Republic of Botswana

BOTSWANA'S THIRD NATIONAL COMMUNICATION TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

OCTOBER 2019

Prepared by: Ministry of Environment, Natural Resources Conservation and Tourism

BOTSWANA'S THIRD NATIONAL COMUNICATIONS

Empowered lives.
Resilient nations.

Foreword

Climate Change is the greatest challenge facing mankind this century and its impact in Botswana is felt across various sectors of the economy. Our high dependence on climate sensitive natural resources for our livelihoods and economic sustenance will inherently increase our vulnerability. The growing scientific evidence on climate change affirms the urgent need for stepping up climate action in the form of adaptation and mitigation.

Since the last submission of the Second National Communication, Botswana has continued to experience extreme weather events and our climate has continued to change. We have experienced climate extremes, hottest years on record, and government declared droughts and severe droughts.

Progress has however been made in other sectors, we are preparing draft policies on energy, climate change, waste management and Integrated Transport Policy that will be submitted to parliament for approval. These policies sets out measures on how to combat climate change and achieve our pledges articulated in our Nationally Determined Contributions (NDC).

This report sets out progress across all areas of government. The report describes a wide variety of activities concerning mitigation, adaptation, technology transfer, finance, research, education and training and public awareness. It is informed by information widely gathered from all stakeholders including National Climate Change Committee, Academic, government institutions, Civil Society, Community Based Organisations and the general public.

Honourable Onkokame Kitso Mokaila

Minister of Environment, Natural Resources Conservation and Tourism

Acknowledgements

Botswana’s Third National Communication would not have been possible without the cooperation and commitment of numerous experts, government institutions, industries, universities and other stakeholder’s contribution on valuable data that was thoroughly analysed and synthesised into the reports.

My sincere gratitude to the National Climate Change Committee (NCCC), for their hard work and dedication in making this report possible. I would also like to extend our gratitude to the Global Environment Facility (GEF) and United Nations Development Programme (UNDP) for providing the funds for this report, Special appreciation also goes to the invaluable contribution of the UNDP country office and the UNDP/UNEP Special Support Programme for their guidance.

Thato Yaone Raphaka

Permanent Secretary

Ministry of Environment, Natural Resources Conservation and Tourism

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List of Acronyms

ALU	Agriculture and Land Use National Greenhouse Gas Inventory Software Program
BAU	Business-as-usual
BITRI	Botswana Institute for Technology, Research and Innovation
BPC	Botswana Power Corporation
BURS	Biennial Update Reports
CBA	Calculation Based Approach
CFLs	Compact Fluorescent Lamp
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e/CO_2eq	Carbon dioxide equivalent
COP	Conference of Parties
CSO	Central Statistics Office
DFRR	Department of Forestry and Rangeland Resources
DoE	Department of Energy
DMS	Department of Meteorological Services
DTRS	Department of Transport Roads and Safety
DWMCP	Department of Waste Management and Pollution Control
Eq.	Equivalence
FAO	Food Agricultural Organisation
GDP	Gross Domestic Product
GIZ	Deutsche Gesellscraft fur Internationale Zusammenarbeit
Gg	Giga gram
GHG	Greenhouse Gases
GOB	Government of Botswana
GEF	Global Environment Facility
GHG	Greenhouse Gas
GWP	Global Warming Potential
GDP	Gross Domestic Product
ITP	Integrated Transport Policy
Ha	Hectares
HFCs	Hydro-fluorocarbons
HH	Household
IPCC	Inter Panel Convention on Climate Change
IPPs	Independent Power Producers
LEAP	Long Range Energy Alternative Planning
LED	Light Emitting Diode
LFG	Landfill Gas
LPG	Liquid Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MBA	Measurement Based Approach

MENT	Ministry of Environment, Natural Resources Conservation and Tourism
MJ	Mega Joules
MRV	Monitoring, Reporting and Verification
MW	Mega Watt
NAMAs	Nationally Appropriate Mitigation Actions
NA1	Non Annex 1 (Developing country parties to the UNFCCC)
N2O	Nitrous oxide
NMVOCs	
NC	National Communications
NCCC	National Climate Change Committee
NPV	Net Present Value
PFCs	Per-fluorocarbons
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
RE	Renewable Energy
REFIT	Renewable Feed In Tariff
SB	Statistics Botswana
SF6	Sulphur hexafluoride
UB	University of Botswana
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention for Climate Change
WUC	Water Utilities Corporations
GSP	Global Support Program
SNC	Second National Communications
IPPU	Industrial Processes and Product Use

Executive Summary

National Circumstance

The information provided on national circumstances is an update since submission of the second national communication. The national population increased from 1,680,863 in 2001 to 2,038,228 in 2011, with an annual growth rate of about 1.9% (Gwebu et al. 2014). Botswana is an upper middle income country with total Gross Domestic Product (GDP) of 15.68 billion US dollars in 2011. The economy has grown at an average annual growth rate of over 8 percent since Independence in 1966. (Source trading economics.com world bank). Real GDP growth was an estimated 4.2% in 2018, up from 2.4% in 2017, boosted largely by the recovery in mining and broad-based expansion of non-mining activities.

Climate

Botswana's climate is semi-arid. Though it is hot and dry for much of the year, there is a rainy season, which runs through the summer months. Rainfall tends to be erratic, unpredictable and highly spatial varied. Showers are often followed by strong sunshine so that a good deal of the rainfall does not penetrate the ground but is lost to evaporation and transpiration.

The day time air temperatures on average during summer months are generally warm to hot due to high insolation, which lead to the extent that the potential evapotranspiration far exceeding precipitation rates.

Energy

Botswana relies mainly on electricity, coal, fuelwood and petroleum for its energy demands Botswana currently generates most of its power from coal, and sits on large coal reserves of around 200 billion tons. The country also has significant solar potential, with 3,200 hours of sunshine per year, and irradiance of 6640 Wh/m2/day. Only a portion (450 MW) of installed capacity is available to produce power, and additional demand is met through electricity imports, primarily from South Africa. Government has set national electricity access target of 82 % by 2016 and 100% by 2030. Currently electrification in urban areas stands at 75 % and 57% in rural areas while national average electrification is 62%. LPG is widely used as a main energy source for cooking in urban areas by 70.7% of the households and 40.5 % in rural areas. LPG is supplied by the private sector with minimum interference from government

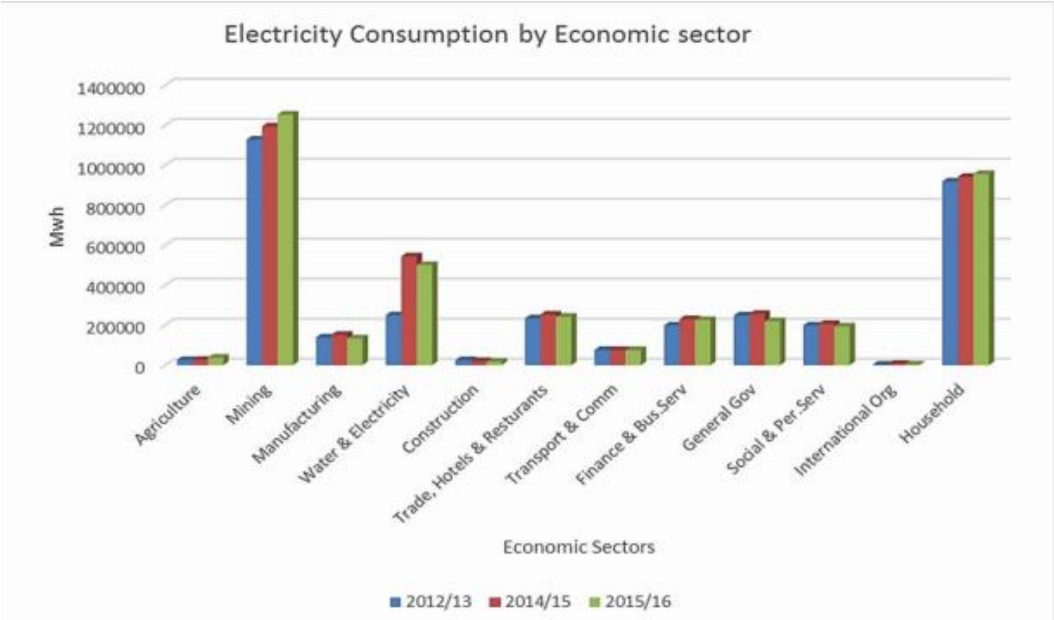


Figure 1: Electricity Consumption by Economic Sector (MWh) (Source: Botswana Energy Accounting report 2015/16; 2018)

Agriculture

The Agricultural sector in Botswana covers both crops and livestock production. Traditional farming is the most dominant in terms of numbers of people involved and the geographical coverage. The majority of farmers are small-scale farmers who typically need continued assistance in capacity building to commercialize agriculture. An effective and vibrant extensive service is therefore an important input in improving the performance of the sector and its resilience to market changes and climate change. The beef industry is the only sub-sector of the agriculture sector that has constantly remained a significant contributor to the national Gross Domestic Product (GDP).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. Nevertheless, horticulture, poultry and piggery sectors are coming up.

Water Resources

Botswana's water resources are characterized by wide spatial variability, extreme scarcity, and a high dependency on internationally shared and trans-boundary waters. Botswana's water sources consist primarily of surface water (in rivers, pans and dams of various sizes) and underground water in aquifers some of which are of a fossil nature with no recharge. Of the eight dams, Dikgatlhong is the largest with a capacity of 400Mm3. All of Botswana's perennial rivers are shared with neighbouring countries. The shared river-basins are Okavango, Zambezi, Orange-Senqu and Shashe-Limpopo.

Botswana's storage capacity is one of the lowest in the region, owing to its flat topography. Groundwater in Botswana is limited, both in quantity and quality, and is unevenly distributed over the country. The national demand for water has increased rapidly over the past few decades. Most of this increased demand has come from domestic consumption and the mining sector, with the current water demand for the entire country estimated at around 250 Mm3 . Over half of the water consumed is through self-providers such as the minerals, livestock and wildlife sectors that accounts for more than 50 percent of all consumption.

Greenhouse Gas Inventory

GHG Emission Trends by Sector from 2000 to 2013

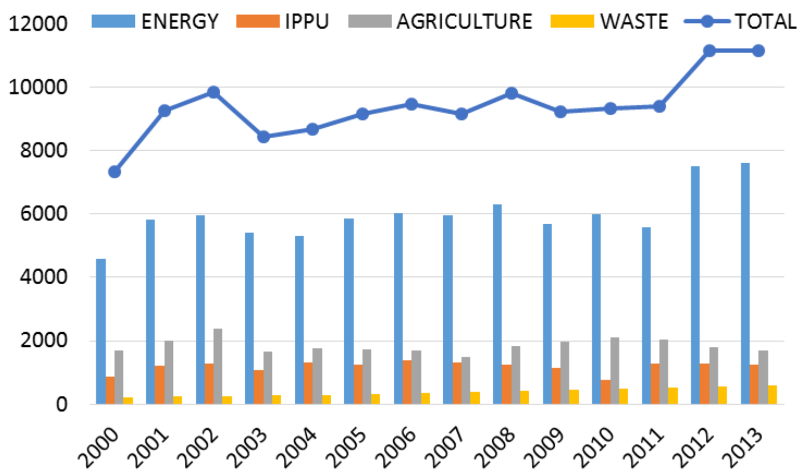


Figure 2: Trend of Botswana's GHG Emissions (without LUCF) by sector: 2000–2013

In the year 2000, the Energy share (excluding LUCF) accounted for 62% of all emissions followed by the Agriculture emissions with 23%, the IPPU sector with 12% and lastly, the Waste sector emissions with 3%. Similarly, in 2013, the Energy share accounted for 68% of all emissions followed by the Agriculture emissions with 15%, the IPPU emissions with 11% and the Waste emissions with 5%. (Figure 2)

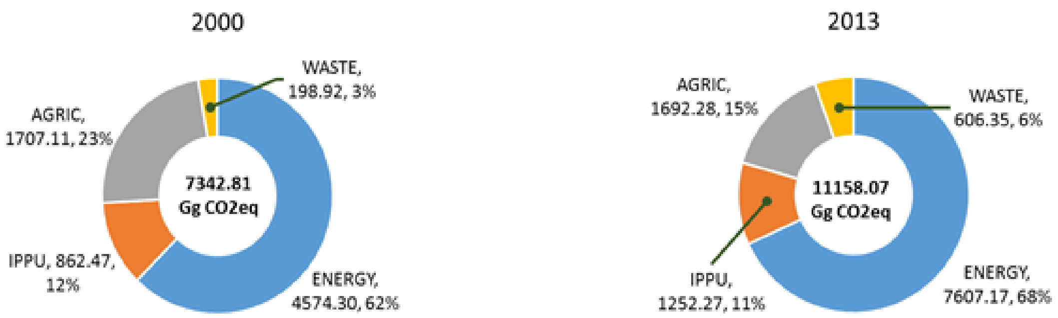


Figure 3: GHG Emission Trends by Gas from 2000 to 2013

Botswana's GHG emissions in 2014 were 7409, 79 Gg CO2 eq from Energy, IPPU 1293,44 Gg CO2 eq, Waste 29,58 Gg CO2 eq AFOLU-2970,67 Gg CO2 eq sectors. The net emission after accounting for the removal was 5721, 91Gg CO2 eq. GHG emissions according to gases and sectors for 2014 inventory are provided in the table below;

Table 1: Botswana's GHG emissions for the year 2014

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 Emissions / removals	CH_4	N_2O	CO	NO_x	NMVOCs	SO_x	HFCs	PFCs*	SF_6 *	Other fluorinated
	(Gg)			(Gg)				CO_2 equivalent (Gg)			
Total National Emissions and Removals	5721.91	152,28	1,50	276,90	16,61			0,64			
1. Energy	7409,79	37,36	1,50								
1A. Fuel Combustion Activities (Sectoral Approach)	7407,28	24,86	0,50								
1A1. Energy Industries	4178,44	0,044	0,50								
1A3. Transport	2264,32	0,57	0,06								
1A4. Other Sectors	964,51	24,24	0,33								
1B. Fugitive Emissions from Fuels	2,50	12,49									
1B1. Solid Fuels		12,49									
2. Industrial Processes and Product Use	1293,44							0,64			
2A. Mineral Industry	129,26										

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 Emissions / removals	CH_4	N_2O	CO	NO_x	NMVOCs	SO_x	HFCs	PFCs*	SF_6 *	Other fluorinated
	(Gg)			(Gg)				CO_2 equivalent (Gg)			
2A1. Cement Production	129,26										
2B. Chemical Industry	1164,17										
2B7. Soda Ash Production	1164,17										
2F. Product Uses as Substitutes for Ozone Depleting Substance								0,64			
2F1. Refrigeration and Air Conditioning								0,64			
3. Agriculture, Forestry and other Land Use (AFOLU)	-2981,32	85,33	0,92	276,90	16,61	0	0				
3A. Livestock		75,53									
3A1. Enteric Fermentation		72,37									
3A2. Manure Management		3,16									
3B. Land	-2970,67		0.018								
3B1. Forest Land	-16196,29										
3B2. Cropland	0.026										
3B3. Grassland	13196,10										
3B4. Wetlands	28,06		0.018								
3B5. Settlements	1,31										
3B6. Other Land	0,10										
3C. Aggregate Sources and Non-CO_2 Emissions Sources on Land	0,25	9,79	0. 90	276,90	16,61						
3C1. Biomass Burning	0	9,79	0.89	276,90	16,61						
3C2. Liming	0,08										
3C3. Urea Application	0,16										
3D. Other	-10,89		0.006								

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 Emissions / removals	CH_4	N_2O	CO	NO_x	NMVOCs	SO_x	HFCs	PFCs*	SF_6 *	Other fluorinated
	(Gg)			(Gg)				CO_2 equivalent (Gg)			
3D1. Harvested Wood Products	-10,89										
<u>4. Waste</u>		29,58	0,07	0	0	0	0				
4A. Solid Waste Disposal		25,90	0	0	0	0	0				
4D. Wastewater Treatment and Discharge		3,68	0,07	0	0	0	0				
<u>Memo items</u>											
<u>International bunkers</u>	31,53	0.0002	0.001								
International Aviation	31,53	0.0002	0.001								
<u>CO_2 Emissions from Biomass</u>											

Notes:

** Optional for Level 1 and Level 2 reporting*

Note: Shaded cells are <u>not applicable</u>. Cells to report emissions of NOx, CO, NMVOC and SO2 have not been shaded although the physical potential for emissions is lacking for some categories.

Source: Table 1 and Table 2 in the annex to UNFCCC decision 17/CP.8, Table A.15 in Ellis et al. 2011 and Table A Summary Table of IPCC 2006 GL, Vol. 1 Ch. 8 Annex 8A.2

Table 2: Summary of GHG Emission from All Sectors

Sectors	Emissions CO_2 eq	Sink CO_2 eq (Gg)
Energy	7409.79	
Industrial Processes	1293.44	
AFOLU		-2970.67
Waste	29. 58	
Total emissions	5721.91	

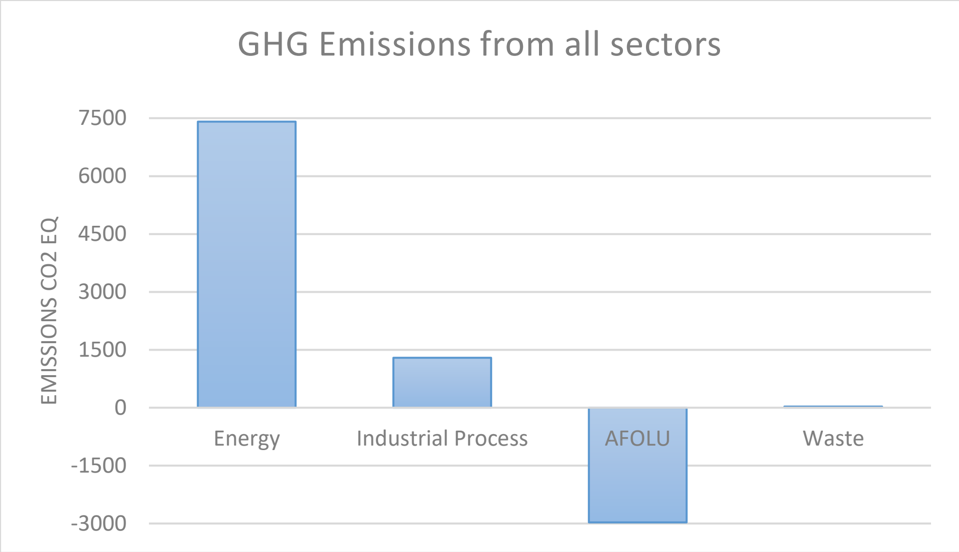


Figure 4: GHG Emissions from all sectors

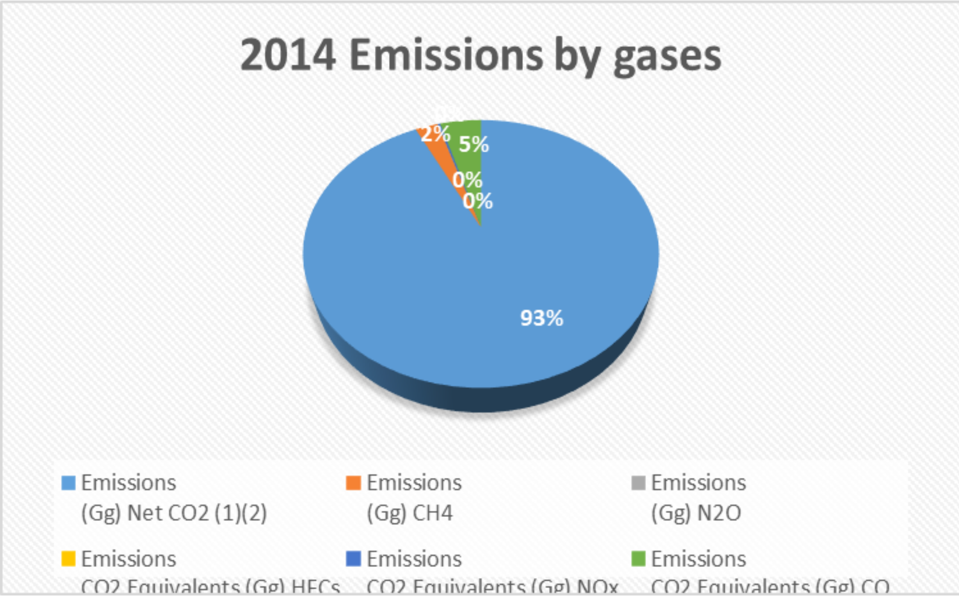


Figure 5: Carbon dioxide dominates by accounting for 93% of the 2014 emissions

PROGRAMMES CONTAINING MEASURES TO FACILITATE ADEQUATE ADAPTATION TO CLIMATE CHANGE

Climate change scenarios

Climate scenarios were constructed for precipitation and temperature for the year 2050 and this was based on the RCP of 4.5 and 8.5. GCM/RCM ensemble. The variables analysed included; seasonal and annual precipitation, mean, maximum, and minimum temperature, drought, extreme precipitation. By 2050, most the country will experience high average temperature of 25.9-26.9. Thus, by 2050 most of the country will be hotter relative to baseline temperatures. The seasonal and annual mean precipitation over Botswana showed a general decrease trend by the 2050.

Water

Water resources in the country is highly driven by climatic variables mainly temperature and rainfall. These variables (temperature and rainfall) act jointly to determine the water stocks and flows. Precipitation determines the inflows and recharge (positive flow), temperature on the other hand affect outflow (negative flows) through evaporations. Therefore, this water-climate relationship was used to assess the vulnerability of the water sector to climate change in the country. Climate and socio-economic scenarios were constructed to determine the vulnerability of the water sector to climate change. Using the GCM/RCM ensemble and RCP 4.5 and 6.0 the results indicate that temperature could increase by between 1.5 ^{o}C and 2 ^{o}C. On the one hand, the model indicates a decrease of rainfall by as much as 15% though there are some insignificant rainfall increases for other percentiles.

These changes will have a negative impact on the water resources in the country. The model indicates that by 2050, climate change will results in a decrease in water inflow into dams by between 3.5 to 19% which represent actual loss of 34 to 75 Mm3 by 2050. Using the PET equation, it is projected evaporation could increase by 3.7% to 7% from the baseline.

On the basis of projected decline in rainfall, increase in temperature and evaporation it is projected that recharge would also decline. Lastly, the overall effect of climate change would be to encourage groundwater abstraction and hence water mining in the country. Thus, increase incidents of surface water scarcity will encourage water depletion by 2050. Overall, it is estimated that climate change will reduce the demand supply ratio by 2050.

On the basis of these results it is imperative that the country undertake significant investment on the water adaptation projects. Some of these projects which are economically feasible include:

- Investing in advanced water leak detection systems

- Introducing smart meters
- Artificial groundwater recharge
- Strengthening of the dam walls
- Construction of water transfer schemes

Implementing these feasible water project will ensure that the water resources which is already under stress conditions become less vulnerable to climate change.

Livestock and Rangelands

Under changing climate, the livestock productivity would be adversely affected by multiple stressors associated with climate change. The LIVSIM results indicated the baseline annual average milk production was 2 977 000L, which is consistent with productivity of small farms). Milk production is projected to decline slightly by 2050 under RCP 4.5 and shall be far less than the base scenario in 2070 under RCP 6.0. These results therefore imply that the dairy sector is particularly vulnerable to climate change in Botswana and subsequently the supply of milk and related products could be far short of the national demand.

The reproductive performance of cattle was also projected to decline in the future due to climatic shocks. The number of calves born are likely to be lower than the baseline and this is more pronounced under RCP 6.0 by 2070 and this could be due to low conception as a result of poor body condition of breeding cows caused by feed shortage in the rangeland. In addition, the increased heat stress could also reduce the fertility of bulls and thus lead to lower calving rate of the national herd. As a result, it was projected that the cattle herd size per household slightly increased under RCP 4.5 by 2050, but is likely to be reduced significantly under RCP 6.0 by both mid-century and end of the century (2070).

Table 3: Adaptation strategies

RISKS	**ADAPTATION**	**COMMENTS**
Increased temperature Reduced rainfall Increased drought frequency Increased risk of Wildfire	Ecosystem based adaptation	Ecosystem-based adaptation (EbA) and its key components are conservation of biodiversity that results in resilient ecosystem services leading to improved livelihood
	Breeding for Adapted animals	Breeding efficient livestock under the future climate leading to shift in vegetation composition and increased temperatures Crossbreeding the indigenous breeds with exotic breeds could improve adaptive capacity and ensure that economically

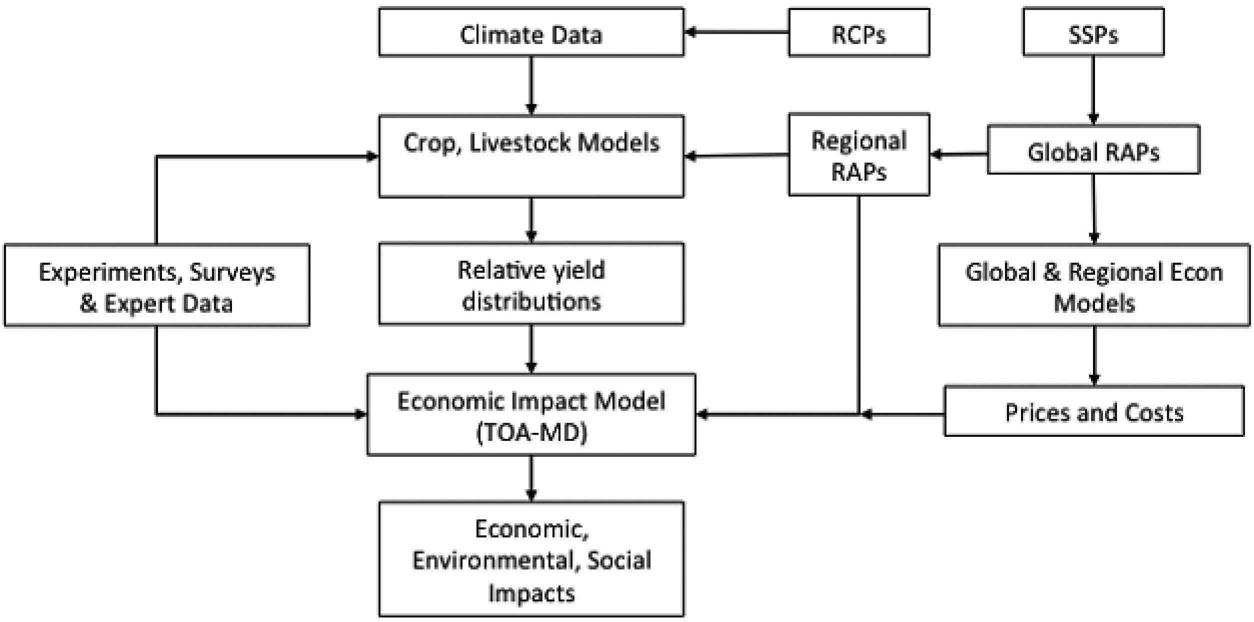
		important traits (e.g growth rate) are maximized through heterosis.
	Fodder production	The forage deficiency resulting from declining rangeland productivity will be addressed through forage production.
	Supplementation	provision of supplementary feeds such as crop residues (stover), dicalcium phosphate and drought pellets
	Destocking	A proactive and coordinated market is essential to reduce livestock loss associated with climate risks.
	Livestock mobility	The livestock has to be continually moved to areas with sufficient grazing resources and overgrazed land allowed to rest.
	Improved herd health	Prevent
	Development of sustainable water sources	Water harvesting technologies to be exploited to ensure continuous water supply for the livestock industry.
	Wildfire Control and Management	Production and operational of Fire Management Strategies and firebreak maintenance as well as use of early warning systems.

Crops

The main focus of this research was to assess and evaluate the impacts of projected climate change scenarios in the five agricultural regions of Botswana on major crops such as maize, sorghum, millet and cowpea using the Decision Support for Agro -Technology Transfer (DSSAT) crop model suit. It includes the exploration of current agricultural systems sensitivity to future climate, and effect of adaptation, as well as the simulation of future agricultural systems under future climate and the effect of adaptation. Those various climate-crop scenarios are used to assess economic consequences in terms of vulnerability and adoption rates for the entire populations using the Trades-off Analysis-Multi-Dimensional (TOA-MD) model. The accumulation of climate, crop, adaptations, economic andvulnerability information in five smallholder farmer regions of Botswana, provides new material and evidence to support risk management and adaptation strategies that hold the greatest potential for reducing smallholder farmer vulnerability and poverty. Specifically, we characterize the vulnerability of smallholder farmers to climate risks, identify the high potential risk coping and adaptation strategies used by farmers, and highlight further key adaptation needs. By increasing knowledge of the future climate-agriculture-economic conditions of farmers, our study provides critical information for development organizations and donors, focused on reducing food insecurity and poverty in Botswana, as well as for policy makers working on the design of national strategies for climate change adaptation, agricultural productivity, and hunger and poverty alleviation.

Methodology

The Agricultural Model Intercomparison and Improvement Project (AgMIP) framework was used. The methodology includes (i) a multi-modelling framework that links climate, crop and economic simulation models, (ii) Representative Agricultural Pathways (RAPs) that describe future socio-economic, institutional, and policy conditions, and (iii) management and adaptation options generated by stakeholders (Rosenzweig et al., 2013; Antle et al., 2015). A sketch of the science base approach followed by AgMIP (An integration of the top-down and bottom-up approaches of assessing the impact of climate change) is represented below,



The AgMIP regional integrated assessment framework. Source: Rosenzweig et al. (2013). RCP = representative concentration pathway; SSP = shared socio-economic pathway; RAP = representative agricultural pathway; TOA-MD = trade-off analysis model for multi-dimensional impact assessment

The framework allows this study to particularly address the following questions. (a) What is the current agricultural system sensitivity to Climate Change? This question explore the sensitivity of our current agricultural systems to a future climate. (b) What is the effect of adaptation options on current agricultural systems? This question explores the effects (e.g., economic and food security resilience) of selected adaptation options to current agricultural systems under current climate. Results also form a basis for comparison with Question (d) below, as the proposed adaptations may have a different effect under future climate. (c) What is the impact of climate change on future agricultural systems? This question explores future agricultural systems under future climate, the future agricultural systems resulting from development in the agricultural sector not directly motivated by climate changes. (d) What are the effect of adaptation options on future agricultural systems, under future climate? This question analyses the response of future agricultural systems, under future climate, to selected adaptation options.

Highlighted results
Climate

Although with minor variations in amplitude and timing, the future climate projections have the same three characteristics across the five regions. Foremost the temperature is going to increase. This is consistent across all future climate scenarios, and the five regions studied in Botswana. This increase is projected to equally affect months and seasons so that current seasonal temperature variations will likely be maintained, only hotter. Pending the scenarios considered mostly, the projected temperature increases range from +1.3 to +2.7 ^{o}C, by mid-century. Projections of future rainfall are much less consistent. Although in general support of literature and with an inclination toward drying, the ensemble of future rainfall scenarios are spread from decreases to increases, and particularly mostly within the one standard deviation from current condition that we use as a proxy for current climate variability. In other words the future rainfall, in terms of long term statistical climate will most likely only marginally vary from our current long term statistical rainfall. However, the most noticeable changes in rainfall may come from changes in rainfall regime and intra-annual variability. Rainfall projections consistently show a decrease in rainfall during 1 or 2 months at the beginning of the rainy season. Whether this translates into a shorter or shifted rainy season, with comparable total but more intense rainfall overall or not, cannot be ascertain without delving into a specific scenario, which we intentionally avoid in this study. Nevertheless this dryer, possibly delayed, onset of the season is likely to impact the growing season of the five regions of Botswana, and to require agricultural systems to consider appropriate measures in terms of timing and duration of cropping practices.

Crop

The results obtained from this study show that, temperatures in the future will either decrease or increase crop yields when crop production is practised without adapting in the future. Factors that will determine whether there will be an increase or decrease in average crop yields were observed to depend on (i) whether the future scenario is RCP 4.5 or 6.0 (ii) Region (Southern, Gaborone, Central, Francistown or Maun) and also (iii) the crop grown (maize-C4 crop, sorghum-C4-crop, cowpea-C3 crop or millet-C4 crop).The results further show that, in the future with no adaptation practises is implemented, in all the regions there is an average increase of cowpea yields under both RCP 4.5 and 6.0. The highest average increase yield (55%) obtained under RCP 6.0 in the Maun region. Also in the future with no adaptation practices, in the Gaborone region results showed an average yield increase in maize (+8% - RCP 4.5) and sorghum (+24% - RCP 4.5 and +21%-RCP 6.0). The highest average yield reduction was observed from the maize (-15%) and sorghum (-37%) crop in the Francistown Region under RCP 6.0.

The results further show the potential adapting options from the current agricultural systems under the current climate, from all the crops and regions there was an average yield increase from all the regions. The highest increase in yield (+37%) was from pearl millet after incorporating stover in the soil from the Maun region.

The results further show the adaptation potential for increasing crop yield in the future also depends on (i) whether the future scenario is RCP 4.5 or 6.0 (ii) Region and also (iii) the crop grown. In most of the Regions the future adaptation strategy that included shifting the planting window forward to be between early January and end of February performed better. Also conservation agriculture was noted to be part of those adaption practices that can improve yields in the future. With the cowpea crop, application of nitrogen fertilizer (most of the small scale farmers do not apply nitrogen fertilizer to a cowpea crop) and increasing the plant population per hector as part adapting to climate change was noted to be an advantage.

Socio- economics

The integrated assessment in the Southern region in the future shows more negative impacts of climate change for the hot dry and cool dry scenarios, the anticipated 20% increase in prices decrease poverty by 6%, however, under RCP 6.0 has slightly low vulnerability values with the same climate scenarios with poverty decreasing by 7%. Policy recommendations can be suggested: government climate change interventions should target agricultural diversification at the household level, with adaptation package showing 54.2-55.1% likely adoption for the two RCPs. The Gaborone region assessment presented that the current system under the RCP 4.5 and RCP 6.0, high vulnerability in the hot dry and cool dry scenarios Poverty increases of 11% on aggregate in the Gaborone region of Botswana for both RCPs. Commendable likely adoption rates for proposed technology in current systems of 58.9%, however, poverty does not seem to reduce even though net farm returns increased. In the future both RCP 4.5 and RCP 6.0, show more negative impacts of climate change and high vulnerability in the dry scenarios. However, RCP 6.0 show small poverty change of 0.4%. In the future, the adaptation package show low likely adoption in the hot wet scenario (44.5%) with poverty decreases of 5.5% likely to be observed.

Central region, current system show high vulnerability in dry scenarios under RCP 4.5, the region is also prone to high likely negative impacts of climate change with small changes in poverty decreases of 0.7% observed, under RCP 6.0 hot scenarios show increases in vulnerability. The forecasts indicate negative impacts of climate change under the hot wet and hot dry scenarios. When tested in the central region, current adaptation has 54.3% likely adoption with small estimated decreases in poverty rate. The assessment, however, reveals that for RCP6.0, the hot dry and the cool dry scenarios has negative impacts. High adoptions under RCP 4.5 and low adoptions under RCP 6.0. In Francistown, RCP4.5 shows scenarios hot dry and cool dry with highest vulnerabilities. All the scenarios have negative impacts of climate change with likely increases in poverty. Under the RCP6.0, negative impacts were observed under the hot dry, likely adoption percentages of 53.3% are observed. In Francistown, RCP4.5 shows scenarios hot dry and cool dry with highest vulnerabilities. All the scenarios have negative impacts of climate change with likely increases in poverty. Under the RCP6.0, negative impacts are observed under the hot dry, likely adoption percentages of 53.3% are observed, Maun region under RCP 4.5 show all scenarios under the current system have vulnerability percentages below 50%, hot wet scenarios has the highest. Low vulnerability under the RCP6.0. In addition, current adaptation show a likely 62.7% potential adoption, in the future RCP4.5 shows likely increases in poverty rate, low increases in poverty rates observed under RCP6.0. Maun showed that the prescribed adaptation package in the future 57.8% likely adoption in the region, with highest observed under the hot wet scenario (62.6%) and lowest under the middle scenario. Poverty rate change in Maun region show higher decreases under the RCP4.5 than under the RCP6.0.

Biodiversity

Climate change and its interactions with other stressors have effect on biodiversity and those species with small distribution, low abundance and specialized habitats are particularly vulnerable (Steffen et al 2009). The birdlife has been shown to be threatened by changes in rainfall distribution and temperatures (Darkoh and Mbaiwa 2014) partially due to shift in composition of natural resources in their habitat. The inflow in Okavango Delta is likely to be reduced due to decline in rainfall in its catchment area. Hulme (1996) estimated that potential evapo-transpiration in the Okavango Delta might increase by 15% by 2050 resulting in a decrease in runoff of about 20%. The water situation will worsen with rising temperatures due to global warming elevating evapo-transpiration leading to rapid losses, i.e. evapo-transpiration rates increase by approximately 3 to 4% for every 1°C rise in temperature (Du Pisani & Partridge, 1990; Schulze et al., 1995). This will result in reduced species richness in the area through either extinction or migration. The shift in proportion of woody and grassy vegetation would be stimulated by change in carbon dioxide concentration in the atmosphere and rainfall patterns.). An increase in frequency, intensity an extent extreme events such as drought, fires, will place vegetation under stress and will to contribute to population decline (Knight, 1995).

Climate change will likely to affect wildlife resources in Botswana through different stressors depending on the status and management of these resources. A 2011 aerial survey over the Okavango Delta established that wildlife species have shrunk in the past 15 years, reaching in by as much as 95% for ostrich, 90% for wildebeest, 84% for antelope tsessebe and 81% for warthogs and kudus; although others, such as elephants and plains zebra, remained stable while hippos increased by 6% (Guardian-UK, 18th June 2011). The results are, however, based on a one-off aerial survey and need to be interpreted with caution, although others have signalled similar trends (Perkins & Ringrose 1996; Rudee, 2011). Raseroka (1975) linked the disappearance of buffalo in the southern parts of Botswana to the drying and loss of forest vegetation along the Molopo and Limpopo River systems. While mass mortality in Kalahari wildlife in 1985 was linked to the cumulative effects of droughts that persisted since 1977 (Knight 1995) and as noted in Table 2, these droughts will be severe under climate change. Hulme (1996) also noted that the Okavango Delta may be less favourable for elephants by 2050 but more attractive to species, such as giraffe and warthogs, as the area gets drier. However, wildlife survival options under the projected changes will be obstructed by inability to migrate first within a country and worse for the case of between countries, due largely to human-made barriers. Thuiller et al.'s (2006) study found that out of the 277 African mammalian species assessed for impacts of climate change, none were committed to extinction where there was unhindered migration, but a maximum of ten species faced extinction by 2080 under the A2 HadCM3 scenario in the case of constrained migration (Thuiller et al., 2006)

Biodiversity adaptation Strategies Monitoring of ecosystem process and biodiversity: facilitate development of effective and adapted policies and strategies to reduce the risks

- Improve the design and enforcement of corridors : to ensure connectivity between protected areas through migration
- Promote ecosystem based adaptation (EBA)
- Sustainable ecosystem management: protect the resilience of habitats and related biodiversity,
- Adaptive management actions to protect vulnerable ecosystems such as water drilling and provision, fire management control, conducting of National Forest inventory, agroforestry practices, in-situ conservation, Reforestation and afforestation

Health

Climate models predict, that the country will be exposed to far reaching negative climate trends, including higher temperatures, droughts, natural disasters such as floods, declining rainfall, increasing evapo-transpiration rates. These trends will have significant implications for the country already experiencing water scarcity and high dependence on ground water resources. These climate trends will increasingly challenge the adaptive capacity of both the country and its people, and when combined with existing water scarcity could threaten the country's agricultural, livestock, health and forestry sectors (Crawford A. 2016).

The National Health Policy (2011) also identifies climate change as a real threat to the well-being of the population. The policy predicts the impacts of climate change on health will exacerbate the incidence of malaria due to increases in temperature and rainfall in some parts of the country, an increase in the incidence of cholera and an increase in malnutrition due to reduction in domestic food production and crop yields.

Many people in Botswana are vulnerable to the health risks of climate change. The disadvantaged communities are the most vulnerable and yet have the least resources to respond to climate change and health risks such as heat stress, communicable diseases, natural disasters, non-communicable disease, and food and water in-security etc. There is therefore need for Botswana National Health Adaptation Strategy and Action Plan as adjunct to NCCSAP to be adopted and implemented during NDP 11 as a public health approach to adaptation to climate change. This also brings an opportunity for Botswana to review the existing Botswana public health systems and policies and to strengthen and adapt the National Health Adaptation Strategy and

Action Plan to respond to the health risks posed by climate change and its effects on human health. This proposed Botswana National Health Adaptation Strategy and Action Plan has been founded on the guiding principles of the Draft Botswana Climate Change Response Policy, Guidance contained in the Alma Ata Declaration on Primary Public Care, the Ottawa Charter for Health Promotion and Botswana National Health Policy (2011).

Adaptation strategies

- Revise public health Act and NHP to include climate change (based on evidence)
- Assess the status of health facilities and their preparedness in handling casualties from climate change events including addressing biological, psychological and social problems as well as ability to work with local community structures and groups to enable protection of the severely injured and disabled by mental disorder.
- Integrated environment and health surveillance
- Develop a set of interventions required to protect nutrition from climate related risks

Mitigation

The GHG emissions for the major gases namely Carbon dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O) for the year 2012 are estimated at approximately 15,818 Gg CO2 eq. and are projected to increase linearly to 25,725 Gg CO2 eq. by the year 2030. The main emitting sectors are energy accounting for 58% of total emissions. Livestock, Land use change and Industrial Processes and Product use contribute roughly 13% each. The drivers of the emissions are population and economic growth which drive demand for fossil fuels, land use change, and industrial processes and product use (IPPU). Defining the low emission pathway for the country was based on feasible and plausible mitigation projects and these include the following:

Biogas plants

Biogas plants generate methane, an energy gas mainly from agro waste (livestock manure) and municipal waste (wastewater and solid waste). There are a number of potential projects on the pipeline for implementation, mainly Botswana Meat Commission biogas plant, Mmamashia Biogas plant and household biogas plants. A planning scenario of construction and installation of 1000 household biogas year-1 was used to simulate low emission pathway from 2020 to 2030. The projected GHG emissions reduction was simulated at 28.3 Gg of CO2 eq. and will increase to approximately 190 Gg CO2 eq. by 2030.

Solar Power stations

There are various mini on-grid to off-grid solar power stations some of which are in operations and others under feasibility studies. The capacities of these solar power stations range from 32 kW to 50 MW. Some of the operational PV plants include Phakalane (1.3 MW), 60 kW mini plants installed in 21 primary schools and 32 kW mini power stations powering camp sites in the delta. At fully operational level, the solar power stations have the potential to reduce GHG emissions by 261 Gg of CO_2 eq. by the year 2030.

Street lights

This is another mitigation project that is being aggressively pursued by the GoB in partnership with BITRI. There are currently 850 streetlights installed throughout the country with an estimated GHG emissions reduction of 0.24 Gg of CO_2 eq. Adopting a planning scenario of installing 1000 street lights per year, it is projected that they have the potential to reduce national GHG emissions by 3.87 Gg of CO_2 eq. by 2030.

Efficient lighting

This is the first government initiative that was implemented through BPC aimed at improving electricity saving by giving households CFL bulbs for free and replacing the incandescent light bulbs. It is estimated that CFL save up to 60% of electricity relative to the incandescent light bulbs. This mitigation action was implemented in 2012 and it contributed to GHG emissions reduction of about 145 Gg CO_2 eq. in 2012 and projected to achieve 300 Gg CO_2 eq. by 2030.

Solar powered Boreholes

Farmers in the country are also voluntarily switching from diesel powered pumps to solar powered borehole influenced mainly by their cost-effectiveness. Similar to other solar appliances, solar powered boreholes replace use of fossil fuel and petroleum products and thus reduce GHG emissions. Currently, it is estimate that there are about 537 solar power boreholes with emission reduction potential of 0.55 Gg CO_2 eq. and projected to increase to 169 Gg of CO_2 eq. by 2030.

Solar geysers

Though solar geysers have been in existence for over 50 years in the country, the absorption rate is extremely low. According to household survey only 0.14% of the households were using solar for heating by 2011 while BPC estimated that only 3% of the high income household are using solar geysers. Using a figure of 0.14%, it is estimated that 750 households use solar energy for heating. This translates into 0.07 Gg of CO_2 emissions reduction which is projected to increase to 8 Gg of CO_2 emissions reduction by 2030.

Methane capture and usage as energy source

This is another mitigation project that is currently being undertaken at Glen Valley wastewater treatment where methane is captured and flared to heat up oxidation ponds. Methane as an energy gas can be captured and used for generating electricity, for heating up the ponds to speed up anaerobic processes or as cooking gas. Capturing methane reduces GHG emissions by 53 Gg of CO_2 eq. and projected to increase to 400 Gg of CO_2 eq. by 2030.

CHAPTER 1 - NATIONAL CIRCUMSTANCES

1.1 Climate

Botswana's climate is semi-arid. The country is landlocked and has a subtropical desert climate characterized by great differences in day and night temperatures and overall low humidity. Though it is hot and dry for much of the year, there is a rainy season which runs through the summer months of October to March. There is little to no rain during the entire winter and humidity is low, typically 20-40%.

Rainfall tends to be erratic, unpredictable and highly spatially variable. The southwest experience the least average annual rainfall of less than 220mmwhile the northeast of the country receives the highest rainfall of approximately 500mm (Figure 6). An analysis of annual rainfall trend for Botswana for the period 1970/71 to 2013/14 for 13 stations across Botswana indicate a general decline.

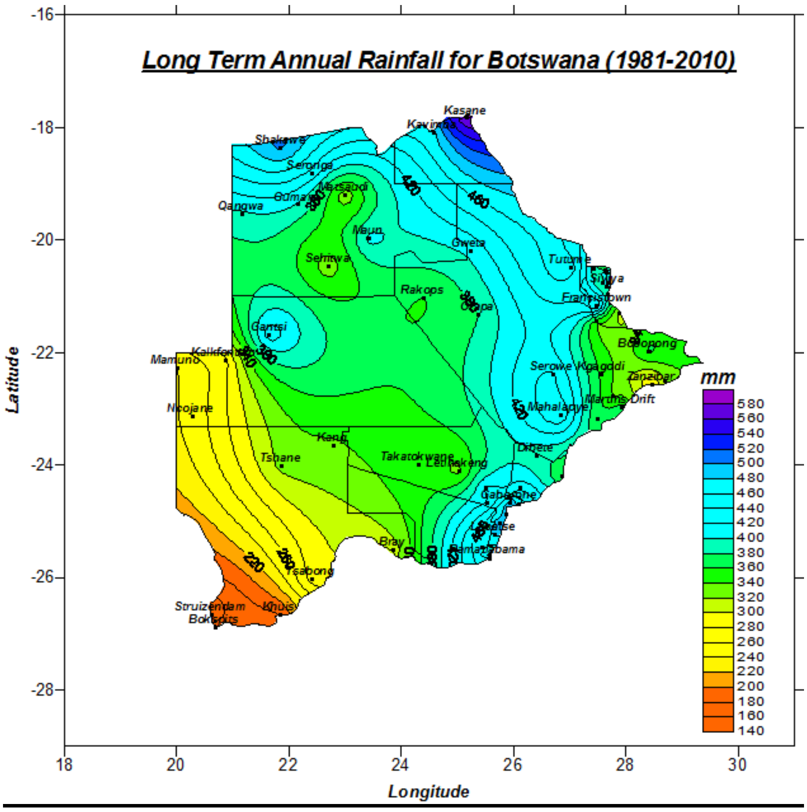


Figure 6: Botswana Annual average rainfall 1981– 2010 (Source: Department of Meteorological Services)

The day time air temperatures during summer months are on average warm to hot due to high insolation, leading to potential evapotranspiration exceeding precipitation rates. The mean monthly maximum temperatures in summer months (October to February) for the past 30 years (1981 – 2010) range from 31˚C to 34˚C (Figure 7). Summer mean monthly minimum temperatures are warm and range from 16 ˚C to 20.5 ˚C for period 1981-2010.

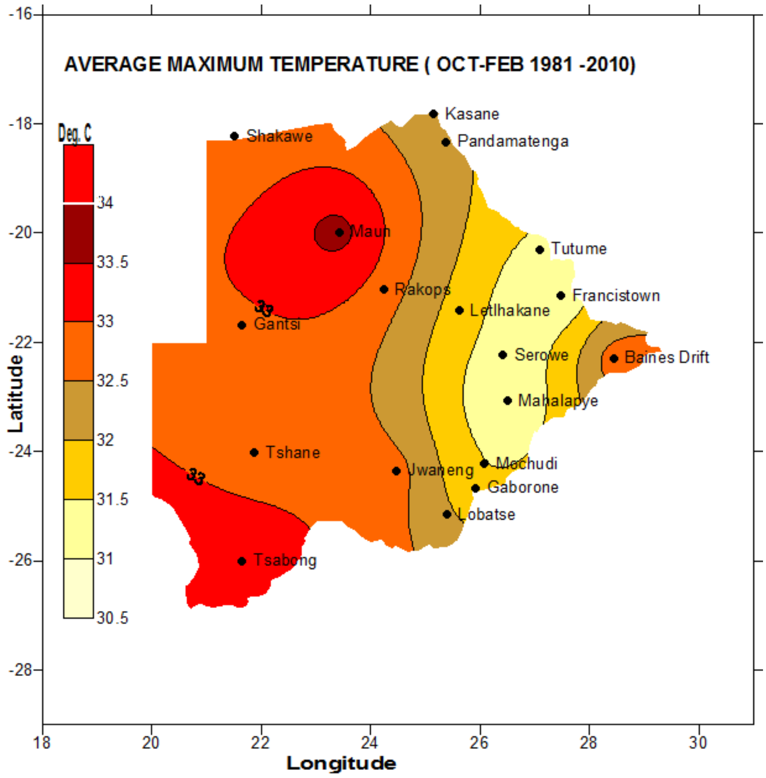


Figure 7: Mean monthly maximum temperature for 30years (1981-2010) (Source: Department of Meteorological Services)

The winter season starting in May to August, has average monthly maximum temperatures range from 22˚C to 29˚C (for the period (1981 – 2010). The season has cool minimum temperatures, indicating between 2.8 to 10.6˚C for the same period (Figure 8). The south western part of the country is colder than the other parts due to its vicinity to the cold dry air from the Benguela current.

The temperature trend is generally increasing in Botswana with minimum temperatures showing a slightly higher increase of 1°C and maximum temperature with an increase of 0.8°C for the period of 1970/71 to 2012/13.

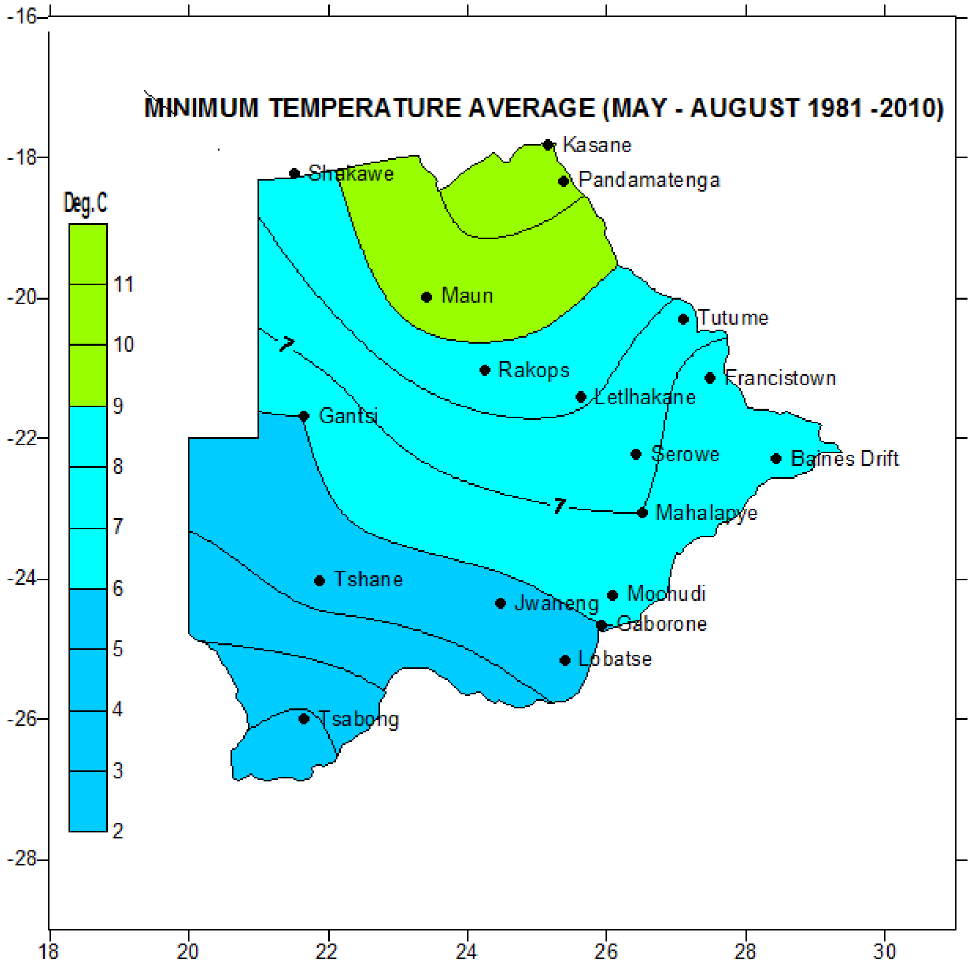


Figure 8: Mean monthly minimum temperature for 30years (1981-2010) (Source: Department of Meteorological Services)

Droughts are recurrent in Botswana. The country experienced moderate to severe droughts in the seasons 1984/85, 1985/86, 1991/92, 2002/03, 2006/07, 2011/12, 2012/13, 2014/15 and 2015/16 which had standardized precipitation indices (SPIs) from -1.0 or below (Figure 9). Conversely, the highest rainfall was experienced during the season 1999/2000 followed by 1973/1974. The diagram also depicts decreasing rainfall trend with large inter-annual variability.

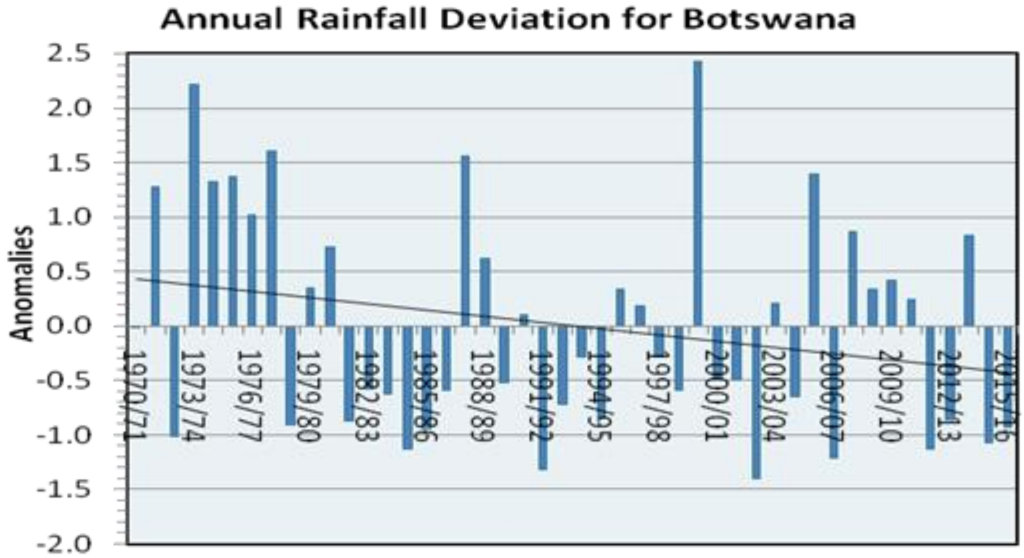


Figure 9: Annual rainfall anomalies (standardized precipitation indices) for aggregated rainfall for the 13 stations (Source: Department of Meteorological Services)

1.2 Population

Botswana’s population has increased over the years, from 574 000 in 1971 to 2 025 000 in 2011. The rapid growth from 1971 to 1991 was the result of the country’s high birth rate and declining mortality rates, which were due to the improved health system. However, since 1991 the rate of population growth has been declining, growing only by 2.4 percent per annum over the decade to 2001, and 1.9 percent to 2011. The contributory factors for the decline of the population growth rate include HIV/AIDS, declining fertility rates, increased female participation in economic activities, increased literacy rates, and access to better healthcare.

1.3 Economy

Diamond exports provide Botswana's economy with strong supplies of foreign exchange and have offered a basis for industrial development and stimulated improvements in Botswana’s infrastructure. The country seeks to further diversify its economy away from minerals. Botswana has a growing financial sector, and the country's national stock market, the Botswana Stock Exchange (BSE), based in Gaborone, is given the responsibility to operate and regulate the equities and fixed interest securities market. Growth prospects for the medium term are favourable, with real GDP growth projected at 3.8% in 2019 and 4.1% in 2020. The outlook for the mining sector is positive due to an anticipated increase in demand for Botswana’s rough diamonds (diamonds account for three-fourths of Botswana’s total exports). The non-mining sectors are expected to pick up further, driven by structural reforms, including an amended immigration law that ensures expeditious processing of work and residence permits and a move that provides utilities at reasonable prices to encourage domestic manufacturers. But growth prospects are clouded by high unemployment (particularly youth unemployment) and income inequality. Downside risks associated with weak global demand for diamond exports remain elevated in light of the threat to global growth from escalating trade tensions. Other notable risks include persistent drought affecting livestock and agricultural production and lower Southern African Customs Union revenues if South Africa's economic conditions remain unfavourable.

The risks underscore the need to accelerate structural reforms to promote economic diversification and higher productivity and thus reduce vulnerability to external shock. With promising medium-term growth prospects and ample fiscal space, policies could prioritize the economic transformation needed to deliver more inclusive, resilient, and job-creating growth. Overcoming the skills shortage, infrastructure bottlenecks, and high cost of doing business could expedite integration into regional and global value chains and thus economic diversification (African Economic outlook, 2018).

1.4 Water resources

Botswana is a water scarce country, with varied rainfall and highly susceptible to drought. Much of the country depend on groundwater resources to meet the water demand for various sectors of the economy. Groundwater resources are mostly fossil type and caution is exercised in its exploitation to avoid their depletion. However, most of these resources are saline. Alternatives sources include amongst others effluent utilisation and transboundary water transfer schemes.

The surface water resources consists of 7reseivoirs created by major dams, rivers and the wetlands of the Okavango Delta. All of these resources in exception of the Okavango Delta, are vulnerable to periodic drying as a result increasing water demand and variation in spatial and temporal water run off patterns. Some of the most important aquifers in the country are transboundary and will require corporation between the neighbouring countries

1.5 Agriculture

The Agricultural sector in Botswana covers both crops and livestock production. Traditional farming is the most dominant in terms of numbers of people involved and the geographical coverage. The majority of farmers are small-scale farmers who typically need continued assistance in capacity building to commercialize agriculture. An effective and vibrant extensive service is therefore an important input in improving the performance of the sector and its resilience to market changes and climate change. The beef industry is the only sub-sector of the agriculture sector that has constantly remained a significant contributor to the national Gross Domestic Product (GDP). Nevertheless, the country is self-sufficient in poultry and horticulture and piggery are coming up well. Dryland crop production has been the most vulnerable part of the agricultural sector due to its heavy reliance on rainfall. Technological advances have been made in the dairy and horticulture sub-sectors through the National Master Plan for Arable Agriculture and Dairy Development (NAMPAADD) where extension services have been revamped through training of extension workers and demonstration farms established.

1.6 Energy

Botswana's energy sources consist primarily of electricity, fuel wood, Liquefied Petroleum Gas (LPG), petrol, diesel and aviation gas. Solar, biogas and biodiesel constitute a small proportion, about 1 %. LPG and all the petroleum based fuels are imported. Fuel wood usage has been declining over the years while LPG and electricity consumption has been on the rise. Local energy resources considered to be in abundance in Botswana include coal (200 billion tonnes), sunshine (3200hrs at 21MJ/m^2), biogas (2.2 million cattle, 3kg dung/LSU/day) and fuel wood (200 tonnes/annum). Petroleum products (LPG, petrol, diesel and paraffin) are imported.

1.7 Forest

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 shrub formations. Forests in Botswana are still a versatile renewable resources, simultaneously providing a wide range of economic, social and environmental benefits and services. Derivation of products from forest resources continue to be under great pressure due to human activities; particularly wood, which contributes significantly to fuel energy used in the country. The Botswana Forest Distribution Map (BFDM) has been developed IN 2015. According to the BFDM 2015 findings, the forest area in Botswana currently stands at 157,279 km^2 (28%), which constitutes Typical Forest: 36, 517 km^2 (1%), Riparian Forest: 1, 552km^2 (8%) and Woodland: 119, 210 km^2 (19%).

CHAPTER 2 - NATIONAL GREENHOUSE GAS INVENTORY

In accordance with Article 4, paragraph 1 (a), and Article 12, paragraph 1(a) of the Convention, communicate to the Conference of the Parties a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol, to the extent its capacities permit, following the provisions in these guidelines.

2.1 Methodologies

The national greenhouse gas national inventories were prepared in accordance with the 2006 IPCC Guidelines for National GHG Inventories, using IPCC 2006 Inventory Software Version 2.54 for data entry, emission calculation, results and analysis, for all sectors.

Good Practice Guidelines and Uncertainty Management in National GHG Inventories in response to the request from the United Nations Framework Convention on Climate Change (UNFCCC) for the Intergovernmental Panel on Climate Change (IPCC) were also used during preparation of this report.

The 100-year time horizon global warming potentials (GWP) relative to CO2 adapted from the Second Assessment Report (SAR) were used to convert the estimated CH4, N2O and HFCs emissions to CO2 equivalents

Inventory was prepared applying Tier 1 Sectoral approach using default values. Data were obtained mainly from Statistics Botswana, Government Ministries and other relevant stakeholders through formal requests. Where suitable data were missing, emission /removals were estimated using methods of interpolation, extrapolation, and surrogate data.

From the four main sectors: (1) Energy, (2) Industrial Processes and Product Use (3), Agriculture, Forestry and Other Land Use (AFOLU), and (4) Waste, emissions were estimated based on inventories by sources categories

The assessment of completeness of the inventory conducted in the report, following the IPCC guidelines, within each source category is summarized in Table.

Table 4: Summary of methods and emission factors

Greenhouse gas source and sink categories	CO2		CH4		N2O		NOx		CO		NMVOCs		SO2		PFC		HFC	
	M	EF	M	EF	M	EF	M	EF	M	EF	M	EF	M	EF	M	EF	M	EF
1 - Energy	T1	D	T1	D	T1	D	T1	D	NE		NE		NE					
1A - Fuel Combustion Activities	T1	D	T1	D	T1	D	T1	D	NE		NE		NE					
1B - Fugitive Emissions from Fuels	T1	D	T1	D	T1	D	NO		NO		NE		NE					
2 - Industrial Processes and Product Use	T1	D	NO		NO		NA		NA		NA		NA		NE		T1	D
2A - Mineral Products	T1	D	NO				NO		NE		NE		NE					
2B - Chemical Industry	T1	D	NO				NO		NE		NE		NE					
2C – Product Use and Substitutes of Ozone Depleting Substances	NO						NO		NE		NE		NE		NA		T1	D
3 – Agriculture, Forestry and Other Land Use	T1	D	T1	D	T1	D	T1	D	T1	D	NE		NE					
3A - Livestock			T1	D			NE		NE		NE		NE					
3B - Land	T1	D			T1	D	NE		NE		NE		NE					
3C – Aggregate Sources and non-CO2 Sources on Land	T1	D	T1	D	T1	D	T1	D	T1	D	NE		NE					
3D - Other	T1	D	NE		NO		NE		NE		NE		NE					

4 - Waste	NA		T1	D	T1	D	NE	NE	NE	NE				
4A - Solid Waste Disposal			T1	D	NA		NE	NE	NE	NE				
4D – Waste Treatment and Discharge			T1	D	T1	D	NE	NE	NE	NE				

T1 = Tier 1

D = IPCC Default values

NA = Not Applicable

NO = Not Occurring

NE = Not Estimated

GHG Emission Trends by Sector from 2000 to 2013

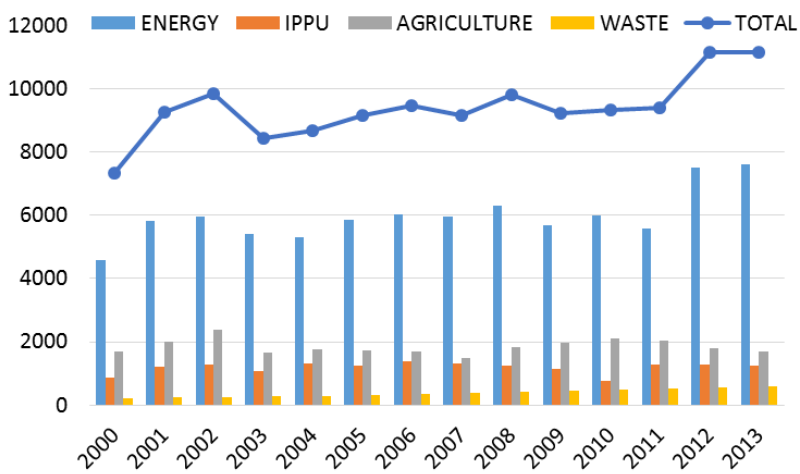


Figure 10: Trend of Botswana's GHG Emissions (without LUCF) by sector: 2000–2013

In the year 2000, the Energy share (excluding LUCF) accounted for 62% of all emissions followed by the Agriculture emissions with 23%, the IPPU sector with 12% and lastly, the Waste sector emissions with 3%. Similarly, in 2013, the Energy share accounted for 68% of all emissions followed by the Agriculture emissions with 15%, the IPPU emissions with 11% and the Waste emissions with 5%.

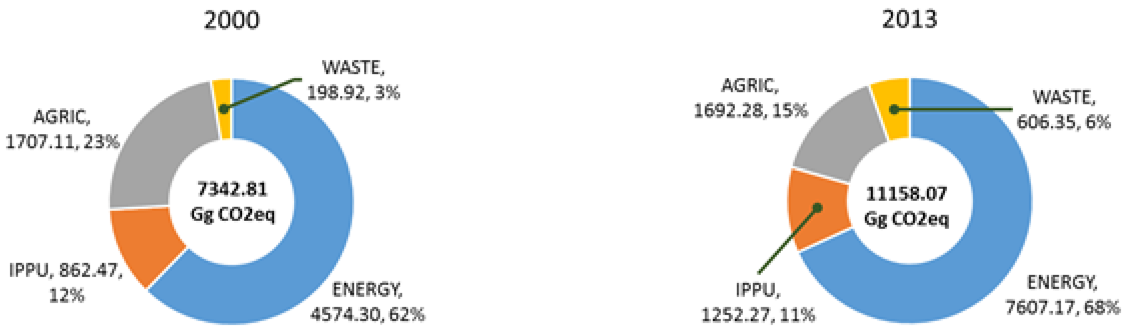


Figure 11: GHG Emission Trends by Gas from 2000 to 2013

When the GHG emissions (without LUCF) are analyzed by gas, CO2 emissions dominate (Figure). Based on breakdown by gas, CO2, CH4 and N2O had increased by 70.4%, 17.4%, and 38.6%, respectively, in the year 2013 from the base year 2000.

In the year 2000, the CO2 share accounted for 63.6% of all emissions followed by the CH4 emissions with 34.7% and N2O emissions with about 1.7%. Similarly, in 2013, the CO2 share accounted for 71.4% of all emissions followed by the CH4 emissions with 27.1% and N2O emissions with about 1.7%.

In view of the F-gases, no data was available for 2000–2003. Further, from 2004 to 2013, the only reported F-gas was the HFCs but its contributions were negligible.

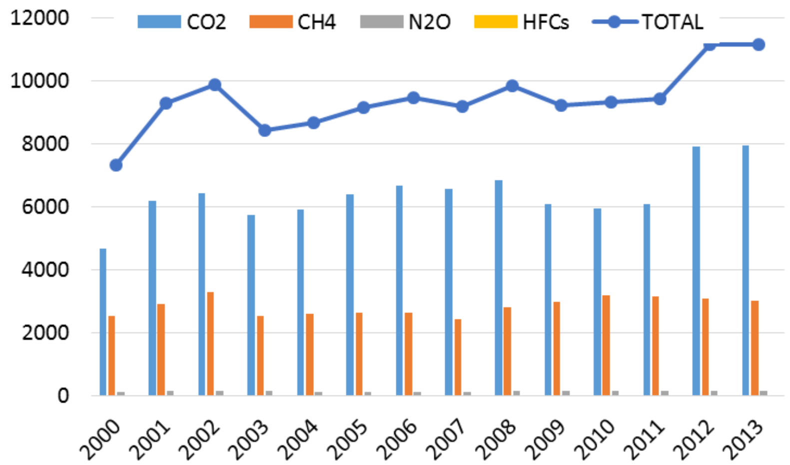


Figure 6: Trend of Botswana's GHG Emissions (without LUCF) by gas: 2000–2013

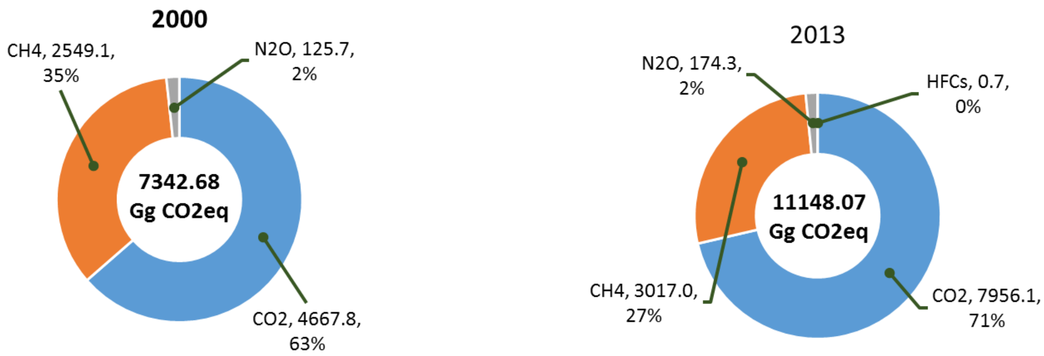


Figure 12: Proportions of the National GHG Emissions by Gas (Gg CO2eq): 2000 and 2013

BOTSWANA NATIONAL GREENHOUSE GAS INVENTORY OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF ALL GREENHOUSE GASES NOT CONTROLLED BY THE MONTREAL PROTOCAL AND GREENHOUSE GAS PRECURSORS

Table 5: Summary report for GHG emissions inventory

2014 National Inventory Year: 2014

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	5721,911039	152,2841	1,5031	0,6402	0	0	0	0	16,6145	276,9076	0	0
1 - Energy	7409,792227	37,36153	0,5071	0	0	0	0	0	0	0	0	0
1.A - Fuel Combustion Activities	7407,28651	24,86204	0,5071	0	0	0	0	0	0	0	0	0

1.A.1 - Energy Industries	4178,44416	0,04417	0,0663						0	0	0	0
1.A.3 - Transport	2264,32855	0,577649	0,1104						0	0	0	0
1.A.4 - Other Sectors	964,5138	24,24022	0,3304						0	0	0	0
1.B - Fugitive emissions from fuels	2,50571652	12,49949	0	0	0	0	0	0	0	0	0	0
1.B.1 - Solid Fuels	2,50571652	12,49949	0						0	0	0	0
2 - Industrial Processes and Product Use	1293,443665	0	0	0,6402	0	0	0	0	0	0	0	0
2.A - Mineral Industry	129,2698413	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	129,2698413								0	0	0	0
2.B - Chemical Industry	1164,173824	0	0	0	0	0	0	0	0	0	0	0
2.B.7 - Soda Ash Production	1164,173824								0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0,6402	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning				0,6402				0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-2981,324853	85,33535	0,9215	0	0	0	0	0	16,6145	276,9076	0	0
3.A - Livestock	0	75,53708	0	0	0	0	0	0	0	0	0	0

3.A.1 - Enteric Fermentation		72,37221							0	0	0	0
3.A.2 - Manure Management		3,164872	0						0	0	0	0
3.B - Land	- 2970,679905	0	0,0179	0	0	0	0	0	0	0	0	0
3.B.1 - Forest land	-16196,2944								0	0	0	0
3.B.2 - Cropland	0,0264								0	0	0	0
3.B.3 - Grassland	13196,10373								0	0	0	0
3.B.4 - Wetlands	28,0676		0,0179						0	0	0	0
3.B.5 - Settlements	1,312622667								0	0	0	0
3.B.6 - Other Land	0,104133333								0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0,250063733	9,79827	0,9036	0	0	0	0	0	16,6145	276,9076	0	0
3.C.1 - Emissions from biomass burning		9,79827	0,8946						16,6145	276,9076	0	0
3.C.2 - Liming	0,082863733								0	0	0	0
3.C.3 - Urea application	0,1672								0	0	0	0
3.C.4 - Direct N2O Emissions from managed soils			0,0022						0	0	0	0

3.C.5 - Indirect N2O Emissions from managed soils			0,0068						0	0	0	0
3.D - Other	- 10,89501113	0	0	0	0	0	0	0	0	0	0	0
3.D.1 - Harvested Wood Products	- 10,89501113								0	0	0	0
4 - Waste	0	29,58719	0,0745	0	0	0	0	0	0	0	0	0
4.A - Solid Waste Disposal	0	25,9044	0	0	0	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge	0	3,682788	0,0745	0	0	0	0	0	0	0	0	0
Memo Items (5)												
International Bunkers	31,5315	0,000221	0,0009	0	0	0	0	0	0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers)	31,5315	0,000221	0,0009						0	0	0	0

2.3 Energy Sector

This sector provides estimates of GHG emissions resulting from electricity and heat production activities, and fuel combustion for energy generation purposes. The main categories under the energy sector are; Fuel Consumption Activities and Fugitive Emissions from Gases

2.3.1 Energy Sector Emissions

In the year 2014, Energy Sector accounted for approximately 70.3% of total national direct GHG emissions (without LUCF). This sector is the major source of GHG emissions at the national level. Energy Sector was also a significant source of CO_2 and N_2O emissions, accounting for approximately 85.1%, and 87.2%, respectively, of total CO_2 and N_2O (in Gg CO_2-eq) emissions registered at the national level. Methane contributed to about 26.2% emission to the 2014 national CH_4 emissions.

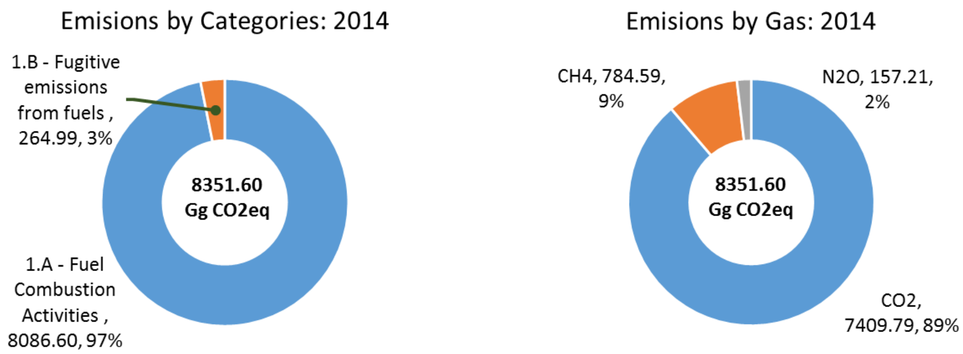


Figure 13: Proportions of the GHG Emissions by Energy Categories and by Gas: 2014

Table 6: Energy sector CO2 emissions estimated by reference approach and sectoral approach for 2014

Fuel Types	**Reference Approach**				**Sectoral Approach**		**Difference**	
	Apparent Consumption (Tj)	Excluded Consumption (Tj)	Apparent Consumption (excluding non-energy use & feedstocks) Tj	CO2 Emissions (Gg)	Energy Consumption (Tj)	CO2 Emission (Gg)	Energy Consumption (%)	CO2 Emissions (%)
2014								
Liquid Fuels: 22 items (s)	41818.70	NE	41818.70	2976.34	41377.70	2975.01	1.07	0.04
Solid Fuels: 11 items (s)	44158.12	NE	44158.12	4093.81	46852.80	4432.27	-5.75	-7.64
Gaseous Fuels:	NE	NE	NE	NE	NE	NE	NE	NE

1 item (s)								
Other Fossil Fuels: 3 items (s)	NE	NE	NE	NE	NE	NE	NE	NE
Peat: 1 items (s)	NE	NE	NE	NE	NE	NE	NE	NE
Total	**85976.82**	**0.00**	**85976.82**	**7070.15**	**88230.50**	**7407.29**	**-2.55**	**-4.55**

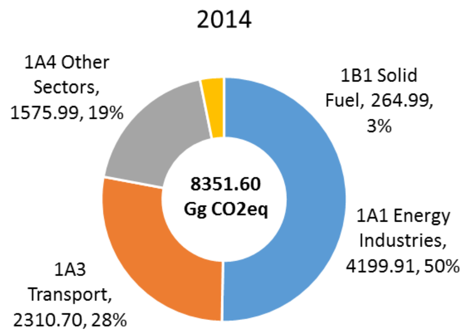


Figure 14: Proportions of the Energy GHG Emissions by Categories for 2014

2.3.2 Emissions by Source Categories: 2014

The total emission under this sector was 8351.60 Gg CO2eq. A large proportion of the GHG emissions within the energy sector arose from the Fuel Consumption Activities (8086.60 Gg CO2eq; 96.8% contribution to the total energy sector) with emissions from Energy Industries (4199.91 Gg CO2eq; a 51.9% contribution to the Fuel Consumption Activities), from the Main Activity Electricity and Heat Production. Contribution of Energy Industries to the Energy Sector are 100% entirely from the Electricity Generation.

Emissions from the Transport were 2310.70 Gg CO2eq (28.6% contribution to the Fuel Consumption Activities). A large proportion of emissions from the transport subsector comes from Road Transportation (specifically Cars), which accounted for 2241.25 Gg CO2 eq (97.0%) whereas the rest arose from Civil Aviation, under the Domestic Aviation subsection with 69.44 Gg CO2eq (3.0%).

The “Other Sectors”, which include; Commercial / Institutional (814.60 Gg CO2eq; 51.7% contribution to the “Other Sectors”), Residential (713.51 Gg CO2eq; 45.3% contribution to the “Other Sectors”) and Agriculture / Forestry / Fishing / Fish Farms specifically from Stationary subcategory (47.69 Gg CO2eq; 3.0% contribution to the “Other Sectors”) contributed to about 1575.99 Gg CO2eq (which is a contribution of 19.5% to the Fuel Consumption Activities).

The Fugitive Emission from Fuels emitted only 264.99 Gg CO2eq, about 3.2% of total GHG emissions from the 2014 energy sector. Greenhouse emissions under this sector emanate almost entirely (264.99 Gg CO2eq; 91.4%) from Coal Mining and Handling under the Underground Mines specifically the Mining subsector, with Post-mining Seam Gas Emission contributing to 22.63 Gg CO2eq (8.6%) to the Fugitive Emission from Fuels.

Table 7: Botswana's Key Categories Identified under the Energy Sector: 2014

IPCC Category		GHG	Identification Criteria
Code	Description		
1.A.1	Energy Industries - Solid Fuels	CO2	L,T
1.A.3.b	Road Transportation	CO2	L
1.A.4	Other Sectors - Liquid Fuels	CO2	L,T

L = Level Assessment; T = Trend Assessment

Recalculation: 2000–2013

Recalculation of time series for the period 2000 to 2013 were made and results obtained were included in this report.

Between 2000 and 2013, the total GHG emissions from the Energy Sector varied, but had increased from 4720.91 Gg CO2eq (in 2000) to 7838.74 Gg CO2eq in 2013 (Table 3-10, Figure 3-9), which is an increase of about 39.8%.

The national direct Energy Sector GHG emissions variations by source category in 2013, from the base year 2000 are summarised as follows:

Energy Industries 64.3%

Transport 40.8%

Other Sectors –22.2%

Solid Fuels 36.7%

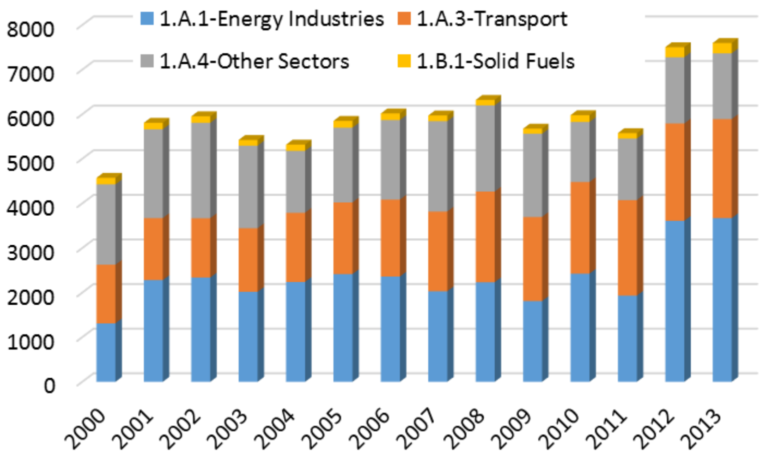


Figure 15: Time series (2000-2013) of national GHG emissions by sector (Gg CO2-eq)

Similarly, the national direct Energy Sector GHG emissions variations by source category in 2013, from the base year 2000 are summarised as follows (Table 3-11, Figure 16):

CO2	43.3%
CH4	13.2%
N2O	16.8%

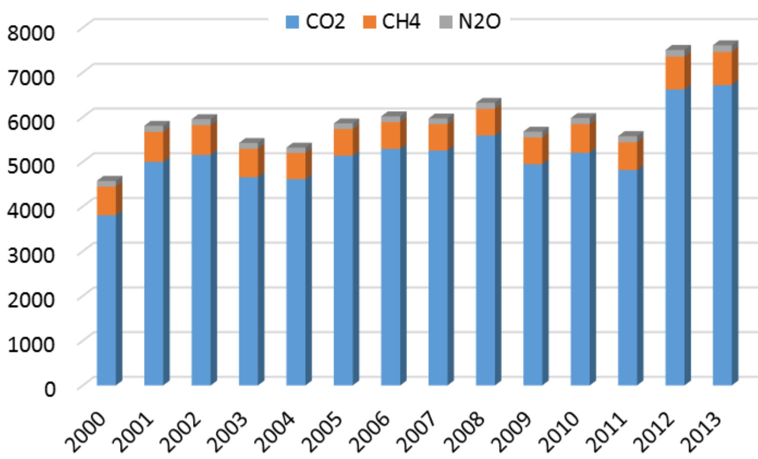


Figure 16: Time series (2000-2013) of national GHG emissions by gas (Gg CO2-eq)

Comparison of Reference and Sectoral Approaches

To conform to the IPCC recommendations, the CO2 emissions were calculated by using two distinct approaches: the reference method (top-down) and the Sectoral method (bottom up) were compared.

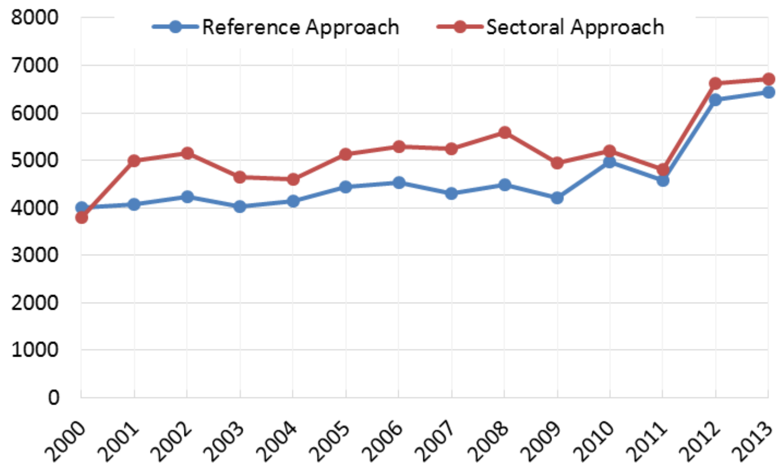


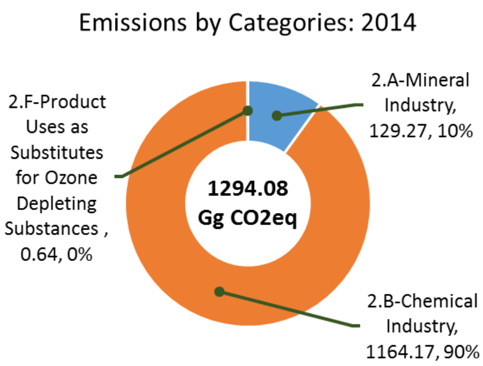
Figure 17: Comparison of CO2 Emissions Estimated by using Reference and Sectoral Approaches

2.3.3 IPPU Sector
Sector Review

This sector provides estimates of GHG emissions resulting from two main subcategories: Cement Production (under the Mineral Industry Category and Soda Ash Production (under the Chemical Industry Category). In addition, Botswana reports, in this document, GHG emissions under the Product Uses as Substitutes for Ozone Depleting Substances Category, specifically, the Refrigeration and Stationary Air Conditioning Subcategory.

2.3.4 IPPU Sector Emissions
Summary of emissions for 2014

In the year 2014, IPPU Sector accounted for approximately 10.9% of total national direct GHG emissions (without LUCF). The sector is a source of CO2 and HFC emissions, accounting for approximately 14.9%, and 100%, respectively, of total CO2 and HFC (in Gg CO2-eq) emissions registered at the national level.



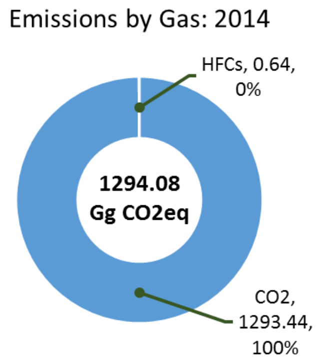


Figure 18: Proportions of the GHG Emissions by IPPU Categories and by Gas: 2014

2.3.5 Emissions by Source Categories: 2014

In 2014, the total emission under this sector was 1294.08 Gg CO2eq. A large proportion of the GHG emissions within the IPPU sector arose from the Chemical Industry (1164.17 Gg CO2eq; about 90.0% contribution to the total IPPU sector) with Soda Ash Production providing a 100% CO2 contribution to the subcategory.

Emissions from the Mineral Industry subcategory were 129.27 Gg CO2eq (about 10% contribution to the sector) with Cement production providing a 100% CO2 contribution to the subcategory.

Greenhouse gas emissions from the Product Uses as Substitutes for Ozone Depleting Substances (0.64 Gg CO2eq; just under 0.05% contribution to the total IPPU sector) category comes from Refrigeration and Air Conditioning–(specifically from the Refrigeration and Stationary Air Conditioning) and emits HFC-152a (CH3CHF2) at a 100% contribution to the HFCs in Gg CO2-eq.

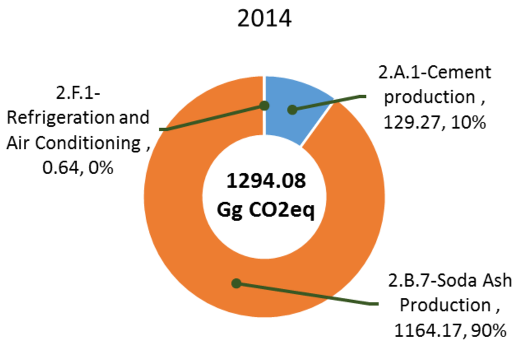


Figure 19: Proportions of the IPPU GHG Emissions by Categories for 2014

2.3.6 IPPU Sector Key Sources for 2014

Key category assessment under the IPPU sector was performed following the 2006 IPCC Tier 1 approach. Information on the sector's identified key categories (by level and trend assessment) is presented in Table 3-17 and Table 3-18, for 2014 and 2015, respectively, and again provided in Section 2 by level and trend assessments.

Table 8: Botswana's Key Categories Identified under the IPPU Sector: 2014

IPCC Category		GHG	Identification Criteria
Code	Description		
2.B.7	Soda Ash Production	CO_2	L

L = Level Assessment; T = Trend Assessment

Recalculation: 2000–2013

Recalculation of time series for the period 2000 to 2013 were made and results obtained were included in this report.

Between 2000 and 2013, the total GHG emissions from the IPPU Sector varied, but had increased from 862.47 Gg CO_2eq (in 2000) to 1252.27 Gg CO_2eq in 2013 (Figure), which is an increase of about 45.2%.

The national direct IPPU Sector GHG emissions variations by source category in 2013, from the base year 2000 are summarised as follows:

2.A.1 – Cement Production 385.6%

2.B.7 – Soda Ash Production 38.1%

2.F.1 – Refrigeration and Air Conditioning 7100% (estimated from base year, 2003)

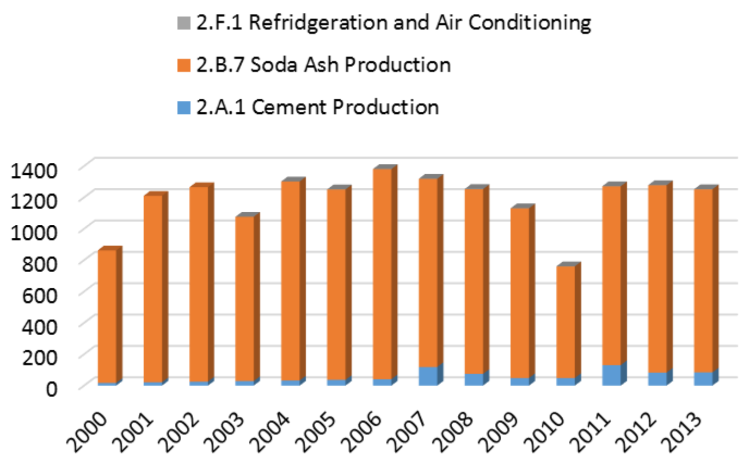


Figure 20: Time series (2000-2013) of national GHG emissions by sector (Gg CO2-eq)

Similarly, the national direct IPPU Sector GHG emissions variations by source category in 2013, from the base year 2000 are summarised as follows (Table 3-20, Figure 21):

CO2	45.1%
HCF	720,000%

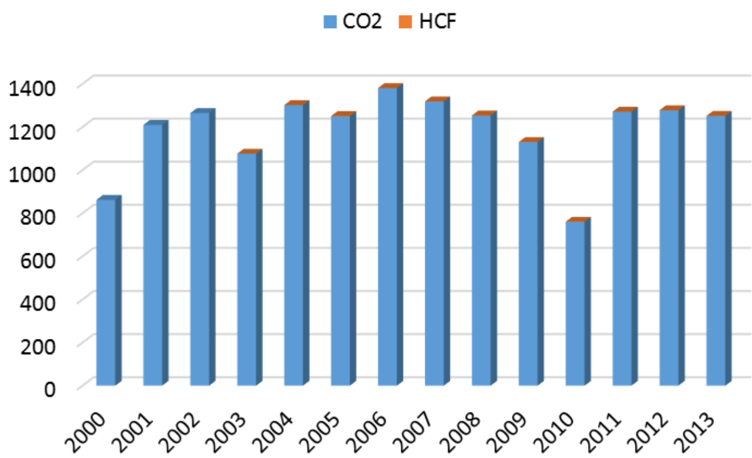


Figure 21: Time series (2000-2013) of national GHG emissions by gas (Gg CO2-eq)

2.3.7 The AFOLU Sector

This sector provides estimates of GHG emissions as follows:

- Agriculture, Forestry, and Other Land Use (AFOLU), based on four clusters: (1) Livestock, (2) Land, (3) Aggregate sources and non-CO2 emissions sources on land and (4) Other (Harvested Wood Products). Each category was further disaggregated into activities that contributed to emissions /removals.
- The Livestock subsector includes GHG emissions from: a) Enteric Formation; Cattle i.e., Dairy Cattle and Other Cows, Sheep, Goats, Horses and Mules & Asses; b) Manure Management; Cattle i.e., Dairy Figure 17. Cattle and Other Cows, Sheep, Goats, Horses, Mules & Asses, Swine and Poultry.
- Land subsector includes GHG emissions from: a) Forest Land; Forest Land Remaining Forest Land and Land Converted to Forest Land (Grass Land Converted to Forest Land); b) Cropland; Crop Land Remaining Crop Land; c) Grassland; Grassland Remaining Grassland (Forest Land Converted to Grassland); d) Wetland; Wetland Remaining Wetland (Peat Lands Remaining Peat Lands); e) Settlements Remaining Settlements and Land Converted to Settlements (Wetlands Converted to Settlements and Other Land converted to Settlements); f) Other Land; Land Converted to Other Land (Wetlands converted to Other Land and Settlements converted to Other Land).
- Aggregate sources and non-CO2 emissions sources on land subsector includes GHG emissions from; a) Emissions from biomass burning, Liming and b) Urea Application.
- The subsector "Other" was the GHG emissions from Harvested Wood Products, though no activity data were available in-country. The output in this subsector emanated from parameters already inbuilt into the 2006 IPCC Software.

2.3.8 AFOLU Sector Emissions

Summary of emissions for 2014

In the year 2014, AFOLU accounted for approximately –2981.32 Gg net CO2 emissions. Greenhouse gas emissions from CH4 and N2O were 1792.04 Gg CO2eq and 285.68 Gg CO2eq, respectively. Without LUCF, AFOLU accounted for 1586.28 Gg CO2eq, that's is, approximately 13.4% of total national GHG emissions. This sector is the second major source of GHG emissions at the national level. Emissions and removals of GHG are given in figure below.

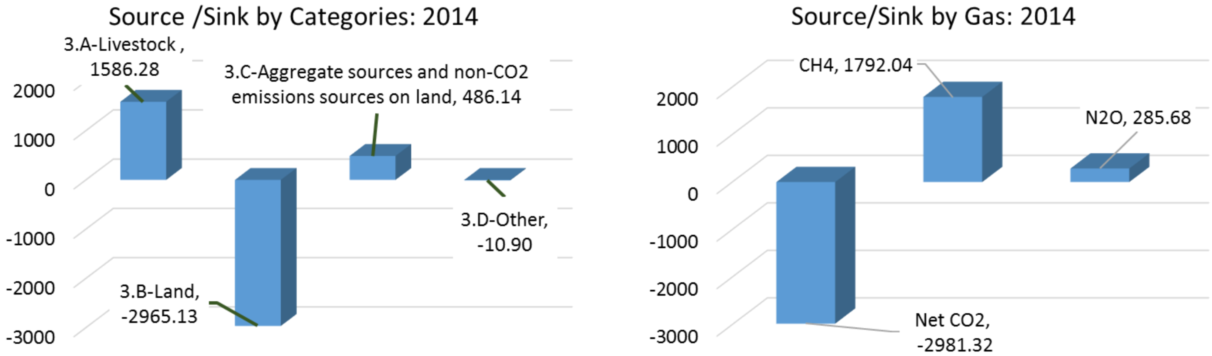


Figure 22: GHG Source and Sink from AFOLU Sector by Categories and by Gas: 2014

2.3.9 Emissions by Source Categories: 2014

In 2014, the total GHG emissions under the Livestock–3.A category was 1586.28 Gg CO2eq. These emanate from Enteric Fermentation and Manure Management at a contribution of 95.8% (1519.82 Gg CO2eq) and 4.2% (66.46 Gg CO2eq), respectively. The only greenhouse gas under and subcategories was CH4 and results from Cattle), Goats, Mules & Asses, Sheep, Horses and Swine; with Cattle being the major source at 84.0% and 71.0%, to the Enteric Fermentation and Manure Management subcategories, respectively, Figure 23.

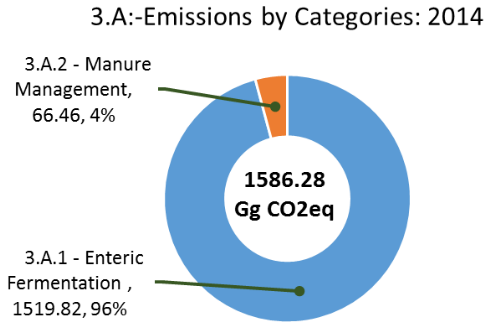


Figure 23: GHG Emissions from Livestock Categories: 2014

The net CO2 emissions under the Land subcategory was –2970.67 Gg CO2eq, resulting in a total of –2965.13 Gg CO2eq from which Forest Land (Forest land Remaining Forest land, and Land Converted to Forest land) and Grassland (Land Converted to Grassland) are the major contributors with –16196.29 Gg CO2eq and 13196.10 Gg CO2eq, respectively.

The Wetlands (Peatlands remaining peatlands) is the only subcategory responsible for a N2O contribution of about 5.55 Gg CO2eq to the Land emissions (Figure 24).

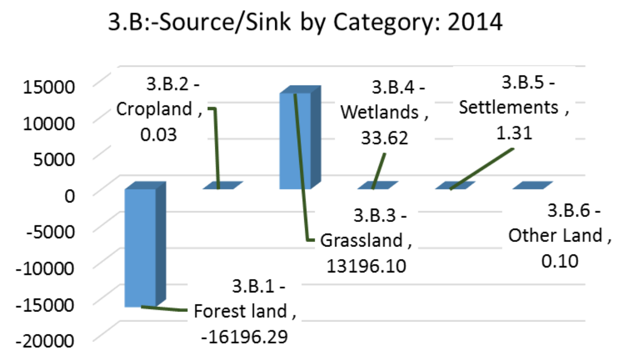


Figure 24: GHG Sources and Sink from Land subcategory: 2014

The total GHG emissions under the Aggregate sources and non-CO2 emissions sources on land category was 486.14 Gg CO2eq. These emanate almost entirely (99.4%) from Emissions from biomass burning with a total of 483.10 Gg CO2eq resulting from CO2 and N2O gases. In addition, "Emissions from biomass burning (Biomass burning in forest lands and Biomass burning in grasslands)" is the only subcategory responsible for NOx and CO emission of approximately 16.61 Gg and 276.91 Gg, respectively at a national level.

Liming and Urea application are responsible for a net CO2 contribution of 0.25 Gg CO2eq, whereas Direct N2O Emissions from managed soils and Indirect N2O Emissions from managed soils contribute 0.69 Gg CO2eq and 2.10 Gg CO2eq, respectively (Figure).

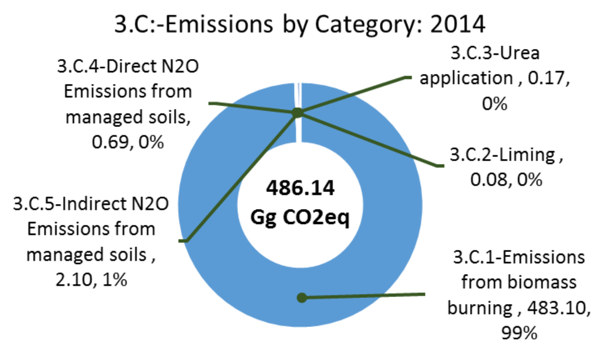


Figure 25: Emissions from Aggregate sources and non-CO2 emissions sources on land subcategory: 2014

2.4 Waste Sector

This sector provides estimates of GHG emissions resulting from two main categories: Solid Waste Disposal–4.A and Wastewater Treatment and Discharge–4.D, particularly Domestic Wastewater Treatment and Discharge subsector (4.D.1).

2.4.1 Waste Sector Emissions

Summary of emissions for 2014 and 2015

In the year 2014, Waste Sector accounted for approximately 5.4% of total national direct GHG emissions (without LUCF). This sector is the least source of GHG emissions at the national level. Gases emitted under this sector are CH4 and N2O. Methane accounts for approximately 20.8%, of total methane (in Gg CO2-eq) emissions registered at the national level, whereas N2O registered 12.8%.

Percentage contributions by major categories and by gas within the waste sector are given in Figure,

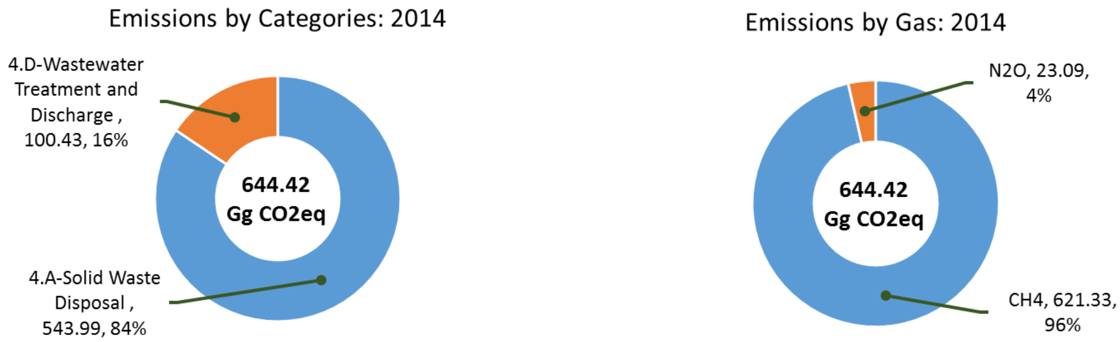


Figure 26: Proportions of the GHG Emissions by Waste Categories and by Gas: 2014

Describe procedures and arrangements undertaken to collect and archive data for the preparation of national GHG inventories, as well as efforts to make this a continuous process, including information on the role of the institutions involved.

GENERAL DESCRIPTION OF STEPS TAKEN OR ENVISAGED TO IMPLEMENT THE CONVENTION

PROGRAMMES CONTAINING MEASURES TO FACILITATE ADEQUATE ADAPTATION TO CLIMATE CHANGE

2.5 Climate change scenarios

The climate scenarios were constructed to determine the impacts of climate change in Botswana. Emphasis was placed on the eastern part of the country and the mining towns of Orapa and Letlhakane and Makgadikgadi Salts Pans. The eastern part of Botswana is where the majority of the country's population resides. Secondly, the capital city and city of Francistown is also located along this corridor.

Climate scenarios were constructed for precipitation and temperature for the year 2050 and this was based on the RCP of 4.5 and 8.5. GCM/RCM ensemble were used with input from University of Cape Town. The variables analysed included; seasonal and annual precipitation, mean, maximum, and minimum temperature, drought, extreme precipitation.

2.6 Temperature scenarios

The seasonal and annual mean, maximum, minimum temperature for the selected sites were projected to increase faster than global temperature, which was projected to increase 1.5 ^{o}C in 2050 RCP4.5, and 2.1 in 2050 RCP8.5 ^{o}C. Map 3 depicts baseline and projected mean temperature for the country for 2050. The map projects that by 2050, most the country will experience high average temperature of 25.9-26.9. Thus, by 2050 most of the country will be hotter relative to baseline temperatures.

2.7 Botswana historical and future mean temperature

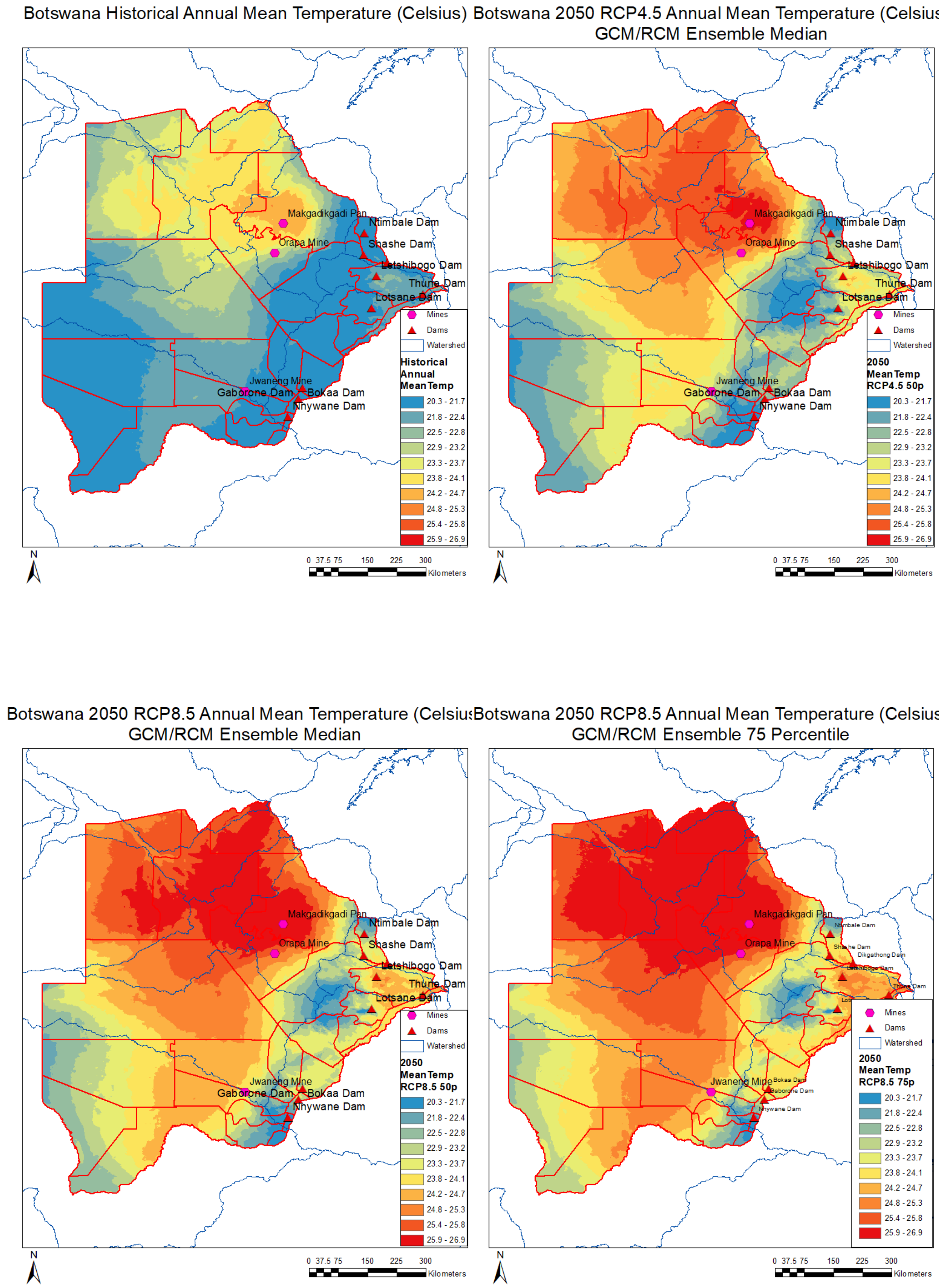


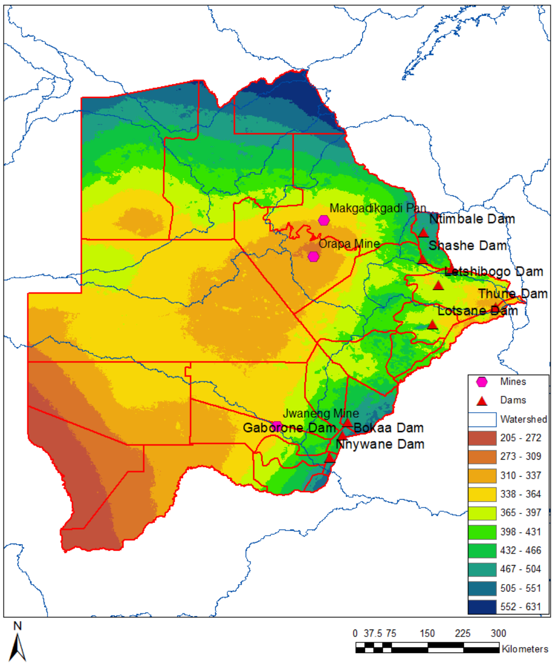
Figure 27: Baseline and temperature scenario by 2050

2.8 Precipitation scenarios

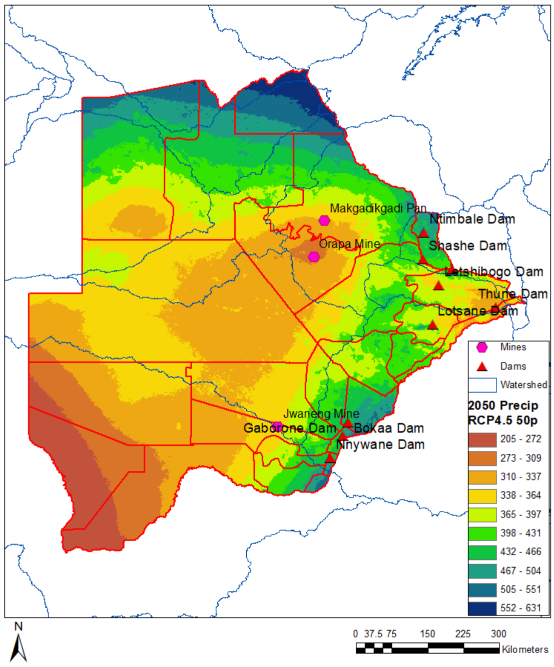
Precipitation scenarios were also constructed for 2050 for the dams' sites along the NSC, Jwaneng, Orapa and Makgadikgadi Salt Pans. The seasonal and annual mean precipitation over Botswana showed a general decrease trend by the 2050. However, for the ensemble median (50 percentile) was projected to increase by 1-2% in 2050. Map 4 depicts precipitation projections for the whole country by 2050 based on RCP 4.5 and 8.5.

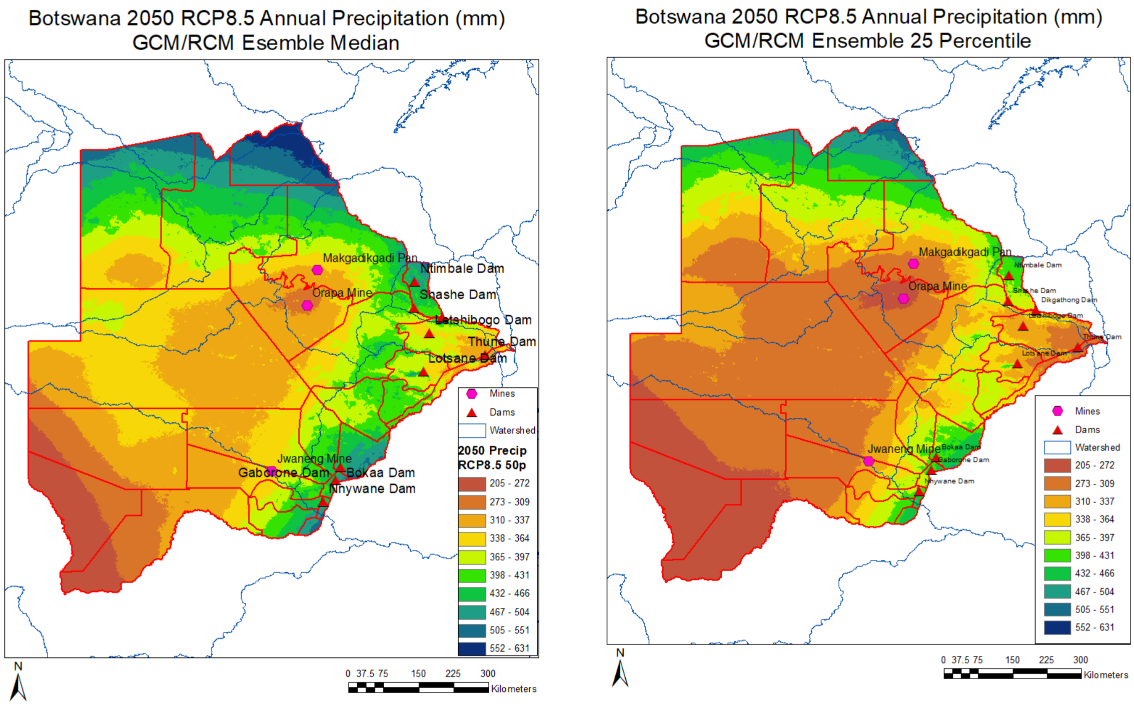
2.9 Botswana historical and future precipitation

Botswana Historical Average Annual Precipitation (mm)



Botswana 2050 RCP4.5 Annual Precipitation (mm)
GCM/RCM Esemble Median





Map 1: Projected precipitation by 2050 based onRCP4.5 and 8.5

2.10 Water Sector

The water sector is one of the most important and possible highly vulnerable sectors that will be affected by climate change is the water sector and wetlands. This sector is intricately linked to climatic variables (temperature and rainfall) making it highly vulnerable to climatic variability.

Given the possibly high vulnerability of the water sector to climate change it is thus important that feasible and effective adaptation measures are identified and implemented. This would technically reduce the country's vulnerability to climate change not only to the water sector but to other sectors that are connected to this critical sector.

2.10.1 Methods approaches and proposed activities

Achieving the objectives of the assignment involved application of multiple methods. Methods consisting of desktop review, consultation/interviews with key stakeholders mainly Water Utilities Corporation (WUC), Department of Water Affairs (DWA), General Circulation models, system dynamic modelling, CBA, activity based budget, were employed.

2.10.2 Socio-economic scenario

Socio-economic scenarios that were generated are for population and economic growth. They were used as additional stress to the water resources. Population growth models and economic growth were used to develop socio-economic scenario.

Linkage between scenario and water resources

System thinking and dynamic model was used to develop environmental and socio-economic trends and risk to the water sector. The approach was used to describe the linkages between climate and socio-economic baseline conditions and the water sector.

2.10.3 Vulnerability assessment of the water sector

The vulnerability of the water sector was devised based on the System dynamic models which is an integrated assessment models based on causal loops. The model simulates water stocks and flows over time as perturbed by physical and socio-economic scenarios. Water stocks (quantity) was categorized into surface (dams and rivers) and groundwater.

Water adaptation strategy and viability assessment

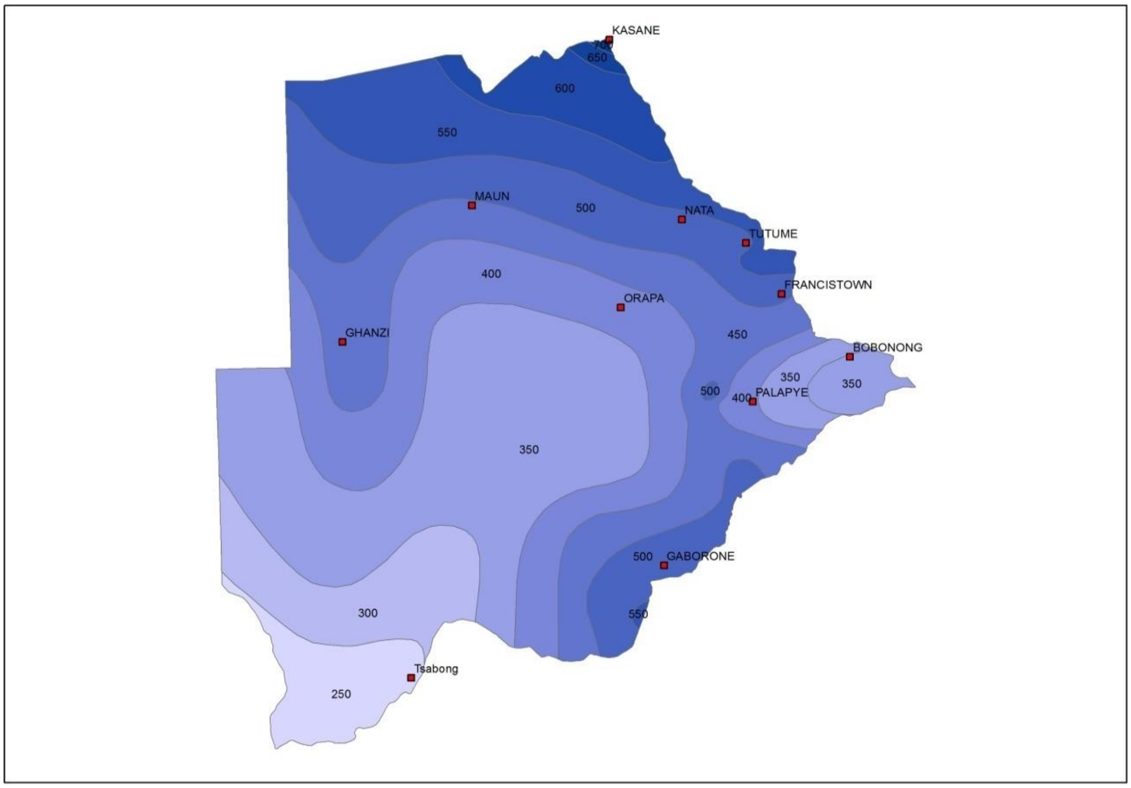
Achieving this thematic area (identification of adaptation strategies, determining economic viability of the feasible adaptation strategy, assessment of the barriers and available opportunities) was based on consultation with the relevant stakeholders mainly WUC, DWS, and University of Botswana. Expert judgement and literature review was used to identify adaptation strategies.

Emphasis was placed on both regional and international best practices for technological advanced and efficient adaptation strategies.

Lastly, Cost Benefit Analysis (CBA), an appraisal technique, was used to assess the economic viability of the proposed projects.

2.10.4 Water Resources

Botswana is characterized by semi-aridity to aridity climate. This is a result of a combination of high evapotranspiration and high erratic low rainfall. Annual rainfall declines from an annual average of 600 mm year^{-1} in the northern part (Chobe district) of the country to approximately less than 250 mm year^{-1} in the south western part of the country, the Kalagadi district). Evapotranspiration is estimated at 2000 mm year^{-1}. As the rainfall and evapotranspiration are the determinants of water resources, the country has limited water resources which become more pronounced during drought periods. Incidentally, drought is a recurrent phenomenon with an average return period of approximately 2 years Posed projects.



Map 2: Precipitation Map for Botswana

Water stock in the country

Water stock in the country is held in surface and groundwater/aquifers. Groundwater is the main source of water supply constituting over half of the water supply followed by surface water from dams (Figure).

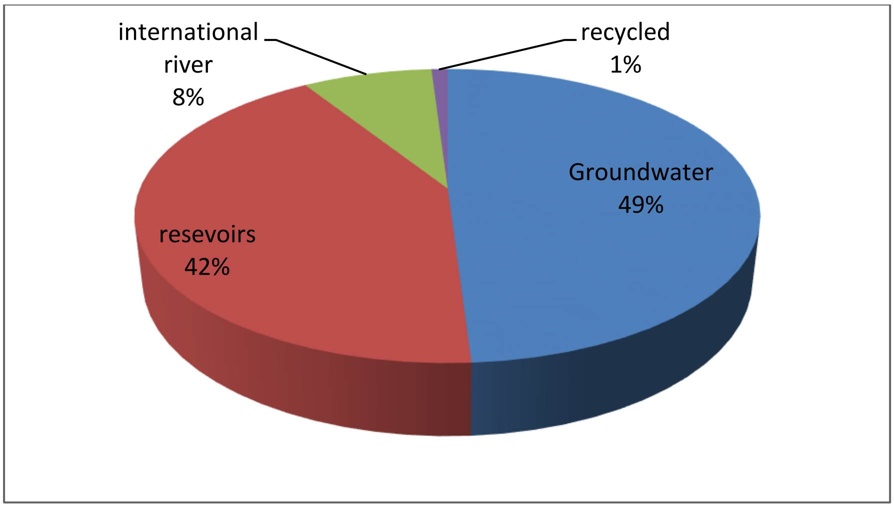


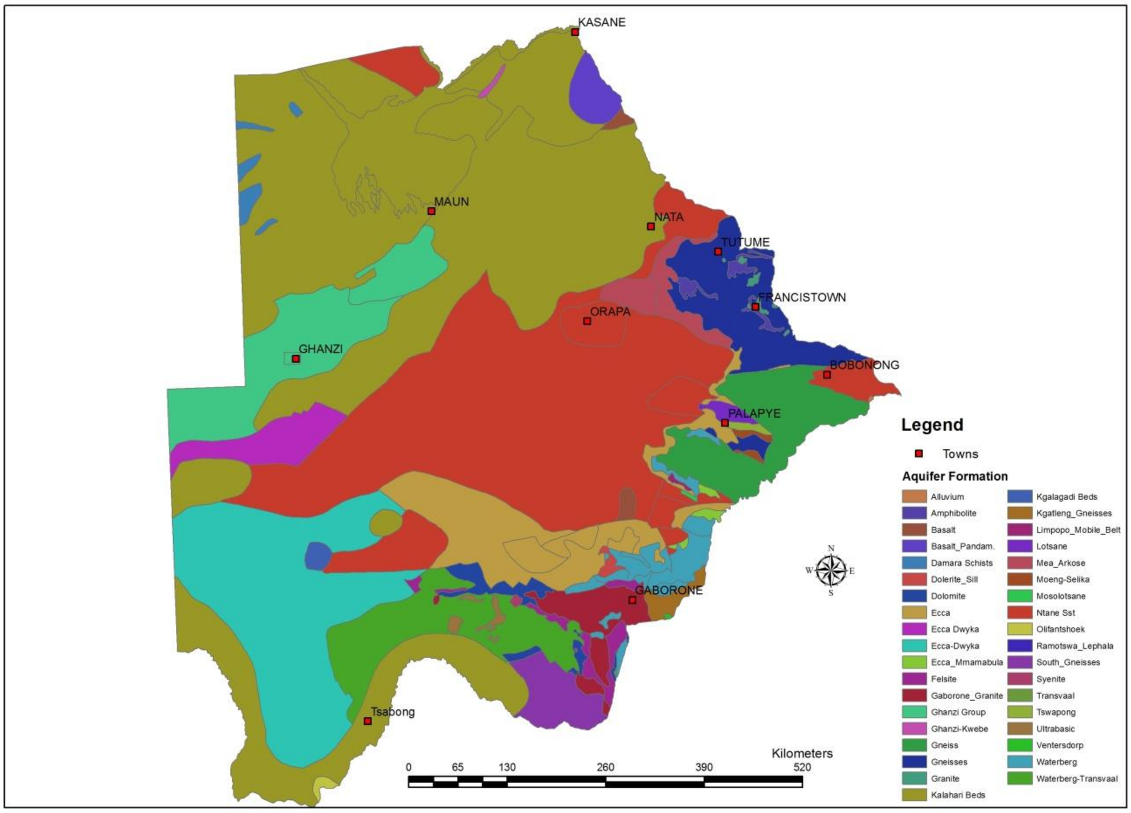
Figure 28: National Water Supply by source

Source: Centre for Applied Research and Department of Water Affairs (2014)

It is estimated that the country groundwater resources is approximately around 100 billion m^3. Various studies have estimated recharge rates with markedly different estimates. For instance Department of Water Affairs (2013) estimates recharge at approximately 96 million m^3 $year^{-1}$ while Department of Surveys and Mapping (2001) estimated it at an average of 1600 million m^3 $year^{-1}$. Map 3: depicts the identified aquifers and water quantity. Some of the most important aquifers in the country are transboundary and will require corporation between the neighbouring countries.

Some of the identified transboundary aquifers include:

- the Ramotswa and the Pomfret-Vergelegen (or Khakhea/Bray) dolomite aquifers, shared with South Africa
- the South West Kalahari/Karoo aquifer, shared with South Africa and Namibia
- the Northern Kalahari/Karoo Basin, shared with Angola, Namibia and Zambia
- possibly groundwater in the Lokalane-Ncojane Basin, shared with Namibia
- the Tuli Karoo Sub-basin, shared with South Africa and Zimbabwe
- the Eastern Kalahari/Karoo Basin, shared with Zimbabwe and
- the Nata Karoo Sub-basin, shared with Namibia and Zimbabwe.



Map 3: Aquifers Distribution in the country

Locally, there are some wellfields which play an important role in augmenting surface water resources in Botswana. These are summarized in Table 4 below.

Table 9: Wellfields and their yields

Well field	Demand (m^3/day)	Yield (m^3/day)	Yield (Mm^3/Year)
Kang	3525	7860	2.9
Matsheng	1680	9637	3.5
Botlhapatlou	14000	14000	5.1
Bobonong	6500	6289	2.3
Masama	25000	25000	9.1
Maun	13700	24650	10.1
Total	**64405**	**87436**	**33**
Source: Department of Water Affairs			

Surface water stocks include rivers (perennial, ephemeral), delta, lakes, pans and dams. There are two (2) perennial rivers being the Okavango and Chobe rivers all located in the north western part of the country. The perennial rivers are supplied by major rivers from neighbouring countries mainly Angola and Zambia and are transboundary. Therefore, use of water resources from these rivers is governed by transboundary legislative.

Ephemeral rivers are dammed to supply major settlements (towns and villages). They are all located in the eastern part of the country which is characterized by the hard veldt. Table depicts major dams, their capacity and safe yield in million m^3.

Table 10: Dams in the country and their capacity

Dam Name	Full Supply Capacity (Mm3)	Safe Yields (Mm3)
Gaborone	140.5	9.4
Bokaa	18.5	4.9
Nnywane	2.3	0.6
Shashe	87.9	25.3
Letsibogo	100	24
Ntimbale	26.4	3.6
Dikgatlhong	400	62
Lotsane	40	6.6
Thune	10	10

Source: Centre for Applied Research and MMWER, 2015

Water flows

Water resource is characterized by inflows and outflows. The inflows are additions to the water stocks (dams, rivers and aquifers). They are runoffs into the dams, rivers and aquifer recharge. Inflow into the dams is totally dependent on rainfall-runoff events and therefore highly variable, one of the characteristics of a semi-arid precipitation. Figure 29: Annual inflows into WUC dams in million m3 **Figure 29 and Figure** show inflow into selected dams and total inflow into WUC dams respectively.

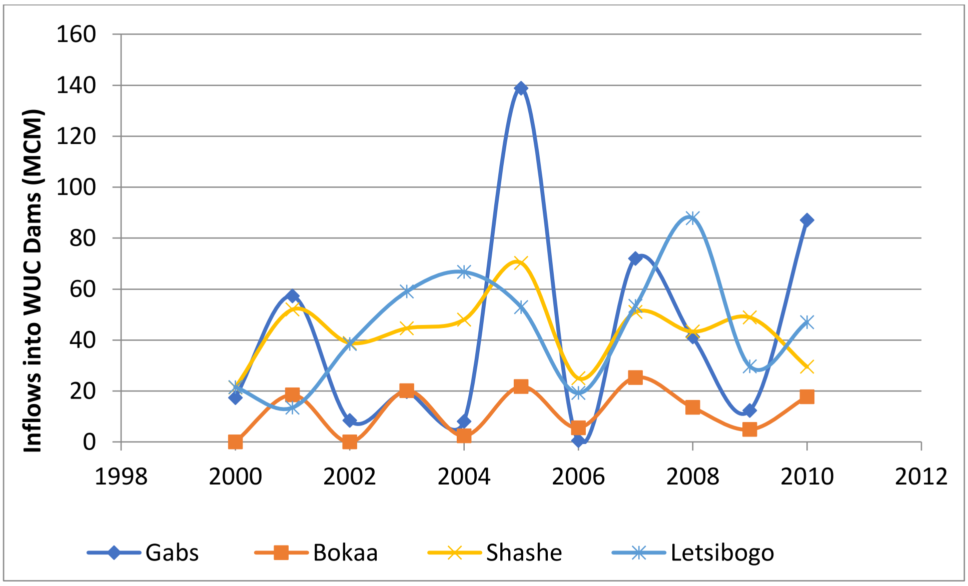


Figure 29: Annual inflows into WUC dams in million m^3

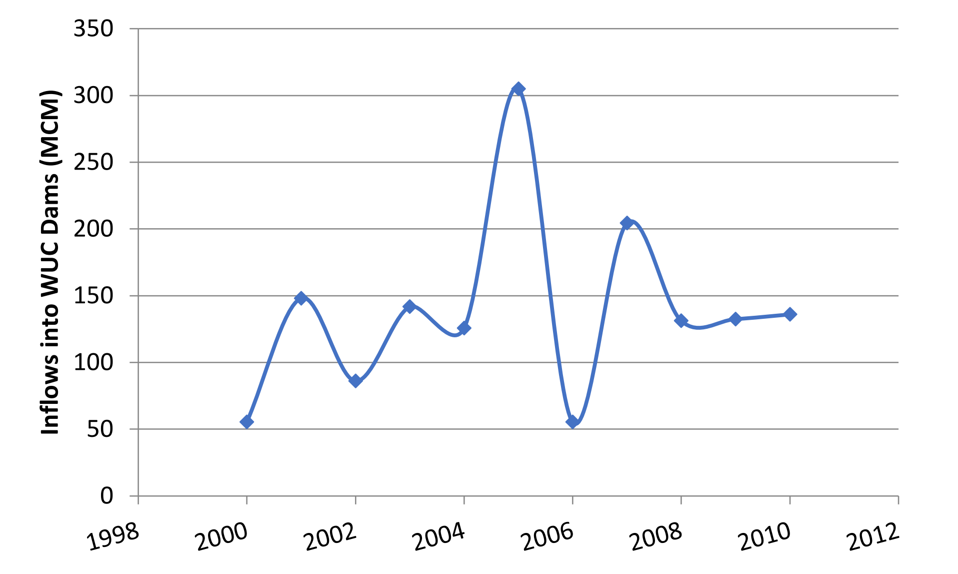


Figure 30: Total inflow into WUC in Million m³

Two critical outflows which will be affected by climate change are abstraction and evaporation. Water abstraction is driven by economic uses mainly agriculture, domestic and industrial. WUC dam abstraction supplies the domestic, industrial, commercial and communal sectors. Mining is mainly supplied from the aquifers. **Figure** depicts abstractions from the WUC over time. With the exception of Letsibogo Dam, all the selected dams are showing an upward abstraction due to increases in population and economic growth. Letsibogo abstraction depicts oscillation as characterized by drought episodes. Abstraction from Letsibogo picks during drought as it acts as a backup storage for NSC to supply Greater Gaborone.

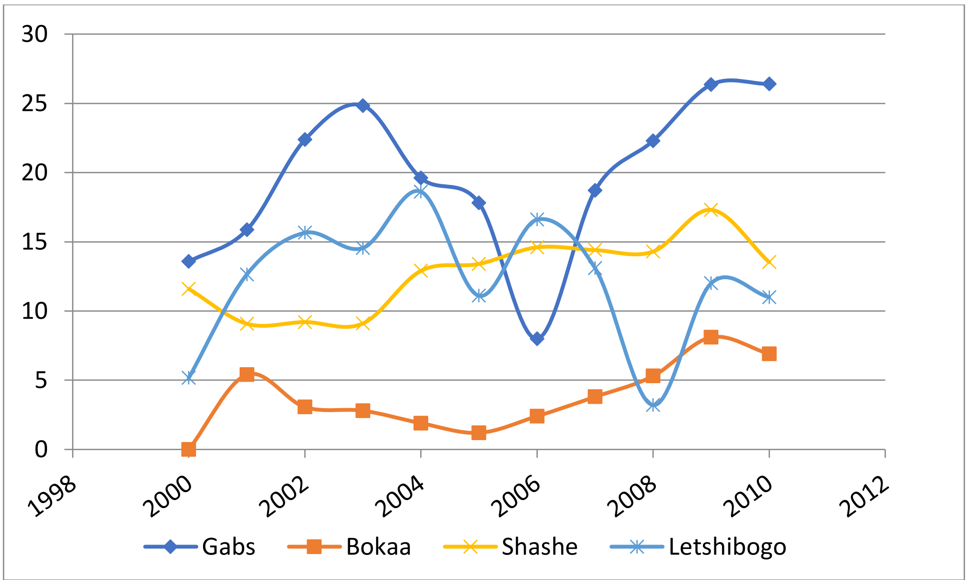


Figure 31: Abstraction from the selected dams over time

Evaporation from the dams is highly significant due to high temperature and the large surface area of the open water bodies (dams). It is estimated that evaporation accounts for more than 58 % of dam water outflows and each dam losses approximately 26% of water to evaporation. Figure depicts water outflows from the selected dams in the country.

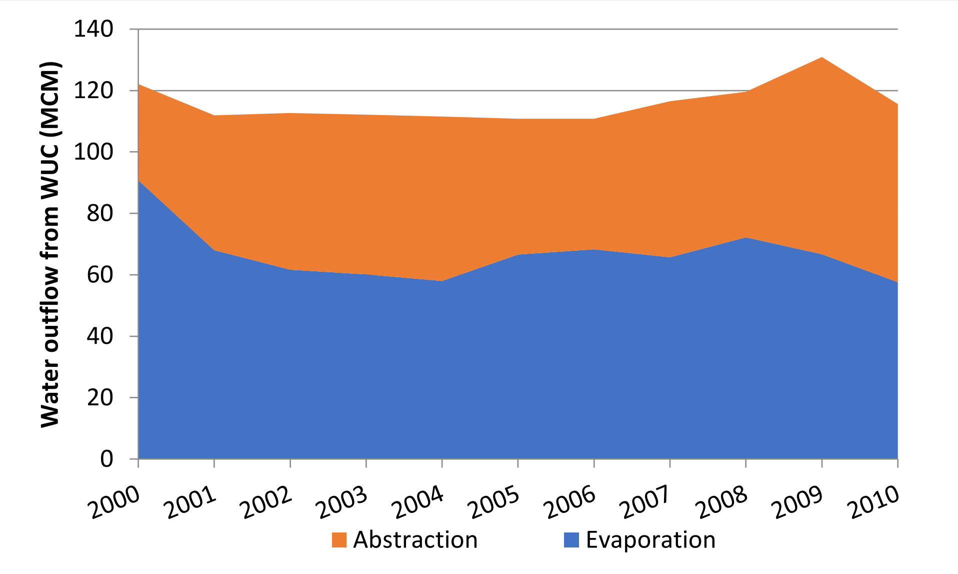


Figure 32: water outflow from the WUC dams (MCM)

Linkages between socio-economic, climatic variables and water resources

Water resources in the country is wholly driven by climatic and socio-economic variables mainly precipitation, temperature, population and economic development. The climatic variables determine inflows (recharge and runoff) into the aquifers and dams respectively. Temperature on the other hand determines the outflow through evapotranspiration which is considered to be four (4) times more than precipitation. Figure 26 and Figure depicted the link between rainfall and inflow into the WUC dams while Figure shows water fluctuations in Gaborone dam with clear influence of rainfall to the water levels. The figures clearly show the high variability nature of rainfall in the country. On the other hand, socio-economic (economic growth and population) determine outflows through abstraction rate from the dams and groundwater. Figure shows population growth rates and the water consumption for the 17 major villages. Rainfall affect water abstraction through a negative feedback mechanism. When there is low annual rainfall, water levels in the dams drop and the government institutes water restrictions which results in decline in water supply.

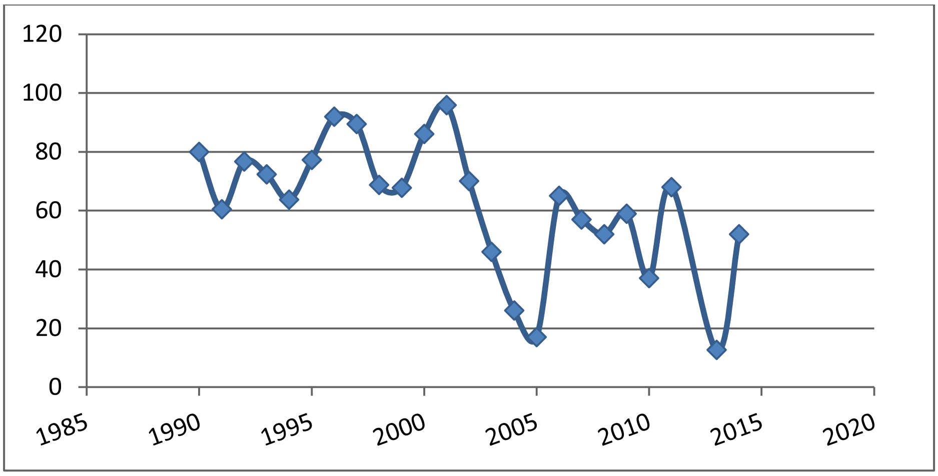


Figure 33: Gaborone Dam levels by percentage of full capacity and rainfall

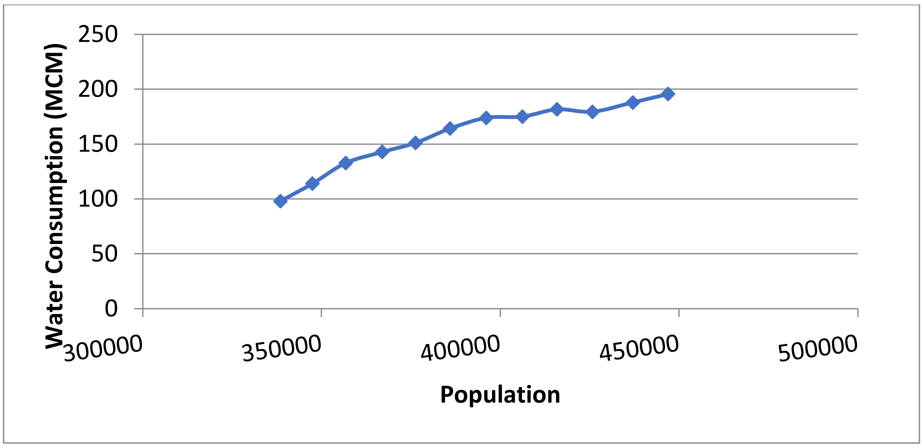


Figure 34: Water Consumption for 17 major villages over time (MCM)

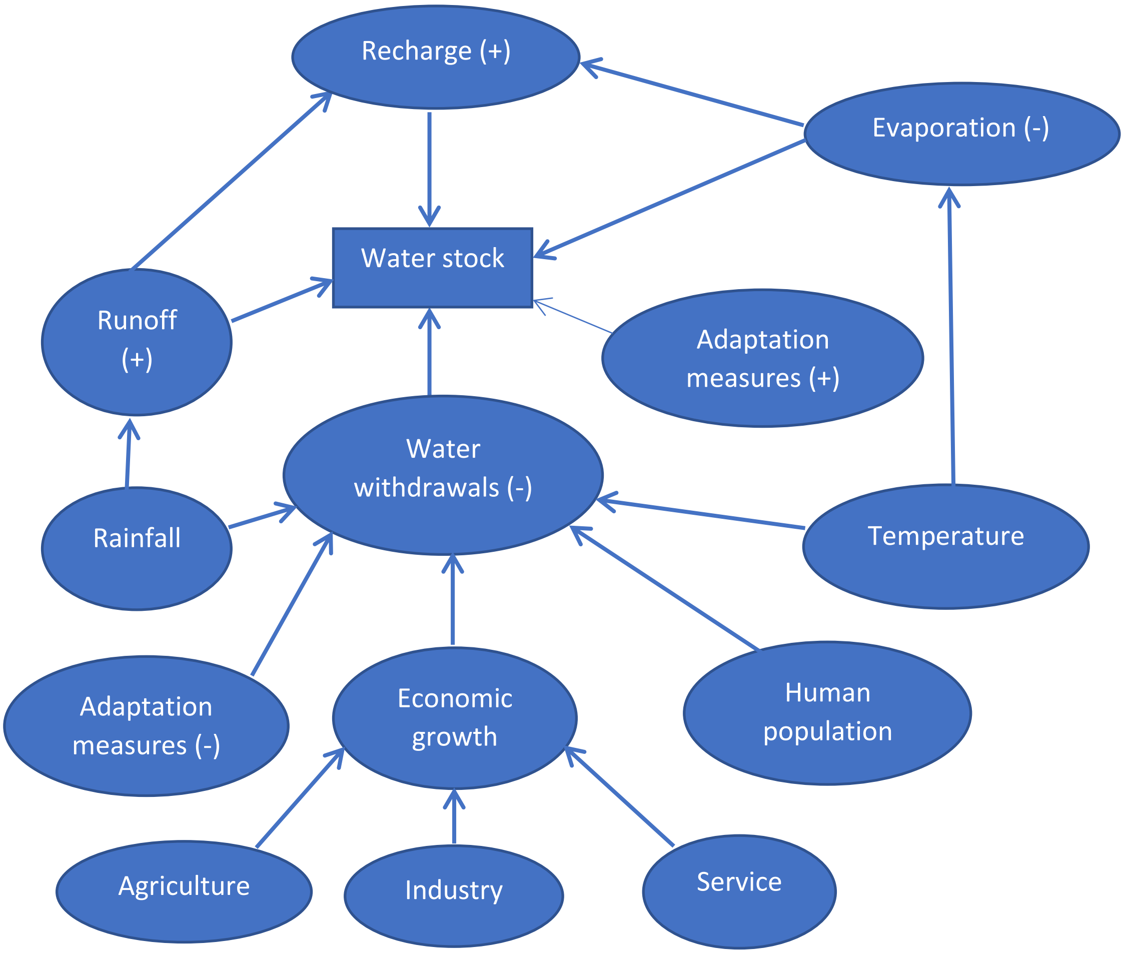


Figure 35: Linkages between climatic variables and surface water resources

Environmental risks in the water sector

Climatic variability of the country results in various risks to the water sectors. These risks are associated with extreme events such as *El Nino* and *La Nina Southern Oscillations*. The climatic/environmental risks that are associated with extreme climatic event include flooding, droughts and water scarcity and heat waves. Some of the environmental risks in the water sector that are associated with the climatic conditions include:

- Water Municipal (urban and rural) water supply failure:
- Flooding and damage to water facilities: Groundwater depletion and excessive drawdown:

- Increased sedimentation and siltation in dams and rivers: Water pollution:

2.10.5 Vulnerability assessment of the water sector

Vulnerability assessment of the water sector was based on the top-down approach as depicted in

Figure below.

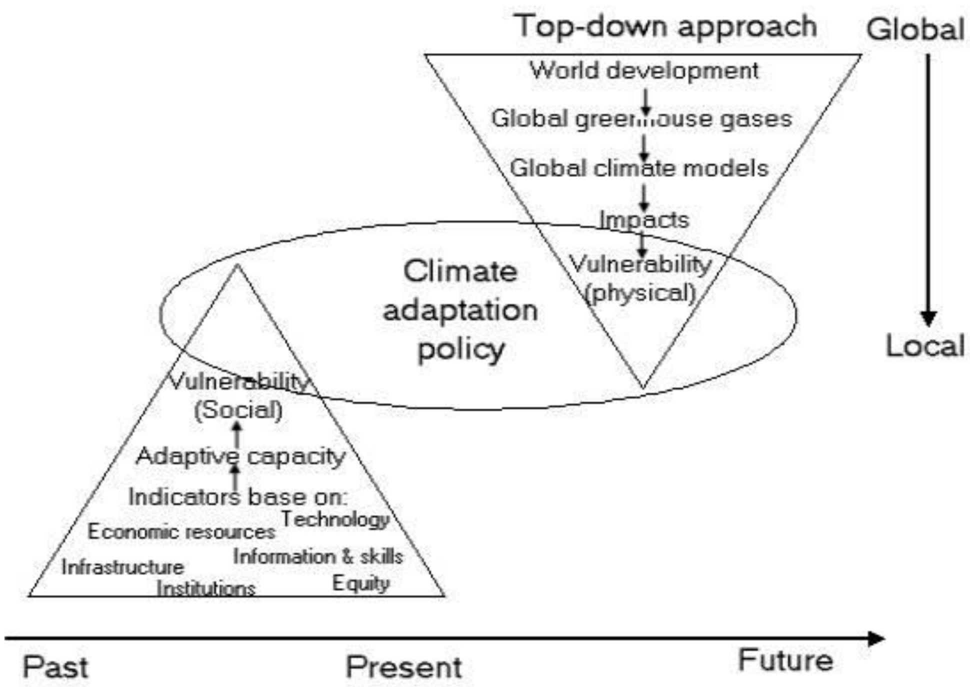


Figure 36: Top-down and bottom-up approaches to assessing vulnerability and adaptation.

Source: Dessai and Hulme, 2004.

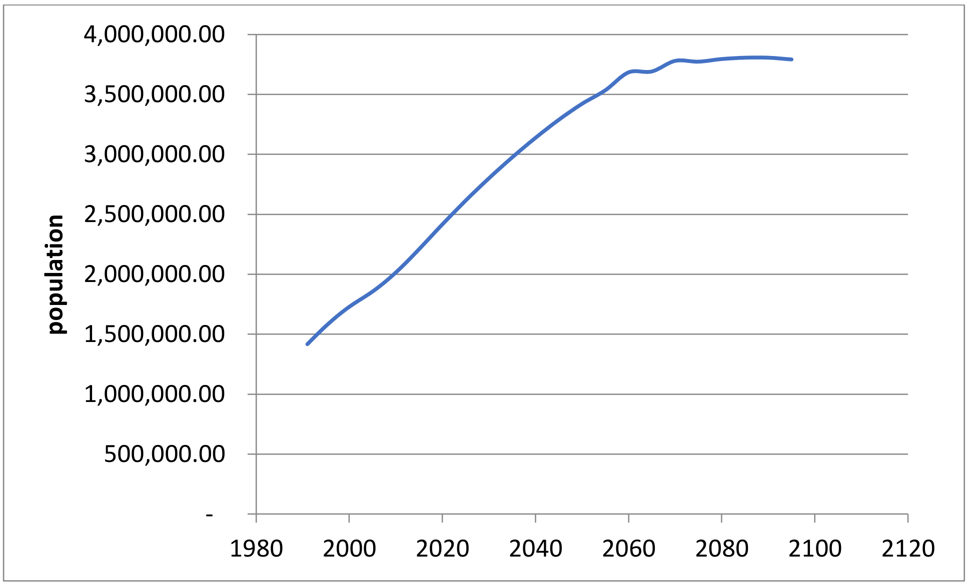
Consequently, vulnerability of the water sector is a function of sensitivity of the water sector to climate change and the adaptive capacity of the system to climatic variability (Dessai and Hulme, 2004; IPCCC, 2009, 2011). Highl sensitivity water system to climate change impacts coupled with low adaptive capacity increases the vulnerability of the water resources. Moreover, surface water and groundwater vulnerability differ markedly due to their linkages with climatic variables. Whilst surface water resources are highly exposed to climate change through increase in temperature and reduced rainfall, groundwater is sensitive to climate change through reduced recharge and increased abstraction to meet the water demands. Therefore, climate change could transfer pressure to groundwater through scarcity of surface water resources.

Climate and socio-economic scenarios are developed and used to perturb the water system to determine the sensitivity of the water sector to climate change. Moreover, the adaptive capacity of the country in dealing with climate change impact was assessed. A combination of the sensitivity analysis and adaptive capacity of the system was assessed to determine the vulnerability of the water sector to climate change.

2.10.6 Socio-economic scenarios

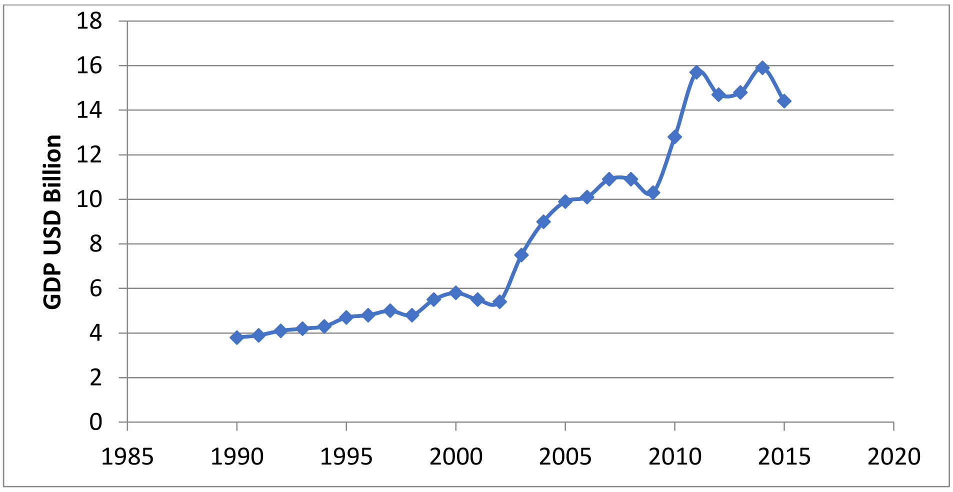
Socio-economic variables in coordination with climatic variables results in vulnerability of the water sector to climate change. The socio-economic variables affect water demand which results in water stress. The socio-economic variables that are relevant when assessing the vulnerability of the water sector to climate change are population and economic growth as measured through Gross Domestic Product (GDP).

Population growth scenario for Botswana was adopted from the United Nations WPP based on medium variant. On the basis of the projection, it is estimated that by 2050 national population will be approximately 3.421 million.



Using the projected national population, the proportion (percentage) of settlement/town was assumed and used to project water demand by 2050.

Botswana experience accelerated growth over the year mainly due to revenue from the mining sector. The growth rate was estimated at around 3% with some significant declines mainly due to the global dips in diamond demands.



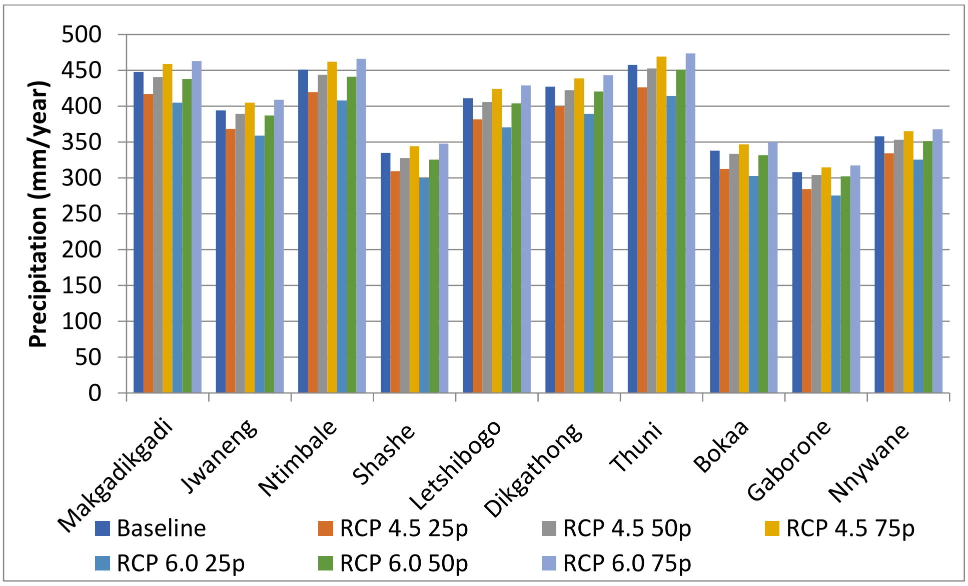


Figure 37: Projected precipitation for dam sites and towns

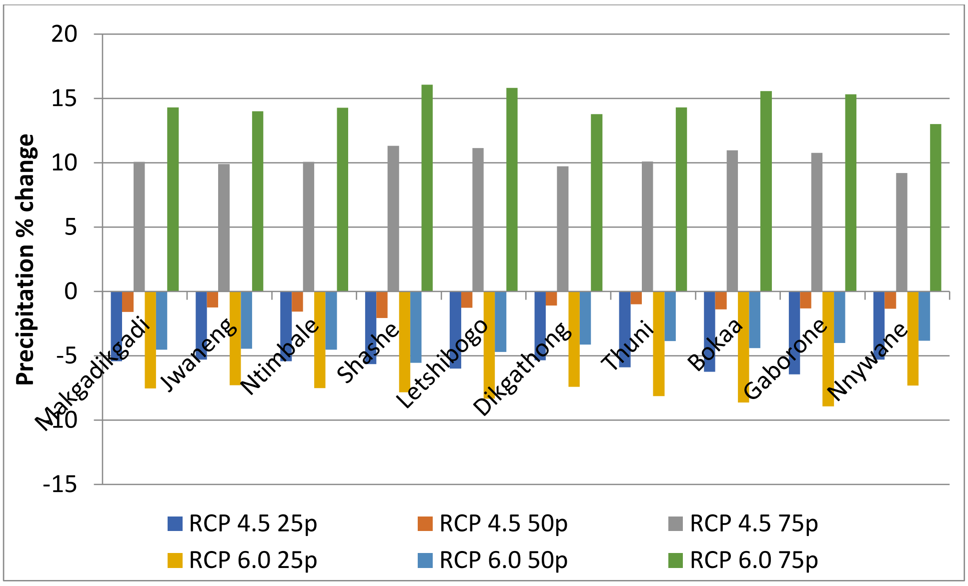


Figure 38: Percentage change in precipitation for the dams and towns

In addition to simulating temperature and precipitation change, extreme event mainly drought was analysed. Drought probability was assessed for different severity and duration analysis using the applied Standard Precipitation Evapotranspiration Index (SPEI) method. The results indicate that even with a projected increase in annual precipitation, increasing temperatures could intensify evapotranspiration, thus the probability of drought severity and duration could increase under all the selected RCP scenarios. In RCPs, the probability of drought (moderate, severe and extreme) increased markedly by 2050 (Annex 13).

Climate change impact on water resources

Climate change will affect water resources through changes in precipitation and temperatures. Changes in precipitation will affect water flow into dams, pans and also through groundwater recharge. Additionally, temperature change will have a significant effect on evaporation from the water bodies. Currently, water loss from evaporation extremely high constitutes approximately 50% of outflows. Therefore, changes in evaporation would have significant impact on open water resources. On the basis of the projected temperature and precipitation changes, table 2 depicts projected inflow to major dams in the country. Figure 14 on the other hand depicts percentage in water inflow due to changes in precipitation.

Table 11: Projected water inflow into major dams

Dam Name	Historical	2040 RCP4.5 50p	2050 RCP4.5 25p	2050 RCP4.5 75p	2050 RCP6.0 50p	2050 RCP6.0 25p	2050 RCP6.0 75p
Bokaa Dam	16.70	15.44	14.69	16.05	14.69	13.97	15.78
Dikgatlhong Dam	127.14	116.46	109.13	121.66	11350	102.68	119.47
Gaborone Dam	27.68	25.64	24.26	26.56	24.88	23.02	26.11
Letsibogo Dam	84.08	77.27	72.85	80.83	74.74	68.82	79.52
Lotsane Dam	92.00	84.79	79.59	88.86	82.11	75.13	87.57
Ntimbale Dam	7.05	6.45	6.04	6.74	6.23	5.68	6.62
Nnywane Dam	1.63	1.51	1.43	1.56	1.46	1.36	1.54
Shashe Dam	47.97	44.00	41.30	45.96	42.53	38.91	45.16
Thune Dam	0.47	0.43	0.41	0.45	0.42	0.39	0.45

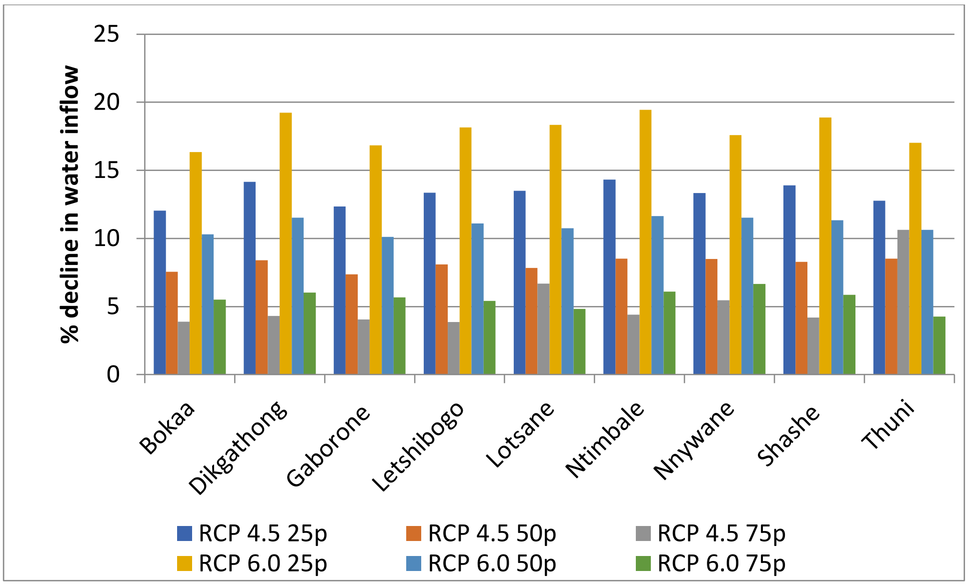


Figure 39: Percentage decline in water inflow based on Different RCP by 2050

As shown in figure 15, decline in water inflow will vary markedly from 4% to 19% depending on the RCP used. Cumulatively, climate change will have a significant effect on inflow as depicted in figure 15 below.

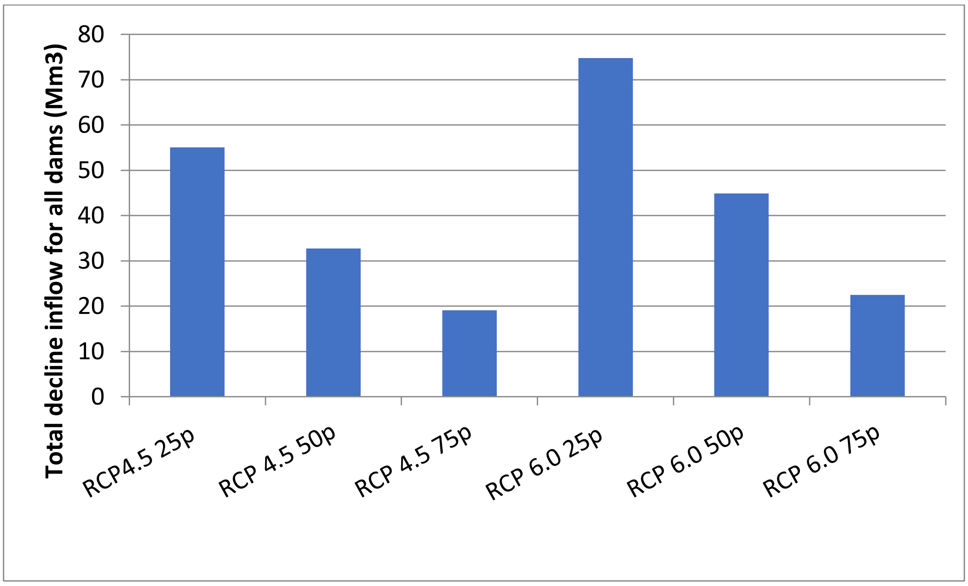


Figure 40: Total decline inflow for all the dams

Another physical direct impact of climate change on water resources will be through evaporation rates. There is a general consensus amongst scientists that decrease in rainfall and increase in temperature will results in increase in evapotranspiration (Abtew and Melesse, 2012, Azam and Farooq, 2005; and bates *et al.*, 2008). Consequently, Botswana is one of the countries that are projected to have an increase in temperature by as much as 2 ^{o}C and a decrease in precipitation. The Hargreaves (1985) equation was used to estimate the annual mean PET changes as follows:

$$PET = 0.0023 * RA * (T\text{-}mean + 17.8) * TD^{0.5}$$

Where;

T-mean is the annual temperature,

TD is the mean temperature range (i.e. the difference between annual maximum and minimum temperature),

RA is the radiation on top of atmosphere, and;

PET is Potential evapotranspiration in mm / day.

In estimation evaporation change, RA and TD were held constant as they will not be affected by climate change. Therefore the PET change is close link to mean temperature change.

As evaporation is a function of surface area which is dependent on water inflows, long term observed water inflow and surface were used to estimate evaporation loss from the dam sites. Table 3 depicts historic water volumes in the dams which were used to estimate evaporation losses.

Table 12: Observed water volumes for the dams

					2050 evaporation loss change (%)					
					RCP4.5	RCP4.5	RCP4.5	RCP6.0	RCP6.0	RCP6.0
Dam name	Annual water intake (Mm3/yr)	Water Surface Area (km2)	Baseline PET (mm/m2/yr)	Baseline evaporation (Mm3)	50p	25p	75p	50p	25p	75p
Bokaa Dam	16.70	5.69	1723	3.925	3.71	3.12	4.47	5.13	4.31	6.17
Dikgatlhong Dam	127.14	38.32	1723	26.411	4.12	3.42	5.04	5.69	4.70	6.94
Gaborone Dam	27.68	16.11	1718	11.069	3.84	3.28	4.62	5.30	4.52	6.37
Letsibogo Dam	84.08	15.38	1719	10.574	4.04	3.43	4.93	5.57	4.72	6.81
Lotsane Dam	92.00	10.33	1760	7.272	4.26	3.53	5.21	5.86	4.88	7.19
Nnywane Dam	7.05	0.44	1624	0.288	4.01	3.30	4.89	5.55	4.56	6.76
Ntimbale Dam	1.63	2.69	1665	1.793	3.98	3.36	4.71	5.48	4.63	6.49

Shashe Dam	47.97	14.82	1717	10.176	3.71	3.11	4.42	5.14	4.32	6.12
Thune Dam	0.47	0.11	1812	0.080	4.19	3.49	5.15	5.79	4.83	7.09

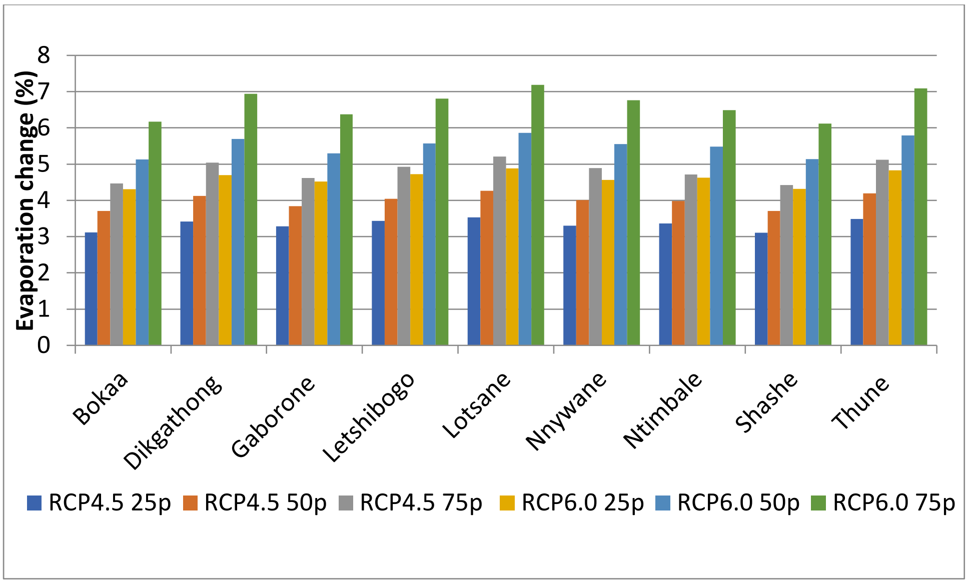


Figure 41: depicts projected total evaporation loss from the dams due to increase in temperature

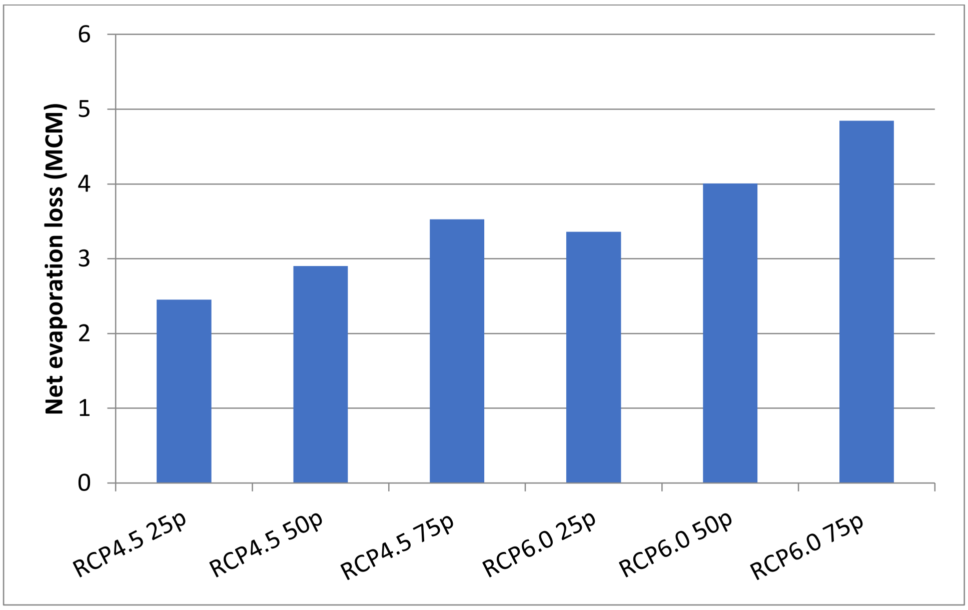


Figure 42: Net evaporation loss from the dams in the country

On the basis of the projected increased evaporation and decline in inflow, the cumulative impact of climate change to surface water resources (dams) is a reduction of water from a low range of 22 MCM to a high of 75 MCM by 2050.

Another impact of climate change to water resources is to increase demand for water consumption particularly outdoor activities (demand for swimming pools and gardens). However, due to lack of disaggregated data on domestic consumption, this impact was not assessed.

Water demand over time and effect of climate change

Water demand for the centers that are currently supplied by the dams and the NSC were projected for 2050 based on socio-economic scenarios (population and GDP). The water demand was compared with the long-time water availability and change in water resources (reduced inflow and increased evaporation) due to climate change. By 2020, it is projected that total water demand for greater Gaborone will be approximately 186.5 Mm^3 year and this could surpass 250 Mm^3 year by 2050 assuming no restrictions in that year. On the basis of the estimate the water demand table 5 depicts a ratio of water inflow to water demand based on the climate scenarios. The impacts of climate change will be to slightly reduce the capacity of the dams to meet the dams by 1 month to 3 months assuming no inflow.

Table 13: Demand supply ratios under baseline and 2050

	baseline	RCP4.5 25p	RCP 4.5 50p	RCP4.5 75p	RCP 6.0 25p	RCP6.0 50p	RCP 6.0 75p
Inflows	404.72	349.813	371.99	388.67	329.96	418.69	382.16
demand	186	250	250	250	250	250	250
demand – supply ratio	1.6	1.39	1.48	1.55	1.3	1.65	1.5

Groundwater water resources and climate change

Climate change will affect groundwater through increased abstraction rates and recharged rates. A combination of increases in droughts, reduced inflow into the dams and increases in evaporation will results in more reliance on groundwater resources particularly the developed wellfield of Masama, Palla Road and Ramotswa. This will be more pronounced during the drought periods which are projected to increase significantly.

On the basis of projected decline in rainfall, increase in temperature and evaporation, it is projected that recharge would also decline. Lastly, the overall effect of climate change would encourage groundwater abstraction and hence water mining in the country. Thus, increase incidents of surface water scarcity will encourage water depletion by 2050.

Depth-Duration-Frequency (DDF) of extreme precipitation was analyzed for each subproject location based on the closest historical time series weather observation station. Selected extreme precipitation values were selected, including 5, 10, 50 and 100 average return intervals (ARI). Annex 14 depicts extreme event analysis for extreme precipitation by 2050. The results indicate that extreme precipitation could increase more rapidly than mean precipitation which is the most noticeable changed parameter for the RCP. Therefore, incidents of flooding are likely going to be experienced in the country which could cause damage to water infrastructures particularly dams.

Feasible water adaptation strategies

Climate change could have slightly impacts on our water resources by the year 2050. These impacts include reduced precipitation which will results in reduced water inflows and increased evaporation which will results in water loss from the dams. Additionally, it is projected that droughts frequency and intensity in the country could worsen. From the baseline, acute water scarcity is experienced during the drought years. Therefore, climate change could worse water situation for the country.

It is therefore important that the country put in place comprehensive robust water adaptation strategies to avert future water crisis. Incidentally, the country has made significant head-start in dealing with water situation. These water adaptation strategies comprise of both demand and supply options. Therefore, the government has taken a stance of adopting an Integrated Water Resource Management (IWRM) strategy as a holistic management strategy of resolving water scarcity in the country. IWRM puts equal weight to both supply and demand side in managing water resources. These IWRM strategies comprise of short term, medium and long term measures to effectively manage the country's limited water resources. These measures are discussed below.

Development of Water transfer schemes and the wellfield

One of the factors that contribute to pronounced water scarcity in the country is the uneven population distribution to the eastern part of the country along the railway line. In order to reduce water scarcity where there is majority of the population, the government initiated a North South Carrier scheme (NSC) in the late 1990s. NSC is a water transfer Scheme that transmits water from the north of the country to the south to meet the rising water demands. The NSC has three (3) phases with phase 1 completed in 1999 and second phase of the scheme commenced in 2012. In future settlements such as Kanye, Moshupa and others will be connected to the pipeline. During the periods of 2012/13 and 2013/14, the transfer scheme supplied 23.6 and 36.1 Mm^3 respectively to Gaborone and the surrounding settlements (Centre for Applied Research and MMEWR, 2015). It is also envisaged that a pipeline will be constructed from Kazungula and Lesotho to transport water to water deficit part of the country.

Linked to the construction of the pipelines is the development of the wellfields in the country. The country has identified significant aquifers which will be connected to the water pipeline.

Water demand management strategies

Water demand management strategy is an innovative approach to managing scarce water resources through optimization of available water resources. It emphasizes on water conservation, increase water use efficiency and reducing water losses during reticulation. This is a shift from the conventional supply oriented management to integrating water demand management strategy. One of the tools that is used in the country to enhance water demand management strategy include the use of economic instruments mainly water pricing. Water pricing scheme is set-up tariff which initiatively encourage water conservation. Other strategies that require exploration include relocation of the water intensive industries to water abundant areas such as Ngami land, Chobe and Okavango.

Another WDS include promotion of water efficiency at the agricultural sector. Agriculture sector is one of the major water consumers and its share to water consumption is likely going to increase due to negative feedbacks from climate change impacts. Thus, it is important that water efficiency in the agricultural sector is promoted. There are various ways through which water efficiency can be improved such as use of computer controlled drip irrigation (Tindula et al., 2013). In addition, it is important that emphasis is put on use of less water intensive crop.

National Action plan for implementation of water adaptation strategies

The purpose of the Water National Adaptation Action Plan (WNAAP) is to guide the implementation of the feasible and viable water adaptation projects to ensure that the country is fully climate proof by the year 2050. This is achieved by drawing a roadmap of the activities to be implemented. Each of the identified adaptation projects is highlighted and the actions to be their implementation as described below.

Time plan for implementation

It is envisaged that the plan will be implemented between 2020 and 2030, to the extent that after 2030, the country would be climate proof. The target is to ensure that all projects are implemented by 2030.

The action plans

The action plan details priority water projects to be implemented to reduce the country's vulnerability to climate change and also increase the country resilience to the impacts of climate change. The priority water projects include smart water meters, Water Transfer Scheme (WTS), National Flood Management (NFM) for flooding and siltation control and re-engineering of the dams to withstand flooding and artificial groundwater recharge. These priority areas are discussed below.

Table 14: Feasible and viable adaptation measures

Adaptation options	Measures	Methods	Status	Budget	Lead Agent
WDM	water conservation campaigns promoting conservation method such as showers instead of bath, timely attending to leaks, use cup for brushing teeth	• Television, • Newspapers • Loud speakers	Implemented during drought periods	TBD	WUC
	water restrictions	• ban on gardening, car wash, use of grey water for construction and swimming pools, • implementation of the smart meters	Implemented during drought periods	TBD	WUC
	water efficiency in agriculture	• use of computerised drip irrigation system,	On-going	TBD	MoA

		• zero to low tillage, • planting across slopes, • plant less water-intensive crops			
	Urban water design	• retro fitting to encourage water reuse • encourage soft surface around building	Planned	TBD	DTCP / DWS

	water reuse and recycling	• treatment of the grey water	On-going	TBD	DWS
water supply	construction of Transfer scheme	• development of transfers schemes • development of wellfields	On-going and some on pipeline	TBD	MLWS WUC/DWS
	Rainwater harvesting	• construction and installation of the water tanks and underground tanks • construction of earth dams for agriculture at the rural areas	On-going	TBD	DWS / MoA
	strengthening dams to accommodate extreme floods	• re-engineering of the dams and strengthening weak points	To be considered	TBD	MLWS

		• encourage revegetation of catchment areas			
	land use planning within dam catchment areas	• encourage revegetation in the catchment to reduce flooding and siltation	To be considered	TBD	MLWS
	enhance groundwater recharge	• induce water recharge through pumping surface water underground	Planned	TBD	DWS

Water smart meters

Table 15: Responsibility, timeframe and barriers for Smart water meter

Activity	Responsible agent	Timeframe	Financing	Barriers /risks
Feasibility study	WUC and consultant	6 months	• Users fees • Donor funding from climate change adaptation funds	• Lack of finance to undertake the project
Consultation	WUC and consultant	2 months		• Reluctance of the service provider to switch to smart meters
Piloting	WUC	1 year		• Lack of buy-in from the government/politicians
Rolling out the programme	WUC and consulting engineers	4 years		• Lack of institutional capacity (technological expertise) to deal and process remotely acquired customer data

Re-engineering dams to accommodate flooding

Table 16: Responsibility, timeframe and financing for dam re-engineering as an adaptation measure

Activity	Responsible agent	Timeframe	Financing	Barriers /risks
Structural inspection of dam walls and design drawings	WUC and engineers	6 months	• GoB to raise financing through loans and water users fees • Donor funding from climate change adaptation funds	• Lack of finance to undertake the project • Lack of buy-in from the government/politicians due to low priority area
Audit report on structure of dams	Audit engineers	4 months		
Re-strengthening of dam walls	WUC	5 year		

Artificial groundwater recharge

Table 17 depicts the responsibility, timeframe for implementation, financial mechanism for implementation and barriers and risks for the proposed project.

Table 17: Responsibility, timeframe and financing for artificial recharge

Activity	Responsible agent	Timeframe	Financing	Barriers /risks
Feasibility to identify aquafers suitable for artificial recharge	DWA and consultants	12 months	• GoB • Donor funding from climate change adaptation funds	• Lack of finance to undertake the project • Lack of buy-in from the government/politicians • Resistance from environmental NGOs
Resource mobilization to raise finance to implement the programme	DWA	6 months		
Technical design of the storage facilities, pipelines and recharge methods	DWA and consultants	5 year		
Piloting of the programme on selected aquifer	DWA	2 years		

Evaluation of the piloting exercise	DWA	1 year		
Upscaling to the national level	DWA	5 years		

Water Transfer Schemes

Table 18 depicts the responsibilities, timeframe for implementation, financial mechanism for implementation and barriers and risks for the proposed project.

Table 18: Responsibility, timeframe and financing for dam re-engineering as an adaptation measure

Activity	Responsible agent	Time frame	Financing	Barriers /risks
Detailed studies on water demand distributions	DWA and consultants	12 months	• GoB • Donor funding from climate change adaptation funds	• Lack of finance to undertake the project • Lack of buy-in from the government/politicians
Resource mobilization to raise finance to implement the programme	DWA	6 months		
Technical design of WTS and aquifers	DWA and consultants	5 year		

Construction of the pipeline	Independent contractors	10 years		• Resistance from environmental NGOs

Natural Flood Management

Table 19 depicts the responsibility, timeframe for implementation, financial mechanism for implementation and barriers and risks for the proposed project.

Table 19: Responsibility, timeframe and financing for dam re-engineering as an adaptation measure

Activity	Responsible agent	Timeframe	Financing	Barriers /risks
Water catchment Land use Policy	DWA	12 months	• GoB • Donor funding from climate change adaptation funds	• Lack of finance to undertake the project • Lack of buy-in from the government/politicians • Resistance from environmental NGOs
Water Catchment Land use maps	DWA	6 months		
Establish PES	DWA	5 year		

2.10.7 Conclusions

Water resources in the country is highly driven by climatic variables mainly temperature and rainfall. These variables (temperature and rainfall) act jointly to determine the water stocks and flows. Precipitation determines the inflows and recharge (positive flow), temperature on the other hand affect outflow (negative flows) through evaporations. Therefore, this water-climate relationship was used to assess the vulnerability of the water sector to climate change in the country. Climate and socio-economic scenarios were constructed to determine the vulnerability of the water sector to climate change. Using the GCM/RCM ensemble and RCP 4.5 and 6.0 the results indicate that temperature could increase by between 1.5 ^{o}C and 2 ^{o}C. On the one hand, the model indicates a decrease of rainfall by as much as 15% though there are some insignificant rainfall increases for other percentiles.

These changes will have a negative impact on the water resources in the country. The model indicates that by 2050, climate change will results in a decrease in water inflow into dams by between 3.5 to 19% which represent actual loss of 34 to 75 Mm3 by 2050. Using the PET equation, it is projected evaporation could increase by between 3.7% and 7% from the baseline.

On the basis of projected decline in rainfall, increase in temperature and evaporation it is projected that recharge would also decline. Lastly, the overall effect of climate change would be to encourage groundwater abstraction and hence water mining in the country. Thus, increase incidents of surface water scarcity will encourage water depletion by 2050. Overall, it is estimated that climate change will reduce the demand supply ratio by 2050.

On the basis of these results it is imperative that the country undertake significant investment on the water adaptation projects. Some of these projects which are economically feasible include:

- Investing in advanced water leak detection systems
- Introducing smart meters
- Artificial groundwater recharge
- Strengthening of the dam walls
- Construction of water transfer schemes

Implementing these feasible water project will ensure that the water resources which is already under stress conditions become less vulnerable to climate change.

2.11 Rangeland and Livestock Dynamics under Changing Climate

2.11.1 Impact of climate change on rangeland ecosystems across Botswana

Climate change and rangeland primary productivity

The historic and current rangeland productivity is characterized by high inter-annual variations and that could be partly explained by the fact that rangeland productivity in drylands is directly correlated to rainfall amount (Fajji et al 2018). The vegetation condition index indicates that there was a severe drought in Maun and Kang between 2002 and 2003 while Palapye experienced light drought during the same period. As shown in Figure 7, the vegetation condition has generally been declining in all sites between 2010 and 2017. A moderate drought was then experienced in 2015 especially in Kang and Palapye and was particularly severe in December across Botswana as shown in Figure 8. The rangeland vegetation condition slightly improved in 2017 especially in Kgalagadi and Ngami land due to high rainfall experienced that particular year. Rangeland productivity is closely coupled to rainfall (Shufen et al 2015) and this partly explains the high inter annual heterogeneity in vegetation condition. So far, droughts have been shown to critically reduce rangeland biomass by over 30 % in Botswana (Setshwaelo 2001). Moreover, Botswana rangelands are also generally degraded (Dougill et al 2016) and thus rather more sensitive to climatic shocks and this could explain the high variation observed in vegetation condition across Botswana. This Inter-annual variation in NPP is a contributing factor to vulnerability regardless of total production, because it leads to unpredictable conditions.

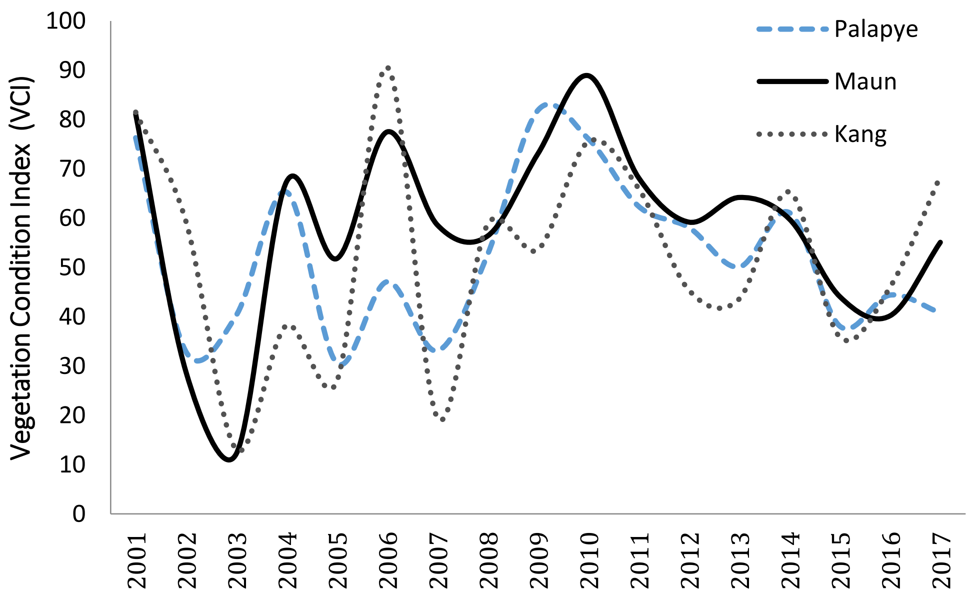


Figure 43: Historical condition of rangeland at selected sites in Botswana (figures/table should correlate)

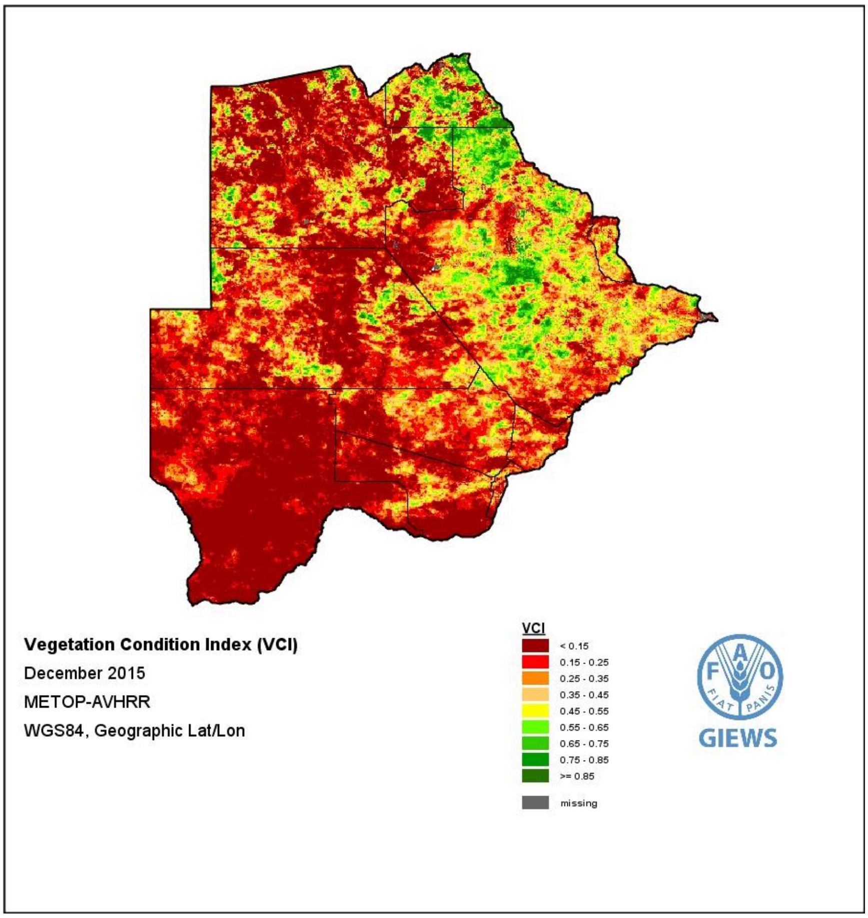


Figure 44: Vegetation condition index showing drought severity across Botswana (December 2015) (Source FAO)

Coupled Model Intercomparison Project Phase 5 (CMIP5) projections indicated a decline in rangeland productivity across Botswana especially under RCP 6.0 (Table 7). The projections suggest that by mid-century (2050), rangeland productivity may decline by approximately 20-30 percent under modest emissions (RCP 4.5) across our selected study sites. If the emissions are slightly higher (RCP 6.0), NPP is projected to decline by 38, 42 and 54 percent for Maun, Palapye and Kang, respectively, indicating that the western part of Botswana is more sensitive to climate change. The rangeland NPP is projected to decline further towards the end of the century (2070) under both RCP 4.5 and RCP 6.0. These results are consistent with other simulations done using the model 'G-Range', which also projected reduced rangeland productivity across Africa and indicated that Botswana is likely to experience 74.4 percent drop in ANPP under RCP8.5 to the 2050s (Thornton et al 2015). Despite the uncertainty associated with models, the projected decline in forage production in response to reduced rainfall and increased evapotranspiration across Botswana is a major concern as the livestock industry is totally dependent on it for feed and this threatens the sustainability of the industry and livelihood of society (Boone et al 2017). The reduced rangeland productivity is also to be further exacerbated by degradation and loss of soil fertility.

Table 20: Net Primary Productivity (g C m-2 year-1) projections at selected sites in Botswana (CMIP5)

Site	**Current**	**2050**		**2070**	
		RCP4.5	RCP6.0	RCP4.5	RCP6.0
Maun	265.1	213.5	165.6	209.6	153.4
Palapye	190.7	150.4	110.5	114.7	106.2
Kang	210.4	147.2	97.3	141.3	91.1

2.11.2 Climate change and bush encroachment

The changes in vegetation composition (herbs vs shrubs) in response to climate change are influential towards suitability of the rangelands for different types of animals (Thornton et al 2015). Historically, bush encroachment, an indicator of rangeland degradation, has been observed across Botswana (Dougill et al 2016; Kgosikoma et al 2012) and is a major current and future environmental concern. As shown in Figure 9, there is high woody plant cover in Kweneng district as observed in Matlolakgang. There are also high encroached patches in the western region such as Xanagas and the problem is prevalent in both communal and privately (ranches) grazed rangelands. The dominant encroacher species include *Senegalia (Acacia) mellifera*, *Acacia tortilis, Acacia karoo, Dichrostachys cinereae* and *Termanalia sericeae* (Moleele et al 2012*)*. These encroacher species often form impenetrable thickets that suppress the growth of the understory grasses (Stafford et al in press) and reduce the economic returns from rangelands as the carrying capacity declines.

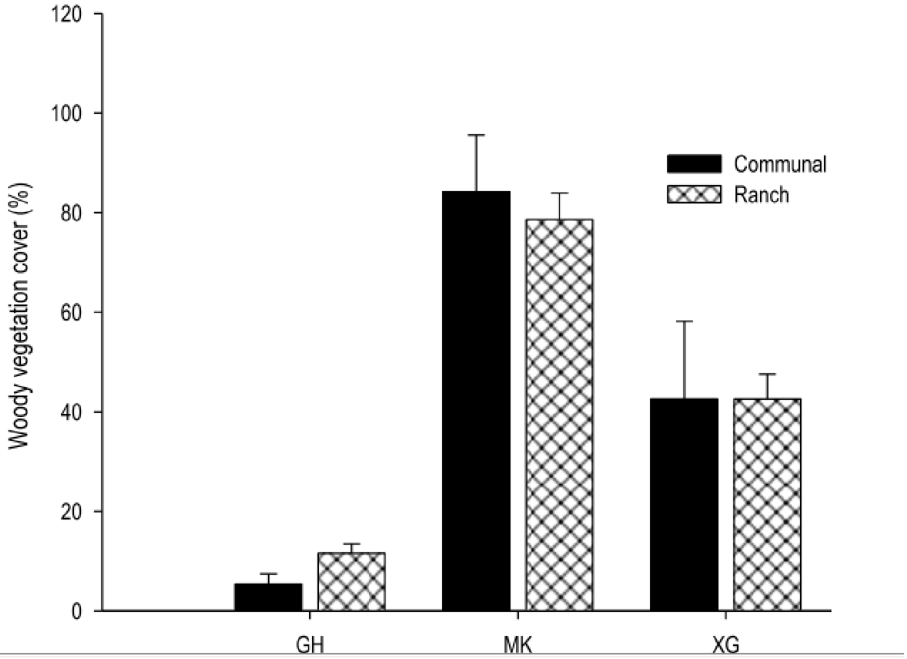


Figure 45: Woody plant cover at Goodhope (GH), Matlolakgang (MK) and Xanagas (XG) in Botswana (Kgosikoma et al 2012)

Climate change is expected to further facilitate proliferation of woody plants due to increased atmospheric carbon. The increased carbon dioxide (CO_2) in the atmosphere may shift vegetation composition favouring plants with the C_3 photosynthetic pathway (e.g. bushes) over plants that possess the C_4 photosynthetic pathway (e.g. grasses) (Smith and Smith 2001).The projected grass-shrub ratio shows great variability at both Maun and Tshane from 2020 to 2100 (Mayaud et al 2017). The Ngami land region represented by Maun is projected to have low grass-shrub ratio representing high shrub dominance especially from 2020 and 2050. The Kgalagadi ecosystem represented by Tshane also shows shrub dominance in the future though it is relatively less encroached than Maun which could be attributed to less moisture to support growth of wood plants (Eschewal 2002).

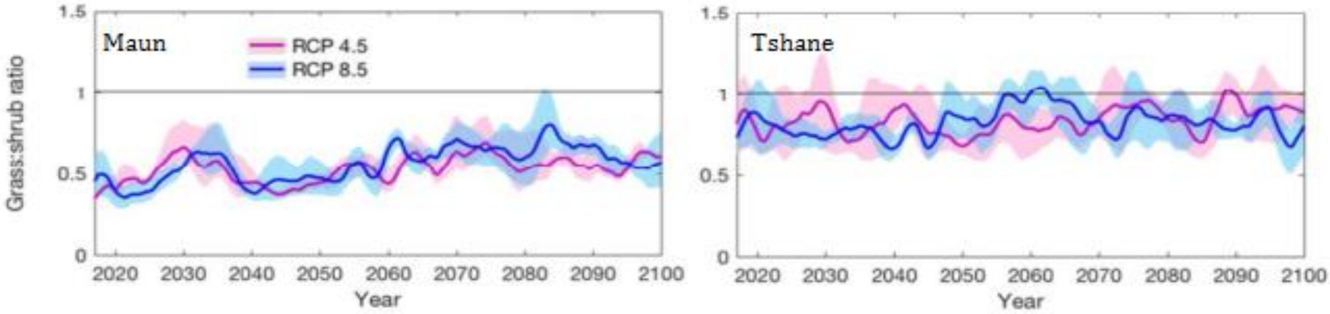


Figure 46: Grass-shrub ratio at selected sites in Botswana (Mayaud et al 2017)

2.11.3 Impact of climate change on the livestock sector

Current climate in Botswana has a strong impact on livestock productivity especially the recurrence of drought (Kgosikoma and Batisani 2016). Livestock populations in Botswana tend to increase during years of high precipitation and then decline during climatic shocks such as drought (Figure 11). The national cattle herd peaked in 2002 and then immediately declined by approximately 33 percent and further declined to the lowest number in 2007. The vegetation condition index of 2001 indicates that the rangeland productivity was high leading to increased forage supply and reduced mortality (4.9 %) of cattle. This pattern highlights the high vulnerability of the rangeland based livestock industry of Botswana to climate shocks which is likely to be exacerbated by climate change.

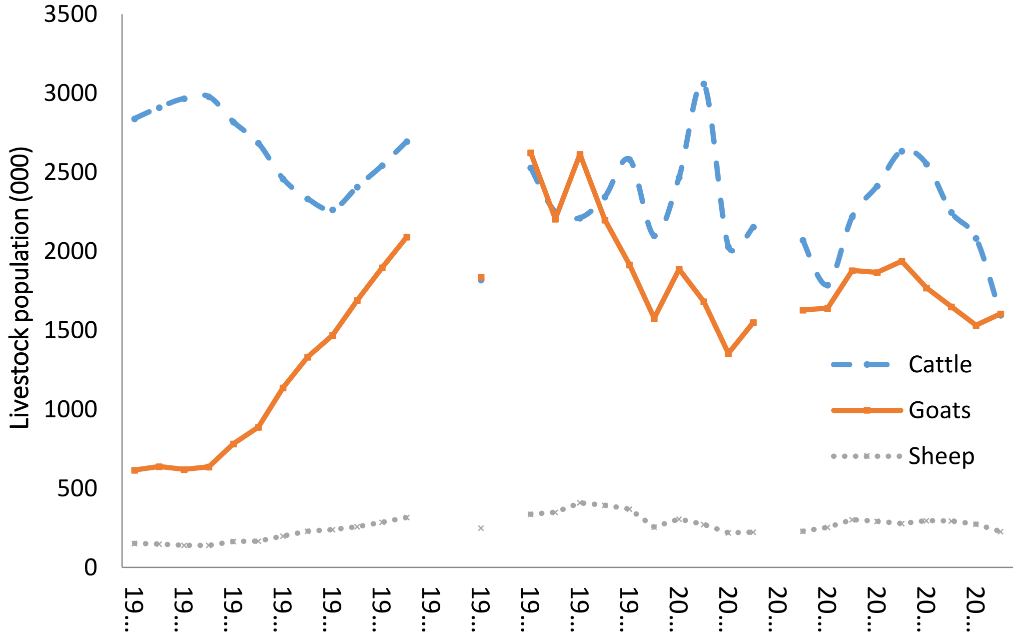


Figure 47: Historic livestock populations in Botswana (Gap: missing data)-

Under changing climate, the livestock productivity would be adversely affected by multiple stressors associated with climate change (Table 8). The LIVSIM results indicated the baseline annual average milk production was 2 977 000L, which is consistent with productivity of small farms as observed by LEA (2001). Milk production is projected to decline slightly by 2050 under RCP 4.5 and shall be far less than the base scenario in 2070 under RCP 6.0 (Figure 12).The decline in milk production due to climate change could be explained by heat stress that will reduce cattle feed intake and inter-annual variability in grass production in future climate scenarios (Descheemaeker et al 2017). These results therefore imply that the dairy sector is particularly vulnerable to climate change in Botswana and subsequently the supply of milk and related products could be far short of the national demand estimated at 83 million litres (Hellyer et al., 2015a).

Table 21: Livestock productivity under different future climate scenarios

Parameter	Base	RCP4.5 (2050 – mid)	RCP 4.5 (2070- far)	RCP 6.0 (2050- mid)	RCP6.0 (2070 – far)
Milk yield (L)	2 977 .63	2 958.43	2 809.77	2 823.24	2 035.26
Births	11.53	11.53	11.98	12.04	9.77
Herd sizes	38	35	38	35	30
Sales	14.35	7.93	7.96	7.87	6.33

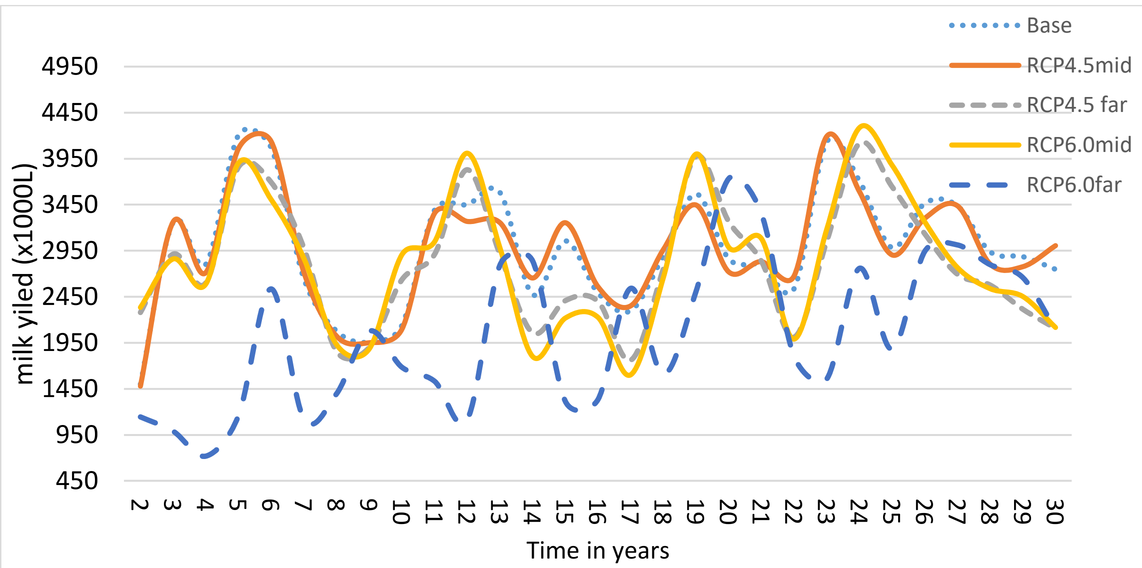


Figure 48: Projected milk production under different climatic scenarios in Botswana

Susceptibility to diseases (Sejian et al 2015) leading to reduced profitability of the livestock sector. As shown in Figure 15, the number of cattle sold by households is projected to decrease strongly under both RCP 4.0 and 6.0 which could lead to loss of income and increased poverty especially among rural communities with limited employment opportunities. However, bush encroachment could also increase resilience of browsers such as goats ,since pods from encroacher species such as *Acacia erioloba* and *Acacia tortilis* The reproductive performance of cattle was also projected to decline in the future due to climatic shocks. The number of calves born are likely to be lower than the baseline and this is more pronounced under RCP 6.0 by 2070 (Figure 13) and this could be due to low conception as a result of poor body condition of breeding cows caused by feed shortage in the rangeland. In addition, the increased heat stress could also reduce the fertility of bulls and thus lead to lower calving rate of the national herd. As a result, it was projected that the cattle herd size per household slightly increased under RCP 4.5 by 2050, but is likely to be reduced significantly under RCP 6.0 by both mid-century and end of the century (2070) (Figure 14). The prolonged recurring droughts could also contribute to reduced household cattle herd and national population (Kgosikoma and Batisani 2014). The climatic stressors such as heat stress cause reduced feed intake, decreased growth, reduced reproduction, and increased are widely consumed.

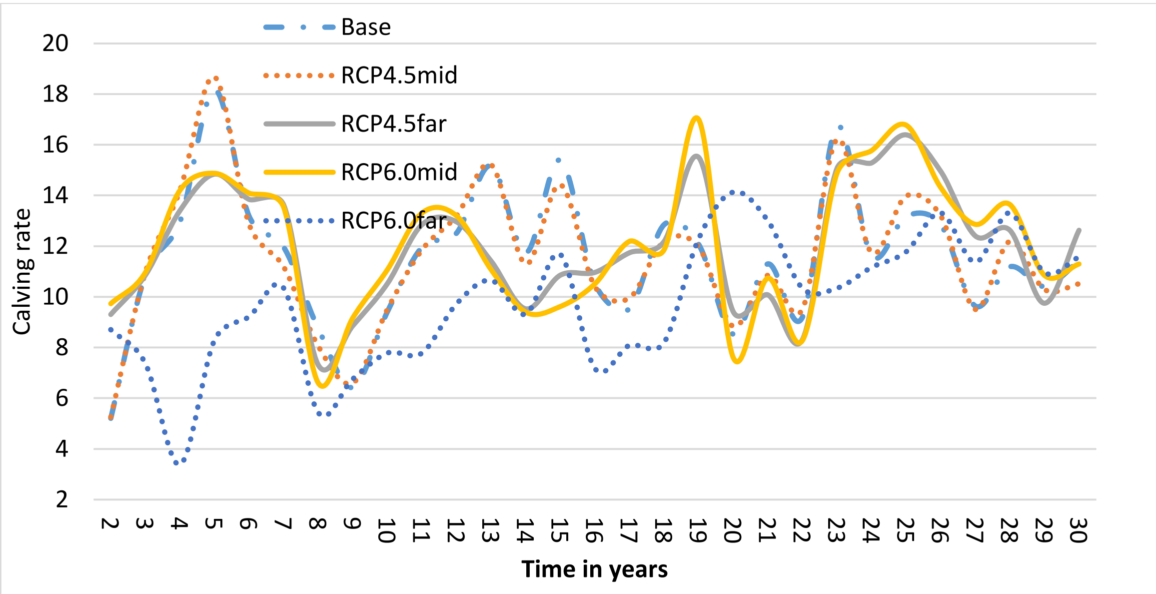


Figure 49: The number of calves born per household herd under different climatic conditions

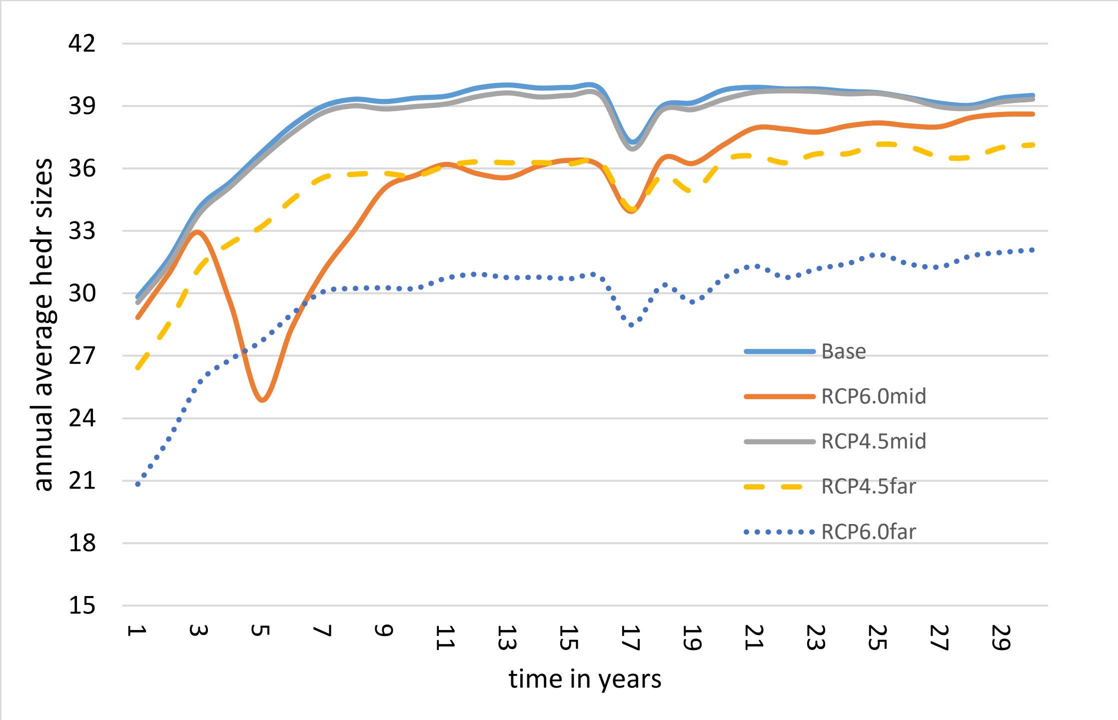


Figure 50: The projected household cattle herd sizes under different climatic scenarios

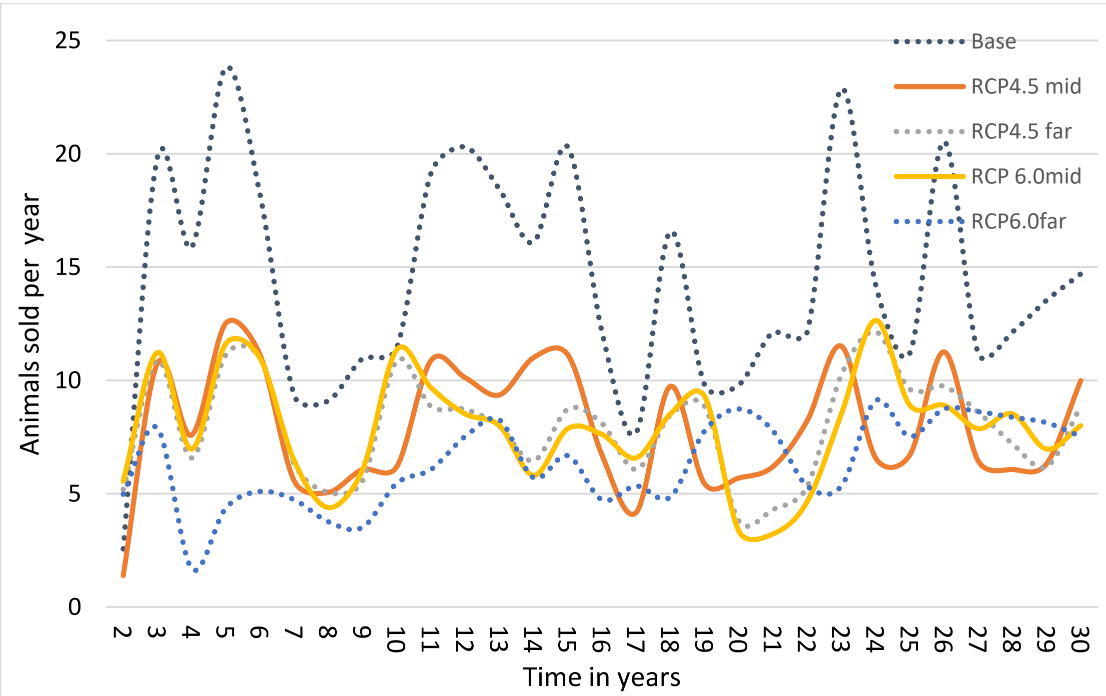


Figure 51: The projected animals sold by households under different climatic conditions

KNOWLEDGE GAP:

It is not yet how livestock pests and diseases are going to respond to climate change in drylands such as Botswana. Therefore there is an urgent need to improve understanding of the dynamics of livestock diseases of economic importance such as Foot and Mouth to develop adequate counter measures.

2.11.4 Adaptation practices to improve livestock resilience to climate change

It is apparent that rangeland based livestock production in Botswana is vulnerable to climate change and therefore there is an urgent need to buffer the industry against the projected climatic shocks that the livestock industry is exposed to (Box 1). In order to build resilience to climate within the livestock sector, sustainable adaptation practices need to be identified and adopted by farming communities. The proposed adaptation practices are expected to contribute substantially to sustainable development of the livestock industry and thus positively promote environmental integrity, society well-being and resilience to climate change. The climate resilient practices identified through the structured questionnaire and literature review are as shown in Box 1 below.

BOX 1

Climate risks

* increased temperature
*Reduced rainfall
*Increased drought frequency
increased risk of Wildfire outbreaks

Adaptation practices

* Ecosystem based adaptation
*Breeding for Adapted animals
*Fodder production
*Supplementation
*Destocking
* livestock mobility
Use of climate early warning systems/technologies
improvved herd health
*Development of sustainable water sources

Table 22: Adaptation practice to climatic shocks

RISKS	**ADAPTATION**	**COMMENTS**
Increased temperature Reduced rainfall Increased drought frequency Increased risk of Wildfire	Ecosystem based adaptation	Ecosystem-based adaptation (EbA) and its key components are conservation of biodiversity that results in resilient ecosystem services leading to improved livelihood
	Breeding for Adapted animals	Breeding efficient livestock under the future climate leading to shift in vegetation composition and increased temperatures Crossbreeding the indigenous breeds with exotic breeds could improve adaptive capacity and ensure that economically important traits (e.g growth rate) are maximized through heterosis.
	Fodder production	The forage deficiency resulting from declining rangeland productivity will be addressed through forage production.
	Supplementation	provision of supplementary feeds such as crop residues (stover), dicalcium phosphate and drought pellets
	Destocking	A proactive and coordinated market is essential to reduce livestock loss associated with climate risks.
	Livestock mobility	The livestock has to be continually moved to areas with sufficient grazing resources and overgrazed land allowed to rest.
	Improved herd health	Prevent
	Development of sustainable water sources	Water harvesting technologies to be exploited to ensure continuous water supply for the livestock industry.

	Wildfire Control and Management	Production and operational of Fire Management Strategies and firebreak maintenance as well as use of early warning systems.

In Botswana, majority of the interviewed livestock producers chose supply of water for livestock as an adaptation practice to climatic shocks and this can be attributed to limited surface water across the country. The other popular adaptation practice used by livestock farmers is improvement of animal health followed by supplementation. All the above practices are heavily subsidized by government through LIMID, Veterinary Services and drought relief programmes and this could explain their popularity.

Ecosystem based adaptation

The reduced rangeland productivity has been identified as one of the impacts of climate change on rangeland ecosystems in Botswana. It is therefore critical to enhance the ecosystems' ecological structures and functions that are essential for ecosystem functioning to enable people to adapt to multiple stressors, including land degradation and climate change (Munang et al 2013). This process is referred to as rangeland ecosystem-based adaptation (EbA) and its key components are conservation of biodiversity that results in resilient ecosystem services leading to improved livelihood (Figure 52).

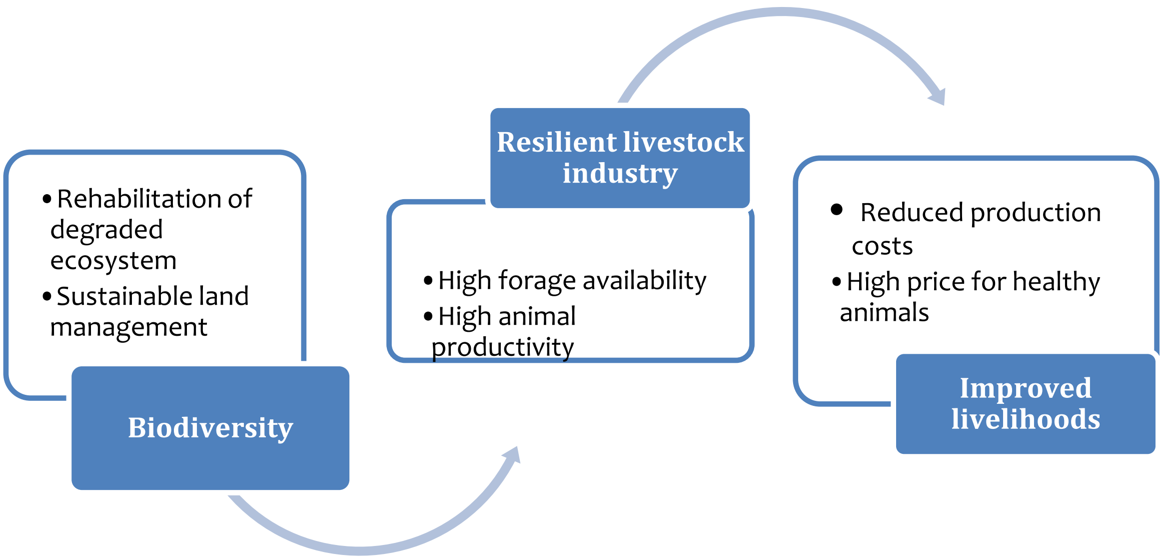


Figure 52: Components of rangeland ecosystem based adaptation (source?)

The rehabilitation of degraded rangeland could significantly improve the carrying capacity that could sustain the national herd through climatic shocks. This could be achieved through:

- control of bush encroachment (e.g. *Senegalia (acacia) mellifera*, *Terminalia sericea*) and invasive plants (*Cenchrus biflorus and Prosopis species)*
- establishment of perennial and palatable grasses (e.g. *Cenchrus cilirias*)
- Adherence to conservative rangeland stocking rates that will results in abundance of standing hay during dry seasons.

Breeding for adapted animals

It is essential to breed livestock that could be productive under the future climate (Scholtz et al 2013) that would lead to shifts in vegetation composition and increased temperature (Figure 21). The combination of high threshold than the 30 °C ambient temperature; ability to walk long distances and digestion of poor grasses gives the Tswana (indigenous) breeds a competitive advantage to cope with future temperatures relative to exotic breeds (Archer Van Garderen 2011). Crossbreeding the indigenous breeds with exotic breeds could improve adaptive capacity and ensure that economically important traits (e.g growth rate) are maximized through heterosis. So far, the development of a composite cattle breed known as Musi in Botswana is an opportunity to increase the adaptive capacity of smallholder farmers though technical knowledge may be a limiting factor in this approach. The impact of climate change on extensive production systems now requires that livestock breeds should have high tolerance and adaptability to more challenging environmental conditions. The objective of the Musi research and development was to find genetic material that could perform like crossbreeds already found in Botswana and well above the indigenous Tswana breed while retaining the hardiness and adaptability of the native stock in one package. The proportions of the selected breeds in the Musi breed were designed to ultimately optimise the overall efficiency for beef production under Botswana conditions.

Fodder production

The forage deficiency resulting from declining rangeland productivity could also be addressed through forage production. Drought tolerant crops such as Lablab, and Salt bush (*Atriplex nummularia)* could be produced even under low rainfall and produce additional biomass to feed livestock. The productivity and quality of different fodder crops that have been produced in Botswana is promising. Fodder production also provides an opportunity for reducing supplementation costs and improved soil fertility (legumes), food security and income (Franzel et al 2014). However, only a few farmers are involved in fodder production and there is a need to build capacity on harvesting and conservation. Shortage of water is the major constraint to fodder production and the use of recycled water for irrigation should be investigated.

Supplementation

In general, supplementation as an adaptation strategy is expensive for smallholder farmers (Masike and Urich 2008) and lack of access to credit facilities also makes it difficult for farmers to purchase enough feed for their livestock. As a result, the government of Botswana tends to subsidise key livestock feeds and vaccines during drought seasons to improve the adaptive capacity of livestock farmers. Shortage of grazing resources during drought is addressed through provision of supplementary feeds such as crop residues (stover), dicalcium phosphate and drought pellets. The agricultural by-products such as crop residues (e.g. maize stover) are cheap feed that could be utilized by smallholder farmers to sustain their livestock and reduce pressure from the rangeland (Müller et al 2015).

Market based adaptation (Destocking)

A proactive and coordinated market is essential to reduce livestock loss associated with climate risks. The market can be used by farmers to regulate the stocking rates where there is shortage of pasture and water resources and subsequently reduce the vulnerability of both livestock producers and natural resources (Gautier et al 2016). The producers that are well informed or supported by early warning systems could strategically reduce animals in the affected areas by selling to either feedlots or other markets. In Botswana, market inefficiency limits the application of this strategy and the monopoly of Botswana Meat Commission reduces farmers' adaptive capacity as they cannot quickly dispose of their animals to regional markets.

Livestock mobility

Under changing climate, the spatial and temporal heterogeneity across the rangeland is likely to increase and herd management has to match the available resources accordingly (Samuels et al 2013). The livestock therefore has to be continually moved to areas with sufficient grazing resources and overgrazed land allowed to rest. The trans- human practice of moving grazing animals to the cattle posts during the summer months and returning them back to the local rangelands during autumn and winter months was historically used to adapt to drought (FAO, 2011). The main advantage of livestock mobility was that it allowed flexibility in livestock and rangeland management. However, the sustainability of this practice is now debatable because reserved areas are no longer available due to settlements, encroachment of arable farming (Reid et al. 2014) and fencing of commons (ranching) which has fragmented the available grazing resources (Nkedianye et al 2011). In addition, the traditional institutions that governed grazing communal lands have been eroded partly due to changes in land tenure system.

Sustainable livestock water supply

The increased temperature due to climate change is going to result in increased livestock demand for water for thermoregulation. However, Botswana has limited surface water and the livestock production especially in the western part of Botswana is dependent on ground water (e.g. Boreholes). As a result, the cost of pumping water is likely to significantly increase by more than 20 % (Masike and Urich 2008) under changing climate. It is therefore critical to sustainably manage aquifers and promote the use of clean energy such as solar and wind to pump water for the livestock sector to be more environmentally and economically sustainable in the long term. Water harvesting technologies should also be exploited to ensure continuous water supply for the livestock industry.

2.12 Crops

Methodology

The framework of the methodology used in the study: The methodology used in the study requires that, the climate model outputs are used as in put in a crop modelling analysis. The crop modelling outputs are further aggregated and used as inputs to an economic model that determines regional vulnerabilities, changes in comparative advantage, price effects, and potential adaptation strategies in the agricultural sector, a science base methodology approach of AgMIP (Rosenzweig *et al.*, 2013; Antle *et al.*, 2015). The baselines is 31 years long (1980-2010) AgMERRA climate data sets for each project stations. Depending on crops, it usually allow to cover at least 30 growing seasons in the southern hemisphere.

The following questions were answered in the study

Question a. What is the current system sensitivity to Climate Change?

Question b. What is the effect of adaptation to climate change in the current system?

This question addresses the benefit (e.g., economic and food security resilience) of potential adaptation options to current agricultural systems given current climate. Results also form a basis for comparison with Question 4 below, as the proposed adaptations may have a higher benefit when the climate changes.

Question c. What is the impact of climate change on future agricultural production systems? This question evaluates the isolated role of climate impacts on the future production system, which will differ from the current production system due to development in the agricultural sector not directly motivated by climate changes.

Question d. What are the benefits of climate change adaptations? This question analyses the benefit of potential adaptation options in the production system of the future, which may offset or capitalize on climate vulnerabilities identified in Question c above.

The resulting crop modelling results (crop and stover yield) are formatted to be directly fed into the DSSAT crop model.

The economic modelling exercise estimated the proportion of farms that might be vulnerable to climate change and the associated changes in net farm income and poverty, and also estimated the proportion of farms that might adopt improved management or climate change adaptation packages, and by how much this would change net farm incomes and poverty. The analyses took into account heterogeneity of rural communities, and allow tailoring options to the needs and interests of particular farm types. The AgMIP RIA models were calibrated for a current 30 years period of climate series and contextual conditions (1980-2010) and for the mid-century period (2040-2070).

Economic model configuration:

The TOA-MD model was designed to simulate technology adoption and impact in a population of heterogeneous farms, with the choice of system based on the distribution of expected economic returns in the farm household population. Impacts are estimated based on the statistical relationship between expected returns to the alternative system and other outcome variables (e.g., economic, environmental or social outcomes).

Impact of climate change on crop production

The projected increased temperatures will either decrease or increase crop yields without adaption. Factors that will determine whether there will be an increase or decrease in average crop yields were observed to depend on (i) whether the future scenario is RCP 4.5 or 6.0 (ii) Region (Southern, Gaborone, Central, Francistown or Maun) and also (iii) the crop grown (maize-C4 crop, sorghum-C4-crop, cowpea-C3 crop or millet-C4 crop) (Table 1).The results further revealed that for cowpeas-C3 crop when no adaptation practice is implemented, in all the regions there is an average increase of yields under both RCPs. The highest average increase was observed in Maun regions at 44 % and 55 % RCP 4.5 and 6.0 respectively. As for the other crops cereals, when no adaptation practices is implemented Maize will have a reduction in yield across all the regions with the exception of Gaborone. Sorghum will perform poorly across three regions exception in Francistown and Maun for both RCPs. Pearl millet will experience a yield decrease in the two major growing regions of Francistown and Maun especially for RCP 4.5. Gaborone region is the only regions that experienced an average yield increase for all the cereals, maize (+8% - RCP 4.5), sorghum (+24% - RCP 4.5 and +21%-RCP 6.0) and pearl millet (+34%- RCP4.5 and +27% -RCP 6.0). The highest average yield reduction was observed from the maize (-15%) and sorghum (-37%) crop in the Francistown Region under RCP 6.0 (Table 23).

Table 23: *Maize, sorghum, cowpea and pearl millet average yields from five regions in Botswana under current climate conditions and adaptation systems (Qb)*

Regions	Crops	Future (RCP Average yield increase or	Future(RCP Average yield increase or
Central	Maize	-7	-16
	Sorghum (grain)	-6	-16
	Cowpea	+11	+1
Francistown	Maize	-14	-15
	Sorghum (grain)	-34	-37
	Cowpea	+36	+16
	Pearl millet	-16	-11
Gaborone	Maize	+8	+0.9
	Sorghum (grain)	+24	+21
	Cowpea	+36	+27
Maun	Maize	-8	+10
	Sorghum (grain)	+7	+8
	Cowpea	+46	+55
	Pearl millet	-6	+6
Southern	Maize	- 9	+ 9
	Sorghum (grain)	- 7	- 0.2
	Cowpea	+ 6	+ 25

Socio-economic impact of climate on crop production

In the current system, RCP 4.5 for Central region shows high vulnerability in the dry and middle scenarios (46.5%), with small decreases in poverty of 0.7%. Francistown region in the current system is highly sensitive to climate change, RCP4.5 (58.1%), dry scenarios have highest % households' vulnerabilities. All the scenarios have negative impacts of climate change with likely increases in poverty of 4%. In the current system under the RCP 4.5 (38.34%) high vulnerability is observed in dry scenarios for Gaborone region, with observed increases in poverty of 11% on aggregate for both RCPs.

Maun region shows high percentage of households vulnerable to climate change under the current system. Percentages of household's vulnerable, net impacts and poverty change are shown in the table 18. RCP4.5 shows 43.8% households vulnerable with hot wet scenarios.

Southern region under RCP 4.5 shows 33.28% of households vulnerable to climate change. This high vulnerability is observed in dry scenarios. Wet scenarios show high positive net impacts of climate change. Poverty decreased by 3.6% on aggregate in the Southern region (Table 24).

Table 24: *Percentage of households vulnerable, poverty change and net impacts of climate change in five regions in the current system under RCP 4.5*

Region	RCP	Class	% hh vulnerable	Net Impact	NR%	PCI%	Poverty% Change
		Without					
CENTRAL	4.5	Middle	47.9	3.5	5.5	1.0	0.0
CENTRAL	4.5	Cool/Wet	45.2	8.7	12.8	2.3	-0.8
CENTRAL	4.5	Hot/Wet	44	12.8	19.5	3.5	-1.2
CENTRAL	4.5	Hot/Dry	50	0	0.3	0.0	0.0
CENTRAL	4.5	Cool/Dry	45.2	9.3	14.1	2.5	-0.8
Francistown	4.5	Without			329.6	285.5	23.5
Francistown	4.5	**Middle**	58.6	-13.3	-16.7	-7.2	3.0
Francistown	4.5	**Cool/Wet**	53.5	-5.5	-6.8	-2.9	3.4
Francistown	4.5	**Hot/Wet**	55.5	-8.4	-10.6	-4.6	3.0
Francistown	4.5	**Hot/Dry**	64.2	-28.8	-22.8	-9.9	5.6
GABORONE	4.5	Without			2302.4	1116.5	20.9
GABORONE	4.5	Middle	38.2	31.2	44.3	32.7	10.5
GABORONE	4.5	Cool/Wet	37.1	43.1	59.4	44.1	10.0
GABORONE	4.5	Hot/Wet	36.9	46.7	63.1	46.9	10.0
GABORONE	4.5	Hot/Dry	38.7	25.8	36.4	26.8	9.6
GABORONE	4.5	Cool/Dry	40.8	16.6	23.2	17.1	9.1
		Without					
MAUN	4.5	Middle	43	6.7	9.2	9.2	-8.0
MAUN	4.5	Cool/Wet	42.6	7	9.7	9.7	-8.5
		Hot/Wet					
MAUN	4.5	Hot/Dry	43.3	6.3	8.7	8.7	-10.3
MAUN	4.5	Cool/Dry	44.1	5.6	7.7	7.7	-8.0
		Without CC					21.0
		Middl e					
		Cool/ Wet					
		Hot/					
		Hot/D					

		Cool/					

The Central region under RCP 6.0, hot scenarios show increases in household vulnerability with 49.08% aggregate and poverty increase of 0.1%. Central region farmers just like in the Southern and Gaborone regions are vulnerable due to identified constraints to agricultural productivity. For the Francistown region under RCP6.0, 46.4% aggregate households' vulnerability is observed with negative impacts under the hot dry scenario. In the current system under the RCP 6.0 (38.76%), high vulnerability is observed in dry scenarios for Gaborone region, in addition, observed increases in poverty by 11% on aggregate for RCPs 6.0. Gaborone region farmers are particularly vulnerable as they obtain low crop yields, which are insufficient to meet household needs, let alone provide surplus for sale. The low (and declining) yields in our study regions probably reflect the limited use of inputs (fertilizers, pesticides, improved seed varieties).

In the Maun region low vulnerability under the RCP6.0 is observed (34.3%), with highest under the hot wet and an aggregate poverty rate decrease of 8.4%.

RCP 6.0 show 27.7% aggregate vulnerability for the Southern region in hot scenarios with 2% decrease in poverty. Farmers in the Southern region are particularly vulnerable due to reductions in crop productivity. First, the farmers cultivate small parcels of land, dedicate most of their land to crop production for household consumption and obtain low crop yields, which are insufficient to meet household needs, let alone provide surplus for sale (Table 25).

Table 25: Percentage of household's vulnerable, poverty change and net impacts of climate change in five regions in the current system under RCP 6.0.

CENTRAL

Region	RCP	Class	% hh vulnerable	Net Impact (%)	NR%	PCI%	Poverty% Change
		Without					
CENTR	6.0	Middle	48.5	2.3	3.5	0.6	0.0
CENTR	6.0	Cool/Wet	43.4	13	18.9	3.4	-1.6
CENTR	6.0	Hot/Wet	51.2	-1.7	-2.0	-0.4	0.8
CENTR	6.0	Hot/Dry	52.3	-3.3	-4.2	-0.8	0.8
CENTR	6.0	Cool/Dry	50	0	0.0	0.0	-0.4
Francistown	6.0	Without CC			114.2	197.6	25.4
Francistown	6.0	**Middle**	44.1	13	20.2	3.6	1.2
Francistown	6.0	**Cool/Wet**	43.7	13.6	20.4	3.7	-1.6
Francist	6.0	**Hot/Dry**	51.3	-2	-2.3	-0.4	0.8
GABOR	6.0	Without CC			2311.6	1119.8	20.9
GABOR	6.0	Middle	38.2	33.2	47.5	35.0	11.5
GABOR	6.0	Cool/Wet	36.8	55.4	68.9	51.8	10.0
GABOR	6.0	Hot/Wet	38	34.1	48.5	35.8	11.0
GABOR	6.0	Hot/Dry	41.9	14.6	20.4	15.0	10.5
GABOR	6.0	Cool/Dry	38.9	28.9	41.5	30.6	12.0
MAUN	6.0	Without CC			[illegible]	[illegible]	[illegible]
MAUN	6.0	Middle	29.7	41.6	56.5	56.4	-3.3
MAUN	6.0	Cool/Wet	36	13.7	18.7	18.6	-16.0
MAUN	6.0	Hot/Wet	36.9	12.7	17.4	17.4	-15.0
MAUN	6.0	Hot/Dry	36.5	13.3	18.2	18.2	-14.1
MAUN	6.0	Cool/Dry	32.4	18.2	24.8	24.7	-15.5
SOUTH	6.0	WithoutCC			43716.6	16407.0	21.0
SOUTH	6.0	Middle	29.2	28.4	38.5	38.3	-7.8
SOUTH	6.0	Cool/Wet	26.8	48.1	64.9	64.5	-6.1
SOUTH	6.0	Hot/Wet	28.2	37.1	50.2	49.8	-5.9
SOUTH	6.0	Hot/Dry	36.3	14.4	19.6	19.5	-5.8
SOUTH	6.0	Cool/Dry	28.9	31.0	41.9	41.7	-7.1

2.12.1 Adaptation Options

In the Southern region under the baseline climate, incorporating stover in the soil always increases baseline yield whether for maize (13%), sorghum (9%) and cowpea (14%). For the Gaborone region under the baseline climate, incorporating stover in the soil increases baseline average yields for maize (19%), sorghum (26%) and cowpea (1%). Therefore, sorghum and maize benefit the most. In the Central region under the baseline climate, increasing the nitrogen fertilizer application by 50% increases baseline yield for all the crops with maize benefiting the most at 34% (Table 26).

Table 26: Maize, sorghum and cowpea average yields in the Southern, Gaborone and Central Regions (Current climatic conditions and adaptation systems).

SOUTHERN REGION	**Base yield kg/ha**	**Adaptation: Adding 1000kg/ha stover at planting Yield (kg/ha**	**Adaptation: Increase nitrogen fertilizer application by 50%) Yield (kg/ha)**	**Yield change (%)**
Maize	748	844	N/A	+13
Sorghum (grain)	654	709	N/A	+9
Cowpea	131	149	N/A	+14
GABORONE				
Maize	709	844	N/A	+19
Sorghum (grain)	607	767	N/A	+26
Cowpea	170	172	N/A	+1
CENTRAL REGION				
Maize	763	N/A	1026	+34
Sorghum	849	N/A	890	+5
Cowpea	179	N/A	195	+9

For the Francistown region under the baseline climate, incorporating the adaptations shown in Table below average yields are increased and the highest yield increase was with maize (23%), having planted a heat tolerant cultivar. In the Maun region under the baseline climate, incorporating the adaptation strategies shown in Table below increases baseline average for all the crops. Pearl millet benefits the most with 37% yield increase after addition of 50% more nitrogen fertiliser (Table 27).

Table 27: Maize, sorghum and cowpea average yields in the Francistown and Maun Regions (Current climatic conditions and adaptation systems).

Crop FTOWN	Base yield kg/ha	Adaptation:	Yield (kg/ha)	Yield change (%)
Maize	1024	Planting a heat tolerant cultivar	1256	+23
Sorghum (grain)	743	Practicing zero tillage plus planting a drought tolerant cultivar	829	+12
Cowpea	156	Applying nitrogen fertilizer	163	+4
Pearl millet	581	Practising zero tillage	661	+14
MAUN				
Maize	954	Adding 1000kg/ha stover at planting	1016	+7
Sorghum (grain)	822	Adding 1000kg/ha stover at planting	912	+11
Cowpea	140	Increase plant population	180	+17
Pearl millet	714	Adding 50% more nitrogen fertilizer	979	+37

In the southern region on average, adaptation practices in the future (adaptation 2) that include shifting the planting window forward were found to perform better, especially with maize (53%). With regards to cowpea, increase in CO_2 (as one of the products of climate change) in the future and increasing the plant population was beneficial to cowpea only under RCP 6.0 scenario.

Regarding the Gaborone region all the adaptation practices (adaptation 2) under future climate that include shifting the planting window forward as part of the adaptation were found to perform better, especially with maize (77%). The increase in CO_2 (as one of the effects of climate change) in the future and increasing the plant population and also shifting the planting window forward was a beneficial to increase cowpea yields.

In the Maun region with all crops except maize the adaptation practices in the future (adaptation 2) that include conserving soil water produce higher average yields than the baseline climate adaptations (adaptation 1). Though the adaptations were similar under the baseline and future climate, the average yields were highest under future climate especially under scenario RCP 4.5 (Table 28).

Table 28: Maize, sorghum and cowpea average yields in the Southern and Gaborone Regions (future climatic conditions and adaptation systems)

Southern Region	**Base – adaptation1**	**Base-yield 1**	**Future- Adaptation 2**	**Average-future yield 2**	**Average Yield change**
Maize	Planting a heat tolerant cultivar	811	Practising zero tillage plus shifting planting window forward to between January and end of February	1238	+53
Sorghum (grain)	Practising zero tillage plus shifting planting window forward to between January and end of February	702	Planting a heat and drought tolerant cultivar and an additional incorporation of 1000kg/ha stover into the soil	725	+3

Cowpea	Applying nitrogen fertilizer	144	Increase plant population	132	-8
RCP 6.0					
Maize	Planting a heat tolerant cultivar	811	Practising zero tillage plus shifting planting window forward to between January and end of February	1317	+62
Sorghum (grain)	Planting a drought tolerant cultivar	702	Practising zero tillage plus shifting planting window forward to between January and end of February plus increasing nitrogen application by 50%	756	+7
Cowpea	Applying nitrogen fertilizer	144	Increase plant population	176	+22
GABORONE REGION					
Maize	Increasing nitrogen fertilizer application by 50%	788	Increasing nitrogen fertilizer application by 50% plus shifting planting window forward (January to end of February)	1280	+62
Sorghum (grain)	Adding 1000kg/ha	675	Practising zero tillage plus increasing nitrogen fertilizer	795	+18

Cowpea	Increase in population	172	Increase in population plus shifting planting window forward to	207	+20
RCP 6.0					
Maize	Increasing nitrogen fertilizer application by 50%	788	Increasing nitrogen fertilizer application by 50% plus shifting planting window forward to between January and end of February	1395	+77
Sorghum (grain)	Adding 1000kg/ha stover at planting	675	Practising zero tillage plus increasing nitrogen fertilizer application by 50% plus shifting planting window forward to between January and end of February	838	+24
Cowpea	Increase plant population	172	Increase plant population plus shifting planting window forward to between January and end of February	226	+31

In the Central region adaptation practices (adaptation 2) that include shifting the planting window forward were found to perform better with maize (44%) and cowpea (5%) for both future scenarios (RCP4.5 and RCP6.0). But with sorghum there was a slight (4%) decrease in average yield (Table 29).

Table 29: Maize, sorghum and cowpea average yields in the Central Region (Future climatic conditions and adaptation systems).

Central Region	**Base – adaptation1:**	**Base-yield 1**	**Future-Adaptation2**	**Average-future yield 2**	**Average Yield change**
Maize	Shifting planting window forward to between January and end of February	765	Shifting planting window forward to between January and end of February	1104	+44
Sorghum (grain)	Increase nitrogen fertilizer application by 50%	890	Plant a drought tolerant cultivar plus shifting panting window forward to between January and end of February	853	-4
Cowpea	Increase in plant population plus shifting panting	195	Increase in plant population plus shifting panting window forward	221	+5

	window forward to between January and end of February		to between January and end of February		
RCP 6.0	Base – adaptation1:	Base-yield 1	Future-Adaptation2	Average-future yield 2	Average Yield change
Maize	Shifting planting window forward to between January and end of February	765	Shifting planting window forward to between January and end of February	1392	+81
Sorghum (grain)	Increase nitrogen fertilizer application by 50%	890	Plant drought tolerant cultivar plus shifting planting window forward to between January and end of February	874	-0.02
Cowpea	Increase plant population	195	Apply nitrogen plus shifting planting window forward to between January and end of February	237	+22

Maize	Shifting planting window forward to	1079	Practising zero tillage plus shifting planting window	1110	1

Sorghum (grain)	Planting a drought tolerant cultivar plus shifting planting window forward to between January and end of February	874	Practising zero tillage plus shifting planting window forward to between January and end of February	873	1
Cowpea	Increase in population plus shifting panting window forward to between January and end of February	221	Apply nitrogen fertilizer	216	1
Central Region					
Maize	Shifting planting window forward to between January and end of February	1392	Practicing zero tillage plus shifting planting window forward to between January and end of February	1358	1
Sorghum (grain)	Shifting planting window forward to between	874	Practicing zero tillage plus shifting planting window forward to between January and end	871	1

Cowpea	Apply nitrogen fertilizer plus shifting panting window forward to between January and end of February	237	Apply nitrogen fertilizer	216	1

2.12.2 Conclusions

Climate

The temperature is projected to largely increase into the future over the whole country. The monthly and seasonal analysis of the temperature suggest that this increase occurs in similar amplitudes through months and seasons of the year. The rainfall projections are widely uncertain in terms of sign of change (whether increase or decrease). For every station analysed, while most GCMs project changes which could result from natural variability (within the 1SD envelop), a few project increases and decreases beyond that threshold. The range of increase and decrease vary from station to station from as much as 20% decrease or 20% increase, but the spread of projections in amplitude and sign does not allow to build confidence in one direction rather than the other. The GCMs however seem to largely agree on a monthly decrease in October which correspond with the beginning of the rainy season. Although this could be explained in a number of ways, the similar annual total precipitation with a decrease in October monthly precipitation possibly translate a delay in the rainfall onset, combined with either more intense or more frequent rainfall during the rest of the season.

Crop

The results obtained from this study show that, temperatures in the future will either decrease or increase crop yields when crop production is practised without adaption. Factors that will determine whether there will be an increase or decrease in average crop yields were observed to depend on (i) whether the future scenario is RCP4.5 or 6.0 (ii) Region (Southern, Gaborone, Central, Francistown or Maun) and also (iii) the crop grown (maize-C4 crop, sorghum-C4-crop, cowpea-C3 crop or millet-C4 crop). The results further show that, in the future with no adaptation practises implemented, in all the regions there is an average increase of cowpea yields under both RCP 4.5 and 6.0. The highest average increase yield (55%) obtained under RCP 6.0 in the

Maun region. Also in the future with no adaptation practices, in the Gaborone region results showed an average yield increase in maize (+8% - RCP 4.5) and sorghum (+24% - RCP 4.5 and +21%-RCP 6.0). The highest average yield reduction was observed from the maize (-15%) and sorghum (-37%) crop in the Francistown Region under RCP 6.0.

The results further show the potential adapting options from the current agricultural systems under the current climate, from all the crops in all the regions there was an average increase in yield. The highest increase in yield (+37%) was from pearl millet after incorporating stover in the soil from the Maun region.

The results further show that the adaptation potential for increasing crop yield in the future also depends on (i) whether the future scenario is RCP 4.5 or 6.0 (ii) Region and also (iii) the crop grown. In most of the Regions the future adaptation strategy that included shifting the planting window forward to be between early January and end of February performed better. Also conservation agriculture was noted to be part of those adaption practices that can improve yields in the future. With the cowpea crop, application of nitrogen fertilizer (most of the small scale farmers do not apply nitrogen fertilizer to a cowpea crop) and increasing the plant population per hectare as part adapting to climate change was noted to be an advantage.

Socio-economics

Vulnerability assessments have shown that maize-based systems in Botswana are vulnerable to climate change. The assessment shows more negative impacts of climate change in Southern region of Botswana. For dry scenarios, RCP 6.0 has slightly low vulnerability values with poverty decreasing by 7%. Policy recommendations can be suggested: government climate change interventions should target agricultural diversification at the household level. The Gaborone region assessment shows that under the current system and RCP 4.5 and RCP 6.0, high vulnerability in the dry scenarios and poverty increases of 11% on aggregate for both RCPs. Commendable likely adoption rates for proposed technology in current systems of 58.9%, however, poverty does not seem to reduce even though net farm returns increased. In the future both RCP 4.5 and RCP 6.0, show more negative impacts of climate change and high vulnerability in the dry scenarios. However, RCP 6.0 show small poverty change of 0.4%. In the future, the adaptation package show low likely adoption in the hot wet scenario (44.5%) with poverty decreases of 5.5% likely to be observed.

Central region, current system shows high vulnerability in dry scenarios under RCP 4.5, the region is also prone to negative impacts of climate change with small changes in poverty decreases of 0.7% observed, under RCP 6.0 hot scenarios show increases in vulnerability. The forecasts indicate negative impacts of climate change under the hot wet and hot dry scenarios. When tested in the central region, current adaptation has 54.3% likely adoption with small estimated decreases in poverty rate.

The assessment, however, reveals that for RCP6.0, the hot dry and the cool dry scenarios has negative impacts. High adoptions under RCP 4.5 and low adoptions under RCP 6.0. In Francistown, RCP4.5 shows dry scenarios having highest vulnerabilities. All the scenarios have negative impacts of climate change with likely increases in poverty. Under RCP6.0, negative impacts are observed under the hot dry scenario, likely adoption percentages of 53.3% are observed. In Francistown, RCP4.5 shows scenarios hot dry and cool dry with highest vulnerabilities. All the scenarios have negative impacts of climate change with likely increases in poverty. Under the RCP6.0, negative impacts are observed under the hot dry, likely adoption percentages of 53.3% are observed, Maun region under RCP 4.5 show all scenarios under the current system have vulnerability percentages below 50%, hot wet scenarios has the highest. Low vulnerability under the RCP6.0. In addition, current adaptation show a likely 62.7% potential adoption, in the future RCP4.5 shows likely increases in poverty rate, low increases in poverty rates observed under RCP6.0. Maun showed that the prescribed adaptation package in the future 57.8% likely adoption in the region, with highest observed under the hot wet scenario (62.6%) and lowest under the middle scenario. Poverty rate change in Maun region show higher decreases under the RCP4.5 than under the RCP6.0.

This regional integrated assessment provides insights on what influences adaptation strategies and what should be targeted to build resilience in the agricultural sector. Smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security. Because smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income and well- being. There is a significant uncertainty regarding the climate change scenarios for Botswana with conflicting scenarios about which areas will get wetter and which will get drier. The only thing that seems clear is that global temperatures will increase but we do not know what will happen at the regional level. This makes it more urgent for the inhabitants to be adaptive in the face of uncertain trends in climate-related socio-economic activities. However, on the basis of both limited resource capacity in relation to present-day population, and of the possible future decrease of the agricultural productivity as a consequence of reduced water availability for crop production, Botswana is vulnerable to climatic change.

2.13 Biodiversity

Methodology

The methodology used was comprehensive desktop review of literature from local and international documents and expert analysis from various sector documents. Sector experts convened in a workshop and worked on various sections of the report. The sections were consolidated into one document and validated by the whole team as the biodiversity and vulnerability assessment and adaptation report.

Introduction

Botswana is 90% covered in savanna, varying from shrub savanna in the southwest in the dry areas to tree savanna consisting of trees and grass in the wetter areas (Botswana in pictures Behnke, Alison 2009).The country constitutes of two main ecological regions; dry land and wetland. The dry land including Kalahari Desert is home to different flora and fauna species which are adapted to hot temperatures and low moistures. However, small areas of forest exist in the far north along the Chobe River. Vegetation and its wild fruits are also extremely important to rural populations living in the desert and are the principal source of food, fuel and medicine for many inhabitants. The wet environment of the Okavango delta and Chobe has variability of living organisms. Okavango Delta alone is habitat to; 1,300 plants, 71 fish, 33 amphibians, 64 reptiles, 444 birds, and 122 mammals (Lars Ramberg1 et al 2006).

Flora

Vegetation in Botswana, is generally defined under four broad categories namely, forests, woodlands, savanna and shrubs.

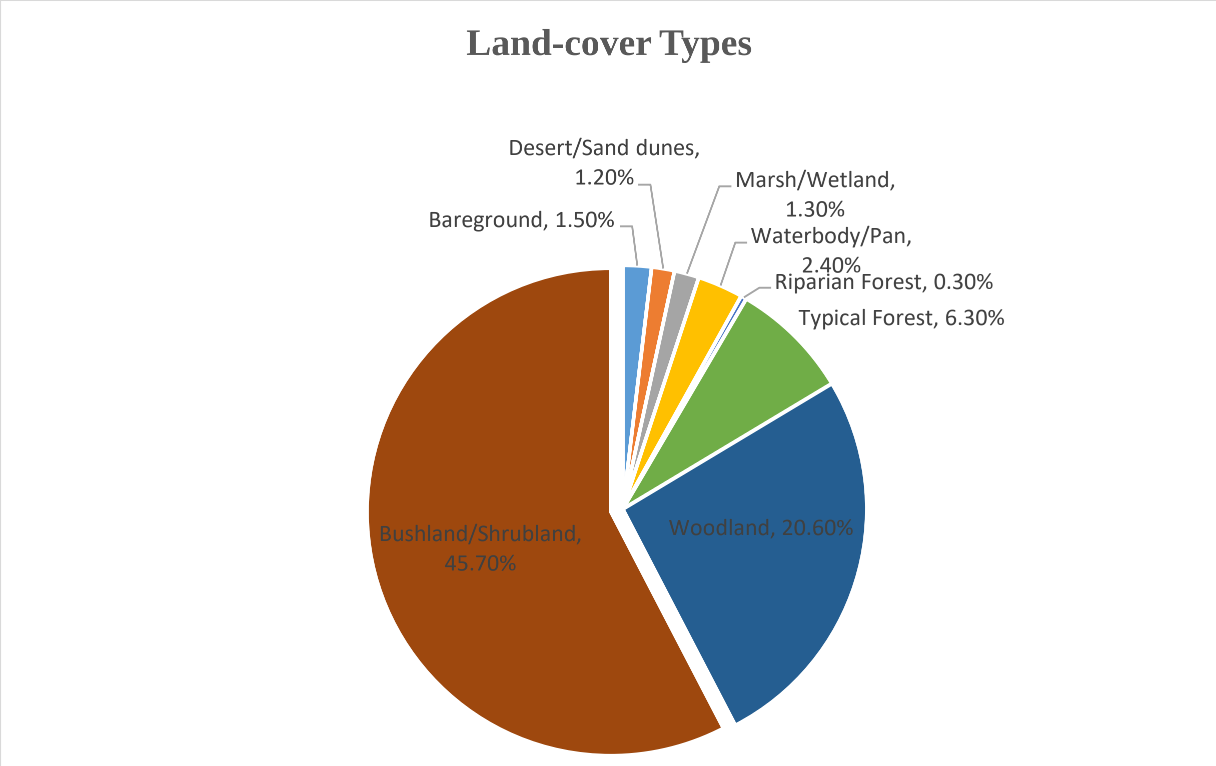


Figure 53: Land cover types

Studies have been undertaken to classify the vegetation of Botswana. Mopane woodland covers roughly one-fourth of the country; distributed in Ngamiland, Chobe and Northern Central Regions Burgess (2006). Adjacent to the swamps is the Riparian Fringe Forests and Swamp Grasslands. As the distance from the swamps increases, the vegetation transitions to dryland woodlands (Tinley (1966), Burgess (2006)). Thornveld flanks the Molopo River, which borders South Africa. Continuing northward, this transitions to savanna vegetation, which is the most widespread vegetation type throughout the country (Weare and Yalala (1971), Burgess (2006)).

The vegetation, in the far northeast of the country, is dominated by Baikiaea plurijuga and Pterocarpus angolensis and is considered the transition from the Miombo woodlands in Zambia and Zimbabwe to the Kalahari savannas (Kgathi and Sekhwela (2003), Burgess (2006)). The Vegetation classification and mapping of the Savuti-Mababe-Linyanti ecosystem (SMLE) was clustered into 15 major vegetation communities. large heterogeneity of plant communities driven by gradients in soil texture or fertility and wetness plays a key role in providing critical functional resource and habitat heterogeneity that allows (1) herbivores to adapt to seasonal variation in resources and (2) allows niche diversity to support a diverse guild of herbivores (KOEDOE) The mosaic of sand-filled paleoriver channels among alluvial deposits that supports the mopane–sandveld woodland mosaic between the Okavango Delta and the Linyanti Swamps was formed by ancient wetlands similar to the current delta, with the river channels subsequently becoming infilled by Kalahari sands of aeolian origin (McCarthy, Gumbricht & Mccarthy 2005). Similarly, the deep sands supporting the Baikiaea forests are of aeolian origin (McCarthy et al. 2005). The vast 3000 km2 MD originates from Paleolake Mababe (Teter 2007).

Fauna

Botswana is habitat to different animal species including lions, leopards, cheetahs, elephants, giraffes, zebras, hippopotamuses, rhinoceroses, African buffalo, hyenas, and antelope. Botswana has 593 bird species out of which eight species are under the globally threatened category. None of the avifauna species in Botswana are endemic and there are only two near-endemics, viz the Slaty Egret, which has approximately 85% of its global population in the Okavango Delta, and the Short-clawed Lark, which has more than 90% of its global population in South-eastern Botswana.

Table 30: Species richness within Botswana taxa

Taxon	Number of described species in Botswana	Species Distribution
Mammals	147	
Birds	593	
Amphibians	34	
Reptiles	131	
Freshwater fish	99	Mostly found in the large permanent river ways of the Limpopo, Chobe-Linyanti-Kwando system and the Okavango Delta.
Invertebrate		Largely undescribed
Plants	2,150-3,000	

Invasive species

There are three (3) important aquatic alien invasive plant species in Botswana viz., Kariba weed, Salvinia molesta Mitchell (Family: Salviniaceae) lettuce, Pistia stratiotes L., (Family: Araceae) and Water hyacinth, Eichlornia crassipes. Okavango Delta on the northwest and Kwando, Linyanti and Chobe River systems in the northeast of the country have been susceptible to exotic plant invasions due to sub-tropical climate and abundance of aquatic habitats. These two “biological pollutants” cause extensive socio-economic and water resource use management problems in Botswana’s wetland systems (Dr. C. Naidu Kurugundla Water Affairs)

Terrestial invasive species includes prosopis juliflora, cenchrus biflora, penniselum setaceum (fountain grass). Spatial distributions of prosopis juliflora is mainly Kgalagadi and Ghanzi areas. Cenchrus biflora is an annual grass, spreading rapidly across the country without any control measures especially in the Western part of the country.

Ecosystems

Forests

Forest cover in Botswana is about 28% and other wooded land (basically rangelands), which constitute 60% of the country (FCB forest strategy 2013-2020). Forests are classified according to the type of land tenure system in which they are located, hence there are forests in State land / protected areas, which include most Forest Reserves, National Parks, Game Reserves and Wildlife Management Areas, communal/tribal land, and freehold/private land. Botswana has six gazetted Forest Reserves (FRs), namely Kasane, Kasane Extension, Chobe, Kazuma, Maikaelelo and Sibuyu. These FRs make about 1% of the total land area of the country (Central Statistics Office, 2004); they were created primarily to safeguard valuable timber resources.

Dryland/grassland ecosystems

Dryland forests provide essential resources critical to the survival of human and animal populations. Community livelihoods are often directly dependent upon the use of natural resources in these habitats. The Makgadikgadi region has the largest continuous expanse of open grassland in Botswana, stretching from east of the Boteti region through the region west to the salt pans outside the national park (Brooks 2005).

Aquatic/wetland ecosystems

The Okavango delta is a RAMSAR and World Heritage site. It is a key area for tourism and wildlife, and at the same time it is vulnerable to climate variability and climate change. Development projects in Angola and Namibia have potential to affect the cross boundary inflow of water into the Okavango, and land degradation. Government intervention towards conservation of the delta is the implementation of ODMP. Given the availability of a relatively large amount of data for Okavango, including a household survey and an ecosystem services valuation study, this area is of importance for the ecosystem account.

The Makgadigadi wetlands are an additional important area, connected to both the Kalahari and the Okavango systems. It is subject to fires and has recurrent wildlife-livestock problems. Government intervention towards conservation of the Makgadikgadi wetlands is the implementation of MFMP. Several studies have been conducted in this area in the field of natural resource management, and there is basic data availability on ecosystem properties and uses.

Protected Areas

Botswana has set aside 45% of its land area as protected areas. This includes national parks, game reserves, private wildlife and nature reserves, wildlife management areas (WMAs), controlled hunting areas (CHAs), forest reserves and national monuments. National parks, game reserves, WMAs (see Table 3) and CHAs are governed by the provisions in the Wildlife Conservation and National Parks Act, 1992 while forest reserves are governed by the Forest Act, 1968.

Table 31: Types of Protected Areas in Botswana

Type of area	Km2	% of total land area	Legal constitution	Level of protection
National Parks	44,420	8	Wildlife Conservation and National Parks Act No 28 0f 1992	Ib No hunting
Game Reserves	59,590	10	Wildlife Conservation and National Parks Act No 28 0f 1992	Ib No hunting
Private Wildlife & Nature Reserves	Not known	<1	No act deals with this	IV No hunting
Wildlife Management Areas (WMA)	75,160	24	Wildlife Conservation and National Parks Act No 28 of 1992	V Controlled hunting
Forest Reserves	4,191	1	Forest Act, 1968	II -Protection of Trees
National Monuments	<100	<1	Monuments and Relics Act 2001	III – Botanical monuments

World Heritage Sites	48 + buffer zone 704	<1	Monuments and Relics Act 2001	World Heritage listing standards
Ramsar Sites	55, 374	9.53	Wildlife Conservation and National Parks Act No. 28 of 1992 Aquatic Weeds Control Act Cap: 34:04	Ramsar management standards

The regular occurrence of wild land fires affects biodiversity. Wild land fires cause loss of feed and habitant with negative effects on wildlife and tourism, livestock, land degradation, loss of veld products, negatively affecting rural livelihoods, loss of property, crops, wildlife and human lives. It is estimated that total burnt area over the whole country 2016 and 2017 is 339, 211.66 ha and 2,101,950 ha respectively (DFRR, 2018).

Table 32: Wildfire area burnt

District	District Size	2006	2007	2008	2009	2010	2011	2012	2013	2014
Central	14,637,419	803,070	56,820	1,460,431	179,136	2,757,523	1,150,172.27	1,345,400	430,677	281,256
Chobe	2,101,920	771,400	309,390	683,599	446,677	534,789	812,350.36	649,600	546,135	427,815
Ghanzi	11,472,587	1,428,153	1,109,580	5,241,479	238,065	5,291,407	5,228,384.24	1,951,300	2,676,749	1,118,966
Kgalagadi	10,491,604	665,520	738,995	397,478	357,151	901,540	3,466,251.20	1,290,000	482,742	358,947
Kgatleng	761,943	3,280	0	111,452	2,571	122,939	159,395.56	5,000	47,613	535
Kweneng	3,696,345	74,427	167,010	1,287,104	9,336	683,658	514,127.39	437,700	532,819	18,462
Ngamiland	11,134,421	1,929,956	854,680	2,565,514	842,762	2,408,697	3,712,408.00	5,120,500	3,862,011	1,180,793
North East	514,619	32,955	1,070	1,910	3,301	494	14,845.86	5,000	1,633	57
South East	85,800	5,350	0	9,888	0	1,503	2,803.88	4,500	200	0

Southern	2,723,320	2,090	58,620	87,933	45,953	884,225	378,296.23	506,800	37600	16,006
Grand Total	**57,619,978**	**5,716,201**	**3,296,165**	**11,846,790**	**2,124,952**	**13,586,774**	**15,439,034.98**	**11,327,500**	**8,620,279**	**3,402,837**

District	**District Size**	**2015**	**2016**	**2017**
Central	14,637,419	473060	20126.2	102154
Chobe	2,101,920	55349	67445.6	190327
Ghanzi	11,472,587	122500	15231.6	851715
Kgalagadi	10,491,604	11649	6562	342441
Kgatleng	761,943	15	0	154
Kweneng	3,696,345	27853	3517.4	3654
Ngamiland	11,134,421	473396	225379.7	712056
North East	514,619	404	23.5	1646
South East	85,800	3493	7.9	28
Southern	2,723,320	643	116.1	4560

Grand Total	**57,619,978**	**1,168,362**	**339, 211.66**	**2,101,950**

A decline in wildlife, especially reduction in large herbivore biomass in the Kgalagadi system, has been noted to be a factor contributing to biomass accumulation leading to fires (Perkins et al., 2002). Reduced wildlife migration and dispersion in dry periods may contribute to the degradation of resources in concentrated wildlife areas, such as the destruction of woodland by the large concentration of elephants in the Chobe district of northern Botswana (Hulme, 1996). Severely degraded areas tend to support fast-growing and more flammable vegetation species when rains return, which fuels wild-land fires, thus reinforcing the negative effects of climate-change-driven changes on wildlife habitats and dietary needs. Nearly 90% of fire ignitions are cause d by humans, indicating that there is a chance to reduce burning where concerted efforts are made to engage communities and invest in fire management (Dube & Mafoko, 2009). In addition to the above, another threat on wildlife linked to climate change is unprecedented disease outbreaks. The dynamics of wildlife diseases are generally not much understood in southern Africa. Disease outbreaks due to changes in temperature, rainfall and humidity will particularly be a threat under restricted migration. Hulme (1996) noted that ticks in the Okavango Delta will multiply by 2050 when temperatures increase by 1.5°C. The tick Boophilus decoloratus larvae was observed to peak twice in the same year in southern Kruger National Park (KNP) after an unusually warm winter in 1998, indicating the role of climate in the lifecycles of ticks or other parasites, which has negative implication for wildlife (Thuiller et al., 2006).

Socio-economic Impacts

Biodiversity provides multiple ecological services in Botswana. Ecosystem services are grouped into four broad categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and oxygen production; and cultural, such as spiritual and recreational benefits. Its contribution to GDP is through economic activities such as service sector (e.g tourism), agriculture and other industrial sector. The rural communities' livelihoods are particularly driven by utilization of biodiversity through Communities based organization. Veldt products are principal source of food, fuel and medicine for many inhabitants. Changes to ecosystems as a result of climate change are likely to have significant and often negative social, cultural and economic consequences. For example, water-based tourism activities such as boating in the Okavango Delta are also negatively affected when water levels are low. This is particularly worrying for locals who depend on the income from transporting tourists around the Okavango swamps in mekoro (canoes; Reinstein, 2016).

Climate change effects on biodiversity

Climate change and its interactions with other stressors have effect on biodiversity and those species with small distribution, low abundance and specialized habitats are particularly vulnerable (Steffen et al 2009). The birdlife has been shown to be threatened by changes in rainfall distribution and temperatures (Darkoh and Mbaiwa 2014) partially due to shift in composition of natural resources in their habitat. The inflow in Okavango Delta is likely to be reduced due to decline in rainfall in its catchment area. Hulme (1996) estimated that potential evapo-transpiration in the Okavango

Delta might increase by 15% by 2050 resulting in a decrease in runoff of about 20%. The water situation will worsen with rising temperatures due to global warming elevating evapo-transpiration leading to rapid losses, i.e. evapo-transpiration rates increase by approximately 3 to 4% for every 1°C rise in temperature (Du Pisani & Partridge, 1990; Schulze et al., 1995). This will result in reduced species richness in the area through either extinction or migration. The shift in proportion of woody and grassy vegetation would be stimulated by change in carbon dioxide concentration in the atmosphere and rainfall patterns.). An increase in frequency, intensity an extent extreme events such as drought, fires, will place vegetation under stress and will to contribute to population decline (Knight, 1995).

Climate change will likely to affect wildlife resources in Botswana through different stressors depending on the status and management of these resources. A 2011 aerial survey over the Okavango Delta established that wildlife species have shrunk in the past 15 years, reaching in by as much as 95% for ostrich, 90% for wildebeest, 84% for antelope tsessebe and 81% for warthogs and kudus; although others, such as elephants and plains zebra, remained stable while hippos increased by 6% (Guardian-UK, 18th June 2011). The results are, however, based on a one-off aerial survey and need to be interpreted with caution, although others have signalled similar trends (Perkins & Ringrose 1996; Rudee, 2011). Raseroka (1975) linked the disappearance of buffalo in the southern parts of Botswana to the drying and loss of forest vegetation along the Molopo and Limpopo River systems. While mass mortality in Kalahari wildlife in 1985 was linked to the cumulative effects of droughts that persisted since 1977 (Knight 1995) and as noted in Table 2, these droughts will be severe under climate change. Hulme (1996) also noted that the Okavango Delta may be less favourable for elephants by 2050 but more attractive to species, such as giraffe and warthogs, as the area gets drier. However, wildlife survival options under the projected changes will be obstructed by inability to migrate first within a country and worse for the case of between countries, due largely to human-made barriers. Thuiller et al.'s (2006) study found that out of the 277 African mammalian species assessed for impacts of climate change, none were committed to extinction where there was unhindered migration, but a maximum of ten species faced extinction by 2080 under the A2 HadCM3 scenario in the case of constrained migration (Thuiller et al., 2006)

Biodiversity adaptation Strategies

Monitoring of ecosystem process and biodiversity: facilitate development of effective and adapted policies and strategies to reduce the risks

- Improve the design and enforcement of corridors : to ensure connectivity between protected areas through migration
- Promote ecosystem based adaptation (EBA)
- Sustainable ecosystem management: protect the resilience of habitats and related biodiversity,
- Adaptive management actions to protect vulnerable ecosystems such as water drilling and provision, fire management control, conducting of National Forest inventory, agroforestry practices, in-situ conservation, Reforestation and afforestation

Methodological approaches

Introduction

The effects of drought, water scarcity on health include malnutrition (under-nutrition, protein-energy malnutrition and/or micronutrient deficiencies) susceptibility to infectious and chronic non-communicable diseases including respiratory diseases, cardio-vascular diseases. Drought diminishes dietary diversity and also reduces overall food consumption and thus lead to micronutrient deficiencies. Malnutrition increases the risk of both acquiring and dying from infectious disease. Drought and the subsequent loss of livelihoods is also a major trigger for population movements particularly rural to urban migration. Population displacement is a recipe to increase in communicable diseases and poor nutritional status resulting in overcrowding and lack of safe water, food and adequate housing. Recently rural to urban migration has been implicated as a driver of HIV/AIDS transmission (Confalonieri U. *et al* 2007).

Communicable Diseases

Despite the achievements realized over the years with regards to safe water, sanitation and hygiene, Botswana has continued to have challenges in the health sector. There is still continuous burden of communicable diseases such as HIV/AIDS, diarrhoeal diseases, acute respiratory infections and malaria. Infant Mortality Rate (IMR) and Under-five Mortality Rate (U5MR) remain relatively high with year-on-year fluctuations. HIV/AIDS and these other communicable diseases cause about 50 percent of the deaths in the population. While HIV/AIDS epidemic is a significant contributor in this regard, an effective ARV programme has resulted in mortality due to HIV/AIDS declining over the past 10 years, but it is still a major concern. More than two-third of deaths in infants and children under-five years of age are attributed to diarrhoeal diseases and pneumonia. These two are the main killers.

A population-based study of a widespread outbreak of diarrhoea with increased mortality and malnutrition, conducted in Botswana (Mach O. *et al* 2009) has shown a significant association between severe or repeated episodes of diarrhoea and acute malnutrition.Heavy rainfall has been associated with diarrhoeal disease due to increased risk of contamination of water supplies with disease-causing pathogens. The health of communities with poor sanitation and hygiene deficiencies is at a greater risk of diarrhoeal diseases, typhoid fever etc. Efforts to improve water quality, sanitation and personal hygiene would reduce episodes of diarrhoea in these communities. Heavy rainfall has also been associated with vector-borne diseases such as malaria in the Okavango, Ngami, Chobe, Boteti and Tutume.

Non Communicable Diseases

As the global surface temperature rises, incidence of heat waves, droughts, storms and floods will increase and become more severe, and these changes will bring heightened risks to human health and likely to exacerbate the cases of some of the chronic non-communicable diseases (NCDs) including cardio-vascular diseases (hypertension and cardiac disease), chronic respiratory diseases, type 2 diabetes, some cancers and their lifestyle risk factors. Other related conditions include mental disorders and injuries, among others (Friel S. *et al* 2010).

Heat Stress

The effects of environmental temperature have been studied on in the context of single episode of sustained extreme temperatures (heat waves and cold waves.) According to IPCC, hot days, hot nights and heat wave have become frequent (IPCC 2007). The heat waves are associated with marked short-term increases in mortality. The vulnerable groups from heat stress are categorized as person with pre-existing disease particularly cardio-vascular and respiratory disease; the very old, the very young, people living with disability, the sick and those working outdoors.

Mental Health and Climate Change

The Fourth IPCC assessment report documents evidence for a wide range of adverse health outcomes consequent on climate change, and alludes that many important outcomes will be psychological (Page L.A. and Howard L.M. 2010). There is minimum research on the link between mental and psychological disorders and this call for urgent studies on the subject.

ADAPTATION MEASURES

A number of adaptation strategies to address impacts of climate change on health are focused on agriculture and food security; maternal and child care and feeding practices; environmental health, water and sanitation. The initiatives that fall into each of the above categories represent the programmes and projects that individuals, institutions, groups and the country (Botswana) must undertake to moderate harm from climate change and variability on food and nutrition. Tackling the negative impacts of climate change on health requires an integrated approach.

The feeding schemes for the under-fives and vulnerable groups should be strengthened to ensure reduction malnutrition. Actions should be taken to build/strength institutional and technical capacities including efforts needed to train health professionals to understand the threats posed by climate change so that they can work on climate change and health.

Furthermore, the public health monitoring and surveillance systems need to be reviewed and strengthened to increase their ability to detect climate change and health trends from an early stage of health impact assessments. The early detection of trends in disease is important to facilitate early intervention. There is need to develop a framework for climate change, health monitoring and surveillance systems across sectors in collaboration with WHO and other technical agencies (Health, Environment, Agriculture and Settlements etc. Strengthening the emergency response systems and sustainable prevention and control programmes will enhance resilience to climate change in the health sector.

Table 5 sets out a National Health Adaptation Strategy and Action Plan to implement those measures being of highest priority, including adaptation category, constraints/challenges, activities to support adaptation, expected results, time frame for implementation of recommended measures, responsibilities of relevant stakeholders and financial estimates for implementation of adaptation measures.

2.13.1 Achievements in the Health Sector

MoHW has achieved some stride over the years as a way of combating effects of climate change on health. These include the following:

- MOHW is a member of NCCC to ensure climate change issues are mainstreamed into health plans
- Formulation of the CCC and SANA conducted for the implementation Libreville Declaration which links health and environment

CLIMATE CHANGE AND HEALTH ACTION PLANS

The following actions are proposed:

Monitoring and Surveillance

The national health impact assessments that will be conducted will provide valuable information on population vulnerability. Work on modelling possible climate change and socio-economic factors affecting transmission and control of infectious diseases is limited yet it will be instrumental in guiding adaptation projects and investments. Even then, models are still limited to a few infectious diseases, thermal extreme and air pollution. Given that considerable uncertainties surround projections including uncertainty about how population health is likely to evolve based on changes in the level of commitment to preventing avoidable ill-health, uncertainty about how the climate-health relationship might change over time etc. (Confalonieri *et al* 2007). Therefore given these considerable uncertainties associated with the consequences of climate change and health, the health sector will also develop or strengthen a health data capture system whose framework will be based on standardized outcome and impact indicators and procedures to track the implementation and impact of the National Climate Change and Health Adaptation Plan Programmes.

National Assessment of Climate Change Impacts, Vulnerability and Adaptation for the Health Sector

It is important that a national vulnerability assessment and adaptation process is undertaken in order to identify high risk health districts and locations and vulnerable groups. The knowledge of such locations and groups will naturally steer the adaptation plan toward those in greatest need and also inform the strengthening of the health policy and health system and management of risks. In this regard, the associated recommended methods developed by WHO, in close consultation with other relevant partners will be most useful.

Research and Development

In Botswana, studies on climate sensitive communicable diseases such as malaria, schistosomiasis, and diarrhoeal diseases are limited. For example, the number of general malaria studies are about twenty-five (25) and malaria and climate change are five (5) and schistosomiasis there are a total of ten (10) general studies and only one (1) is on schistosomiasis and climate change (Dube and Chimbari – no date). With regards to diarrhoeal diseases, the only study is by Alexander (2013), which mentions diarrhoeal diseases and climate in Botswana.

Research in Botswana addressing linkages between climate change and health and emphasis on evaluation of efforts to adapt to climate change is very limited. Given that there are already many networks within the SADC region on climate change and health, efforts will be made to collaborate with those networks to avoid duplication of activities. It is also possible to initiate an integrated, cross-sectoral and long-term programme of research to ensure that decision-making and planning are evidence-based and that the adaptation measures implemented are the most researched and therefore cost-effective and efficient.

2.13. 2 Health Impact Assessments

Health impacts assessment (HIA) has been defined in the WHO fact sheets) as "a combination of procedures, methods and tools by which a policy, project or hazard may be judged as to its potential effects on health of a population and the distribution of those effects within a population." Despite its demonstrated value, Botswana has not conducted HIA. Estimates, even if approximate, of the potential health impacts of climate change are an essential input to policy discussion on reducing greenhouse gas emissions and on social adaptation to climate change.

HIA processes is useful to identify the concerns of vulnerable groups and its context, describe health burden and risks and identify key partners and issues for the assessment; estimates future impacts and adaptive capacity and evaluation of adaptation plans, policies and programmes and actions to minimize impacts on health including follow up assessments.

It is also of considerable important that the MoHW develops nodes of expertise in HIA and then work across sectors to ensure that the negative health consequences of any major developments are averted and that every opportunity is seized to maximize the health benefits thereof. It is therefore, proposed that a systematic approach to HIA be developed for the purposes of scoping, assessing, appraising and formulating management action plans to address issues of highest priority in development of project and programme implementation of health adaptation to climate change.

Intersectoral Action for Climate Change and Health Sector

In 1972/74, the Government of Botswana launched the Accelerated Rural Development Programme (ARDP) aimed at providing Basic Health Services to all citizens of the country by assuring geographical access to health facilities at appropriate levels with special emphasis on the rural communities. The Basic Health Care Services approach evolved into Primary Health Care approach (PHC), especially after the PHC concept was articulated in the Alma Ata Declaration on Primary Health Care in Alma Ata, USSR in 1998. PHC was a broader, more comprehensive approach than the Basic Health Services as it incorporated Community Involvement and the Multi-sectoral approach and also espoused decentralization of services to empower local communities (SNC 2011).

The recognition of climate change and its impact on the health sector and the commitment of the Government of Botswana to formulate a strategy and action plan to adapt to climate change, has added urgency to develop health measures, and integrate them into a National Climate Change Strategy and

Action Plan (NCCSAP) to implement the Climate Change Response Policy. In addition, this whole phenomenon of climate change and its effects on the health sector, means that the health needs to engage systematically across Government and other sectors to address the health and well-being dimensions of their activities.

The Government of Botswana needs institutionalized processes which value cross-sector problem solving. An analysis of Government policies and strategies has shown that, while there's some intersectoral consideration in most of them, more needs to be done to address health and well-being in sectors other than health to address this dimension (WHO Regional Office for Africa 2013). For example the MoHW will engage with the Ministry of Transport and Communications in improving the transport system to reduce the number of vehicles on the roads – this may result in reducing of vehicle emissions. Liaising with other ministries (Agriculture – food security as undernourishment results in poor health; land management, water and sanitation services and Local Government and Rural Development – to ensure housing meets the minimum health requirements; safe drinking water, improved sanitation; Mineral Resources, Green Technology and Energy Security – air quality management etc.). This engagement may dramatically improve public health and reduce vulnerability to climate change and its effects on health.

Preparedness of Health System to deal with Gradual Climate Change and Sudden Shocks (Floods, Cyclones, Droughts)

The capacity and resilience within hospitals and other health facilities will be assessed and strengthened where necessary. In line with the Sixty-first World Health Assembly (2008) to strengthen the capacity of health system for monitoring and minimizing the public health impacts of climate change through adequate preventive measures; preparedness, timely response and effective management of natural disasters; and promote effective engagement of the health sector and its collaboration with all related sectors, agencies and key partners at national and international levels to reduce the current and projected health risks from climate change.

This act of preparedness will enable the Health Sector to prevent avoidable casualties and other acute health impacts and disease outbreaks resulting from extreme weather events. The capacity and needs within emergency response services should also be strengthened. The assessments of the health system preparedness will also pay particular attention to the effectiveness of preparedness to the health needs of climate change of the rural communities and the poor districts and sub-districts.

Model and Pilot Climate Change and health Adaptation Projects

Botswana's Ministry of Health and Wellness is currently not implementing projects or programmes on health adaptation to climate change. In the implementation of the health approach to climate change through the National Climate Change Strategy and Action Plan to operationalise the Climate Change Response Policy, MoHW will, in high risk areas and vulnerable groups, establish a series of model projects, in which a range of climate change adaptation actions might be implemented. Particular focus will be on prevention and intersectoral action. The lessons learned in the pilot projects may be considered for scaled up implementation in other parts of the country.

The various aspects of the activities will be best implemented at national, district, sub-district and local levels. There will be ongoing dialogue with all these levels of Government with active participation of the stakeholders and civil society. Such an approach will inform the separation of functions and responsibilities. This therefore means that review of development policies to identify climate change and health protection opportunities will need to occur at all levels of Government while human settlement planning and design as well as natural disaster preparedness may be considered at district or local level. It is envisaged that perhaps, the Steering Committee will play a significant role.

Improvement of Health Interventions to address Social Determinants of Health

The basic public health programmes such as access to safe drinking water, improved sanitation, access to safe fuel, management of infectious diseases, air quality, food security, control of climate sensitive diseases (malaria, diarrhoeal diseases etc.) need to be strengthened or implemented (where such programmes do not exists) to enhance resilience to the health risks of climate change.

The following key activities are proposed for the MoHW (Public Health):

- To publicize educational material on communicable diseases which are sensitive to climate change (malaria, diarrhoeal diseases, meningococcal meningitis to increase community awareness
- Strengthening of epidemic disease preparedness and response DHMTs through scaled up training initiatives
- Establish water sanitation and hygiene committees as part of DHMT and VDC in the Districts, Sub-districts and Villages throughout the country. These committees will be guided by the local DHMTs to plan and coordinate key activities related to the prevention and control sanitation/hygiene and water-related diseases

- Improving surveillance and reporting of cases toward early detection and case management of key diseases

2.14 Recommendations

Currently in Botswana, no data is available that could relate the impacts of climate change on under nutrition and nutrition security as well as adaptation measures for nutrition security. It is recommended that appropriate investment should be made in terms of research initiatives on climate change on nutrition security and nutrition focused adaptation strategies in Botswana. The research agenda should be spearheaded by Botswana national research institutes and the relevant scientific communities. These have critical roles to initiate building and validating evidence about successful projects in at-risk communities and vulnerable groups.

With regards to adaptation strategies, it is recommended that the current coping strategies for the vulnerable groups and communities in the country should be identified and analysed, including identifying and testing nutrition sensitive adaptation interventions to address climate change shocks and their effects on nutritional status.

2.15 Conclusion

The Botswana's Second National Communication 2011 (SNC) submitted to UNFCCC includes health implications of climate change mitigation policies. The SNC also suggests appropriate adaptation activities required to address the climate change vulnerabilities. Although Botswana is comparatively less vulnerable to the impacts of climate change and variability than its Southern African neighbours, climate models predict, that the country will be exposed to far reaching negative climate trends, including higher temperatures, droughts, natural disasters such as floods, declining rainfall, increasing evapo-transpiration rates. These trends will have significant implications for the country already experiencing water scarcity and high dependence on ground water resources. These climate trends will increasingly challenge the adaptive capacity of both the country and its people, and when combined with existing water scarcity could threaten the country's agricultural, livestock, health and forestry sectors (Crawford A. 2016).

The National Health Policy (2011) also identifies climate change as a real threat to the well-being of the population. The policy predicts the impacts of climate change on health will exacerbate the incidence of malaria due to increases in temperature and rainfall in some parts of the country, an increase in the incidence of cholera and an increase in malnutrition due to reduction in domestic food production and crop yields.

Despite identifying climate change as a potential health risk, the National Health Policy (2011) does not offer response or adaptation measures for addressing the threat. This appears to stem from the fact that Botswana's political and legislative bodies have been slow to respond to the threat climate change poses (Crawford 2016). The country does not seem to view climate change as a national priority except the mention of climate change is made within the NDP documents. Botswana is currently implementing NDP 11 which runs from 2017 to 2023 and Vision 2036 and climate change is mentioned prominently in both medium (2017-2023) and long-term (2036) documents. The Government of Botswana has also established a parliamentary committee to guide national direction and response on climate change and has begun to increase the capacity of the Ministry of Environment, Natural Resources and Tourism to address issues of climate change, however, the extent to which the country's ill-preparedness is basically absence of policy, capacities and resources needed at government level to design and implement adaptation responses to climate change.

Despite the recommendations from SNC (2011) for appropriate adaptation strategies required to address the vulnerabilities, there are no projects and programmes that directly address the priorities of health and environment risks.

Many people in Botswana are vulnerable to the health risks of climate change. The disadvantaged communities are the most vulnerable and yet have the least resources to respond to climate change and health risks such as heat stress, communicable diseases, natural disasters, non-communicable disease, and food and water in-security etc.

There is therefore need for Botswana National Health Adaptation Strategy and Action Plan as adjunct to NCCSAP to be adopted and implemented during NDP 11 as a public health approach to adaptation to climate change. This also brings an opportunity for Botswana to review the existing Botswana public health systems and policies and to strengthen and adapt the National Health Adaptation Strategy and Action Plan to respond to the health risks posed by climate change and its effects on human health. This proposed Botswana National Health Adaptation Strategy and Action Plan has been founded on the guiding principles of the Draft Botswana Climate Change Response Policy, Guidance contained in the Alma Ata Declaration on Primary Public Care, the Ottawa Charter for Health Promotion and Botswana National Health Policy (2011).

CHAPTER 3- Programmes Containing Measures to Mitigate Climate Change

Methodological approaches -.

Literature review: Various documents were reviewed to obtain the baseline and past GHG inventories for the country. Importantly, the GHG inventories were reviewed to gain an understanding of the GHG inventory methods, underlying assumptions and scenarios. This procedure was followed to allow for GHG emissions simulations over time. Additionally, INDCs reports were also reviewed to identify feasible mitigation actions and those that are currently operational in the country. Lastly, literature review on IPCC GHGs emissions inventory guidelines was also undertaken. These guidelines were used in development of the GHG emission scenarios. Data was collated from Botswana, environment statistics.IPCC Inventory Software and Guidelines of 2006 was used to estimate baseline emissions and for projections based on scenarios Consultation with the experts: Consultation was undertaken with the objective of identifying the ongoing and planned mitigation projects in the country. The following line ministries and departments were consulted: Department of Energy, BITRI, private sector, Botswana Housing Corporation and Department of Housing and building.

3.1 Projected GHG emissions

Projections for GHG emissions were undertaken based on different emission scenarios consistent with the UNFCCC emission scenarios. Specifically, projections were done based on the following scenarios:

- Business-as-usual scenario: under the business as usual (BAU) scenario, population and economy will grow at the same previous rate of approximately 1.8% and 3% over time respectively. It is further assumed that there will be less emphasis on climate change mitigation actions. Therefore, the country will aggressively pursue development of coal based energy sources (expansion of Morupule). There will be no technology nor fuel shift under the BAU scenario. Thus, the demand for private cars and fossil fuel consumption will be driven by population and economic growth. There will be no policy changes to influence a major switch towards public transportation and cycling. However, over the years, there will be an increase in the proportion of households to national electricity grid system. Therefore, the demand for fuel wood as a source of energy will gradually decline with time.
- Technologically advanced economy scenario: under this scenario, it is assumed that population and economy will grow at the same growth rate as under BAU. Additionally, the economy will be more technological

driven with emphasis on renewable energy and efficiency for both vehicles and energy appliances. There will be a shift from biomass energy towards solar and biogas from agricultural waste (livestock waste) particularly at the rural sector and waste facilities (landfills and wastewater). Moreover, there will be a shift towards the use of solar appliances on street lighting and geysers for private, government and parastatals. Therefore, under this scenario, the economy will be more climate mitigation driven.

On the basis of the developed scenarios, GHG emissions for the country were simulated over time.

3.2 GHG and socio-economic scenarios

GHG emissions were simulated for the three (3) main gases mainly CO_2, CH_4 and N_2O. Simulation under BAU was based on population growth rates of 1.8 $year^{-1}$ and an economic growth rate of 3% $year^{-1}$. The GHG emissions were projected from Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste sectors. It is assumed that demand for energy (petrol, diesel, paraffin) and electricity are driven by population growth and incomes. Additionally, it is assumed that the waste generation per capita is a function of incomes. Lastly, GHG emissions for the livestock sector are based on the assumption that the livestock number will oscillate around 2.2 million cattle annually. Therefore, throughout the simulation years, a cap of 2.2 million cattle was assumed. Another important sector that was simulated is the land use change and forestry. Under the BAU scenario, simulations were based on the past observed changes for residential and agriculture using the satellite imageries.

For the industrial processing, growth was matched with the economic growth and its output is assumed to grow annually, similar to the national economy at 3% $year^{-1}$.

3.4 Projected GHG emissions under business as usual

GHG emissions for the country are projected to increase from 26,386.6 Gg of CO2 eq. in 2012 to 48,973.5 Gg of CO_2 by 2030. Figure 54 below depicts the simulated GHG emissions under BAU from 2012 to 2030. The figure depicts a growth in GHG emissions driven by population growth and economic development. Major emitting sectors are AFOLU and Energy sectors. All the economic sectors with the exception of livestock sector depict an up-ward growth in GHG emissions.

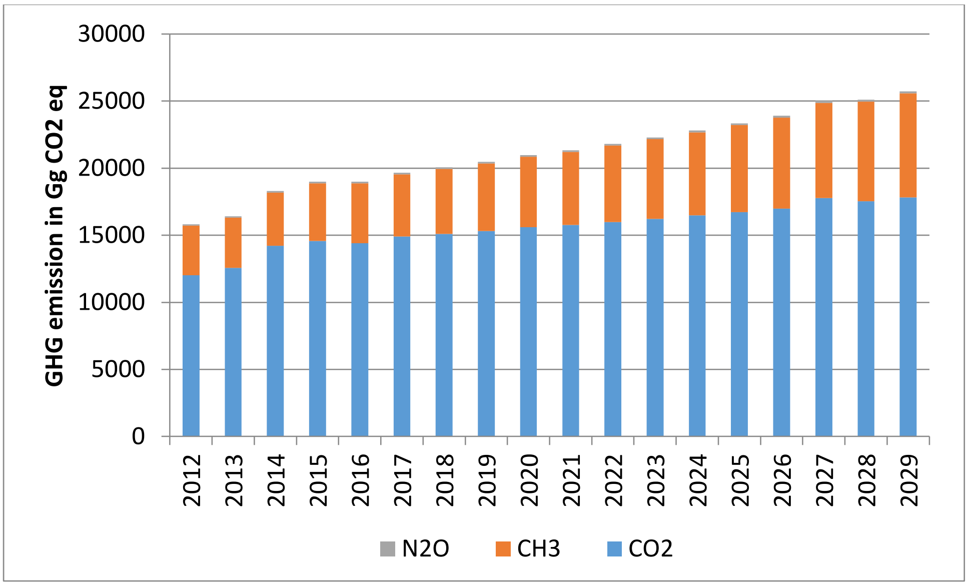


Figure 54: GHG emissions under business as usual

Similarly, the energy sector depicted an upward trend in GHG emissions over the years. The emissions from the energy sector are driven by increase in the number of private vehicles, increase in coal consumption from Morupule Power Station and domestic fuel wood consumption. Figure 55 depicts GHG emissions from the energy sector over the years.

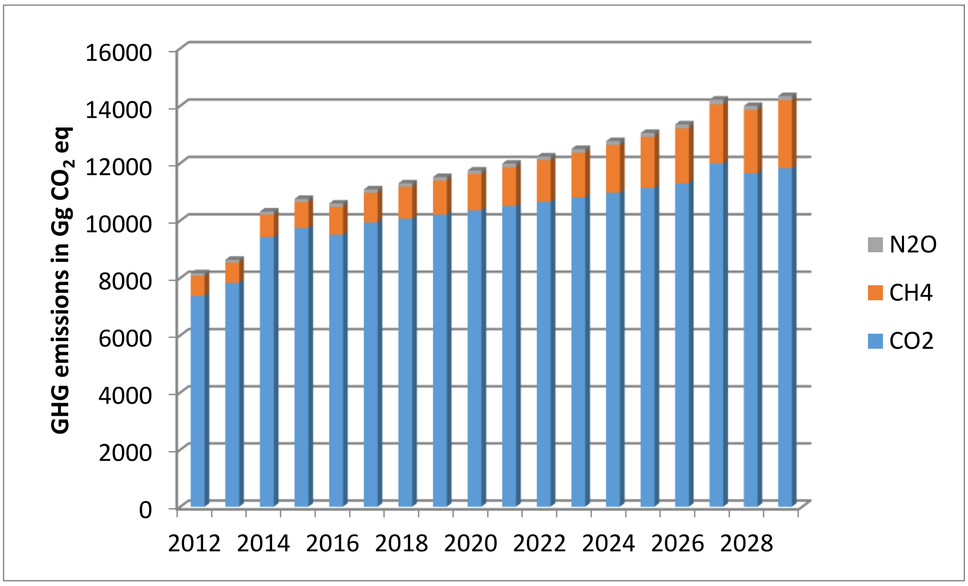


Figure 55: GHG emissions from the Energy sector in Gg of CO_2 eq.

Industrial processes and product use (IPPU) is another important GHG emitting sector in the country. The emissions are specifically from cement and soda ash production. CO_2 is the only GHG that is emitted from cement and soda ash production. Figure 56 depicts the GHG emissions from the two production processes.

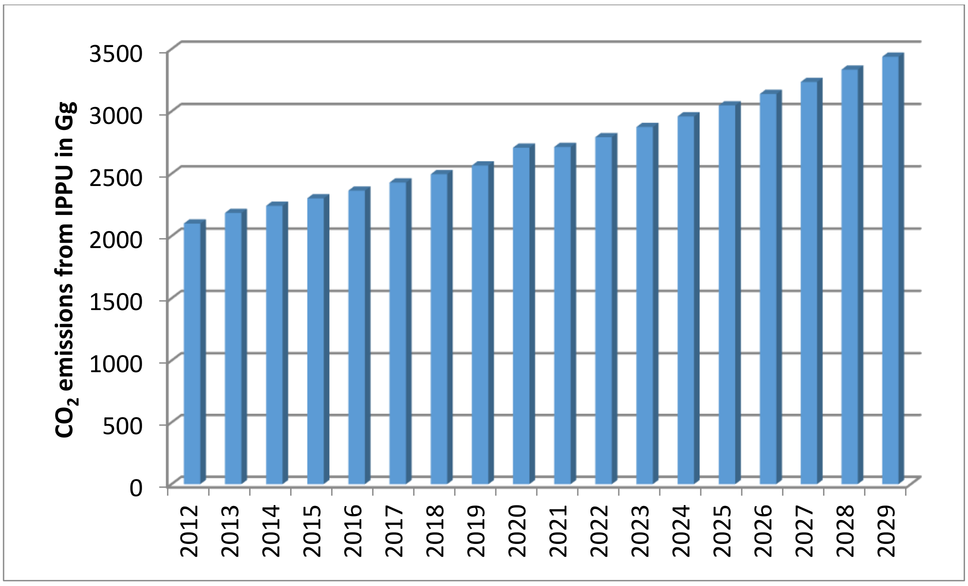


Figure 56: GHG emissions from IPPU in Gg of CO_2 over time

Fugitive GHG emissions arise from coal mining and CH_4 is emitted during mining and post mining of coal. CH_4 projections were based on coal production, a function of economic growth. Figure 57 depicts simulated CH_4 emissions in CO_2 eq. over the years.

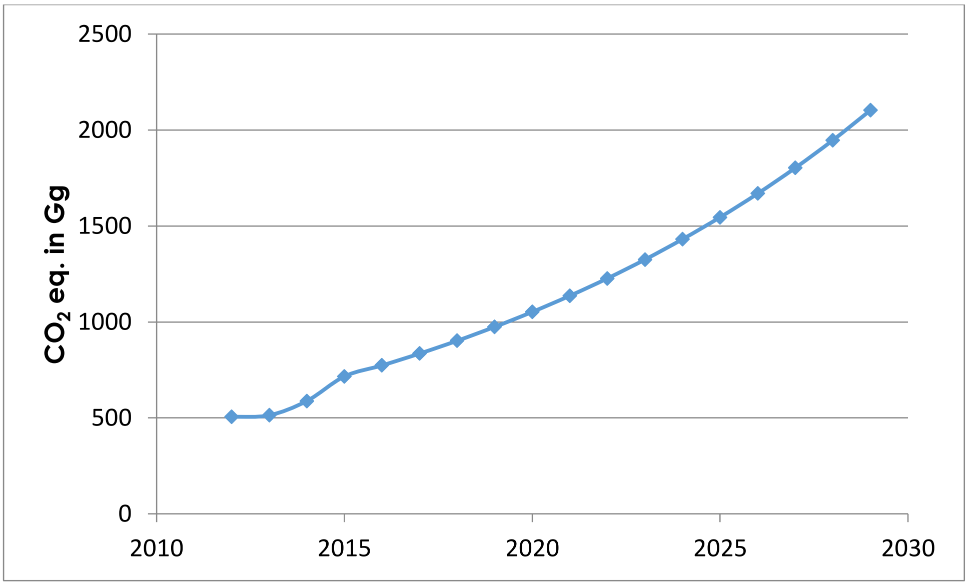


Figure 57: CH_4 emissions from coal mining

Livestock sector is another sector that contributes to GHG emissions in the country. The main GHG emitted is CH_4 and it is emitted through enteric fermentation and manure management. It is assumed that livestock in the country has reached a carrying capacity and therefore cattle population is capped at 2.2 million. On the basis of these assumptions, Methane emissions from the livestock sector are estimated at a constant value of 2375 Gg of CO_2 eq.

The emissions of CH_4 through Biomass burning occur mostly through uncontrolled burning of Forest Lands and Grasslands. The main assumption is that for as long as fire mitigation measures in the country remain consistent approximately 3,918,882.93 ha of forests and grasslands will be burnt, emitting 244.96 Gg of CO_2 eq.

Waste sector comprises of domestic waste, industrial waste and wastewater. The GHG emitted from the waste sector is primarily CH_4 with traces of CO_2. Similar to other economic sectors, there is a steady increase in CH_4 emissions as depicted in figure 58.

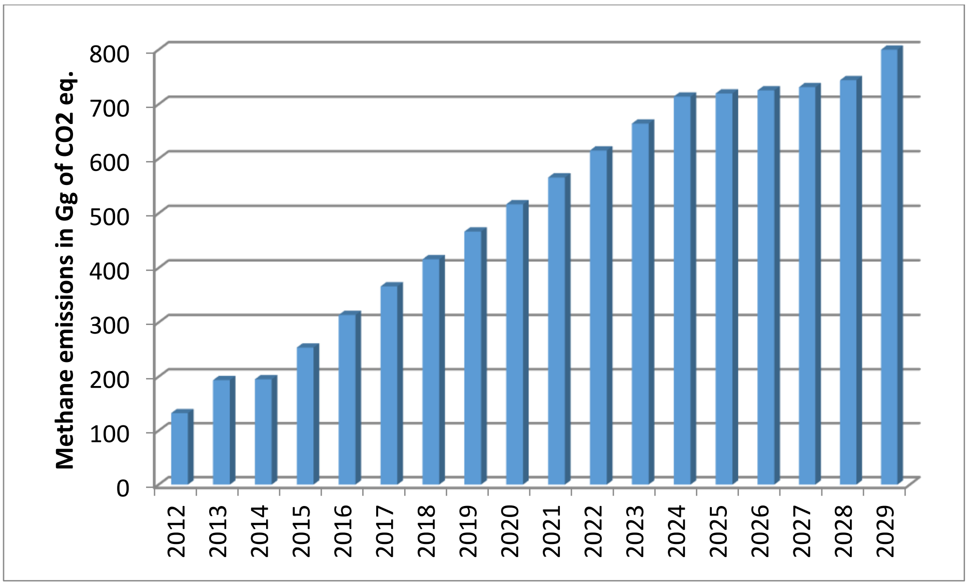


Figure 58: Methane emissions from waste sector in Gg of CO2 eq.

3.5 Feasible GHG emission mitigations

Over the years, GoB has been intensifying its efforts to reduce the country's GHG emissions with emphasis on renewable energy. In addition, the country has also been actively involved in feasibility studies on climate change mitigation actions. Below is a description of the mitigation projects currently implemented in the country?

3.6 Biogas plants at household level, private businesses and schools

Biogas plants involve production of biogas, mainly methane as an energy gas for cooking, heating, lighting and for electricity generation. The biogas plants can be operated at the household level for cooking and lighting, commercial level for heating and power generation mainly at abattoirs (cattle and chicken) and also at community levels (primary and secondary schools). Under the biogas production initiative, there are a number of projects under feasibility studies to assess the viability of the biogas production at various levels. These are discussed below.

3.6.1 Botswana Meat Commission (BMC) Plant

This is a significantly large scale proposed biogas project which will involve establishing and operating a biogas plant and gas upgrading plant which will generate methane from effluent disposed into an open pond water treatment plant and cow dung collected from BMC and feedlots. It is envisaged that the gas will be used to generate electricity for the national grid system and for cooking gas to replace Liquid Petroleum Gas (LPG). The plant capacity is estimated at 2.5-3 MW and constructed at a cost of BWP 100 million.

3.6.2 Mmamashia Biogas Project

This is another proposed biogas project with a capacity of approximately 1 MW. The electricity will be generated from agro-waste (chicken and cattle manure) and municipal waste. The proposed plant will be constructed at an estimated cost of BWP 250 million.

3.6.3 Mabesekwa Biogas plant

This is another CDM project that has been earmarked as both a climate change mitigation action and also to increase the country's main objective of increasing renewable energy in the energy mix. The project will involve construction and operation of a 200 m^3 biogas plant which will provide cooking gas for 400 students on daily basis and a gas-generator to supply 100 households and power 20 streetlights in the village. It is envisaged that success of the biogas plant will be replicated to 3 villages at a rate of one village per year for 4 years. Similar to other biogas projects, the emissions reduction will be two-ways. Firstly, capture of produced CH_4 in the atmosphere and secondly, avoided emissions from the use of paraffin and from the use of fuel wood as a source of energy.

3.6.4 Household biogas plants

Household biogas plants are mini biogas plants with an average capacity of 6 m^3 that are operated at the household level to generate methane for cooking, heating and lighting. This is one of the most feasible, economic and cost-effective climate mitigation options for the country, particularly at the rural population. Household biogas plants have the potential to provide rural household with sufficient renewable energy for both cooking, heating and lighting. This project is still at the planning stage and it is projected that it will commence with construction and operation of 1500 household biogas plants. The cost of construction and installation of the biogas plant including biogas stove is estimated at approximately BWP 15 000.00

Estimating the emissions reduction of the household biogas plants was based on fuel wood consumption displacement at the household level. According to FOSA study, fuel wood per capita in the country is 0.58 tons $year^{-1}$ (Sekgopo, 2000). Assuming a household size of 4 as per population census, fuel wood consumption in the country is estimated at 25-50 kg per day per household. Therefore, this figure was used to estimate emission reductions from the household biogas plants.

3.7 GHG emission reduction potential of the biogas plants initiatives

The GHG emissions reduction from the biogas plant was estimated based on electricity generated and the resultant displaced electricity from coal fired power plants and from avoided fuel wood consumption assuming that the plants will be operated on daily basis. Table 33 depicts CO_2 emissions reduction potential of the plants per year.

Table 33: GHG emissions reduction from Biogas plants

Plant	Capacity	CO2 emissions reduction (Gg)
BMC biogas	2.5 mw	2.8
Mmamashia Bio plant	1 mw	1.118
Mabesekwa Bio plant	50 kw	Insignificant
Household plants	6 m3 *1500	23.919

A planning scenario of 1000 household biogas plants per year between 2020 and 2030 was used to simulate household biogas plants over time. Figure 59 depicts emissions reduction potential of the household biogas plants.

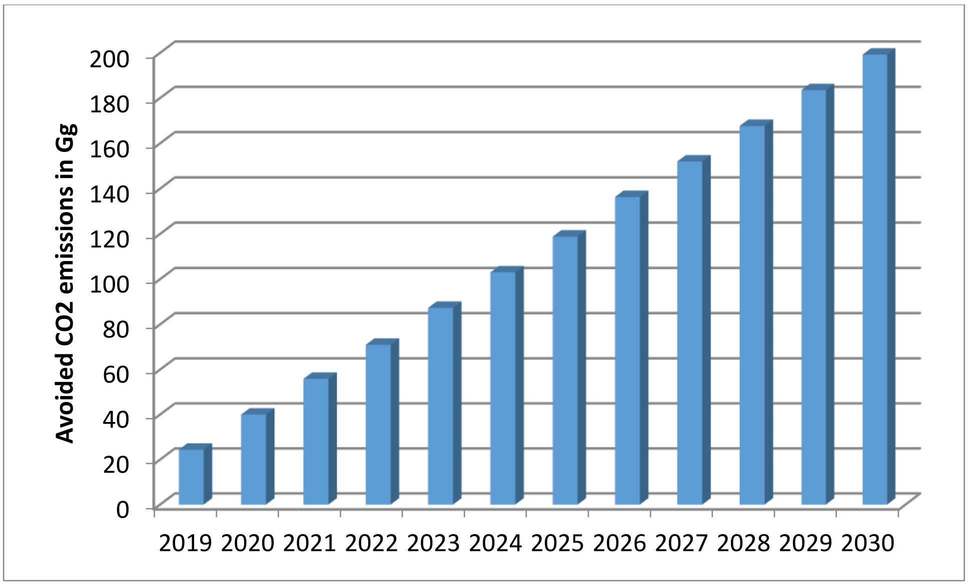


Figure 59: Avoided CO_2 emission in Gg over time

3.7.1 Solar streetlights

Solar street lighting project is currently on-going in the country as an initiative to reduce reliance on coal-based electricity generation. It is a government initiative implemented through Botswana Institute for Technology, Research and Innovation (BITRI). Solar streetlights will result in displacement of coal-based electricity generation and thus a reduction in the GHG emissions. Currently, there are approximately 850 solar streetlights that are operational and their emissions reduction is 0.24 Gg of CO_2 eq. A planning scenario of 1000 streetlights year^{-1} was used to project GHG emissions for the country over a 10 year planning period. Figure 60 depicts the avoided CO_2 emissions through a switch to solar streetlights by the year 2030.

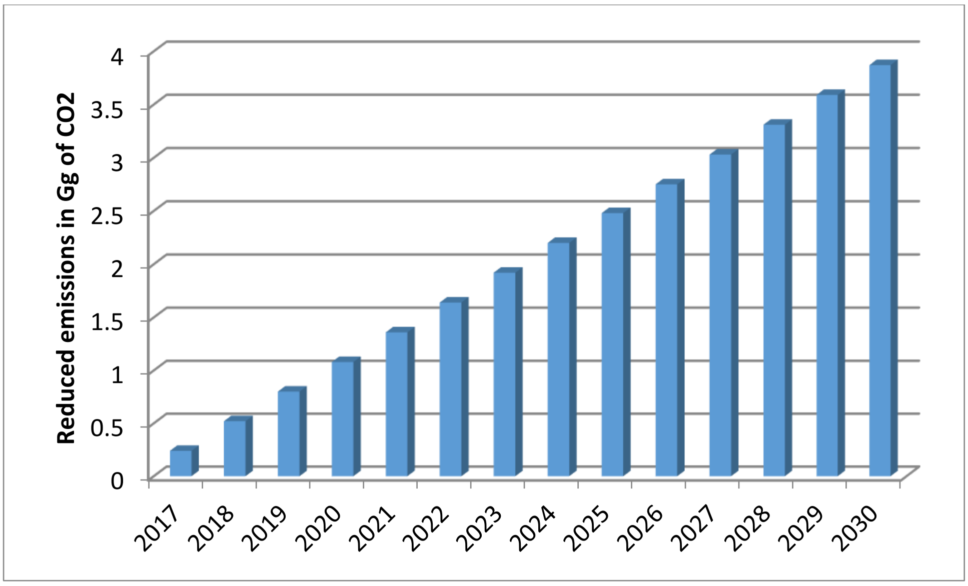


Figure 60: Avoided CO2 emissions from solar streetlights over time

3.7.2 On-going and Planned Solar power stations

There are a number of planned and on-going mini and relatively medium scaled solar photovoltaic power plants. These efforts are government initiatives of increasing the contribution of the RE in the country's energy mix. Table 4 below depicts operational and planned solar PV plants for the country and potential emissions reduction per year at full operational level of all the proposed stations.

Table 34: Operational and planned Solar Power Stations

Location	Capacity	Status	Potential of GHG emissions reduction (Gg CO_2 eq.)	Cost
Phakalane	1.3 MW	operational	1.5	BWP 100 million
S/Phikwe	50 MW	planned	55.94	BWP 7.5 billion
Jwaneng	50 MW	planned	55.94	BWP 7.5 billion
Seronga	2 MW	planned	2.23	BWP 200 million
Nationally	20*2 MW	planned	44.7	BWP 4 billion
Tobela	1	planned	1.115	BWP 100 million
Nationally	21*60 kW	planned	1.4	BWP 150 million
Mmokolodi	12 kW	constructed	insignificant	BWP0.5 million
Herelela	50 kW	on-going	insignificant	BWP 1 million
12 Grid-tied solar projects	65 MW	planned	72.7	
20 villages electrification (not grid-tied solar project)	1 MW	planned	22.3	BWP 100 million
Sekhutlane	12 kW	constructed	insignificant	BWP 0.5 million
BOTEC	5 kW	Decommissioned	insignificant	BWP 0.25 million
Scales Broadhurst	34 kW	operational		BWP 0.4 million

Okavango Delta	74*50 kW	operational	4.14	BWP 0.5 million
		Total	261.965	

3.7.3 Solar energy pumps for livestock sector

Livestock sector is supported by approximately 50 900 boreholes, majority of which are diesel powered for groundwater abstraction. Therefore, a switch to solar pumps is one of the cost-effective climate change mitigation strategies to reduce GHG emissions. Evidently, the share of solar energy pumps is increasingly high as farmers are switching from diesel water engines as a way of reducing operational fuel costs. Table 35 depicts the number of solar energy pumps at traditional cattle posts.

Table 35: Number of solar pumps in the country

Year	National boreholes	Number of solar powered boreholes
2012	52996	87
2013	50030	199
2014	51512	358
2015	51512	537

On the basis of the observed growth of solar powered pumps and consultation with suppliers of solar pumps, a conservative figure of 50% solar pumps by 2030 is used to simulate GHG emissions reduction. Figure 61 depicts the projected switch towards solar pumps up to 2030.

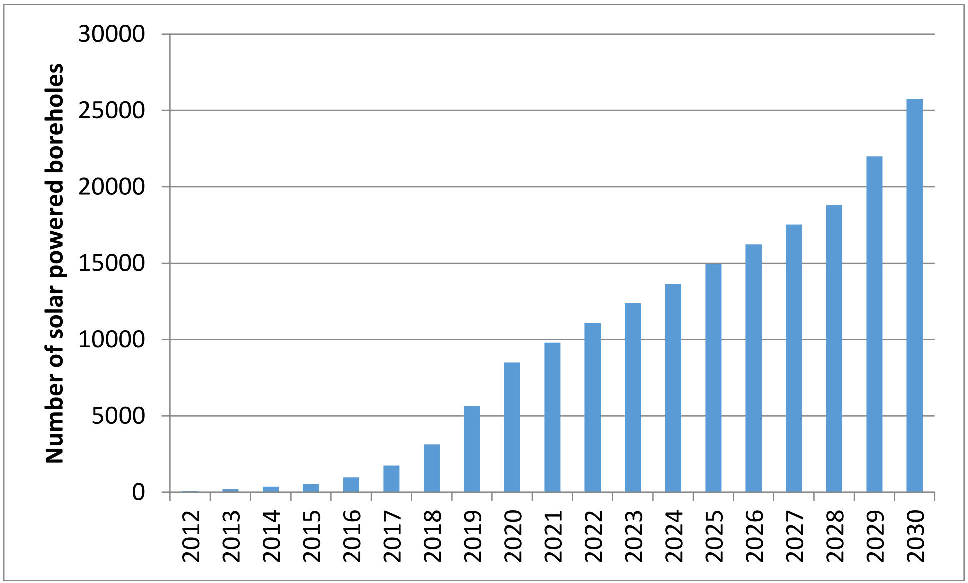


Figure 61: Projected number of solar powered boreholes

On average, it is estimated that a borehole supplying 500 heads of cattle uses approximately 200 litres of diesel in 1.5 months. Using this information, emissions reduction from the projected number of solar pumped boreholes is as depicted in figure 62 below.

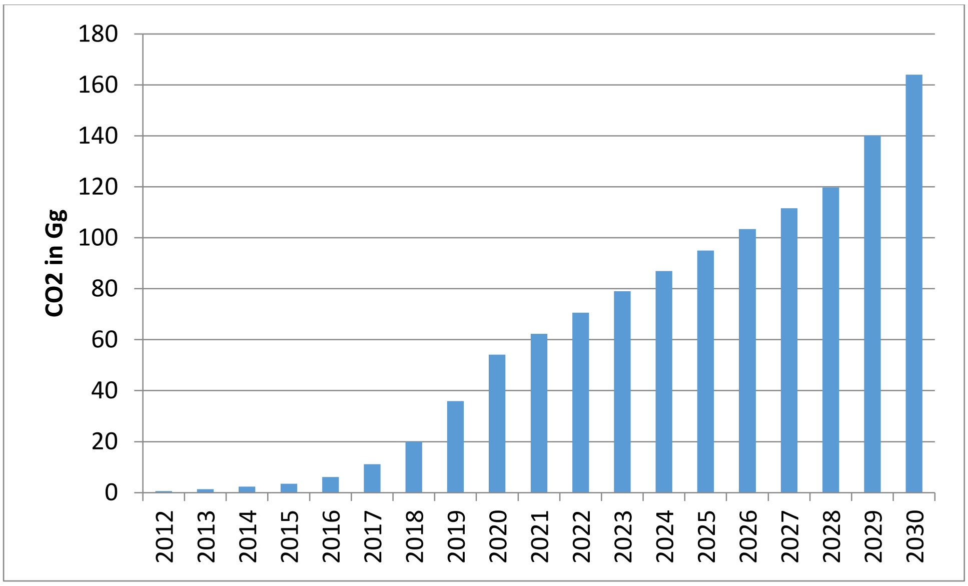


Figure 62: Avoided CO2 emissions from solar boreholes

3.7.4 Solar Geysers

Another highly feasible and cost-effective climate change mitigation measure is the intensification of the solar geysers in replacement of the conventional electric ones. Though solar geysers have been in existence for over 40 years, its penetration into the market is extremely low. For instance, it is estimated that only 0.41% of the households use solar energy for heating. This translates into approximately 750 households from 550 946 households in 2013 (CSO, 2013). On the other hand, Botswana Power Corporation estimated that approximately 3% of the high income households use solar water heaters/geysers (ECCG, 1999). A scenario of the penetration of solar geysers is that by 2030, 10% of the total households will be using solar geysers

Assuming that conventional electric heaters are switched for 3 hours per day with a capacity of 300 watts, one geyser consumes approximately 328.5 kWh $year^{-1}$. Therefore, one solar geyser has the potential to reduce approximately 0.00011 Gg of CO_2 emissions, which is approximately 110 kg of CO_2 eq. while the cost of one unit is approximately P20 000.00. Based on figure 63 depicts simulated avoided CO_2 emissions in Gg over time.

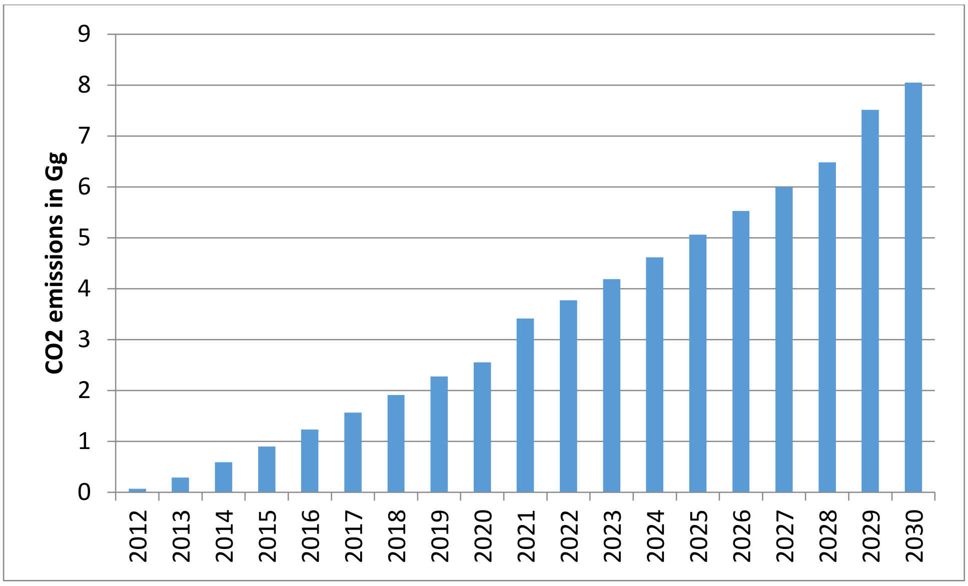


Figure 63: Avoided CO2 emissions from a switch to solar geysers

3.7.5 Captured methane as energy source

Methane from the waste sector (solid waste and wastewater) can be captured and used to generate energy at the waste facilities (landfill and treatment plant). At Glen Valley water treatment plants, methane should be captured and flared to heat the oxidation ponds as a way of speeding up anaerobic processes. Capturing methane as a source of energy reduces GHG emissions in two ways. Firstly, it prevents methane from escaping into the atmosphere. Secondly, it results in displacement of coal fired electricity thereby reducing CO_2 emissions at the coal fired power stations. Figure 64 depicts methane captured based on an assumption of 50% capture from landfills and treatment plants and hence avoided GHG emissions.

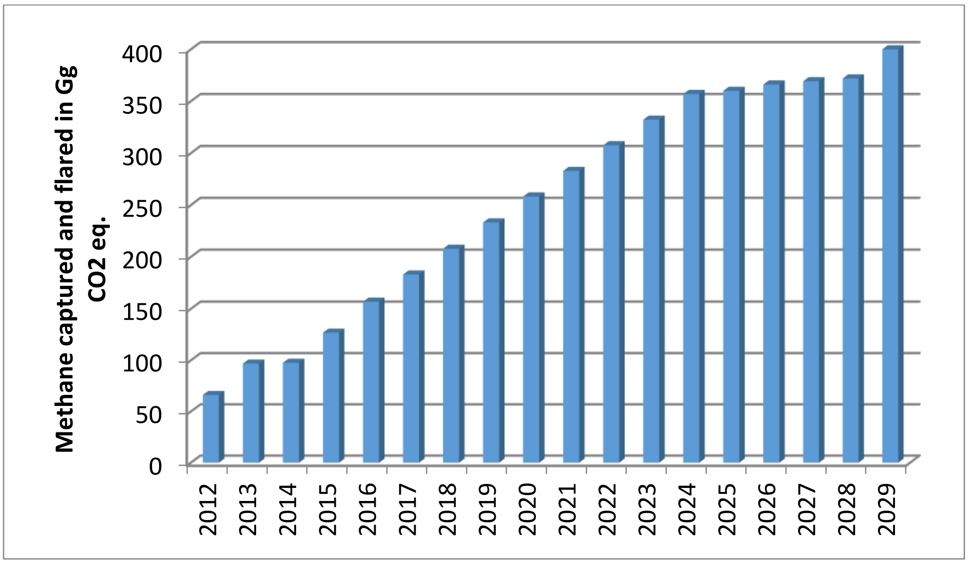


Figure 64: Captured methane in Gg of CO2 eq.

3.7.6 Efficient lighting systems

This is one of the government energy saving initiatives that has resulted in almost 100 % penetration by the year 2015. It was rolled out by Botswana Power Corporation which replaced incandescent light bulbs with Compact Fluorescent Lamps (CFLs) for free. This initiative was aimed at saving electricity at the household level which is the main electricity consumer. CFLs and LEDs are efficient lighting saving bulbs that reduce electricity consumption by as much as 50% to 75%. Estimating energy saving for electricity at the household level was based on the following assumption:

- Lights work approximately 9 hours per day
- Energy saving between Incandescent bulb and CFL is 35 watts
- Average number of bulbs per household is approximately 8
- Household connected to the grid will be 80% by 2030

Therefore, annual electricity saved by the CFL is approximately 920 kWh per household per year. On the basis of the estimated saving per household, figure 65 depicts avoided GHG emissions assuming 1.8 % population growth rate.

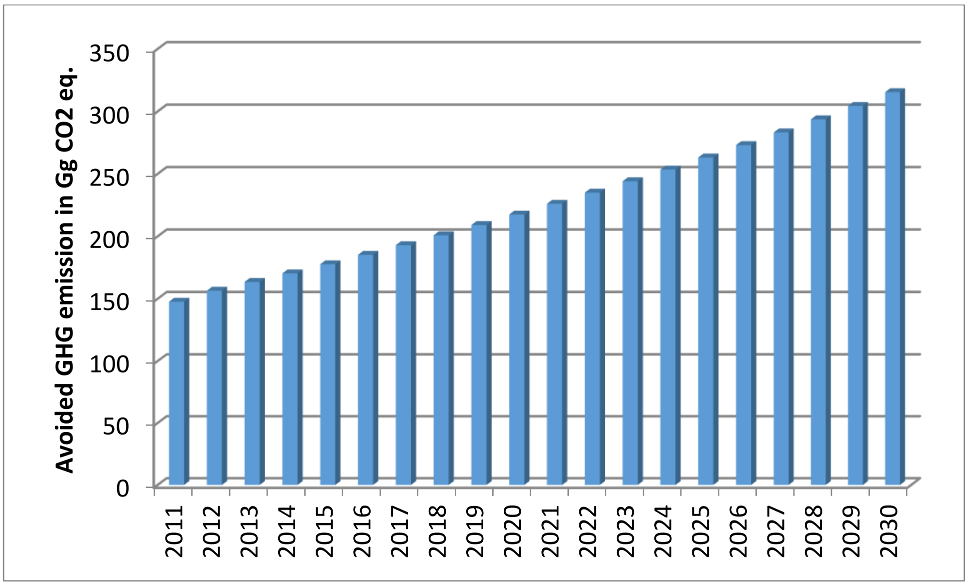


Figure 65: Avoided GHG emission from efficient lighting systems

3.7.7 Improved public transport

Transport sector is one of the major consumers of petroleum products (petrol and diesel) accounting for well over 90% of total petroleum products. The primary factor that contributes to high petroleum consumption is high use of private vehicles as opposed to public transportation. The poor service offered by the public transport sector has resulted in the demand for private vehicles. Thus, one of the feasible mitigation actions is improved public transportation system. In the endeavour to encourage use of public transport, the government has undertaken feasibility study to upgrade the road infrastructure systems to accommodate public transport systems at a cost in excess of BWP 2 billion. Additionally, the initiative will also involve replacement of the mini-buses with buses, and buses to run on cleaner LPG and biodiesel. It is envisaged that the mitigation will be more efficient in cities where the infrastructure will be improved. Thus, the daily use of private cars will decline during the week days. It is projected that improved transport sector will affect utilisation of the private vehicles in Gaborone and Francistown. A survey indicates that households travel approximately 20 km to work and with improved public transport, individuals will reduce costs and save in the 20 km travelled per day. Total avoided fuel consumption is estimated at 100 million liters which represents about 10% of total petroleum consumption.

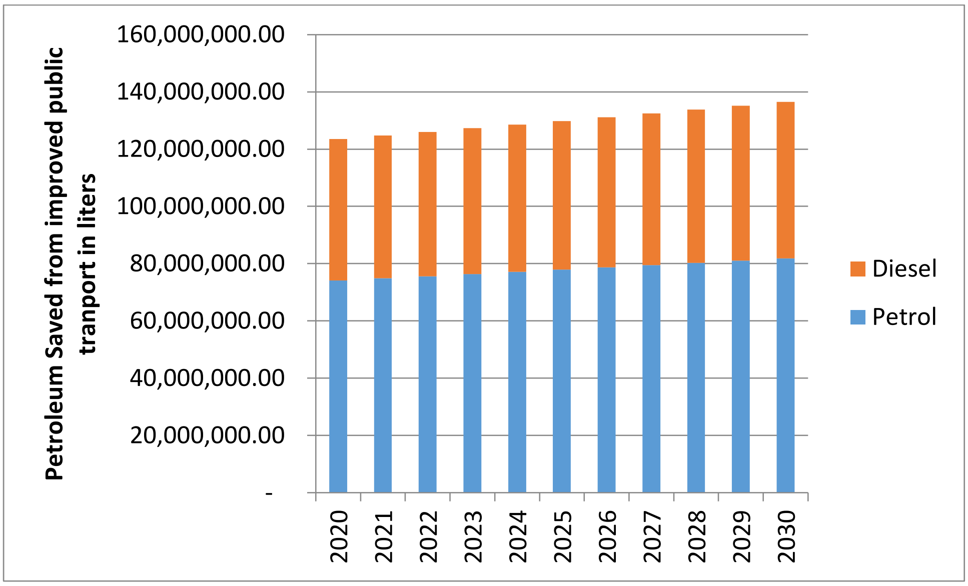


Figure 66: projected Petroleum Saving from improved public transport

Figure 67 depicts avoided GHG emissions in Gg CO_2 eq. from improved public transport systems over the years. It is assumed that improved transport system will take effect from 2020.

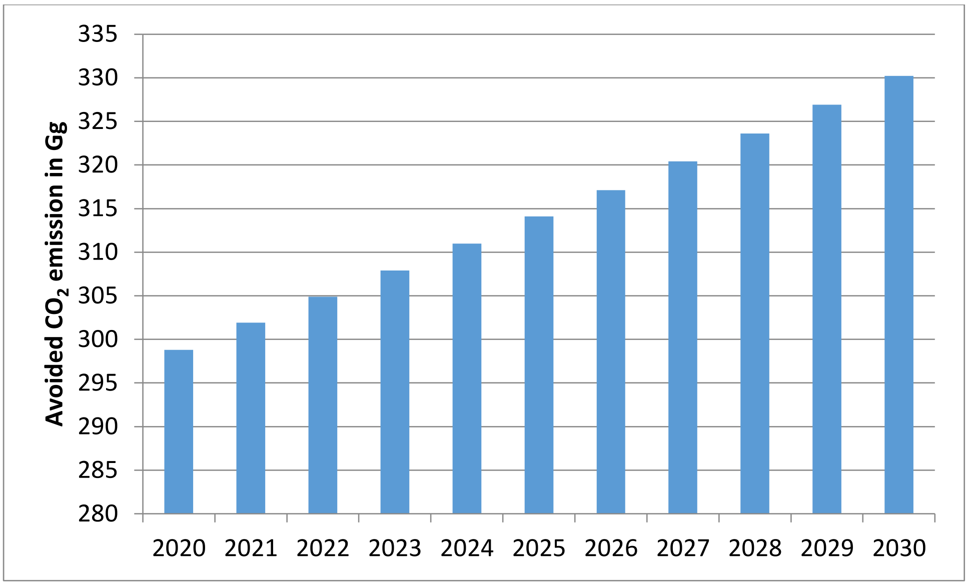


Figure 67: Avoided GHG emissions in Gg CO2 eq. from improved public transport

3.7.8 Agriculture, Forestry and Other Land Uses (AFOLU)

AFOLU is one of the GHG emitting sectors, mainly from land use change. The main contributor of GHG emission within the land use change is as a result of conversion from grassland to crop land. One of the plausible and feasible mitigation measures that can reduce conversion of grassland is improved land uses management through intensification of the crop land (ploughing fields). This will reduce the rate of cropland (ploughing fields) encroachment into grassland. Additionally, reallocation of the unused crop land (fields) will decelerate the rate of land use change thereby reducing the GHG emissions from the AFOLU sector. Additionally, improved pasture management to reduce deforestation will also reduce grassland degradation and thus reducing conversion of the grasslands.

Total GHG emissions reduction and low emission pathway

Figure 68 depicts total GHG emissions reduction from the various on-going and planned mitigation projects over the years. As highlighted, the main GHG emitter is the land use change, and it is within this sector where major reductions can be achieved.

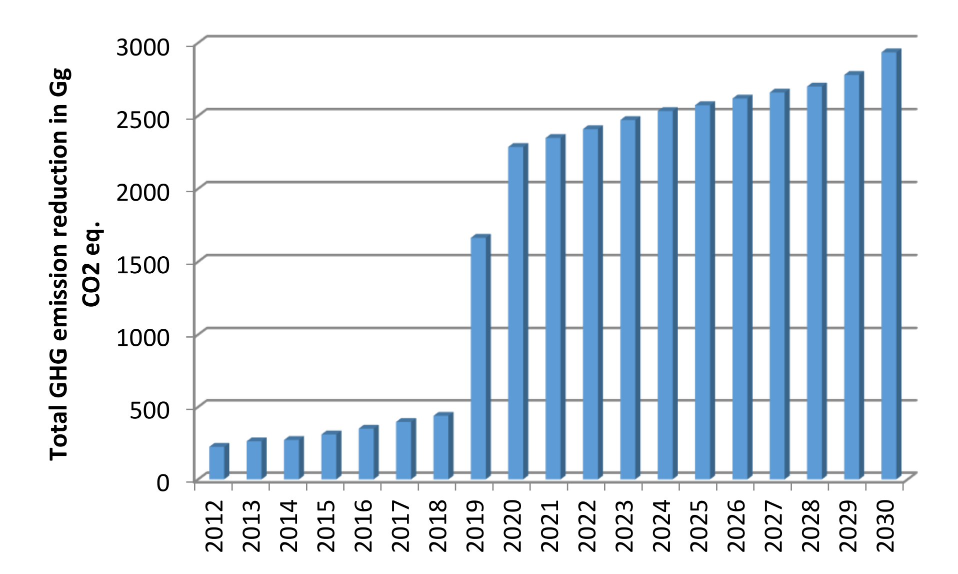


Figure 68: Total GHG emission reductions from feasible mitigation actions

Based on the different feasible mitigation actions and their potential emission reductions, figure 69 shows low emission pathway for the country. It is thus estimated that the country can achieve a total GHG emissions reduction of 12% by 2030. This will be achieved at a cost in excess of over BWP 22.656 billion.

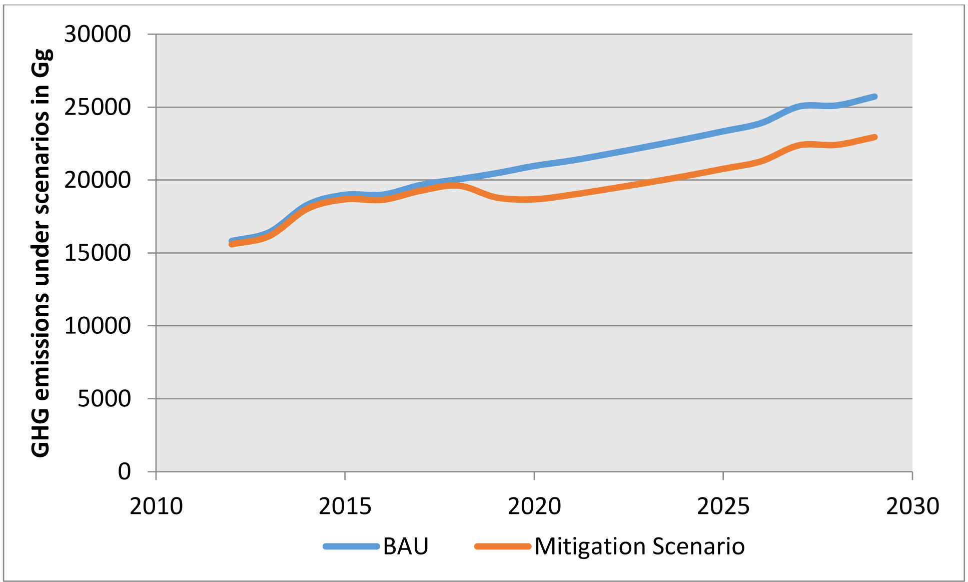


Figure 69: Low GHG emission pathway for the country

3.8 Financing options for the identified mitigation projects

Evidently most of the identified mitigation projects are operational while a few mainly large scale PV solar plants and biogas plants are still at planning stage. For most of the operational projects, they have been domestically financed either by the GoB or private sector and individuals. Table 36 below depicts the financing options for the identified mitigation projects.

Table 36: Financing options for possible mitigation projects

Project	Unit cost	possible financing option(s)
solar street lights	P20 000	Government of Botswana
Solar boreholes	P60 000	farmers, Government, parastatals
solar Geysers	P15 000	households, Government,
Sola PV station (50 kw)	P1 million	GoB, Climate fund
solar PV station (20 kw-30 kw)	0.5 million	Private individuals , Climate fund
Solar PV station (1 mw)	P100 million	PPP, GoB
Solar PV station (50 mw) P2billion	P5-10 billion	PPP, GoB, Climate Fund
Household biogas plant	P20 000	GEF
large scale Biogas plants	P100 million	GEF, GoB, PPP

3.9 Barriers to mitigation implementation investment

The identified mitigation projects are being implemented at a low pace. Subsequently, there are numerous impeding barriers that prevent the private sector, households and the government from investing in these cost-effective mitigation projects. This section thus discusses factors that inhibit investment flow into climate change mitigation actions.

- **High investment costs and long term return on investment on identified projects**

Most of the identified mitigation projects have high initial investment costs and long term return on investment. The projects have long durations to break-even and start to realise positive return on investment (Berliner et al., 2013). For instance, two (2) 50 MW solar power stations and improved public transport will cost approximately BWP 15 billion and BWP 2 billion respectively as initial investment costs. On the other hand, the return on investment is extremely long. For developing countries with multiple socio-economic challenges, the high investment costs become a hindrance to invest in these mitigation projects. Given the associated risks and uncertainty, the private investors are less optimistic to invest in these projects.

- **Existing subsidies on surrogates of the climate change mitigation projects**

Another factor that creates barriers to financing and investing in climate mitigation projects is existence of subsidies on alternative or competing substitutes. The effect of subsidies is to lower the cost of investment for the alternatives to the extent that prices/charges by the providers become extremely lower. Incidentally, this results in mitigation projects which have high investment costs to be non-viable projects as the on-going market prices results in loss over time. Consequently, economic analysis of the mitigation action results in non-viability based on the market price for the alternatives which effectively creates barriers to the investors. The high investment and long term nature of these projects to break-even and the existing subsidies on substitutes jointly act to create barriers for investing in these mitigation projects in the country.

- **Existence of externalities and public good nature of environment**

In addition to existing subsidies, existence of externalities creates barriers for investing in climate change mitigation projects. Externalities ensure that the producers of environmentally dirty projects such as coal fired electricity generation and private vehicle users do not integrate their cost of operation in economic decision making. Evidently, this results in producers charging lower electricity prices which out-competes and edges out the solar electricity projects out of the market. It is therefore critical that externalities are internalised to allow investment in the environmentally friendly projects such as improved public transport, solar appliances such as solar geysers, solar street lights, etc.

- **Competing developmental priorities and limited resources**

Botswana as developing country has various competing developmental needs coupled with limited financial resources. Therefore issues such as health, access to water, education and poverty tend to take precedence over climate change mitigation actions. Consequently, this creates barriers particularly for domestic financing of the mitigation projects.

- **Lack of enabling and conducive environment for mitigation actions**

In order for climate change mitigation actions to be profitable and attract financial flow both domestically and internationally, there is a need to create an enabling and conducive environment for their operations. This enabling environment is created through legal framework in the form of financial incentives such as tax exemptions, internalisation of externalities amongst others. Consequently, lack of enabling and conducive environment ensures that environmentally clean projects such as public transport are exposed to unfair competition resulting in them being out-competed by dirty projects. For instance, there is conspicuous lack of policy framework that encourages investment in climate change mitigation projects. In the country, there are no existing policy guidelines on appliance standards in terms of energy consumption and sources of energy at the national level.

- **Absence of economies of scale in the country**

One of the factors that inhibit adequate investment/funding in climate change mitigation projects is lack of economies of scale for most of the climate change mitigation projects (Berliner, 2013) particularly in countries with small populations such as Botswana. Incidentally, projects in the country are generally small scale coupled with high investment and transaction costs. The small population of the country thus dictates that small projects which have high investment and transition costs are implemented which inevitably results in low production output and high average cost per unit. The high average cost does not decline over time as production is already curtailed by small production hence diseconomies of scale. This thus creates a barrier to enter into climate change mitigation measures as the products become continuously expensive and lowers demand over time.

- Some Climate Change related Policies are still in draft form. Expediting approval of these strategic documents will assist in coordination and implementation of mitigation projects. **Lack of technical know-how and skilled manpower**

Some of the mitigation projects (e.g. biogas plants, solar water heaters) have been constructed but are not operational due lack of skilled manpower.

Table 37 summaries the barriers that inhibit investment flow in mitigation projects and factors that intensify the barriers.

Table 37: Summary of barriers to investing in climate change projects

Barriers to climate change financing	**Factors that create barriers**
High investment cost and long term investment	• Lack of technology • Lack of existing infrastructure • Lack of skilled manpower
Existing subsidies on climate change mitigation projects substitutes	• Government policies
Disregarding existence of the externalities	• Public good nature of the environment • Government policies
Limited resources and competing developmental needs	• Development level of the country
Lack of capacity to develop bankable and green projects	• Lack of funds for specialised training
Policies in draft format	• Long
	•
Absence of economies of scale for most climate change projects	• Small population size of the country

3.10 Conducive environment for implementation

Large scale implementation and optimal operation of the mitigation projects particularly renewable energy projects will require removal of barriers and a conducive environment. It is therefore pertinent that all the identified barriers are removed and incentives implemented. Some of the activities that are essential for creating an enabling environment are discussed below.

- **Removal of subsidies on Coal Powered Electricity**

Removal of subsidies will hike the electricity price and thereby making solar power generation an attractive investment. This is because the price per unit of electricity will make it economically viable to invest in solar power stations. Currently, the price of electricity is significantly lower and thus discourages investment in solar projects.

In addition, removal of subsidies will make it cost-effective for individuals to invest in electricity saving appliances including solar appliances such as solar geysers.

- **Introduce Net Metering for renewable energy**
- A Renewable Net Metering policy instrument used by Governments to encourage and promote the local growth of electricity generation from renewable energy (hereinafter RE) resources for input into the national grid. Net metering is a utility billing mechanism that allows utilities such as BPC to offer electricity on credit to customers who are making excess electricity with their roof-top systems and sending it back to the grid. This ensures that those who produce excess electricity from renewable sources can trade it back into the grid.
- **Introduce subsidies on solar electricity**

The initial investment in the solar projects is relatively high compared to the coal based power generation. However, the environmental costs of solar energy are insignificantly lower to non-existence compared to the counterparts. Therefore, it is imperative that subsidies are introduced to encourage high investment in solar projects. There are various forms of subsidies that can be allocated to the solar electricity as follows:

a. Tax exemption on solar investment
b. Zero interest loan on solar investment
c. Part payment by the government on solar electricity tariffs

- **Introduce tax on petroleum products**

The transport sector is one of the major GHGs emitters in the country through consumption of the petroleum products (petrol and diesel). One of the factors that results in the transport sector to be a major GHGs emitter is the use of private vehicles. Factors that encourage the excessive use of private vehicles as opposed to public transport include lower costs of petroleum products, the unattractiveness of the public transport which encompasses lack of public transport facility, roads, reliability of the public transport. Thus, introduction of tax and removal of the subsidies on petroleum products would deter excessive use of private vehicles. In addition to introducing tax and removal of subsidies, it is critical that the government invests intensively on public transport and transform the sector to comparative standard as developed countries. This will involve replacement of mini-buses with buses and introduce public bus lanes to enhance reliability and efficiency.

- **Introduce subsidies on solar appliances**

Currently, solar appliances such as solar geysers and solar panels are excessively expensive relative to the counterparts. For instance, a solar geyser costs in the range of between P10, 000.00 to P20, 000.00 while conventional geysers cost around P2, 000.00 per unit. It is therefore recommended that subsidies on solar appliances be introduced which would reduce demand for coal-based electricity production.

- **Introduce tax exemption on house sales that have solar appliances**

Introduction of tax exemption on house sales that are environmentally friendly, would act as an incentive for the public to invest in solar appliances. The rationale for introducing tax exemption is generally based on the fact that individuals who have constructed environmentally friendly houses have internalised the externalities. Hence, there is a need to refund the expenses they incurred by exempting them from paying tax from house sale. In addition, it is also recommended that council rates for environmentally friendly houses be lowered as an incentive to invest in solar appliances.

- **Introduce government to guarantee climate change mitigation projects**

Lack of guarantor for the climate change mitigation projects has been identified as one of the barriers to finance climate change mitigation projects. It is therefore important that the government considers being a guarantor for the climate change mitigation projects. This would encourage foreign direct investment in climate related projects by reducing the country risks that have been identified as barriers to climate change.

Table 38 below summarises the proposed policy instruments that would create a conducive environment for financing climate change mitigation projects.

Table 38: Summary of activities to be undertaken for creation of conductive environment for RE

Policy instrument	**Anticipated impacts**
Removal of subsidies on coal powered electricity generation	• Cost reflective market price of coal based electricity which would make solar based electricity to be competitive and economically viable • Internalise the externalities associated with coal based electricity and reflect the true cost of producing coal based electricity
Introduce Net Metering	• Encourages and promotes electricity generation from renewable energy resources • Ensures that producers of electricity from renewable sources have a guaranteed market • Ensures that REis a sound long-term investment for locals and investors • Encourages foreign direct investment
Introduce subsidies on solar generated electricity and solar appliances	• Reflect the benefits associated with solar electricity • Lower the unit cost of solar electricity to increase demand and take up • Encourage use of solar appliances, e.g. solar geysers
Introduce tax on petroleum products	• Increase the cost of using private vehicles • Discourage individuals to use large engine vehicles
Introduce parking fees and control parking on empty spaces	• Increase the cost of using private vehicles • Increase the number of people using public transport
	•
Tax exemptions on environmentally friendly and energy efficient houses	• Encourage individuals to invest in solar energy, environmentally friendly and energy efficient houses
Government as guarantor on climate change projects loans	• Reduce country risks for foreign direct investment • Increase foreign direct investment
Introduce carrying capacity quotas.	• Avoided land degradation and increase ecosystem functions and services.

3.11 Conclusions

There is strong evidence that the GoB has intensified its efforts in implementing and undertaking feasibility studies for projects that will ultimately reduce the country's GHG emissions. These efforts are in accordance with COP commitment to limit GHG and resultant increase in temperature to below 1.5 ^{o}C by year 2050. Some of the efforts that are currently in operation include solar PV power stations; a 1.3 MW plant in Phakalane, installation of PV solar streetlights, proposed two (2) 50 MW plants, switch to solar powered boreholes and control of veldt fires amongst others. There are other planned projects with the potential to significantly reduce GHG emissions and these include biogas plants, improved public transport system, veldt fire monitoring and management and rangeland management to reduce deforestation and forest degradation. Implementation of all these projects has the potential to reduce the overall country's GHG emissions by 12% by the year 2030 at a cost in excess of BWP 22.656 billion. The biggest emission reduction will come from the energy sector which accounts for well over 60% of the country's GHG emissions. This will be the low emission pathway for the country. Though some efforts have been undertaken in implementing some mitigation projects, a lot of work is still required to encourage investment in large scale projects that have the potential to significantly reduce the country's GHG emissions.

Some of the factors that are currently inhibiting significant financial investment flow into the mitigation projects include the following:

- High investment and long term return on investment for the majority of the mitigation projects
- Heavy subsidies on alternative/competing alternative projects, mainly coal generated electricity, petroleum products, etc.
- Existence of externalities which results in producers charging lower prices
- Uncertainty and high risk coupled with long term return on investment
- Lack of economies of scale due to small population which results in non-declining average production costs
- Lack of guarantor on loans for climate change mitigation projects

Some of the policy instruments that are required to create an enabling environment to facilitate investment flow into RE projects and mitigation projects include the following:

- Removal of subsidies on alternative projects competing with mitigation projects
- Introduction of Net Metering Policy
- Introduction of Tax on petroleum products

- Introduction of subsidies on solar appliances, solar geysers and solar powered boreholes
- Tax exemption and low council rates for RE houses
- Introduction of a grace period for climate change mitigation loans

3.12Recommendations

On the basis of the findings of the assignment, the following recommendations are made:

- Develop a national mitigation strategy and action plan that will guide the implementation and operation of the mitigations in the country. The national strategy and action plan should be used to implement the NAMAs and INDCs
- Develop resource and financial mobilisation strategy for the climate mitigation sectors with emphasis of using funds collected from the petroleum sector and using it to finance and subsidise solar appliances and projects
- Strengthen collaboration between Climate Change focal point, Department of Energy, BITRI and BPC to facilitate a platform for coordinated implementation of the project
- Conduct a thorough financial and economic analysis for mitigations to achieve cost-effectiveness. For instance, it is cost-effective to install solar streetlights or building a mini solar PV station and power conventional LED streetlights
- The government to play an active role of encouraging Public Private Partnership and act as a guarantor for mitigation projects
- Removal of all the barriers by introducing the recommended policy instruments.

Table 39: Recommendations sector

Component	Organisation	What is Ongoing	What is planned
Technology Transfer			
	Department of Energy	Technical assistance to develop Integrated Resource Plan through IAEA assistance	Introduce grid codes for connecting renewable energy systems into the grid
		Technical assistance from World Bank to implement the Energy Efficiency Strategy	Rolling out off-grid solar solutions to 245000 off-grid customers
		Extension of existing solar grid in 20 schools to cover government facilities	
	Ministry of Tertiary Education – Department Research Science and Technology	The Joint research committee on research, science, technology and innovation is currently implementing the solar farm project at BIUST.	Waste to Energy Project at BIUST
		The Department of Research, Science and Technology in collaboration with different institutions (BITRI, BIUST) is working on energy projects that will assist with supplementing the grid	
	Department of Forestry and Range	Early warning Systems for Fire Management	Forecast on fire danger rating

	Resources/National Parks		
Research and Systematic Observation			
	Ministry of Health and Wellness	Water quality surveillance – Rolling out water sampling plans to district and villages to trace and detect early contaminants	Strengthen surveillance system for early detection and reporting of climate related health impacts
			Research on linkages between climate change and health
	Department of Energy	Feasibility study on waste to energy	
		National Energy Use Survey through EU assistance	
	Botswana Red Cross		Conduct research on indigenous knowledge on climate hazards and risks
	Botswana Climate Change Network	Conducting study with University of Botswana – Analysis of landscape of climate governance in Botswana	Conduct Baseline and Endline Surveys on the Development of Government Policies, Plans and Actions enacted and/or Reviewed
		Phase two – sector specific analysis: climate finance flows (public and private sector based climate finance), Agriculture and food security,	

		Energy access and transformation, Adaptation, Loss and damage, Technology, knowledge management and capacity building, Gender, Youth and Marginalized groups, Private Sector engagement including trade and just transition issues.	
		Case Studies on Climate Change Policy and Gender / IEC Material	
		Training of trainers on Indigenous knowledge systems – e.g Community Trusts, Individuals within communities	
	Department Of forestry and Range Resources/National Parks	Conducting national forest inventory	Conducting national forest inventory
			Land degradation Neutrality Project
			Research on Impact of climate change on distribution of animal species in Kgalagadi dry ecosystem
			Developing Red list index of animals and plants
		Department of Water and Sanitation	Conducting Feasibility Study on Total water management system
	Ministry of Mineral Resources, Green		Establish publicly funded grants for

	Technology and Energy Security , Tertiary Education, Research, Science and Technology , Research Institutes, Higher Education Institutes		climate change research – focused on both adaptation and mitigation – for each of the sectors covered by the national climate change strategy and action plan and stipulating that the majority of such grant funding would be disbursed to research institutions located within Botswana.
	Ministry of Mineral Resources, Green Technology and Energy Security ,Tertiary Education, Research, Science and Technology , Research Institutes , Higher Education Institutes , Ministry of Investment, Trade and Industry		Set up a Climate Innovation Center (CIC) or a Climate Innovation Hub (CIH) to support the generation and growth of climate-compatible business models by providing business incubation, business acceleration, and market access guidance and tools to micro, small, and medium enterprises.
	Department of Meteorological Services		
Education , Training and Public Awareness			
	Botswana Red Cross	Conducting trainings to red cross volunteers and communities in disaster prone areas	Assist communities craft climate change projects in disaster prone areas

		Zambezi River Basin and Limpopo Initiative – Build resilience to climate change and disaster risk of communities along the two major rivers	
	Ministry of Health and Wellness		Training of health professionals on the identification and tracking of climate related health impacts
			Public awareness on health impacts of climate change aimed at promoting resilience building measures
	Gender Affairs Department / BCCN /UNDP /UN Women		Assist GAP and climate change experts to develop submissions on the elements of gender and climate change as per COPs and the SBI decisions in its Sessions
	Botswana Climate Change Network	Establishment of CBOs – Elevate work on awareness (Central district 5 CBOs established)	Phase two- Integrating Youth Perspectives into National Climate Change Agenda
		Regional Learning Community exchange programmes	
		Development and dissemination of campaign tools with strategic communications on climate change and SDGs and other Multi-lateral	

		Environment Agreements	
	Department of Energy	Energy efficiency awareness programme targeting Primary Schools	Infusing energy efficiency into courses at BPSC
	Department of Forestry and Range Resources	Raising awareness on Tree planting events e.g. National Tree planting	Raising awareness on Tree planting events e.g. National Tree planting
	Department of Water and Sanitation	Wastewater reuse at institutional level	
		Wastewater reuse for social acceptability	
	Ministry of Tertiary Education, Research, Science and Technology, Ministry of Basic Education ,Vocational Institutes and Universities		National school educational curriculum shall be revised and updated to include (distinct from existing environmental education) a study of climate change causes, impacts, responses, and solutions, and a focus on both mitigation and adaptation.
	Ministry of Tertiary Education, Research, Science and Technology, Ministry of Basic Education ,Ministry of Mineral Resources, Green Technology and Energy Security		Training modules and knowledge-transfer workshops shall be developed and conducted annually across all spheres of government to strengthen understanding of climate change through continuing education.

Capacity Building			
	Gender Affairs Department / BCCN /UNDP /UN Women		Strengthen the capacity of Gender Affairs Department , grassroots women, parliamentarians, CSOs in gender and climate change responsive negotiations and responses during the COPs and related UNFCCC processes and regional sessions
			Develop capacity and build a cadre of gender experts who will contribute and document evidence-based gendered and more effective climate policies, and related case studies,
	Botswana Climate Change Network	Strengthen CSO Engagement in Post Paris Climate Change Dialogue and Engagement	
		Community based capacity building in the 10 districts of the Country	
	BCCN/MET Services and UNDP		Media capacity building on climate change
	Department of Forestry and Range Resource/National Parks	Train community members on forestry related aspects	Train community members on forestry related aspects

			Technical assessment on Biodiversity especially modelling
	NDMO	Build capacity of communities targeting women's groups for participation in regional gatherings and information dissemination exercises.	
Legislative Development			
	Gender Affairs Department / BCCN /UNDP /UN Women		Develop national gender and climate change strategy and action plan , as guided by the UNFCCC Gender Action Plan under the Lima Work Programme on Gender
			Mainstream gender into national climate change policies, programmes and strategies
			Technical assistance to develop elements of national climate change and gender action plans

	Ministry of Health and Wellness		Revise public health act and the national health policy to encompass climate change
	Department Of Forestry and Range Resource	Review of Forest Act ,1968	Implementation of UNCCD National Action Programme
	Department of Water and Sanitation	National Water conservation and Demand Strategy – Implementation stage	
		Managed Aquifers Strategy	
	NDMO	Reviewing National Disaster Management Policy of 1996	Dissemination of revised NDM Policy to stakeholders
	Department of Energy	Introduced renewable energy and energy efficiency codes at PPADB	
		Introduced energy efficiency into Building Regulations	
Communication and Knowledge Management			
	Media producers Media outlets (including Televised media, radio, theatre etc), Ministry of Transport and Communications ,Ministry of Mineral Resources, Green Technology and Energy Security ,Tertiary Education, Research, Science		Media grants and incentives shall be provided to print and broadcast media platforms to increase content on and dissemination of credible information on climate change (e.g. community radio).

	and Technology Ministry of Youth Empowerment, Sport and Culture Development		
	Ministry of Local Government and Rural Development ,Ministry of Youth Empowerment, Sport and Culture Development ,Ministry of Transport and Communications Ministry of Mineral Resources, Green Technology and Energy Security		Community groups, youth groups, NGOs, civil society, and the private sector will be engaged regularly through climate change forums, town halls, and panel discussions to enhance the dialogue on climate change in Botswana.
Resource Mobilisation			
Monitoring and Evaluation			

CHAPTER 5- Constraints and Gaps, and Related Financial, Technical and Capacity Needs

Gaps/Challenges

Gaps and Constraints	Description
Data Organisation	Data scattered in many agencies
Non-availability of relevant data	Data for refining inventory to higher tier levels: AFOLU is a key source greenhouse gases there is lack of data such as harvested wood, manure management. Amount of fertiliser used. • The production of beverages (e.g. alcoholic) under the IPPU sector in the country. This will lead to emission of NMVOCs which was not reported in this NIR, though it is occurring. • Land use conversions between the single years covering the period 2000 to 2015. • The quantity of clinker used during the production of cement in Botswana. • The amount of waste generated in Botswana, disaggregated by waste category (e.g. chemical waste, municipal waste, food waste, paper/plastic, rubber etc.) and by source (e.g. household, industry/construction). • Fuelwood gathering/consumption in Botswana. This led to the use of FAOSTATS data which is for the period 2002 to 2009. Extrapolation method was used to fill in the data gaps, among other methods.
Access to data	Lack of institutional arrangements for data sharing
Technical and institutional capacity needs	• Training in data gathering for relevant institutions in GHG inventory methodologies and data formats

	• Climate change modelling • socio-economic analysis • Proposal development • Insufficient financial resources • Weak Institutional arrangement • Absence of legislative/policy frameworks • Inadequate mainstreaming of climate change
Lack of specific country emission factors	Inadequate data for representative emission measurements in the sectors

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ANNEX

A: Annex: List of Institutions Represented in the NCCC

1. Attorney General's Chambers (International and Commercial Division)
2. Botswana Bureau of Standards
3. Business Botswana
4. Botswana Council of Nongovernmental Organizations (BOCONGO)
5. Botswana Institute for Technology Research and Innovation
6. Botswana Meat Commission
7. Botswana Power Corporation
8. Department of Energy Affairs
9. Department of Mines
10. Department of Water Affairs
11. Department of Environmental Affairs
12. Department of Forestry and Range Resources
13. Department of Meteorological Services
14. Department of Wildlife and National Parks
15. Department of National Museum, Monuments and Art Gallery
16. Department of Tourism
17. Department of Waste Management and Pollution Control
18. Gaborone City Council
19. Ministry of Agricultural Development and Food Security
20. Ministry of Tertiary Education, Research, Science and Technology
21. Ministry of Finance and Economic Development
22. Ministry of Health and Wellness
23. Ministry of Transport and Communications
24. National Disaster Management Office
25. Statistics Botswana
26. United Nations Development Program
27. University of Botswana

28. Water Utilities Corporation

30. Somarelang Tikologo

31. Ministry of Basic Education

32. Department of Gender Affairs

33. Ministry of International Affairs and Cooperation

34. Forestry Conservation Botswana

Annex B: Key Category Analysis

Table 0-1: 2014 Key Categories: Level Assessment

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2014 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO2)	-14158.96	14158.96	0.34	0.34
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO2)	13196.10	13196.10	0.32	0.65
1.A.1	Energy Industries - Solid Fuels	CARBON DIOXIDE (CO2)	4178.44	4178.44	0.10	0.75
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO2)	2195.49	2195.49	0.05	0.81
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO2)	-2037.33	2037.33	0.05	0.86
3.A.1	Enteric Fermentation	METHANE (CH4)	1519.82	1519.82	0.04	0.89
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO2)	1164.17	1164.17	0.03	0.92

1.A.4	Other Sectors - Liquid Fuels	CARBON DIOXIDE (CO2)	710.68	710.68	0.02	0.94
4.A	Solid Waste Disposal	METHANE (CH4)	543.99	543.99	0.01	0.95
1.A.4	Other Sectors - Biomass	METHANE (CH4)	505.76	505.76	0.01	0.96
3.C.1	Emissions from biomass burning	NITROUS OXIDE (N2O)	277.33	277.33	0.01	0.97
1.B.1	Solid Fuels	METHANE (CH4)	262.49	262.49	0.01	0.97
1.A.4	Other Sectors - Solid Fuels	CARBON DIOXIDE (CO2)	253.83	253.83	0.01	0.98
3.C.1	Emissions from biomass burning	METHANE (CH4)	205.76	205.76	0.00	0.99
2.A.1	Cement production	CARBON DIOXIDE (CO2)	129.27	129.27	0.00	0.99
1.A.4	Other Sectors - Biomass	NITROUS OXIDE (N2O)	99.55	99.55	0.00	0.99
4.D	Wastewater Treatment and Discharge	METHANE (CH4)	77.34	77.34	0.00	0.99
1.A.3.a	Civil Aviation	CARBON DIOXIDE (CO2)	68.84	68.84	0.00	0.99

3.A.2	Manure Management	METHANE (CH4)	66.46	66.46	0.0 0	1.00
1.A.3.b	Road Transportation	NITROUS OXIDE (N2O)	33.64	33.64	0.0 0	1.00
3.B.4.a. i	Peatlands remaining peatlands	CARBON DIOXIDE (CO2)	28.07	28.07	0.0 0	1.00
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N2O)	23.09	23.09	0.0 0	1.00
1.A.1	Energy Industries - Solid Fuels	NITROUS OXIDE (N2O)	20.54	20.54	0.0 0	1.00
1.A.3.b	Road Transportation	METHANE (CH4)	12.12	12.12	0.0 0	1.00
3.D.1	Harvested Wood Products	CARBON DIOXIDE (CO2)	-10.90	10.90	0.0 0	1.00
3.B.4.a. i	Peatlands remaining peatlands	NITROUS OXIDE (N2O)	5.55	5.55	0.0 0	1.00
1.B.1	Solid Fuels	CARBON DIOXIDE (CO2)	2.51	2.51	0.0 0	1.00
3.C.5	Indirect N2O Emissions from managed soils	NITROUS OXIDE (N2O)	2.10	2.10	0.0 0	1.00
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH4)	1.93	1.93	0.0 0	1.00

1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N2O)	1.64	1.64	0.0 0	1.00
1.A.4	Other Sectors - Solid Fuels	METHANE (CH4)	1.35	1.35	0.0 0	1.00
1.A.4	Other Sectors - Solid Fuels	NITROUS OXIDE (N2O)	1.25	1.25	0.0 0	1.00
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO2)	1.07	1.07	0.0 0	1.00
1.A.1	Energy Industries - Solid Fuels	METHANE (CH4)	0.93	0.93	0.0 0	1.00
3.C.4	Direct N2O Emissions from managed soils	NITROUS OXIDE (N2O)	0.69	0.69	0.0 0	1.00
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0.64	0.64	0.0 0	1.00
1.A.3.a	Civil Aviation	NITROUS OXIDE (N2O)	0.60	0.60	0.0 0	1.00
3.B.5.a	Settlements Remaining Settlements	CARBON DIOXIDE (CO2)	0.25	0.25	0.0 0	1.00
3.C.3	Urea application	CARBON DIOXIDE (CO2)	0.17	0.17	0.0 0	1.00
3.B.6.b	Land Converted to Other land	CARBON DIOXIDE (CO2)	0.10	0.10	0.0 0	1.00

3.C.2	Liming	CARBON DIOXIDE (CO_2)	0.08	0.08	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO_2)	0.03	0.03	0.00	1.00
1.A.3.a	Civil Aviation	METHANE (CH_4)	0.01	0.01	0.00	1.00

Table 0-2: Botswana's Key Categories: Trend Assessment

A	B	C	D	E	F	G	H
IPCC Category code	IPCC Category	Greenhouse gas	2000 Year Estimate Ex0 (Gg CO_2 Eq)	2015 Year Estimate Ext (Gg CO_2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO_2)	25684.77	15198.92	0.30	0.59	0.59

1.A.1	Energy Industries - Solid Fuels	CO2	1303.32	5088.82	0.05	0.10	0.69
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO2)	-26039.46	-15241.32	0.03	0.06	0.75
3.C.1	Emissions from biomass burning	NITROUS OXIDE (N2O)	1563.24	254.28	0.03	0.06	0.81
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO2)	-2037.33	-2778.28	0.02	0.04	0.85
3.C.1	Emissions from biomass burning	METHANE (CH4)	1159.82	188.66	0.02	0.04	0.89
3.A.1	Enteric Fermentation	METHANE (CH4)	1643.96	1337.31	0.01	0.03	0.92
1.A.4	Other Sectors - Solid Fuels	CO2	751.73	200.14	0.01	0.02	0.95
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO2)	1200.83	2351.48	0.01	0.02	0.97
4.A	Solid Waste Disposal	METHANE (CH4)	138.88	584.07	0.01	0.01	0.98
1.A.4	Other Sectors - Biomass	CH4	486.65	515.09	0.00	0.00	0.99
1.B.1	Solid Fuels	METHANE (CH4)	145.22	316.81	0.00	0.00	0.99

2.A.1	Cement production	CARBON DIOXIDE (CO2)	17.38	126.42	0.00	0.00	0.99
1.A.3.a	Civil Aviation	CARBON DIOXIDE (CO2)	87.75	28.12	0.00	0.00	0.99
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO2)	845.09	1094.72	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass	N2O	95.79	101.38	0.00	0.00	1.00
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N2O)	0.00	23.09	0.00	0.00	1.00
3.A.2	Manure Management	METHANE (CH4)	63.15	66.46	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	N2O	6.41	25.01	0.00	0.00	1.00
1.A.3.b	Road Transportation	NITROUS OXIDE (N2O)	18.06	35.84	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	CO2	460.30	624.37	0.00	0.00	1.00
3.B.4.a.i	Peatlands remaining peatlands	CARBON DIOXIDE (CO2)	28.07	28.07	0.00	0.00	1.00
3.D.1	Harvested Wood Products	CARBON DIOXIDE (CO2)	-8.17	-11.09	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	N2O	3.70	0.98	0.00	0.00	1.00
1.A.3.b	Road Transportation	METHANE (CH4)	8.15	13.82	0.00	0.00	1.00

3.C.5	Indirect N2O Emissions from managed soils	NITROUS OXIDE (N2O)	0.00	2.10	0.00	0.00	1.00
3.B.4.a.i	Peatlands remaining peatlands	NITROUS OXIDE (N2O)	5.55	5.55	0.00	0.00	1.00
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO2)	1.00	0.08	0.00	0.00	1.00
1.B.1	Solid Fuels	CARBON DIOXIDE (CO2)	1.39	3.02	0.00	0.00	1.00
4.D	Wastewater Treatment and Discharge	METHANE (CH4)	59.91	78.76	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	CH4	1.67	1.23	0.00	0.00	1.00
1.A.3.a	Civil Aviation	NITROUS OXIDE (N2O)	0.76	0.25	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	CH4	0.29	1.13	0.00	0.00	1.00
3.C.4	Direct N2O Emissions from managed soils	NITROUS OXIDE (N2O)	0.00	0.69	0.00	0.00	1.00
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0.00	0.55	0.00	0.00	1.00
3.C.3	Urea application	CARBON DIOXIDE (CO2)	0.35	0.15	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	N2O	1.04	1.49	0.00	0.00	1.00

3.C.2	Liming	CARBON DIOXIDE (CO_2)	0.00	0.09	0.00	0.00	1.00
3.B.5.a	Settlements Remaining Settlements	CARBON DIOXIDE (CO_2)	0.25	0.25	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	CH_4	1.24	1.73	0.00	0.00	1.00
3.B.6.b	Land Converted to Other land	CARBON DIOXIDE (CO_2)	0.04	0.10	0.00	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO_2)	0.00	0.03	0.00	0.00	1.00
1.A.3.a	Civil Aviation	METHANE (CH_4)	0.01	0.00	0.00	0.00	1.00

Annex C: Uncertainty Analysis

Table 0-2: Uncertainty Analysis

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor or Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory trend in national emissions for year t increase with respect to base year (% of base year)	Uncertainty introduced into the trend in total national emissions (%)
1 - Energy									

1.A.1 - Energy Industries - Solid Fuels	CO2	1303.32	5088.82	5.00	5.00	7.07	1.25	390.45	5.42
1.A.1 - Energy Industries - Solid Fuels	CH4	0.29	1.13	5.00	5.00	7.07	0.00	390.45	0.00
1.A.1 - Energy Industries - Solid Fuels	N2O	6.41	25.01	5.00	5.00	7.07	0.00	390.45	0.00
1.A.3.a - Civil Aviation - Liquid Fuels	CO2	106.67	65.96	7.07	7.07	10.00	0.00	61.83	0.00
1.A.3.a - Civil Aviation - Liquid Fuels	CH4	0.02	0.01	7.07	7.07	10.00	0.00	61.88	0.00
1.A.3.a - Civil Aviation - Liquid Fuels	N2O	0.93	0.57	7.07	7.07	10.00	0.00	61.88	0.00
1.A.3.b - Road Transportation - Liquid Fuels	CO2	1200.83	2351.48	5.00	5.00	7.07	0.27	195.82	1.03
1.A.3.b - Road Transportation - Liquid Fuels	CH4	8.15	13.82	5.00	5.00	7.07	0.00	169.51	0.00
1.A.3.b - Road Transportation - Liquid Fuels	N2O	18.06	35.84	5.00	5.00	7.07	0.00	198.49	0.00

1.A.3.b - Road Transportation	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
1.A.4 - Other Sectors - Liquid Fuels	CO2	460.30	624.37	8.66	8.66	12.25	0.01	135.64	0.06
1.A.4 - Other Sectors - Liquid Fuels	CH4	1.24	1.73	8.66	8.66	12.25	0.00	139.39	0.00
1.A.4 - Other Sectors - Liquid Fuels	N2O	1.04	1.49	8.66	8.66	12.25	0.00	143.88	0.00
1.A.4 - Other Sectors - Solid Fuels	CO2	751.73	200.14	7.07	7.07	10.00	0.00	26.62	0.16
1.A.4 - Other Sectors - Solid Fuels	CH4	1.67	1.23	7.07	7.07	10.00	0.00	73.70	0.00
1.A.4 - Other Sectors - Solid Fuels	N2O	3.70	0.98	7.07	7.07	10.00	0.00	26.62	0.00
1.A.4 - Other Sectors - Biomass	CO2	8651.60	9157.08	7.07	7.07	10.00	4.04	105.84	21.36
1.A.4 - Other Sectors - Biomass	CH4	486.65	515.09	7.07	7.07	10.00	0.01	105.84	0.07
1.A.4 - Other Sectors - Biomass	N2O	95.79	101.38	7.07	7.07	10.00	0.00	105.84	0.00
1.B.1 - Solid Fuels	CO2	1.39	3.02	0.00	0.00	0.00	0.00	218.16	0.00

1.B.1 - Solid Fuels	CH4	145.22	316.81	5.00	0.00	5.00	0.00	218.16	0.00
1.C - Carbon dioxide Transport and Storage	CO2	0.00	0.00	12.25	0.00	12.25	0.00	100.00	0.00
2 - Industrial Processes and Product Use									
2.A.1 - Cement production	CO2	17.38	126.42	0.10	4.00	4.00	0.00	727.30	0.00
2.A.2 - Lime production	CO2	0.00	0.00	15.00	0.00	15.00	0.00	100.00	0.00
2.A.3 - Glass Production	CO2	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.A.4 - Other Process Uses of Carbonates	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
2.B.1 - Ammonia Production	CO2	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.B.2 - Nitric Acid Production	N2O	0.00	0.00	2.00	0.00	2.00	0.00	100.00	0.00
2.B.3 - Adipic Acid Production	N2O	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00

2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.B.5 - Carbide Production	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
2.B.5 - Carbide Production	CH4	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
2.B.6 - Titanium Dioxide Production	CO2	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.B.7 - Soda Ash Production	CO2	845.09	1094.72	0.50	10.00	10.01	0.12	129.54	0.12
2.B.8 - Petrochemical and Carbon Black Production	CO2	0.00	0.00	24.49	0.00	24.49	0.00	100.00	0.00
2.B.8 - Petrochemical and Carbon Black Production	CH4	0.00	0.00	24.49	0.00	24.49	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CHF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH2F2	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH3F	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00

2.B.9 - Fluorochemical Production	CF3CHFCHFCF2CF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CHF2CF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CHF2CHF2	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH2FCF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH3CHF2	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CHF2CH2F	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CF3CH3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CF3CHFCF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CF3CH2CF3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH2FCF2CHF2	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00

2.B.9 - Fluorochemical Production	CF4	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	C2F6	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	C3F8	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	C4F10	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	c-C4F8	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	C5F12	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	C6F14	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	SF6	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CHCl3	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CH2Cl2	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00
2.B.9 - Fluorochemical Production	CF3 I	0.00	0.00	1.00	0.00	1.00	0.00	100.00	0.00

2.C.1 - Iron and Steel Production	CO2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.C.1 - Iron and Steel Production	CH4	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.C.2 - Ferroalloys Production	CO2	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.C.2 - Ferroalloys Production	CH4	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.C.3 - Aluminium production	CO2	0.00	0.00	2.00	0.00	2.00	0.00	100.00	0.00
2.C.3 - Aluminium production	CF4	0.00	0.00	2.00	0.00	2.00	0.00	100.00	0.00
2.C.3 - Aluminium production	C2F6	0.00	0.00	2.00	0.00	2.00	0.00	100.00	0.00
2.C.4 - Magnesium production	CO2	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.C.4 - Magnesium production	SF6	0.00	0.00	5.00	0.00	5.00	0.00	100.00	0.00
2.C.5 - Lead Production	CO2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.C.6 - Zinc Production	CO2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00

2.D - Non-Energy Products from Fuels and Solvent Use	CO2	0.00	0.00	14.14	0.00	14.14	0.00	100.00	0.00
2.E - Electronics Industry	C2F6	0.00	0.00	14.14	0.00	14.14	0.00	100.00	0.00
2.E - Electronics Industry	CF4	0.00	0.00	17.32	0.00	17.32	0.00	100.00	0.00
2.E - Electronics Industry	CHF3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.E - Electronics Industry	C3F8	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.E - Electronics Industry	SF6	0.00	0.00	14.14	0.00	14.14	0.00	100.00	0.00
2.E - Electronics Industry	C6F14	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.1 - Refrigeration and Air Conditioning	CH3CHF2	0.00	0.55	0.10	5.00	5.00	0.00	0.00	0.00
2.F.4 - Aerosols	CH2FCF3	0.00	0.00	10.00	10.00	14.14	0.00	100.00	0.00
2.F.4 - Aerosols	CH3CHF2	0.00	0.00	10.00	10.00	14.14	0.00	100.00	0.00

2.F.4 - Aerosols	CF3CHFCF3	0.00	0.00	10.00	10.00	14.14	0.00	100.00	0.00
2.F.4 - Aerosols	CF3CHFCHFCF2CF3	0.00	0.00	10.00	10.00	14.14	0.00	100.00	0.00
2.F.5 - Solvents	CF3CHFCHFCF2CF3	0.00	0.00	10.00	50.00	50.99	0.00	100.00	0.00
2.F.5 - Solvents	C6F14	0.00	0.00	10.00	50.00	50.99	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CHF3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CH2F2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CH3F	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CF3CHFCHFCF2CF3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CHF2CF3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00

2.F.6 - Other Applications (please specify)	CHF2CHF2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CH2FCF3	0.00	0.00	10.00	50.00	50.99	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CH3CHF2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CHF2CH2F	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CF3CH3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CF3CHFCF3	0.00	0.00	10.00	50.00	50.99	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CF3CH2CF3	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CH2FCF2CHF2	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	CF4	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	C2F6	0.00	0.00	10.00	50.00	50.99	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	C3F8	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00

2.F.6 - Other Applications (please specify)	C4F10	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	c-C4F8	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	C5F12	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.F.6 - Other Applications (please specify)	C6F14	0.00	0.00	10.00	0.00	10.00	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	SF6	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	CF4	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	C2F6	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	C3F8	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	C4F10	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	c-C4F8	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	C5F12	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00

2.G - Other Product Manufacture and Use	C6F14	0.00	0.00	60.00	58.31	83.67	0.00	100.00	0.00
2.G - Other Product Manufacture and Use	N2O	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3 - Agriculture, Forestry, and Other Land Use									
3.A.1 - Enteric Fermentation	CH4	1643.96	1337.31	1.23	66.14	66.16	0.79	81.35	5.63
3.A.2 - Manure Management	N2O	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3.A.2 - Manure Management	CH4	63.15	66.46	1.03	84.85	84.86	0.00	105.25	0.01
3.B.1.a - Forest land Remaining Forest land	CO2	-2037.33	-1681.49	8.00	10.00	12.81	0.45	0.00	3.38
3.B.1.b - Land Converted to Forest land	CO2	-26039.46	631.24	8.00	10.00	12.81	0.06	0.00	1037.77
3.B.2.a - Cropland Remaining Cropland	CO2	0.00	0.03	9.00	75.00	75.54	0.00	0.00	0.00
3.B.2.b - Land Converted to Cropland	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

3.B.3.a - Grassland Remaining Grassland	CO2	0.00	0.00	1.00	50.00	50.01	0.00	100.00	0.00
3.B.3.b - Land Converted to Grassland	CO2	25684.77	10994.48	1.00	25.00	25.02	72.84	42.81	3540.59
3.B.4.a.i - Peatlands remaining peatlands	CO2	28.07	28.07	2.00	20.00	20.10	0.00	100.00	0.00
3.B.4.a.i - Peatlands remaining peatlands	N2O	5.55	5.55	2.00	30.00	30.07	0.00	100.00	0.00
3.B.4.b - Land Converted to Wetlands	N2O	0.00	0.00	5.00	50.00	50.25	0.00	100.00	0.00
3.B.4.b - Land Converted to Wetlands	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3.B.5.a - Settlements Remaining Settlements	CO2	0.25	0.25	0.10	60.00	60.00	0.00	100.00	0.00
3.B.5.b - Land Converted to Settlements	CO2	1.00	0.83	0.81	58.31	58.32	0.00	83.13	0.00
3.B.6.b - Land Converted to Other land	CO2	0.04	0.10	1.13	70.71	70.72	0.00	273.08	0.00
3.C.1 - Emissions from biomass burning	CH4	1159.82	188.66	0.91	9.04	9.09	0.00	16.27	0.01
3.C.1 - Emissions from biomass burning	N2O	1563.24	254.28	0.91	0.14	0.92	0.00	16.27	0.00

3.C.2 - Liming	CO2	0.00	0.09	0.80	5.00	5.06	0.00	2380650.00	0.00
3.C.3 - Urea application	CO2	0.35	0.17	0.50	8.00	8.02	0.00	47.11	0.00
3.C.4 - Direct N2O Emissions from managed soils	N2O	0.00	0.69	0.10	0.30	0.32	0.00	0.00	0.00
3.C.5 - Indirect N2O Emissions from managed soils	N2O	0.00	2.10	0.40	2.00	2.04	0.00	0.00	0.00
3.C.6 - Indirect N2O Emissions from manure management	N2O	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3.C.7 - Rice cultivations	CH4	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3.D.1 - Harvested Wood Products	CO2	-8.17	-11.09	0.00	0.00	0.00	0.00	0.00	0.00
4 - Waste									
4.A - Solid Waste Disposal	CH4	138.88	584.07	0.80	10.00	10.03	0.03	420.56	0.04

4.B - Biological Treatment of Solid Waste	CH4	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4.B - Biological Treatment of Solid Waste	N2O	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4.C - Incineration and Open Burning of Waste	CO2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4.C - Incineration and Open Burning of Waste	CH4	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4.C - Incineration and Open Burning of Waste	N2O	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4.D - Wastewater Treatment and Discharge	CH4	59.91	78.76	0.80	10.00	10.03	0.00	131.46	0.00
4.D - Wastewater Treatment and Discharge	N2O	0.00	23.09	0.80	10.00	10.03	0.00	0.00	0.00
5 - Other									
Total									
		Sum(C): 16371.490	Sum(D): 32231.315				Sum(H): 79.865		Sum(M): 4615.672
							Uncertainty in total inventory: 8.937		Trend uncertainty: 67.939

Annex D: ENERGY Sector Reporting Tables

Table 0-3: 2014 Energy Sectoral Table

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	7409.79	37.3615	0.5071				
1.A - Fuel Combustion Activities	7407.29	24.8620	0.5071				
1.A.1 - Energy Industries	4178.44	0.0442	0.0663				
1.A.1.a - Main Activity Electricity and Heat Production	4178.44	0.0442	0.0663				
1.A.1.a.i - Electricity Generation	4178.44	0.0442	0.0663				
1.A.1.a.ii - Combined Heat and Power Generation (CHP)							
1.A.1.a.iii - Heat Plants							
1.A.1.b - Petroleum Refining							
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries							

1.A.1.c.i - Manufacture of Solid Fuels							
1.A.1.c.ii - Other Energy Industries							
1.A.2 - Manufacturing Industries and Construction							
1.A.2.a - Iron and Steel							
1.A.2.b - Non-Ferrous Metals							
1.A.2.c - Chemicals							
1.A.2.d - Pulp, Paper and Print							
1.A.2.e - Food Processing, Beverages and Tobacco							
1.A.2.f - Non-Metallic Minerals							
1.A.2.g - Transport Equipment							
1.A.2.h - Machinery							
1.A.2.i - Mining (excluding fuels) and Quarrying							
1.A.2.j - Wood and wood products							
1.A.2.k - Construction							
1.A.2.l - Textile and Leather							
1.A.2.m - Non-specified Industry							
1.A.3 - Transport	2264.33	0.5776	0.1104				

1.A.3.a - Civil Aviation	68.84	0.000 5	0.00 19				
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	68.84						
1.A.3.b - Road Transportation	2195. 49	0.577 2	0.10 85				
1.A.3.b.i - Cars	2195. 49	0.577 2	0.10 85				
1.A.3.b.i.1 - Passenger cars with 3-way catalysts							
1.A.3.b.i.2 - Passenger cars without 3-way catalysts							
1.A.3.b.ii - Light-duty trucks							
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts							
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts							
1.A.3.b.iii - Heavy-duty trucks and buses							
1.A.3.b.iv - Motorcycles							
1.A.3.b.v - Evaporative emissions from vehicles							
1.A.3.b.vi - Urea-based catalysts							
1.A.3.c - Railways							
1.A.3.d - Water-borne Navigation							

1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation							
1.A.3.e - Other Transportation							
1.A.3.e.i - Pipeline Transport							
1.A.3.e.ii - Off-road							
1.A.4 - Other Sectors	964.51	24.2402	0.3304				
1.A.4.a - Commercial/Institutional	809.91	0.1009	0.0083				
1.A.4.b - Residential	107.75	24.0963	0.3217				
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	46.85	0.0430	0.0004				
1.A.4.c.i - Stationary	46.85	0.0430	0.0004				
1.A.4.c.ii - Off-road Vehicles and Other Machinery							
1.A.4.c.iii - Fishing (mobile combustion)							
1.A.5 - Non-Specified							
1.A.5.a - Stationary							

1.A.5.b - Mobile							
1.A.5.b.i - Mobile (aviation component)							
1.A.5.b.ii - Mobile (water-borne component)							
1.A.5.b.iii - Mobile (Other)							
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	2.51	12.4995					
1.B.1 - Solid Fuels	2.51	12.4995					
1.B.1.a - Coal mining and handling	2.51	12.4995					
1.B.1.a.i - Underground mines	2.51	12.4995					
1.B.1.a.i.1 - Mining	1.25	11.4674					
1.B.1.a.i.2 - Post-mining seam gas emissions	1.25	1.0321					
1.B.1.a.i.3 - Abandoned underground mines							
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2							

1.B.1.a.ii - Surface mines							
1.B.1.a.ii.1 - Mining							
1.B.1.a.ii.2 - Post-mining seam gas emissions							
1.B.1.b - Uncontrolled combustion and burning coal dumps							
1.B.1.c - Solid fuel transformation							
1.B.2 - Oil and Natural Gas							
1.B.2.a - Oil							
1.B.2.a.i - Venting							
1.B.2.a.ii - Flaring							
1.B.2.a.iii - All Other							
1.B.2.a.iii.1 - Exploration							
1.B.2.a.iii.2 - Production and Upgrading							
1.B.2.a.iii.3 - Transport							
1.B.2.a.iii.4 - Refining							
1.B.2.a.iii.5 - Distribution of oil products							
1.B.2.a.iii.6 - Other							
1.B.2.b - Natural Gas							
1.B.2.b.i - Venting							

1.B.2.b.ii - Flaring							
1.B.2.b.iii - All Other							
1.B.2.b.iii.1 - Exploration							
1.B.2.b.iii.2 - Production							
1.B.2.b.iii.3 - Processing							
1.B.2.b.iii.4 - Transmission and Storage							
1.B.2.b.iii.5 - Distribution							
1.B.2.b.iii.6 - Other							
1.B.3 - Other emissions from Energy Production							
1.C - Carbon dioxide Transport and Storage							
1.C.1 - Transport of CO2							
1.C.1.a - Pipelines							
1.C.1.b - Ships							
1.C.1.c - Other (please specify)							
1.C.2 - Injection and Storage							
1.C.2.a - Injection							
1.C.2.b - Storage							
1.C.3 - Other							

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
Memo Items (3)							
International Bunkers	31.53	0.0002	0.0009				
1.A.3.a.i - International Aviation (International Bunkers) (1)	31.53	0.0002	0.0009				
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.5.c - Multilateral Operations (1)(2)							
Information Items							
CO2 from Biomass Combustion for Energy Production	8991.36						

Annex E: IPPU Sector Reporting Tables

Table 0-4: 2014 IPPU Sectoral Table

Categories	(Gg)			CO2 Equivalents(Gg)				(Gg)				
	CO2	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	NOx	CO	NMVOCs	SO2
2 - Industrial Processes and Product Use	1293.4437	0	0	0.640	0	0	0	0	0	0	0	0
2.A - Mineral Industry	129.2698	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	129.2698								0	0	0	0
2.A.2 - Lime production	0								0	0	0	0
2.A.3 - Glass Production	0								0	0	0	0

2.A.4 - Other Process Uses of Carbonates	0	0	0	0	0	0	0	0	0	0	0	0
2.A.4.a - Ceramics	0								0	0	0	0
2.A.4.b - Other Uses of Soda Ash	0								0	0	0	0
2.A.4.c - Non Metallurgical Magnesia Production	0								0	0	0	0
2.A.4.d - Other (please specify) (3)	0								0	0	0	0
2.A.5 - Other (please specify) (3)									0	0	0	0
2.B - Chemical Industry	1164.174	0	0	0	0	0	0	0	0	0	0	0
2.B.1 - Ammonia Production	0								0	0	0	0
2.B.2 - Nitric Acid Production			0						0	0	0	0
2.B.3 - Adipic Acid Production			0						0	0	0	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0						0	0	0	0
2.B.5 - Carbide Production	0	0							0	0	0	0
2.B.6 - Titanium Dioxide Production	0								0	0	0	0
2.B.7 - Soda Ash Production	1164.174								0	0	0	0

2.B.8 - Petrochemical and Carbon Black Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.8.a - Methanol	0	0							0	0	0	0
2.B.8.b - Ethylene	0	0							0	0	0	0
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	0	0							0	0	0	0
2.B.8.d - Ethylene Oxide	0	0							0	0	0	0
2.B.8.e - Acrylonitrile	0	0							0	0	0	0
2.B.8.f - Carbon Black	0	0							0	0	0	0
2.B.9 - Fluorochemical Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.9.a - By-product emissions (4)				0					0	0	0	0
2.B.9.b - Fugitive Emissions (4)									0	0	0	0
2.B.10 - Other (Please specify) (3)									0	0	0	0
2.C - Metal Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.C.1 - Iron and Steel Production	0	0							0	0	0	0
2.C.2 - Ferroalloys Production	0	0							0	0	0	0
2.C.3 - Aluminium production	0				0				0	0	0	0
2.C.4 - Magnesium production (5)	0					0			0	0	0	0

2.C.5 - Lead Production	0								0	0	0	0
2.C.6 - Zinc Production	0								0	0	0	0
2.C.7 - Other (please specify) (3)									0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use (6)	0	0	0	0	0	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	0								0	0	0	0
2.D.2 - Paraffin Wax Use	0								0	0	0	0
2.D.3 - Solvent Use (7)									0	0	0	0
2.D.4 - Other (please specify) (3), (8)									0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor (9)				0	0	0		0	0	0	0	0
2.E.2 - TFT Flat Panel Display (9)					0	0		0	0	0	0	0
2.E.3 - Photovoltaics (9)					0				0	0	0	0
2.E.4 - Heat Transfer Fluid (10)					0				0	0	0	0
2.E.5 - Other (please specify) (3)									0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0.640	0	0	0	0	0	0	0	0

2.F.1 - Refrigeration and Air Conditioning	0	0	0	0.640	0	0	0	0	0	0	0	0
2.F.1.a - Refrigeration and Stationary Air Conditioning				0.640					0	0	0	0
2.F.1.b - Mobile Air Conditioning				0					0	0	0	0
2.F.2 - Foam Blowing Agents				0				0	0	0	0	0
2.F.3 - Fire Protection				0	0				0	0	0	0
2.F.4 - Aerosols				0				0	0	0	0	0
2.F.5 - Solvents				0	0			0	0	0	0	0
2.F.6 - Other Applications (please specify) (3)				0	0			0	0	0	0	0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1 - Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1.a - Manufacture of Electrical Equipment					0	0			0	0	0	0
2.G.1.b - Use of Electrical Equipment					0	0			0	0	0	0
2.G.1.c - Disposal of Electrical Equipment					0	0			0	0	0	0

2.G.2 - SF6 and PFCs from Other Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.2.a - Military Applications					0	0			0	0	0	0
2.G.2.b - Accelerators					0	0			0	0	0	0
2.G.2.c - Other (please specify) (3)					0	0			0	0	0	0
2.G.3 - N2O from Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.3.a - Medical Applications			0						0	0	0	0
2.G.3.b - Propellant for pressure and aerosol products			0						0	0	0	0
2.G.3.c - Other (Please specify) (3)			0						0	0	0	0
2.G.4 - Other (Please specify) (3)									0	0	0	0
2.H - Other	0	0	0	0	0	0	0	0	0	0	0	0
2.H.1 - Pulp and Paper Industry									0	0	0	0
2.H.2 - Food and Beverages Industry									0	0	0	0
2.H.3 - Other (please specify) (3)									0	0	0	0

Annex F: AFOLU Sector Reporting Tables

Table 0-5: 2014 AFOLU Sectoral Table

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	-2981.325	85.335	0.922	16.614	276.908	0.000
3.A - Livestock	0.000	75.537	0.000	0.000	0.000	0.000
3.A.1 - Enteric Fermentation	0.000	72.372	0.000	0.000	0.000	0.000
3.A.1.a - Cattle	0.000	60.440	0.000	0.000	0.000	0.000
3.A.1.a.i - Dairy Cows		0.052		0.000	0.000	0.000
3.A.1.a.ii - Other Cattle		60.388		0.000	0.000	0.000
3.A.1.b - Buffalo		0.000		0.000	0.000	0.000

3.A.1.c - Sheep		1.135		0.000	0.000	0.000
3.A.1.d - Goats		8.030		0.000	0.000	0.000
3.A.1.e - Camels		0.000		0.000	0.000	0.000
3.A.1.f - Horses		0.486		0.000	0.000	0.000
3.A.1.g - Mules and Asses		2.270		0.000	0.000	0.000
3.A.1.h - Swine		0.011		0.000	0.000	0.000
3.A.1.j - Other (please specify)		0.000		0.000	0.000	0.000
3.A.2 - Manure Management (1)	0.000	3.165	0.000	0.000	0.000	0.000
3.A.2.a - Cattle	0.000	2.246	0.000	0.000	0.000	0.000
3.A.2.a.i - Dairy cows		0.001	0.000	0.000	0.000	0.000
3.A.2.a.ii - Other cattle		2.245	0.000	0.000	0.000	0.000
3.A.2.b - Buffalo		0.000	0.000	0.000	0.000	0.000
3.A.2.c - Sheep		0.058	0.000	0.000	0.000	0.000

3.A.2.d - Goats		0.363	0.000	0.000	0.000	0.000
3.A.2.e - Camels		0.000	0.000	0.000	0.000	0.000
3.A.2.f - Horses		0.079	0.000	0.000	0.000	0.000
3.A.2.g - Mules and Asses		0.348	0.000	0.000	0.000	0.000
3.A.2.h - Swine		0.048	0.000	0.000	0.000	0.000
3.A.2.i - Poultry		0.023	0.000	0.000	0.000	0.000
3.A.2.j - Other (please specify)		0.000	0.000	0.000	0.000	0.000
3.B - Land	-2970.680	0.000	0.018	0.000	0.000	0.000
3.B.1 - Forest land	-16196.294	0.000	0.000	0.000	0.000	0.000
3.B.1.a - Forest land Remaining Forest land	-2037.333			0.000	0.000	0.000

3.B.1.b - Land Converted to Forest land	-14158.961	0.000	0.000	0.000	0.000	0.000
3.B.1.b.i - Cropland converted to Forest Land	0.000			0.000	0.000	0.000
3.B.1.b.ii - Grassland converted to Forest Land	-14158.961			0.000	0.000	0.000
3.B.1.b.iii - Wetlands converted to Forest Land	0.000			0.000	0.000	0.000
3.B.1.b.iv - Settlements converted to Forest Land	0.000			0.000	0.000	0.000
3.B.1.b.v - Other Land converted to Forest Land	0.000			0.000	0.000	0.000
3.B.2 - Cropland	0.026	0.000	0.000	0.000	0.000	0.000
3.B.2.a - Cropland Remaining Cropland	0.026			0.000	0.000	0.000
3.B.2.b - Land Converted to Cropland	0.000	0.000	0.000	0.000	0.000	0.000
3.B.2.b.i - Forest Land converted to Cropland	0.000			0.000	0.000	0.000
3.B.2.b.ii - Grassland converted to Cropland	0.000			0.000	0.000	0.000
3.B.2.b.iii - Wetlands converted to Cropland	0.000			0.000	0.000	0.000
3.B.2.b.iv - Settlements converted to Cropland	0.000			0.000	0.000	0.000
3.B.2.b.v - Other Land converted to Cropland	0.000			0.000	0.000	0.000

3.B.3 - Grassland	13196.104	0.000	0.000	0.000	0.000	0.000
3.B.3.a - Grassland Remaining Grassland	0.000			0.000	0.000	0.000
3.B.3.b - Land Converted to Grassland	13196.104	0.000	0.000	0.000	0.000	0.000
3.B.3.b.i - Forest Land converted to Grassland	13196.104			0.000	0.000	0.000
3.B.3.b.ii - Cropland converted to Grassland	0.000			0.000	0.000	0.000
3.B.3.b.iii - Wetlands converted to Grassland	0.000			0.000	0.000	0.000
3.B.3.b.iv - Settlements converted to Grassland	0.000			0.000	0.000	0.000
3.B.3.b.v - Other Land converted to Grassland	0.000			0.000	0.000	0.000
3.B.4 - Wetlands	28.068	0.000	0.018	0.000	0.000	0.000
3.B.4.a - Wetlands Remaining Wetlands	28.068	0.000	0.018	0.000	0.000	0.000
3.B.4.a.i - Peatlands remaining peatlands	28.068		0.018	0.000	0.000	0.000
3.B.4.a.ii - Flooded land remaining flooded land				0.000	0.000	0.000
3.B.4.b - Land Converted to Wetlands	0.000	0.000	0.000	0.000	0.000	0.000

3.B.4.b.i - Land converted for peat extraction			0.000	0.000	0.000	0.000
3.B.4.b.ii - Land converted to flooded land	0.000			0.000	0.000	0.000
3.B.4.b.iii - Land converted to other wetlands				0.000	0.000	0.000
3.B.5 - Settlements	1.313	0.000	0.000	0.000	0.000	0.000
3.B.5.a - Settlements Remaining Settlements	0.246			0.000	0.000	0.000
3.B.5.b - Land Converted to Settlements	1.066	0.000	0.000	0.000	0.000	0.000
3.B.5.b.i - Forest Land converted to Settlements	0.000			0.000	0.000	0.000
3.B.5.b.ii - Cropland converted to Settlements	0.000			0.000	0.000	0.000
3.B.5.b.iii - Grassland converted to Settlements	0.000			0.000	0.000	0.000
3.B.5.b.iv - Wetlands converted to Settlements	0.288			0.000	0.000	0.000
3.B.5.b.v - Other Land converted to Settlements	0.779			0.000	0.000	0.000
3.B.6 - Other Land	0.104	0.000	0.000	0.000	0.000	0.000
3.B.6.a - Other land Remaining Other land				0.000	0.000	0.000
3.B.6.b - Land Converted to Other land	0.104	0.000	0.000	0.000	0.000	0.000

3.B.6.b.i - Forest Land converted to Other Land	0.000			0.000	0.000	0.000
3.B.6.b.ii - Cropland converted to Other Land	0.000			0.000	0.000	0.000
3.B.6.b.iii - Grassland converted to Other Land	0.000			0.000	0.000	0.000
3.B.6.b.iv - Wetlands converted to Other Land	0.070			0.000	0.000	0.000
3.B.6.b.v - Settlements converted to Other Land	0.034			0.000	0.000	0.000
3.C - Aggregate sources and non-CO2 emissions sources on land (2)	0.250	9.798	0.904	16.614	276.908	0.000
3.C.1 - Emissions from biomass burning	0.000	9.798	0.895	16.614	276.908	0.000
3.C.1.a - Biomass burning in forest lands		4.943	0.451	8.382	139.705	0.000
3.C.1.b - Biomass burning in croplands		0.000	0.000	0.000	0.000	0.000
3.C.1.c - Biomass burning in grasslands		4.855	0.443	8.232	137.202	0.000
3.C.1.d - Biomass burning in all other land		0.000	0.000	0.000	0.000	0.000
3.C.2 - Liming	0.083			0.000	0.000	0.000
3.C.3 - Urea application	0.167			0.000	0.000	0.000

3.C.4 - Direct N2O Emissions from managed soils (3)			0.002	0.000	0.000	0.000
3.C.5 - Indirect N2O Emissions from managed soils			0.007	0.000	0.000	0.000
3.C.6 - Indirect N2O Emissions from manure management			0.000	0.000	0.000	0.000
3.C.7 - Rice cultivations		0.000		0.000	0.000	0.000
3.C.8 - Other (please specify)				0.000	0.000	0.000
3.D - Other	-10.895	0.000	0.000	0.000	0.000	0.000
3.D.1 - Harvested Wood Products	-10.895			0.000	0.000	0.000
3.D.2 - Other (please specify)				0.000	0.000	0.000

Annex G: WASTE Sector Reporting Tables

Table 0-6: 2014 AFOLU Sectoral Table

Categories	Emissions [Gg]						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	0	29.587	0.0745	0	0	0	0
4.A - Solid Waste Disposal	0	25.904	0	0	0	0	0
4.A.1 - Managed Waste Disposal Sites				0	0	0	0

4.A.2 - Unmanaged Waste Disposal Sites				0	0	0	0
4.A.3 - Uncategorised Waste Disposal Sites				0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.C.1 - Waste Incineration	0	0	0	0	0	0	0
4.C.2 - Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge	0	3.683	0.0745	0	0	0	0
4.D.1 - Domestic Wastewaster Treatment and Discharge		3.683	0.0745	0	0	0	0
4.D.2 - Industrial Wastewater Treatment and Discharge		0		0	0	0	0
4.E - Other (please specify)				0	0	0	0