households owning more cattle. Thus, as drought episodes become more common and frequent small holders are unable to cope and lose their herds, never recover and end up leaving livestock farming altogether. Thus, the ability to adapt and cope with weather hazards depends on economic resources. In addition, lack of agricultural insurance schemes, savings and credit make it even harder for those who do not have alternatively sources of income to replace the livestock lost during a drought or a disease episode.

3.2.4.3 Adaptation strategies

Adaptation techniques in livestock farming include feeding animals during drought, vaccination against opportunistic diseases as a result of a drought and moving cattle to better pastures. It is clear that these strategies will easily be adopted by richer farmers who may have other sources of income apart from cattle farming. The poor livestock owners may find it impossible to adapt to this kind of situation. Additional adaptation strategies in the livestock sector include: Keeping livestock breeds that are more drought and disease tolerant; fencing of grazing areas as individuals or syndicates; proper matching breeds to the environment; diversification of farm produce; use of fall-back grazing areas (livestock mobility), mixed small stock and large stock herds of various breeds.

3.2.5 Forestry

Vulnerability of the forest sector to climate change was evaluated in terms of rainfall trends in the various regions. The underlying socioeconomic dynamics in the concerned communities and their perception of forest resources dynamics was also used to assess the vulnerability of forests and woodland to climate change.

3.2.5.1 Woody biomass measurements (field data collection)

Chanda et al. (2000) divided the vegetation of Botswana into 11 regions and came up with species composition for those regions. These 11 regions were used as the basis for this study with additional measurements of stand density, species composition, vegetation cover and woody biomass. Woody biomass in the sampling areas was quantified using Tietema's (1993) regression curves formulas above. In order to estimate woody biomass, species composition, stand density, diameter class, vegetation cover and vegetation structure in the sampling areas, rectangular quadrates of 50m*10m were demarcated at a distance of 100m from each other. In demarcating sample points some stratification according to soil and topography was considered. For every sample point three (3) quadrates each of 50m x 10m were demarcated in the field using measuring tapes and survey poles (Figure 3.17).

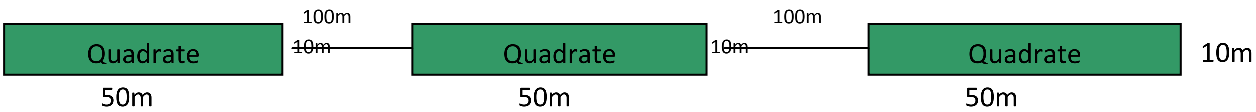


Figure 3.17: Layout of quadrates in a sample point.

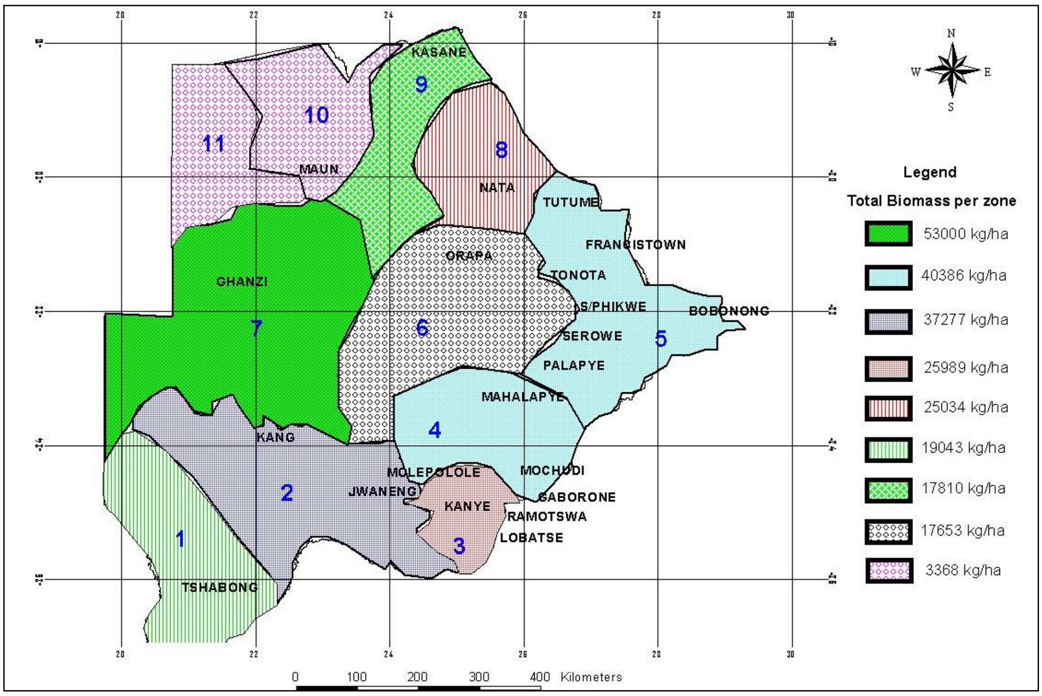


Figure 3.18: Total woody biomass (kg/ha) of all trees species as per area/zone.

Ecological regions 5 and 6 are the most vulnerable to drought and ecological regions 1, 9 and 10 are the least vulnerable. While regions 2, 4, 5, and 7 have the most biomass, regions 1, 6 and 9 have least biomass. Community observed an overall decline in forest resources in all the regions.

3.2.5.2 Perception of forest resources dynamics

All respondents harvest at least one type of forest resource, but only 10.3 percent mentioned that they sell these forest products. Firewood was harvested by 93.1 percent of the respondents, followed by construction timber at 86.2 percent. The least harvested resource was medicinal plants, for which only 21.4 percent responded in the affirmative. Except for livestock forage, for all forest products harvested, women represented the majority of harvesters. The percentage of women versus men who harvested forest resources was statistically significant with p-value < 0.05; with the exception of forage livestock (Table 3.6). This implies that significantly more men than women harvest and utilize forest products, and therefore men are most likely to be affected by the impacts of climate changes on forests.

Table 3.10: Forest products harvested by gender.

Forest products harvested	Women (%)	Men (%)	p value
Construction timber	24.0	76.0	0.000
Firewood	30.0	70.0	0.000
Fruits	23.8	76.2	0.016
Thatching grass	21.7	78.3	0.002
Medicinal plants	33.3	66.7	0.002
Livestock forage	25.0	75.0	0.450
Other forest resources	0	100.0	0.002

So as to understand the possible impacts of climate change on forest, respondents were asked to compare the distance travelled ten years back, versus now, to obtain forest products. Except for construction timber, there was no statistically significant change in the distance travelled to obtain forest resources. The distance travelled to get construction timber was statistically significant (p-value < 0.05). This implies that there has been a change in woodland composition that requires that communities travel further than they used to obtain construction timber. A number of reasons can be cited for these changes, among them climate change.

Table 3.11: Coping strategies for changes in the availability of forest resources.

Coping Strategy – Construction timber	Percent	p-value
Use non-indigenous supplements	42.1	**0.655**
Use less preferred alternatives	10.5	**0.000**
Travel longer distances to obtain resource	47.4	**0.211**
Use transport to obtain resource	21.1	**0.003**
Buy resource	10.5	**0.000**
No coping strategy	10.5	**0.000**
Coping Strategy – Firewood	**Percent**	p-value
Use non-indigenous supplements	20.8	**0.000**
Use less preferred alternatives	37.5	**0.005**
Travel longer distances to obtain resource	41.7	**0.008**
Use transport to obtain resource	29.2	**0.001**
Buy resource	12.5	**0.000**
No coping strategy	4.2	**0.000**
Coping Strategy – Fruits	**Percent**	p-value
Use non-indigenous supplements	6.7	**0.002**
Use less preferred alternatives	0	**0.035**
Travel longer distances to obtain resource	53.3	**0.818**
Use transport to obtain resource	26.7	**0.148**
Buy resource	0	**0.035**
No coping strategy	40.0	**0.751**
Coping Strategy – Thatching grass	**Percent**	p-value
Use non-indigenous supplements	46.2	**0.027**
Use less preferred alternatives	7.7	**0.000**
Travel longer distances to obtain resource	46.2	**0.117**
Use transport to obtain resource	23.1	**0.009**
Buy resource	7.7	**0.000**
No coping strategy	15.4	**0.019**
Coping Strategy – Livestock forage	**Percent**	p-value
Use non-indigenous supplements	**0**	**0.227**
Use less preferred alternatives	**0**	**0.227**
Travel longer distances to obtain resource	**85.7**	**0.008**
Use transport to obtain resource	**14.3**	**0.008**
Buy resource	**0**	**0.227**
No coping strategy	**14.3**	**0.008**

4 PROGRAMS CONTAINING MEASURES TO FACILITATE ADEQUATE MITIGATION TO CLIMATE CHANGE

4.1 Mitigation Analysis

4.1.1 Introduction.

As a Non-Annex I Country, Botswana does not have any commitments under the UNFCCC to reduce GHG emissions but under article 4.1(b) is required to formulate, implement, publish and regularly update national programmes containing measures to mitigate climate change. Botswana is already undertaking some of the mitigation measures identified under the INC. However. The greenhouse gases inventory prepared for Botswana within the SNC for the year 2000 indicated that the sector with the highest GHG emissions is the Energy sector. Consequently the mitigation analysis put emphasis on the energy sector However, this does not mean that sectors such as Waste, Agriculture and Forestry were not considered in the mitigation analysis, but rather that their share (excluding Forestry as a GHG sink) compared to the Energy sector is not significant. To estimate future trends of GHG emissions under different mitigation policies, the software LEAP (Long-range Energy Alternatives Planning system) was used, which was provided free of charge by the Stockholm Environment Institute

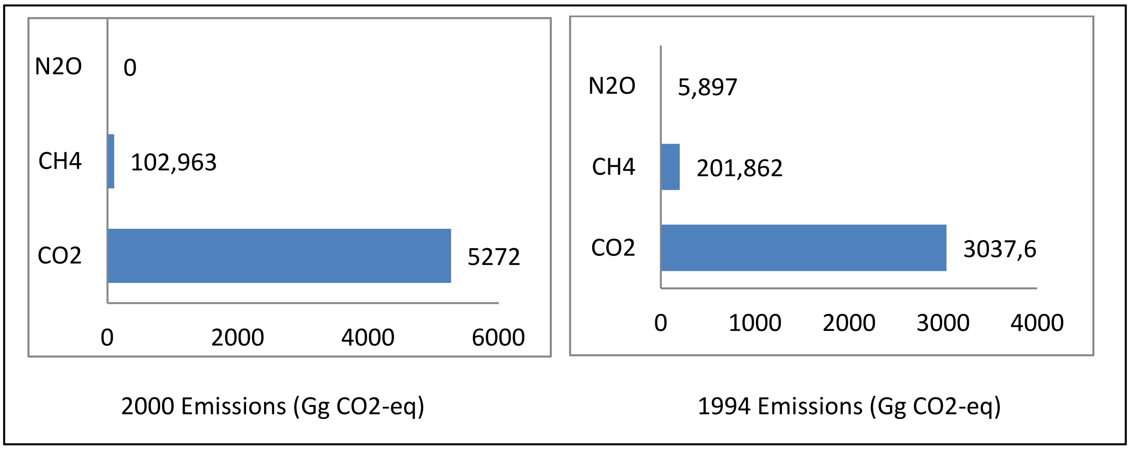


Figure 4.1: Comparison of the INC Inventory and SNC Inventory.

4.2 Energy

Both traditional and conventional energy sources are used in Botswana. The most prevalent traditional energy source is fuel wood while the prevalent conventional energy sources include gas (LPG) and paraffin for households, diesel for agriculture, coal for industry and petrol for transport. Fuel wood is the principal energy source for cooking in households. Approximately 77 percent households in rural areas and 46 percent nationally use it. But the trend observed is a move away from wood to use of LPG gas for cooking, and a move towards use of electricity for lighting. The main consumer of electricity over the years is mining. It is worth noting that the uptake of solar electricity is still very low at 0.23 percent of households countrywide.

Sectorally, households, industry and transport are the dominant contributors to final energy demand. Among them households are the principal users of energy in the country. Its share of final energy demand was 38 percent in 2003. The transport sector saw a growth in share of final energy demand from 13 percent in 1981 to 25 percent in 2003 with principal energy sources being petrol and diesel. Industry sector share was 26 percent in 2003.

4.2.1 Methodology.

LEAP software was used for estimating Botswana's mitigation potential for the energy sector. LEAP is a flexible, easy to use, scenario-based system for the integrated management of the energy sector. The software enables forecasting of the evolution of the energy sector, integrated planning of resources, analysis of mitigation policies and inventory of GHGs and energy balances. LEAP is a scenario-oriented model which is different from forecasting models.

4.2.2 Creation of the structure of the energy sector (Current accounts)

LEAP is a bottom-up, demand driven model. The structure of the Energy sector in this model consists of three subsectors:

- The Energy Demand Sector
- The Transformation and Distribution Sector
- The Energy Resources Sector.

The mitigation assessments were prepared with reference to business-as-usual (BAU) baseline projections from 2000 until 2030, taking into account national economic and social policies, development trends and projections. The assessments then considered the emission reduction potential of certain interventions if successfully implemented. The mitigation analysis was done for base year 2000, for the construction of current accounts and scenarios, the different studies and reports carried out in Botswana were also used. The basic assumptions for the baseline include the estimation of population and GDP projections.

The 2000 macro-economic indicators (table 4.1 and table 4.2) show Botswana's economy strengthening, the mining sector contributed to the increase followed by transport and trade, hotels and restaurants. The mining sector continued to increase by 5.2 per cent after a decline of 3.8 per cent in 2006. In 2005/06, it remained the largest contributor to GDP at 40.5 per cent. Growth in the non-mining sectors surged to 6.8 per cent in 2006/07, up from3.9 per cent in the previous fiscal year. The non-mining sectors that recorded significant growth rates are transport and communications (20.3 per cent); trade, hotels and restaurants (16.3 per cent); manufacturing (12.0 per cent); and banks, insurance and business services (6.6 per cent).The rest of the non-mining sectors registered real growth rates of less than 2 percent.

Table 4.1: GDP growth in Botswana for 2001-2015.

Year	2001	2002	2003	2004	2005	2006	2010	2015
Real GDP Growth	3.5%	9%	6.3%	6%	1.6%	5.1%	8.6%	7.7%

Assumptions in the baseline are population growth rate, the development GDP growth rate. GDP growth in the Baseline scenario is based on National Development plan 8 and 9 and expert estimations. Population is projected to reach 2.08 million by 2021 and population growth rate is 1%, GDP is expected to grow at 5.5%.

Table 4.2: 2000 quarterly gross domestic product (GDP) by type of economic activity at current prices (millions of Pula).

Sector	GDP Million BWP	% GDP	Annual % increase
Agriculture	755.2	2.6	13.5
Industry		30.8	
Transport	1 092.6	3.8	16.8
Residential	1 106.7	3.9	
Trade, hotels & restaurants	3 193.3	11.1	16.8
General government	4 567.6	15.9	11.3
Mining	10 085.6	35.2	20.2
Manufacturing	1 344.1	4.7	8.4
Construction	1 562.7	5.5	9.8

Source (CSO Stats Brief 2007)

4.2.3 Mitigation options

The proposed mitigation measures are based on the broad energy policy objectives and guiding principles as outlined in the National Development Plan 8 of the Republic of Botswana with regard to economic efficiency and environment are such that; energy should be used efficiently and energy extraction, production, transportation and use should not damage the environment or people's health.

The mitigation measures are also based on the draft energy policy which aims to provide a least cost mix of energy supply, which reflects total life cycle costs and externalities, such as environmental damage and The Long Term Vision for Botswana (Vision 2016) which recognizes the potential role that solar energy can play in meeting the energy requirements of rural communities not served by the national grid and recommends that Botswana should be developed into a centre of excellence for solar energy technology.

4.2.4 Demand side management strategies

The demand-supply strategy addresses the current energy supply situation in Botswana and measures taken to ensure long term energy security.

Table 4.3: Assumptions for the baseline scenarios in the energy sector and suggested mitigation measures.

Sector	Baseline	Policy and measures
Residential	Growth at 0.8% from 2000, 8.4% from 2005, 7.9% from 2010, 5.2% from 2015 3.0% Note: Percentages of households (HH) with cooking, lighting, from the CSO Environment report 2006	Growth 2%
Cooking	LPG from 40.59% of HH in 2001; 86.7% in 2009 to 91% in 2015; electricity: from 5% of HH in 2001,15.6% in 2009 to 10% in 2015 Firewood: from 45.72% in 2001, 15.4% in 2010 to 5% in 2015	LPG from 40.59% of HH in 2001; 91% in 2015 to 95% in 2025; electricity: from 5% of HH in 2001, 15.6% in 2009 to 10% in 2015 Firewood: from 45.72% in 2001, 15.4% in 2010 to 5% in 2015
Lighting	CFLs in use about 5% penetration	CFLs in use (distributed to some residences during 2010 so assume penetration of 50% in 2010 and 90% as of 2015)
Industry	Electrical energy and diesel fuel used Growth rate (customers) 3% to 2015; 1% to 2030 No change in energy intensity	Growth rate same as reference 10% Reduction in overall energy by 2015 and 15% by 2030 due to energy conservation measures (education)
Transport	Economic growth reflects the transport sector, no new technologies introduced , GDP for transport increases by 16%	No change in the transport sector
Agriculture	No new technologies	
Transmission & Distribution		
Electricity Distribution	Losses reduced from 12% in 2008 to 8% in 2015	Same as Baseline
Electricity Generation		
Additional thermal plants coal	600 MW in 2011	
Diesel (Orapa Matshelagabedi)	160 MW 2010	
solar		50 MW 2026 200 MW 2020
Gas (Coal Bed Methane gas)		250 MW 2025

The policies and strategies mentioned above contains several measures that have GHG abatement effect:

1. Encouragement of the use of efficient bulbs in households, service sector and industry
    - To raise awareness for loads Implementation of Compact Fluorescent Lamps (CFLs) project.

- use of efficient bulbs

2. Energy efficient buildings
   - promotion of the energy efficiency through leaflets and flyers
3. Promotion of energy efficiency
   - encouraging people to switch off unnecessary Hot Water Load Control (HWLC) system
   - Installation of smart meters
   - Promotion of the use of energy efficient appliances
   - Conducting energy audits for various industrial
4. Promotion of Renewable energy
   - Installation of solar panels on private and public buildings
   - Promotion of the use of solar water heaters
5. Renewable energy grid installations
   - Renewable Energy based rural Electrification.
   - Substitution of fossil Fuel grid power with solar
6. Substitution of fossil fuels

Table 4.4: Mitigation options in key sectors.

Sector	Mitigation options
Energy	Energy efficiency in Residential (efficient bulbs, efficient refrigerators, smart meters) Replacing fuel wood with use of LPG and biogas Building insulation PV electricity
Waste	Landfill gas recovery
Agriculture	Livestock waste management through • Aerobic manure composting • Biogas capture (for rural households)
LULUCF	Reforestation
Industrial Process	Energy efficiency (electric furnace, *space heating, general lighting purposes and* motors) Energy audits
Transport	Modal shift Fuel economy CNG/biodiesel buses

4.2.5 Projected Energy Demand

Figure 4.1 shows the final and estimated final energy demand by sector in Botswana, The annual growth rate is projected to grow at 2% from 2000 to 2035 in the business as usual scenario. During this period the agricultural sector final energy demand is expected to increase at an average annual growth rate of 6% while the transport sector's final energy demand is projected to increase at an average annual rate of 2.4%. Industry is projected to increase at an average annual growth rate of 6.5% and non energy use to increase at an average annual rate of 2% but final energy demand for households is expected to decrease at an annual rate of 0.5%.

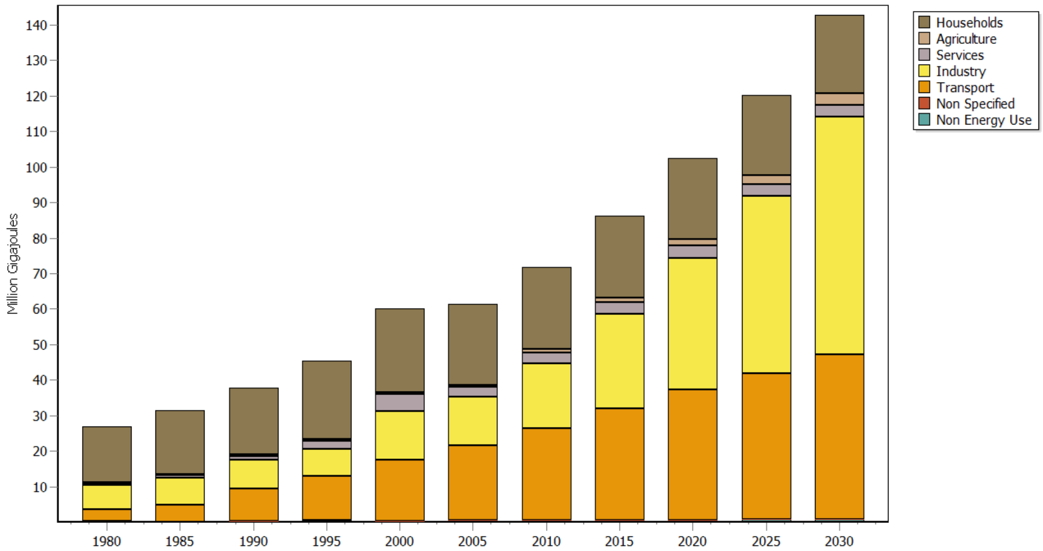


Figure 4.1: Historical and projected energy demand (baseline scenario).

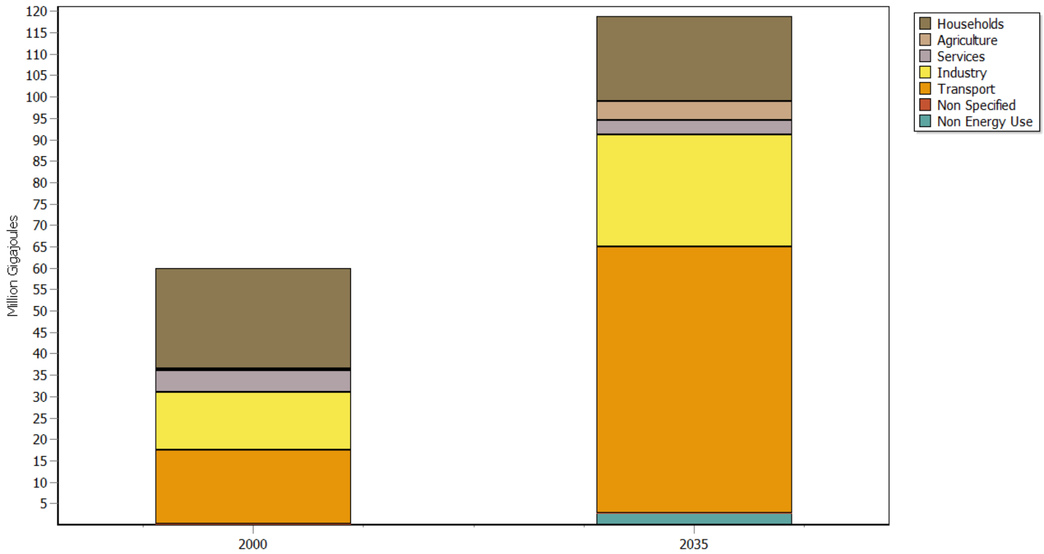


Figure 4.2: Base year and final energy demand (baseline scenario).

5 OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENT OF THE OBJECTIVE OF THE CONVENTION

5.1 Education, training and public awareness

The University of Botswana, Environmental Science Department provides training on environmental issues.

UNDP/GEF small grants projects have also contributed to training and awareness to Non Governmental Organizations (NGOs) who are implementing them and also the institutions where the projects are housed particularly on energy efficiency, energy audits and waste water recycling. During the preparation of this report awareness activities were carried out for various groups such as the Cabinet, House of Chiefs, Members of Parliament, Council Sessions, Environmental Education school teachers, farmers, communities (Kgotla meetings – public gatherings), environmental clubs and students. The Cabinet, House of Chiefs, Members of Parliament, Council Sessions were addressed during their full sessions and sometimes special arrangements were made such as holding breakfast meetings to make climate change presentations for them on information on the science of climate change, summaries for policy makers from the IPCC and outcomes of COP meetings. The indicator for level of understanding will be shown by the questions asked, suggestions forwarded, and request for guidance on the way forward by the group. Environmental Education school teachers usually hold Environmental Education forums and it is at these forums that presentations will be made on the subject of climate change. Farmers and environmental clubs hold quarterly meetings and it would be at these provide an opportunity to make climate change presentations. Climate change presentations were also made at schools' career fairs and at public gatherings and the level of understanding would be measured by the type of questions asked.

5.2 Research and systematic observation

A large part of the ongoing research is contributed by individual research efforts at the University of Botswana and other tertiary education centres. Recent studies have looked at vulnerability, impacts and adaptation in the whole of the Botswana

Limpopo Basin. The research looked at the various sectors of agriculture, water resources, wildlife, natural products and potential adaptation strategies. Some of the simulations studies highlighted above are part of the follow up work, and there are other studies in the planning that arise from the main study.

Ongoing research in Botswana is looking at potential production systems for biofuels from plant oil and sugar, and the government has commissioned studies to evaluate *Jatropha sp* and other potential plants (Government, 2009). Work is also being carried out on looking at the potential of invading woody plants to produce wood chips for bio energy supply from rural areas where such species have replaced original economic value of land systems

At present there is no single institution which is responsible for collection of data and information specifically for climate change monitoring and impact assessments. But regular climate observations are maintained by the National Meteorological Services and one meteorological station is included in the global climate observing stations.

5.3 Technology transfer

Technology needs assessment report was prepared in 2004, in this report technologies for mitigation and adaptation were identified and prioritized, the report singled out policy improvement that could lead to more enabling environments, demonstrated how the capacity of local institutions and experts could be increased, and showed how public awareness of climate change issues could be enhanced. The identified technologies are listed in the table5.1 below.

The Government has also set up a Botswana Innovation Hub (BIH) that is set to promote technology transfer. It has so far held one workshop on Climate Technology and Carbon Markets Partnership in Botswana.

Table 5.1: Key technology needs for Botswana.

	Category	Identified technology
1. Energy	Solar	Solar PV Technologies
		Solar Cooling
		Passive Solar Designs
		Solar Cooking
		Solar Water Pumping
		Solar Water Heating
		Solar Thermal Electricity Generation
	Biomass	Wood Chip Briquetting
		Elephant Grass
	Biogas	Sewerage Biogas Generation
		Slaughterhouse Biogas Generation
		Household Biogas Plants
		Landfi ll Biogas Generation
	Coal	Coal washing
		Coal bed methane
2. Water	Water Treatment Technologies	Reverse osmosis
		Polymer technology
		Demineralisation
		Activated Sludge
		Trickling/Percolating Filter
		Vacuum Sewerage System
		Rotating Bio-Contactors
		Waste Stabilisation Ponds
	Rain water harvesting	Ground Catchment Tanks
		Roof Catchment Tanks
3. Agriculture	Livestock	Reducing livestock numbers
		Improving Animal Productivity
		Ionophores
		Probiotics
		Improved Forage Quality
		Manipulating Nutrient Composition
		Animal Breeding
		Livestock Methane Vaccine
	Crops	Conservation Tillage
		Tractor Operation and Selection

5.4 Capacity building

The UNDP/Government of Botswana Environmental Support Programme project built capacity of officers from different institutions on climate mitigation and vulnerability and adaptation assessments. Also funding under the SNC was used to build capacity on mitigation and vulnerability assessments. Capacity was also built through attending domestic and regional workshops on key areas and also through hands on involvement in the preparation of this report.

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

6.1 Constraints and gaps

The main constraints are related to lack of activity data and information, and the lack of expertise in the respective sectors. Due to the unavailability of relevant data, assumptions were made and data obtained from secondary sources. Due to the low level of awareness on climate change by policy makers, climate change is not yet a priority for the country even though there is a Parliamentary Committee on Climate Change and therefore the integration of climate change issues in development programmes and projects still remains a challenge. As a result, there are no national climate change plans or policies and legal framework to implement the convention. Climate Change is weakly infused in social, economic and environmental policies

Some of the capacity constrains identified under the National Capacity Self Assessment report were inappropriate institutional structure, inadequate manpower and inadequate policy framework.

6.2 Technical and capacity needs

Technical and financial support is urgently needed for capacity building and to establish research programs within universities and research institutes. In this respect, support is needed for:

- Research capacity to generate data and information needed to derive locally, regionally and continentally applicable solutions
- Development of data and information management systems that allow sharing, integrated analysis and synthesis for local, regional and continental application
- Develop networked critical mass of scientists and other expertise that could provide needed services in the entire spectrum of emerging climate change related challenges.

- Harness technology transfer particularly where advantages are emerging like in the area of bio energy and other energy source developments that are geared to explore potential of African resources.
- Building capacities for modeling and early warning of extreme events and disasters such as flash floods, dust storms and droughts
- Development of appropriate policies and institutions that are geared to address climate change related challenges, including the participation of private sector particularly in the provisions of specialised services.
- Develop capacity to negotiate effectively from informed positions in international fora to attract meaningful resources to address emerging challenges facing the developing countries from climate change, including reparations where due or assistance in lieu.
- re-training of local experts in cross-cutting issues,
- Building capacities for modeling and early warning of extreme events and disasters such as flash floods, dust storms and droughts

6.3 Financial needs

Funding is needed for the country to cope with the adverse impact of climate change and the funding needs are expressed in the relevant chapters of this report.

Cooperation with Annex 1 Parties and other international Institutions:
Botswana has received support from developed countries through various programmes. There were some projects financed in the field of climate change through international organizations such as the World Bank. Botswana received the following support for institutional strengthening of the Designated National Authority for Clean Development projects:

Table 6.1 Financial support received.

Organisation	Year funded	Amount (USD)
World Bank Carbon Finance – Assist Program	2005	60 000
UNEP/Risø	2010	78 000

The SADC has sponsored a study on the development of regional grid emission factors (GEF) for Southern Africa from which Botswana will benefit.

Table 6.2: Project proposals related to climate change, technologies to be used and equipment required.

Type of project	Project	Technology to be used	Equipment required
GHG mitigation	Generation of Energy from biogas (BMC waste)	Electricity generation from biogas	Biogas extractor, gas containers
	Large Scale power generation from solar energy	Electricity generation from solar	Solar panels, connectivity to the grid
	Coal Bed Methane Investigations	Coal bed methane	Methane extractors. Gas containers
	Substitution of fuel-wood in rural areas through promotion and use encroaching bush	Fuel switching	Bush-cutting equipment
	Efficient lighting programme	Energy efficiency	CFL bulbs
	Residential and Commercial Energy Efficiency	Energy efficiency in buildings	CFL bulbs
	Fuel efficiency in transport.	Energy efficiency in the transport sector	Fuel efficiency enhancement devices
	Wind farm	Wind	Wind, connectivity to the grid
	Power generation from landfill gas	Electricity generation from biogas	Biogas extractor, gas containers
Climate change adaptation	Monitoring of mophane trees around the Okavango Delta		

6.4 Adaptation measures/projects and barriers

The major barrier with the use of recycled water is social acceptability, other barriers with regard to water treatment technologies are high operational cost and lack of skilled manpower. In agriculture the barriers are associated with limited knowledge on the technologies. The following are some of the adaptation measures suggested in the study of the technology needs for Botswana.

Table 6.3: Barriers to adaptation measures.

Adaptation measure	Barrier	Ways to overcome the barrier
Reverse osmosis	Cost, maintenance needs, and lack of skilled manpower	Flexible financing mechanisms
Demineralisation	Cost	
Polymer Technology- Scale Formation Inhibiting	Uncommon	Need for piloting and marketing
Waste Stabilisation Ponds	Need for large area of land	Use where suitable like in rural areas
Constructed Wetland Systems for Wastewater Treatment	Need for large area of land	Use where suitable like in rural areas
Ground Catchment Tanks	Compromised water quality	Use of other material than mud such as polyethylene tanks to improve water quality
Reducing Livestock Numbers	Resistance from farmers	Enhance knowledge in climate change
Improving Animal Productivity	Cost and limited knowledge	Enhance knowledge and flexible financing mechanisms
Ionophores	Long-term implications of the feed and limited knowledge	Enhance knowledge
Probiotics	Suitability to different types of livestock and limited knowledge	Enhance knowledge
Improved Forage Quality	Limited knowledge and implementation	Enhance knowledge
Manipulating Nutrient Composition	Suitability, implications and limited knowledge	Enhance knowledge and explore suitability
Animal Breeding	Limited knowledge	Enhance knowledge
Livestock Methane Vaccine	Availability and limited knowledge	Enhance knowledge and piloting
Conservation Tillage	Cost and lack of marketing the technology	Piloting and flexible financing mechanisms
Tractor Operation and Selection	Availability of equipment and limited knowledge	Enhance knowledge

7 REFERENCES

Bank of Botswana Annual Report 2002

Bhalotra YPR, 1987. Climate of Botswana: Part II - Elements of Climate. Department of Meteorological Services, Republic of Botswana

Botswana Environment Statistics, Central Statistics Office 2008

Botswana Initial National Communications 2001

Botswana Power Corporation Annual Report 2007

Botswana Power Corporation Annual Report 2008

Botswana Power Corporation Annual Report 2010

Botswana Climate Variability and Change: Understanding the Risks 2011 World Bank

Botswana's Initial National Communication to the United Nations Framework Convention on Climate Change, 2001

Central Statistics Office (CSO), 2000. Botswana Environment Statistics. Ministry of Finance and Development Planning, Botswana.

Central Statistical Office (CSO), 2004. Botswana Agricultural Census Report 2004. Ministry of Finance and Development Planning, Botswana.

Central Statistical Office (CSO), 2004. 2001 Population and Housing Census. Ministry of Finance and Development Planning, Botswana

Central Statistics Office (CSO), 2006. Botswana Environment Statistics. Ministry of Finance and Development Planning, Botswana.

Central Statistics Office (CSO), 2007. Botswana Transport Statistics. Ministry of Finance and Development Planning, Botswana.

Central Statistics Office (CSO), 2007. Stats Brief 2007

ICCT Analysis. Data from International Road Federation, World Roads Survey 2006

Environment Statistics CSO (2006)

Field DI, 1976. A handbook of common grasses in Botswana, Ministry of Agriculture, Private bag 003, Gaborone, Botswana. (pp 15-17)

Gombalume DB, Manthe C,. 1995. AGRINEWS: Forestry Reserves are diminishing. Agriculture Information and Public Relations Division, Gaborone, Botswana

Hewitson BC, Crane RG, 2006. Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. International Journal of Climatology, 26: 1315-1337

Parida BP, Moalafhi DB, Kenabatho PK, 2006. Forecasting runoff coefficients using ANN for water resources management: The case of Notwane catchment in Eastern Botswana.

State of the Environment Review Report 2002

Vulnerability Assessment and Adaptation in the Crop Sector 2011

Vulnerability Assessment and Adaptation in the Forestry Sector 2008

Vulnerability Assessment and Adaptation in the Health Sector 2009

Vulnerability Assessment and Adaptation in the Livestock and Rangelands Sector 2007

Vulnerability Assessment and Adaptation in the Water Sector 2008

Wolski P, Coop L, Tadross M, 2010. Assessment of change in rainfall under climate change projections for Botswana based on statistical downscaling.

The World Bank, 2002. World Development Indicators 2002 online. http://publications.worldbank.org/ecommerce/catalog/product?item_id=631625). Washington, D.C.; USA.

8 ANNEXES

SUMMARY OF ANNUAL GHG EMISSIONS BY SOURCE AND CATEGORY (YEAR 2000)

Table A1: 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.

Country	**BOTSWANA**
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	**(Reference approach) 5,272**	**-42,941**	**90**	**0**	**0**	**0**	**0**	**0**
1. Energy	**5,272**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A. Fuel combustion (sectoral approach)	3,979		0	0	0	0	0	0
1. Energy Industries	0		0	0	0	0	0	0
2. Manufacturing industries and construction	1,468		0	0	0	0	0	0
3. Transport	490		0	0	0	0	0	0
4. Other sectors	76		0	0	0	0	0	0
5. Other (please specify)	1,945		0	0	0	0	0	0
B. Fugitive emissions from fuels	0		0		0	0	0	0
1. Solid fuels			0		0	0	0	0
2. Oil and natural gas			0		0	0	0	0
2. Industrial processes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A. Mineral products	0				0	0	0	0

B. Chemical industry	0		0	0	0	0	0	0
C. Metal production	0		0	0	0	0	0	0
D. Other production	0		0	0	0	0	0	0
E. Production of halocarbons and sulphur hexafluoride								
F. Consumption of halocarbons and sulphur hexafluoride								
G. Other (please specify)	0		0	0	0	0	0	0
3. Solvent and other product use	**0**			**0**			**0**	
4. Agriculture			**85**	**0**	**0**	**0**	**0**	**0**
A. Enteric fermentation			81					
B. Manure management			3	0			0	
C. Rice cultivation			0				0	
D. Agricultural soils				0			0	
E. Prescribed burning of savannahs			0	0	0	0	0	
F. Field burning of agricultural residues			0	0	0	0	0	
G. Other (please specify)			0	0	0	0	0	
5. Land-use change and forestry [1]	**0**	**-42,941**	**0**	**0**	**0**	**0**	**0**	**0**
A. Changes in forest and other woody biomass stocks	0	-42,941						
B. Forest and grassland conversion	0	0	0	0	0	0		
C. Abandonment of managed lands		0						
D. CO_2 emissions and removals from soil	0	0						
E. Other (please specify)	0	0	0	0	0	0		
6. Waste			**5**	**0**	**0**	**0**	**0**	**0**
A. Solid waste disposal on land			5		0		0	
B. Waste-water handling			0	0	0	0	0	
C. Waste incineration					0	0	0	0

D. Other (please specify)			0	0	0	0	0	0
7. Other (please specify)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Memo items								
International bunkers	**0**		**0**	**0**	**0**	**0**	**0**	**0**
Aviation	0		0	0	0	0	0	0
Marine	0		0	0	0	0	0	0
CO_2 emissions from biomass	**0**							

Table A2: Sheets 1 of 3 of the calculation of carbon dioxide emissions from the energy sector (Reference approach).

	Sheet 1	Sheet 2	Sheet 3
MODULE	ENERGY	ENERGY	ENERGY
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1	1-1	1-1
SHEETS	1 OF 5	2 OF 5	3 OF 5
COUNTRY	Botswana	Botswana	Botswana
YEAR	2000	2000	2000

			A	B	C	D	E	F	G (b)	H	I	J	K	L	M	N	O	P
			Production	Imports	Exports	International Bunkers	Stock Change	Apparent Consumption	Conversion Factor	Apparent Consumption	Carbon Emission Factor	Carbon Content	Carbon Content	Carbon Stored	Net Carbon Emissions	Fraction of Carbon	Actual Carbon Emissions	Actual CO_2 Emissions
				1000 t					(TJ/Unit)	(TJ)	(t C/TJ)	(t C)	(Gg C)	(Gg C)	(Gg C)	Oxidised	(Gg C)	(Gg CO_2)
FUEL TYPES								F=(A+B-C-D-E)		H=(FxG)		J=(HxI)	K=(J/1000)		M=(K-L)		O=(MxN)	P=(Ox[44/12])
Liquid Fossil	Primary Fuels	Crude Oil						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Orimulsion						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Natural Gas Liquids						0.00		0.00		0.00	0.00		0.00		0.00	0.00
	Secondary Fuels	Gasoline		391.962				391.96	44.95	17,618.69	18.9	332,993.28	332.99	0.8	332.19	0.99	328.87	1,205.86
		Jet Kerosene		13.242				13.24	44.15	584.63	19.5	11,400.37	11.40	0.5	10.90	0.99	10.79	39.57
		Other Kerosene		25.738				25.74	43.16	1,110.85	19.6	21,772.70	21.77	0.75	21.02	0.99	20.81	76.31
		Shale Oil						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Gas / Diesel Oil		314.137				314.14	43.16	13,558.15	20.2	273,874.69	273.87	0.33	273.54	0.99	270.81	992.97
		Residual Fuel Oil		6.475				6.48	40.57	262.69	21.1	5,542.77	5.54	0.5	5.04	0.99	4.99	18.31
		LPG		23.856				23.86	47.65	1,136.74	17.2	19,551.90	19.55	0.80	18.75	0.99	18.56	68.07
		Ethane						0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00
		Naphtha						0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00

		Bitumen						0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00
		Lubricants		6.186				6.19	43.12	266.74	20	5,334.81	5.33	0.80	4.53	0.99	4.49	16.46
		Petroleum Coke						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Refinery Feedstocks						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Other Oil						0.00		0.00		0.00	0.00		0.00		0.00	0.00
Liquid Fossil Totals										34,538.50		670,470.52	670.47	4.48	665.99		659.33	2,417.55
Solid Fossil	Primary Fuels	Anthracite [a]						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Coking Coal						0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00
		Other Bit. Coal	918.5					918.50	33.01	30,319.69	26.2	794,375.75	794.38		794.38	0.98	778.49	2,854.46
		Sub-bit. Coal						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Lignite						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Oil Shale						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Peat						0.00		0.00		0.00	0.00		0.00		0.00	0.00
	Secondary Fuels	BKB & Patent Fuel						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Coke Oven/Gas Coke						0.00		0.00		0.00	0.00		0.00		0.00	0.00
Solid Fuel Totals										30,319.69		794,375.75	794.38	0.00	794.38		778.49	2,854.46
Gaseous Fossil		Natural Gas (Dry)						0.00		0.00		0.00	0.00	0.00	0.00		0.00	0.00
Total										**64,858.19**		**1,464,846.26**	**1,464.85**	**4.48**	**1,460.37**		**1,437.82**	**5,272.00**
Biomass total										42,458.00		689,093.34	689.09	0.00	689.09		0.00	0.00
		Solid Biomass	1420					1,420.00	29.9	42,458.00	16.23	689,093.34	689.09		689.09		0.00	0.00
		Liquid Biomass						0.00		0.00		0.00	0.00		0.00		0.00	0.00
		Gas Biomass						0.00		0.00		0.00	0.00		0.00		0.00	0.00

Table A3: Emissions from coal mining (figures for the year 2000).

Type of mining		A Amount of coal produced (million t)	B Emission factor (m^3 CH_4/t)	C Methane Emissions (million m^3) **C = (A x B)**	D Conversion factors (0.67 Gg CH_4/106m^3)	E Methane Emissions (Gg CH4) **E = (C x D)**
Underground Mines	Mining	0.945	17.500	16.538	0.670	11.080
	Post Mining	0.945	2.500	2.363	0.670	1.583
Surface mines	Mining	0.000	1.200	0.000	0.670	0.000
Stock Pile	Post Mining	0.000	0.100	0.000	0.670	0.000
Total						**12.663**

Table A4: Emissions from alcoholic beverages.

MODULE	INDUSTRIAL PROCESSES			
SUBMODULE	FOOD AND DRINK			
WORKSHEET	2-13			
SHEET	1 OF 2 ALCOHOLIC BEVERAGE PRODUCTION - NMVOC EMISSIONS			
COUNTRY	Botswana			
YEAR	2000			
STEP 1				
	A	B	C	D
Alcoholic Beverage Type	Quantity of Alcoholic Beverage Produced	Emission Factor	NMVOC Emitted	NMVOC Emitted
	(hl)	(kg NMVOC/hl beverage produced)	(kg)	(Gg)
			C = (A x B)	D = C/1 000 000
Chibuku	1111650	0.035	38,907.75	0.04
			0.00	0.00
			Total (Gg):	0.04

Table A5: Summary of annual GHG emissions from the agriculture sector.

	MODULE	**AGRICULTURE**				
	SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK**				
		ENTERIC FERMENTATION AND MANURE MANAGEMENT				
	WORKSHEET	**4-1**				
	SHEET	**1 OF 2 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC**				
		FERMENTATION AND MANURE MANAGEMENT				
	COUNTRY	**Botswana**				
	YEAR	**2000**				
		STEP 1			**STEP 2**	**STEP 3**
	A	B	C	D	E	F
Livestock Type	Number of Animals	Emissions Factor for Enteric Fermentation	Emissions from Enteric Fermentation	Emissions Factor for Manure Management	Emissions from Manure Management	Total Emissions from Livestock
		(kg/head/yr)	(t/yr)	(kg/head/yr)	(t/yr)	(Gg/yr)
			C = (A x B)/1000		E = (A x D)/1000	F =(C + E)/1000
Dairy Cattle			0.00		0.00	0.00
Non-dairy Cattle	2098000	32	67,136.00	1	2,098.00	69.23
Buffalo			0.00		0.00	0.00
Sheep	275000	5	1,375.00	0.21	57.75	1.43
Goats	1576000	5	7,880.00	0.22	346.72	8.23
Camels			0.00		0.00	0.00
Horses	48000	18	864.00	2.18	104.64	0.97
Mules & Asses	318000	10	3,180.00	2.18	693.24	3.87
Swine	5000	1	5.00	0.023	0.12	0.01
Poultry	928000	1	928.00	0.023	21.34	0.95
Totals			81,368.00		3,321.81	84.69

Table A6: Estimated changes of biomass for the different types of forest in Botswana.

		MODULE	**LAND USE CHANGE AND FORESTRY**				
		SUBMODULE	**CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS**				
		WORKSHEET	**5-1**				
		SHEET	**1 OF 3**				
		COUNTRY	**Botswana**				
		YEAR	**2000**				
			STEP 1				
			A Area of Forest/Biomass Stocks (kha)	B Annual Growth Rate (t dm/ha)	C Annual Biomass Increment (kt dm)	D Carbon Fraction of Dry Matter	E Total Carbon Uptake Increment (kt C)
					C=(A x B)		E=(C x D)
Tropical		Forbland	171	0	0.00	0.45	0.00
		Grassland Savanna	24617	0.3	7,385.10	0.45	3,323.30
		Tree/Shrub Savanna	29120	1.3	37,856.00	0.45	17,035.20
		Shrub/Woodland Savanna	3418	1	3,418.00	0.45	1,538.10

	Other Forests	Swamp/Shrub/Woodland Savanna	848	0.1	84.80	0.45	38.16
		Woodlots	0.2211	4.2	0.93	0.45	0.42
		Fields	94.161	0	0.00	0.45	0.00
	Other (specify)				0.00		0.00
Temperate	Plantations	Douglas fir			0.00		0.00
		Loblolly pine			0.00		0.00
	Commercial	Evergreen			0.00		0.00
		Deciduous			0.00		0.00
	Other				0.00		0.00
Boreal					0.00		0.00
Non-Forest Trees (specify type)			A Number of trees (1000s of trees)	B Annual Growth Rate (kt dm/1000 trees)			
					0.00		0.00
					0.00		0.00
						Total	**21,935.17**

MODULE	**LAND USE CHANGE AND FORESTRY**
SUBMODULE	**CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS**
WORKSHEET	**5-1**
SHEET	**2 OF 3**
COUNTRY	**Botswana**
YEAR	**2000**

STEP 2

Harvest Categories (specify)	F Commercial Harvest (if applicable) (1000 m^3 roundwood)	G Biomass Conversion/ Expansion Ratio (if applicable) (t dm/m^3)	H Total Biomass Removed in Commercial Harvest (kt dm)	I Total Traditional Fuelwood Consumed (kt dm)	J Total Other Wood Use (kt dm)	K Total Biomass Consumption (kt dm)	L Wood Removed From Forest Clearing (kt dm)	M Total Biomass Consumption From Stocks (kt dm)
			H = (F x G)	FAO data		K = (H + I + J)	(From column M, Worksheet 5-2, sheet 3)	M = K - L
Fuel wood	22720		0.00	22720		22,720.00		
Totals	22720.00		0.00	22,720.00	0.00	22,720.00	0.00	22,720.00

Table A7: Total amount of carbon absorbed by the different types of forests during the year 2000.

MODULE	**LAND USE AND FORESTRY**		
SUBMODULE	**CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS**		
WORKSHEET	**5-1**		
SHEET	**3 OF 3**		
COUNTRY	**Botswana**		
YEAR	**2000**		
STEP 3		**STEP 4**	
N	O	P	Q
Carbon Fraction	Annual Carbon Release (kt C) O = (M x N)	Net Annual Carbon Uptake (+) or Release (-) (kt C) P = (E - O)	Net annual CO_2 Emission (-) or Removal (+) (Gg CO_2) Q = (P x [44/12])
0.45	10,224.00	11,711.17	**42,940.97**

TableA8: Estimated methane emissions from solid waste disposal.

	MODULE	WASTE	
	SUBMODULE	METHANE CORRECTION FACTOR	
	WORKSHEET	6-1C (SUPPLEMENTAL)	
	SHEET	1 OF 1	
	COUNTRY	Botswana	
	YEAR	2000	
	W	X	Y
Type of Site	Proportion of Waste (by mass) for each Type of SWDSs	Methane Correction Factor (MCF)	Weighted Average MCF for each Type of SWDS
			Y = W x X
Managed	0.04	1.0	0.04
Unmanaged - deep (>=5m waste)	0.1	0.8	0.08
Unmanaged - shallow (< 5m waste)	0.86	0.4	0.34
Total		0.6	0.46

Table A9: Total Annual MSW Disposed to SWDSs (Gg MSW).

MODULE	**WASTE**
SUBMODULE	**QUANTITY OF MSW DISPOSED OF IN SOLID WASTE DISPOSAL SITES** **USING COUNTRY DATA**
WORKSHEET	**6-1A (SUPPLEMENTAL)**
SHEET	**1 OF 1**
COUNTRY	**Botswana**
YEAR	**2000**

A Population whose Waste goes to SWDSs (Urban or Total)	B MSW Generation Rate	C Annual Amount of MSW Generated	D Fraction of MSW Disposed to SWDSs (Urban or Total)	E Total Annual MSW Disposed to SWDSs
(persons)	(kg/capita/day)	(Gg MSW) C = (A x B x 365)/ 1 000 000		(Gg MSW) E = (C x D)
1663990	0.4	242.94	0.9	**218.65**

Table A10: Emissions from solid waste disposal.

MODULE	WASTE
SUBMODULE	METHANE EMISSIONS FROM SOLID WASTE DISPOSAL SITES
WORKSHEET	6-1
SHEET	1 OF 1
COUNTRY	Botswana
YEAR	2000

STEP 1	STEP 2	STEP 3			STEP 4							
A	B	C	D	E	F	G	H	J	K	L	M	N
Total Annual MSW Disposed to SWDSs (Gg MSW)	Methane Correction Factor (MCF)	Fraction of DOC in MSW	Fraction of DOC which Actually Degrades	Fraction of Carbon Released as Methane	Conver-sion Ratio	Potential Methane Generation Rate per Unit of Waste ($Gg\ CH_4/Gg\ MSW$)	Realised (Country-specific) Methane Generation Rate per Unit of Waste ($Gg\ CH_4/\ Gg\ MSW$)	Gross Annual Methane Genera-tion ($Gg\ CH_4$)	Recovered Methane per Year ($Gg\ CH_4$)	Net Annual Methane Genera-tion ($Gg\ CH_4$)	One Minus Methane Oxidation Correction Factor	Net Annual Methane Emissions ($Gg\ CH_4$)
						G= (C x D x E x F)	H= (B x G)	J= (H x A)		L= (J - K)		N= (L x M)
218.65	**0.46**	**0.13**	**0.55**	**0.5**	**16/12**	**0.05**	**0.02**	**4.79**	**0**	**4.79**	**1**	**4.79**
					16/12	0.00	0.00	0.00		0.00		0.00
					16/12	0.00	0.00	0.00		0.00		0.00

Table A11: Emissions from liquid waste disposal.

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER AND SLUDGE TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**1 OF 4 ESTIMATION OF ORGANIC WASTEWATER AND SLUDGE**				
COUNTRY	**Botswana**				
YEAR	**2000**				
STEP 1					
A	B	C	D	E	F
Region or City	Population	Degradable Organic Component	Fraction of Degradable Organic Component Removed as Sludge	Total Domestic/Commercial Organic Wastewater	Total Domestic/Commercial Organic Sludge
	(1,000 persons)	(kg BOD/1000 persons/yr)		(kg BOD/yr)	(kg BOD/yr)
				E = [B x C x (1-D)]	F = (B x C x D)
All country	1663.99	13505	0	22,472,184.95	0.00
				0.00	0.00
			Total:	22,472,184.95	0.00

Table A12: Emission Factor for domestic/commercial wastewater.

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**2 OF 4 ESTIMATION OF EMISSION FACTOR FOR WASTEWATER HANDLING SYSTEMS**				
COUNTRY	**Botswana**				
YEAR	**2000**				
STEP 2					
A Wastewater Handling System	B Fraction of Wastewater Treated by the Handling System	C Methane Conversion Factor for the Handling System	D Product	E Maximum Methane Producing Capacity (kg CH_4/kg BOD)	F Emission Factor for Domestic/Commercial Wastewater (kg CH_4/kg BOD)
			D = (B x C)		F = (D x E)
Lagoon	0.05	0.8	0.04		
Pitlatrine/septic tank	0.1	0.15	0.02		
			0.00		
			0.00		
		Aggregate MCF:	0.06	0.6	0.03

Table A13: Total emissions from waste water.

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER AND SLUDGE TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**4 OF 4 ESTIMATION OF METHANE EMISSIONS FROM DOMESTIC/COMMERCIAL WASTEWATER AND SLUDGE**				
COUNTRY	**Botswana**				
YEAR	**2000**				
	STEP 4				
	A	B	C	D	E
	Total Organic Product	Emission Factor	Methane Emissions Without Recovery/Flaring	Methane Recovered and/or Flared	Net Methane Emissions
	(kg BOD/yr)	(kg CH_4/kg BOD)		(kg CH_4)	(Gg CH_4)
	from Worksheet 6-2, Sheet 1	from Worksheet 6-2, Sheets 2 and 3	C = (A x B)		E = (C - D)/1 000 000
Wastewater	22,472,184.95	0.03	741,582.10	0	0.74
Sludge	0.00	0.00	0.00		0.00
				Total:	0.74