BOTSWANA
GREENHOUSE GAS (GHG) INVENTORIES FOR
BIENNIAL UPDATE REPORT (BUR)

2016

PREPARED FOR THE MINISTRY OF ENVIRONMENT, WILDLIFE AND TOURISM

AUTHORS

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Inventory Year: 2011

Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total National Emissions and Removals	30924.74607	51026.3098	193.677021995	40.242361996	140.4853504	8.42793358	0	0
1 - Energy	6894.49287		0	0	0	0	0	0
1A - Fuel Combustion Activities	6878.207216		0	0	0	0	0	0
1A1 - Energy Industries	3657.592822		0	0	0	0	0	0
1A2 - Manufacturing Industries and Construction (ISIC)	1235.518877		0	0	0	0	0	0
1A3 - Transport	1985.096517		0	0	0	0	0	0
1A4 - Other Sectors	0		0	0	0	0	0	0
1A5 - Other	0		0	0	0	0	0	0
1B - Fugitive Emissions from Fuels	16.28565367		0	0	0	0	0	0
1B1 - Solid Fuels	16.28565367		0	0	0	0	0	0
1B2 - Oil and Natural Gas	0		0	0	0	0	0	0
2 - Industrial Processes	540.7236182		0	0	0	0	0	0
2A - Mineral Products	7.67243724		0	0	0	0	0	0
2B - Chemical Industry	533.051181		0	0	0	0	0	0
2C - Metal Production	0		0	0	0	0	0	0
2D - Other Production	0		0	0	0	0	0	0
2E - Production of Halocarbons and Sulphur Hexafluoride					0	0	0	0
2F - Consumption of Halocarbons and Sulphur Hexafluoride					0	0	0	0
2G - Other (please specify)	0		0	0	0	0	0	0
3 - Solvent and Other Product Use	0		0	0	0	0	0	0
4 - Agriculture			188.3880538	40.15672961	140.4853504	8.42793358	0	0
4A - Enteric Fermentation			96.877734		0	0	0	0
4B - Manure Management			0	29.9963358	0	0	0	0
4C - Rice Cultivation			0		0	0	0	0
4D - Agricultural Soils				9.706582	0	0	0	0
4E - Prescribed Burning of Savannas			91.5103198	0.453811808	140.4655597	8.42793358	0	0

4F - Field Burning of Agricultural Residues			0.000580815	1.50582E-05	0.019790718	0.000537791	0	0
4G - Other (please specify)	0		0	0	0	0	0	0
5 - Land-Use Change & Forestry	23505.81524	51026.3098		0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	23505.81524				0	0	0	0
5B - Forest and Grassland Conversion		46186.19971			0	0	0	0
5E - Other (please specify)		4840.110092			0	0	0	0
6 - Waste	0		5.288968195	0.085632386	0	0	0	0
6A - Solid Waste Disposal on Land			1.147096485		0	0	0	0
6B - Wastewater Handling			4.141871709	0.085632386	0	0	0	0
6C - Waste Incineration	0		0	0	0	0	0	0
6D - Other (please specify)	0		0	0	0	0	0	0
7 - Other (please specify)	0		0	0	0	0	0	0
Memo Items								
International Bunkers	0		0	0	0	0	0	0
1A3a1 - International Aviation	0		0	0	0	0	0	0
1A3d1 - International Marine (Bunkers)	0		0	0	0	0	0	0
CO2 emissions from biomass	0							

Documentation box

The data used for this GHG inventory were obtained from the stakeholders within the public and private sectors of the economy. Statistics Botswana (SB) provided some other basic data requirements. Statistics Botswana is mandated by Botswana Government to collect data from all sectors of the economy. Statistics Botswana sends formal requests to these sectors for submission of data in prescribed templates or formats, some of which conform to international guidelines. In cases where activity data are not available from SB, the process of estimating the values was through expert knowledge of members of the GHG Inventory team. The inventory studies used the Tier 1 default values in all estimates. This is found to be adequate in all sectors but the estimates for methane emissions from livestock might have been a bit higher than the reality. This is because Botswana is a tropical dry climate and emissions from animal waste may need to be assessed using Tier 2 in subsequent studies. The current Tier 1 default in 2006 IPCC Inventory Software assumes a wetter environment. The emission factors in all categories of the study are derived from 2006 IPCC Inventory Software. Although not mandatory, this study opted for this version of the software largely for currency.

EXECUTIVE SUMMARY

This report presents an inventory of sources and sinks of greenhouse gases in the Republic of Botswana for the year 2011. Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOC) are described by sector categories.

ENERGY

The total CO_2 emissions from this sector in 2011 were estimated at 6894.50 Gg broken down as:

CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION ACTIVITIES

Energy Industries sub-sector is 3657.59 Gg with the main activity being electricity and heat production.

Manufacturing Industries and Construction sub-sector is 1235.52 Gg with the main activity being mining (82% of CO_2 emissions).

Transport sub-sector is 1985.10 Gg with the main activity being road transportation which contributed 98% of these emissions.

CARBON DIOXIDE EMISSIONS FROM FUGITIVE EMISSIONS FROM FUELS

Solid Fuels sub-sector is 16.29 Gg with the main activity being the underground mining of coal (92% of CO_2 emissions).

CARBON DIOXIDE EMISSIONS FROM BIOMASS BASED FUELS

- The total CO_2 emissions from this sector in 2011 were estimated at 645.24 Gg. This emission is not normally included in GHG inventories for the Energy Sector.

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

The total CO_2 emissions from this sector in 2011 was estimated at 540.72 Gg

AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

The total CO_2 emissions from this sector in 2011 were estimated at **16540.89 Gg** broken down as:

METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT

- The methane emissions from domestic livestock enteric fermentation and manure management total 100.1093522 Gg (ALU Software) which translates to about 2502.73 Gg of CO_2. This compares very well with the figure of 96.877734 Gg (IPCC Software) in Appendix 1.

There are some reservations as regards these figures. We have used the IPCC defaults in estimating these values but in reality, these could be over-estimating the GHG emissions because the climate of the country is Tropical Dry. Animal waste may then dry up very quickly before the biological processes that enhance GHG emissions commence. This development is informing the consideration of Tier 2 methods of estimates in subsequent inventories.

The study, for comparative purposes and for the reason adduced above, embarked on manual estimates of GHG from Agriculture Sector directly from IPCC guidelines and formulae. The summaries of results are:

- **The 2011 estimate of methane emitted from enteric fermentation was computed to be 83.25 Gg which converts to 2081.17 Gg of CO_2**
- **The 2011 estimate of CO_2 from livestock manure was computed to be 22.28 Gg**

These figures give a total of 105.53 Gg of CO_2. Within a margin of error of 5%, the figures obtained from manual estimates, ALU and IPCC software are consistent; but the study is of the opinion that they may over-estimate the emissions from domestic livestock enteric fermentation and manure management. A Tier 2 approach in subsequent studies is envisaged to give more realistic figures for the country.

NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS

- Nitrous oxide emissions from animal production emissions from animal waste management systems total 29.996 Gg which translates to about 8938.81Gg of CO_2.

INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING

- Indirect nitrous oxide emissions from leaching total 9.706 Gg which translates to about 2892.39Gg of CO_2.

BIOMASS BURNING

- The 2011 estimate of CO_2 from biomass burning was estimated at 91.51 Gg of methane which translates to about 2287.75Gg of CO_2 (Appendix 1).

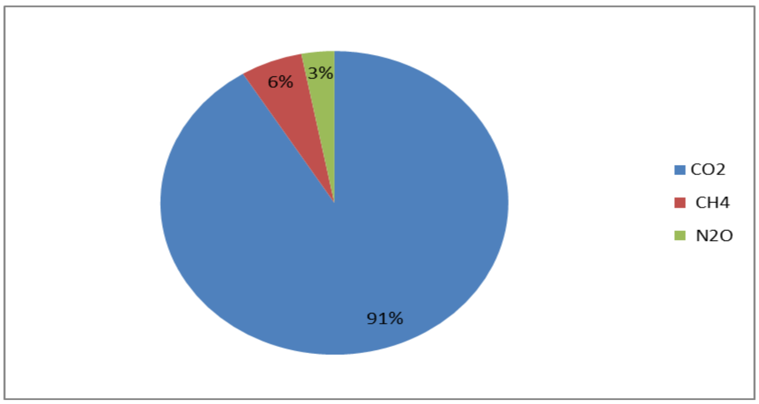
LAND-USE CHANGE AND FORESTRY

The total CO_2 emissions/removals from this sector in 2011 were estimated at 27520.56 Gg broken down as:

Source/Sink Category	**Gg (gas) yr $^{-1}$**		
	CO_2	**CH_4**	**N_2O**
Conversions to Forest	-46186.19971		
Conversions to Cropland	745.688346		
Conversion to Grassland	22363.24739		
Conversions to Wetland	0		
Conversions to Settlements	396.81829		
Conversions to Other Lands	-4840.110092		
Net gas emissions (Gg CO2-eq yr-1)	**(27520.555776)**		

The conversion of land to grassland in the table above was limited to events within 2011. The special case of recovery from the extensive wildfires of 2010 was calculated separately. In 2010, 13,586,774.41 Ha of land was affected by wildfire. This translates to 23.4% of the total area of the country. The recovery processes, which included fire policy legislation by Government, resulted in the massive carbon stock through conversion to grassland. In a tropical dry climate zone, 8.7 tonnes d.m. ha^{-1} is the default for biomass carbon stocks present when land is converted to grassland (IPCC, 2003). In the case of 2011 in Botswana, this translates to about 500,000 Gg of CO_2 sink. However, given the El-Niño event of 2010 and the associated drought in Botswana, we estimate that about one-fifth (20%) of the expected carbon stock would result from the recovery process. The study therefore estimates a carbon-sink-recovery of about 100,000 Gg of CO_2 in 2011 from the extensive wildfire of 2010.

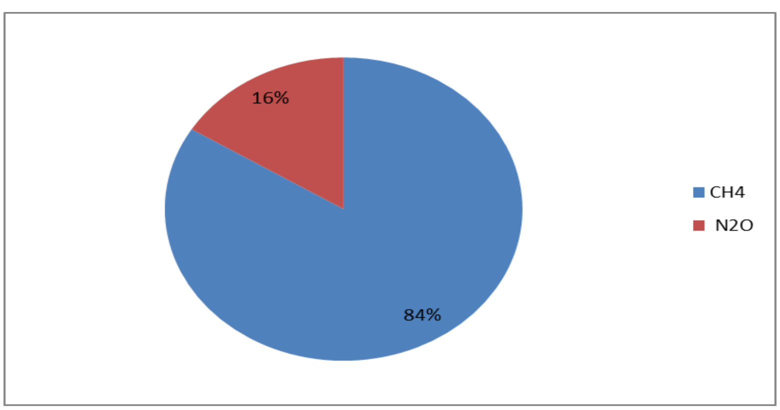
The emissions by category of GHG gas are depicted in the figure below:



AFOLU Emissions by GHG Gas Category

WASTE

The total CO_2 emissions from this sector in 2011 was estimated as 132.34 Gg (Table 20)



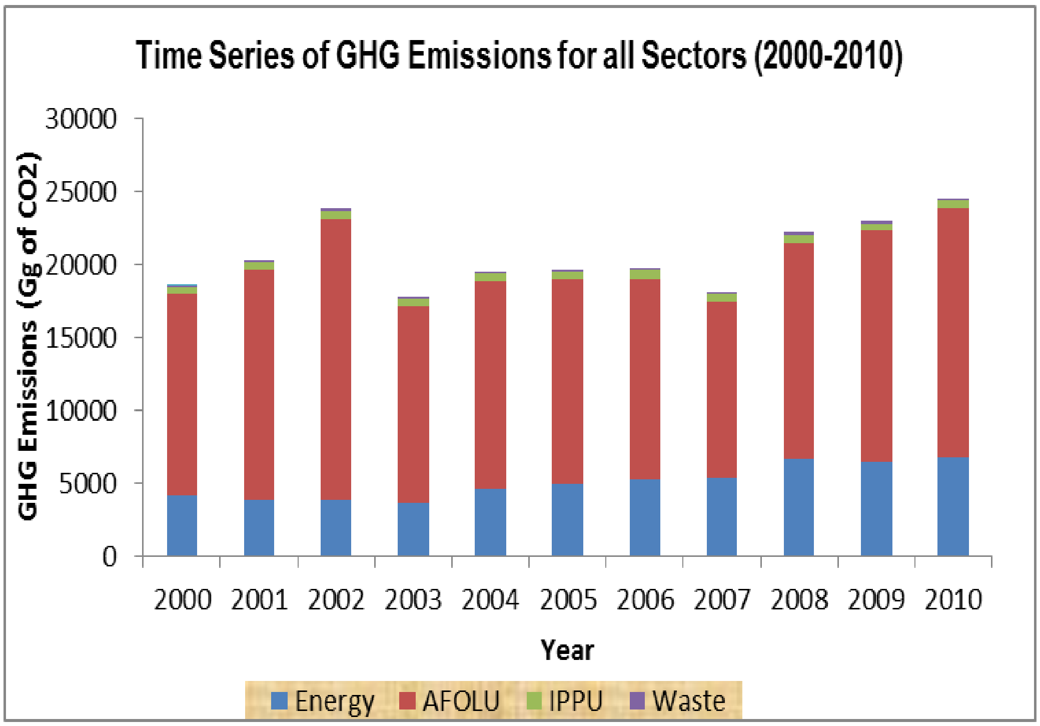
Waste Emissions by GHG Gas Category

SUMMARY OF RESULTS

A detailed summary of results of GHG emissions by source and sector categories is given below:

SUMMARY OF ANNUAL GHG EMISSIONS BY SOURCE AND CATEGORY (BASE YEAR 2011)

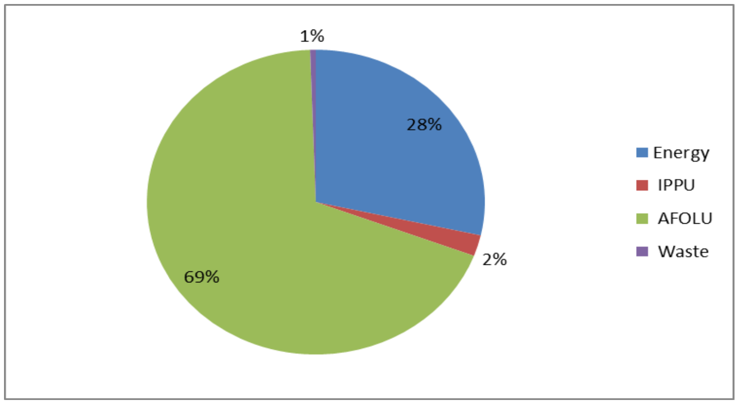
Sectors	Emissions CO_2 eq (Gg)	Sink CO_2 eq (Gg)
Energy	6,894.50	
Industrial Processes (IPPU)	540.72	
AFOLU	16,540.89	-127,520.56
Waste	132.34	
Total emissions	24,108.45	
Net Total (after subtracting	(103,412.11)	



GENERAL UNCERTAINTY ASSESSMENT

Estimation of GHG emissions has inherent uncertainties. One source of uncertainty is the use of expert knowledge in some circumstances. This inventory has encountered Tier 1 uncertainties in the estimates. Managing and reducing these uncertainties is a recognized IPCC Good Practice. The uncertainties in these estimates are largely from primary sources. This has reduced the total level of uncertainty in the inventory to 3.856

EMISSIONS BY SOURCE CATEGORIES



BOTSWANA IS HEREBY ESTIMATED TO BE A NET SINK FOR GREENHOUSE GASES

ACKNOWLEDGEMENTS

The methodology used to determine the sources and sinks of greenhouse gases was developed by Working Group I of the Intergovernmental Panel on Climate Change (IPCC). Financial support for the inventory was provided by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF).

1.0 INTRODUCTION

1.1 BACKGROUND

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. The UNFCCC, to which the Government of Botswana is a signatory, also requires all parties to develop, periodically update, publish and make available to the Conference of Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies.

Towards the realization of the UNFCCC objective, the following long-term objectives were put in place in Botswana:

- To have a more complete understanding of the role of GHG emissions and sinks in global climate change with respect to human and natural events, To identify policies and technologies which countries might incorporate into national planning with the aim of minimizing GHG emissions;
- To increase both the quantity and quality of base line data available in order to further scientific understanding of the relationship of GHG emissions to climate change;

along with the following short term objectives:

- To enhance the ability of environmental agencies in Botswana to estimate, monitor and report national inventories of GHG emissions and sinks;
- To promote the exchange of information related to climate change, national policy options and technology choices that could lead to the eventual reduction of GHG emissions worldwide;
- To promote the establishment of permanent links between national environment agencies in Botswana and international institutions for the exchange of scientific, technological and policy information related to the effects of GHG emissions on global climate change.

In realization of these objectives, Botswana prepared and submitted an initial National Communication to UNFCCC in October 2001 followed by a Second National Communication in January 2013.

Following the decision of the Conference of Parties in Cancun, Mexico, in 2010, developing countries such as Botswana are obligated to submit NCs every four years and BURs every two years. The first BUR was due towards the end of 2014 while the country envisages that the Third National Communication will be submitted in 2016.

The Department of Meteorological Services, within the Ministry of Environment, Wildlife and Tourism, is the lead agency and contact point for this national study.

1.2 BOTSWANA NATIONAL CIRCUMSTANCES

Botswana lies between 20.0°-29.4˚ E and 17.8°-26.8˚ S and occupies an area of 600,370 km², with a land area 581,730 km² (INC, 2001) while Okavango swamps covers 18,640 km2. It is a landlocked country located in Southern Africa, dominated in geographical terms by the Kalahari Desert - a sand-filled basin averaging 1,100 meters above sea level. Botswana is bordered by Zambia and Zimbabwe to the northeast, Namibia to the north and west, and South Africa to the south and southeast.

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

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

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

The energy sector plays a key role in socio-economic activities of Botswana. It supports the mining, agriculture, transport, commercial, institution and household sub-sectors. Energy per capita is often used as an indicator of the level of economic development of a country. Per capita energy consumption in Botswana is estimated to be slightly less than two tons of oil. Consumption by the transport and industrial sectors are about the same level. For the country, biomass energy (wood, charcoal and crop residues) still accounts for the bulk of the energy used in households, which still have a low access to grid electricity. Those who have access to electricity use it mostly for lighting and powering of electrical appliances rather than cooking and water heating. The local generation of electricity is from coal.

The agriculture sector in Botswana, like in many countries, plays an important role in providing food, income, employment and investment opportunities for majority of people, particularly the rural community. Livestock production dominates Botswana agriculture, particularly beef cattle. Agriculture meets only a small portion of food needs and contributes just 2.8% to GDP primarily through beef exports. Cattle population in Botswana is slightly over 3 million, with about 85% of the livestock raised in communal lands and 15% in ranches, all producing 37 000 tons of beef annually (Republic of Botswana, 2015). Apart from beef production there is some little milk production which puts the country’s dairy industry at infancy stage. The country’s farm management practice is three-fold: extensive small-scale farm practice, semi-intensive production system, and intensive production system. The extensive production system is characterized by natural grazing of animals with little supplementation. In this management practice, milk production is seasonal, occurring mostly during the wet season when there is abundance of good quality forage. On the other hand, the semi-intensive systems involve letting dry animals to graze openly while the milking ones are normally fed with high protein feeds to boost their milk production. The intensive system is usually practiced by large-scale farmers in ranches. In most cases total zero grazing of the animals is practiced.

Only about 0.7% of total land area is arable. Crop production is hampered by physical constraints such as poor soils, inadequate economic infrastructure, scarce water resources and recurrent drought. Production systems in Botswana are constituted by small scale and commercial farming systems. The majority of the small scale farms are rain fed with little to no fertilization and liming, while a few (commercial farms) are irrigated, fertilized and limed. Minimum tillage is widely promoted among small holder farmers through Poverty Eradication Program and NGOs in Botswana. The small scale and commercial farming systems are dominated by sorghum, maize, pulses, and millet. The nationally grown crops are sorghum, maize and pulses. Commercial yields are better than yields from the subsistence systems. For example, commercial yields are 3000 kg ha-1 for maize, while the subsistence systems yields are 250 kg ha^{-1} maize. This production does not meet the country's total annual cereal (maize) requirement of 160 000 tons maize.

Botswana's total land area is about 581,730 square kilometers and it is considered that all land ais managed. The majority of the country is covered by grasslands, that is about 57% which is made up of open woodlands, dry deciduous forests, sparse savannah and shrub-like vegetation About 20% of Botswana's land area is forested (approx. 11 million ha). Nearly the same area of about 20% is considered as other land, like deserts and rocks. Only a very tiny proportion of 0.01 % of the country is used as cropland. Also settlements are only 0.01 %. Forests in Botswana are still a versatile renewable resource, providing simultaneously a wide range of economic, social, and environmental benefits and services. The loss of forest cover raised concerns over the past years. For example, between 1990 and 2010, the country lost an average of 118,350 ha or 0.86% per year resulting in a 17.3% in forest cover (Republic of Botswana, 2015). This is attributable to the fact that the livelihood (energy source, crafts, buildings, etc.) of the urban and rural population is dependent on woodlands and forest resources. About 53% of the households use fuelwood as their principal source of energy for cooking, heating, and lighting. Furthermore, the forestry subsector continues to suffer because of recurrent wild fires, deforestation and overgrazing with little or no conservation awareness by communities. This has resulted in land degradation which is compunded by climate change in the form of extreme natural events like floods and droughts.

The mining industry is highly developed in the country. Botswana is the top diamond-producing country by value in 2011 (US$3,902,000,000), the base year for this inventory study. The open-pit method of extracting diamond does not contribute much to emission of greenhouse gases; except for fuel consumption associated with mining procedures. The commencement of cement production in the country in the last quarter of 2009 has marginally increased the release of greenhouse gases from this sector.

The bulk of greenhouse gas emissions from this sector is from municipal solid wastes, which are dumped in valleys or shallow pits originally used for extraction of materials for road construction. The wastes end up in relatively shallow, open piles decomposing mainly under aerobic conditions to produce carbon dioxide and a small amount of methane. Further, there is no classification of municipal garbage into the international components of: vegetable matter, paper, plastic, metal, glass, aluminium (empty cans) and debris. GHGs are therefore difficult to estimate by category of waste.

1.3 INSTITUTIONAL ARRANGEMENT FOR GHG INVENTORY STUDIES

The preparation of national report including the national greenhouse gas inventory is coordinated by the Botswana Climate Change Focal Point, which is the Department of Meteorological Services and overseen by the National Committee on Climate Change (NCCC), a multi-sectoral committee consisting of various experts from the government, private sector, the academia and non-governmental organizations. The list of the institutions represented on NCCC is:

1. Department of Forestry and Range Resources
2. University of Botswana
3. Department of Energy Affairs
4. Department of Environmental Affairs
5. Ministry of Health
6. Botswana Power Cooperation
7. Botswana Bureau of Standards
8. Department of Mines
9. Ministry of Finance and Development Planning
10. Statistics Botswana
11. Attorney General's Chambers
12. Department of Tourism
13. Ministry of Agriculture
14. Botswana Institute for Technology Research and Innovation
15. National Disaster Management Office
16. Department of Water AffairsGender Affairs
17. Ministry of Education
18. Department of Waste management and Pollution Control
19. Botswana Meat Commission
20. United Nations Development Program (UNDP)
21. Botswana Council of Nongovernmental Organizations (BOCONGO)
22. Botswana Confederation of Commerce, Industry & Manpower (BOCCIM)
23. Water Utilities
24. Gaborone City Council
25. Ministry of Transport and Communications
26. University of Botswana

NCCC is a national initiative and so the institutions do not require any memoranda of agreement or contracts to operate and deliver their mandates. NCCC commissioned the current study on GHG inventories in Botswana.

1.4 OBJECTIVES OF THE STUDY

- Undertake national GHG inventories for the year 2011, according to the guidelines for the preparation of National Communications (17/CP.8)
- Incclude iInclude information on other non-direct GHGs: HFCs, PFCs and SF_6 as well as CO, NO_X, SO_X and NMVOCs
- Recalculate the time series for the period 2000-2010 and provide information for 2011

- Calculate emissions for the year 2011 for all sectors
- Provide uncertainties in inventory estimates
- Gather available data from national sources to fill inventory data gaps
- Revise the iRevise the input data, taking into consideration data gaps and areas needing improvement identified in the stocktaking exercise
- Identify and develop methods for overcoming inventory data gaps if there is no available data
- Archive the GHG inventory data
- Discuss inventory data gaps
- Identify barriers to obtaining existing data for key sources and propose solutions
- 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
- Utilize the deliverables under the regional project, such as the National Strategy for improvement of the GHG Inventory, Manual of Procedures for GHG Inventory and the ACCESS database
- Organise (in cooperation with the Project Manager) a workshop for presentation and discussion on the results obtained from the GHG Inventory
- Prepare a summary on GHG Inventory that will go into the Botswana's First Biennial Update Report
- Prepare final report on GHG Inventory

Deliverables

- An inception Report which clearly indicates the methodology and anticipated target outputs
- A draft comleted GHG Inventory report including the methodologies used in compiling the inventory and the data sources
- A final GHG inventory
- 2 hard copies of the GHG inventory report
- A copy in CD-ROM containing an electronic version of the GHG Inventory report using Microsoft Word

Team

The above deliverables shall be achieved through the GHG Inventory Team as approved by the National Climate Change Committee herein attached as Appendix 3.

1.5 METHODOLOGY FOR GHG INVENTORY PREPARATIONS

The GHG inventory studies will cover the UNFCCC identified key sectors, namely:
Energy
Industrial Processes
Agriculture
Land Use and Land Use Change
Waste

The data used for this GHG inventory were obtained from the stakeholders within the public and private sectors of the economy. Statistics Botswana (SB) provided some other basic data requirements. Statistics Botswana is mandated by Botswana Government to collect data from all sectors of the economy. Statistics Botswana sends formal requests to these sectors for submission of data in prescribed templates or formats, some of which conform to international guidelines. In cases where activity data are not available from SB, the process of estimating the values was through expert knowledge of members of the GHG Inventory team.

The inventory studies used the Tier 1 default values in all estimates. This is found to be adequate in all sectors but the estimates for methane emissions from livestock might have been a bit higher than the reality. This is because Botswana is a tropical dry climate and emissions from animal waste may need to be assessed using Tier 2 in subsequent studies. The current Tier 1 default in 2006 IPCC Inventory Software assumes a wetter environment.

The emission factors in all categories of the study are derived from 2006 IPCC Inventory Software. Although not mandatory, this study opted for this version of the software largely for currency.

1.5.1 ENERGY

The data obtained from the various sources were in units of either weight (or mass, i.e. metric tonnes) or volume (litres) of fuel. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors. However, for bio-fuels combustion, specific emission factors were determined by experts in the project team.

1.5.2 INDUSTRIAL PROCESSES

The data obtained from the various sources were in units of either weight (or mass, i.e. metric tonnes) or volume (litres) of fuel. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors.

1.5.3 AGRICULTURE

1.5.3.1 Methodology for Estimating Emissions from Livestock Manure

Reports are from major steps of the methodology recommended in IPCC 2006 as follows:

- Estimate the amount of volatile solid produced for each animal type (VS) using published statistics on animal populations, animal sizes and manure generation rates.
- Estimate the maximum methane producing capacity for the manure from each animal type (B_0).
- Define the manure management systems in use and for each system estimate its methane producing potential (MCF).

- Estimate methane emissions for each animal type and manure management system (TM) by multiplying the amount of volatile solids produced by the animal type (VS) by the methane producing capacity of the manure B_0 and by the methane producing capacity potentials of the manure management system (MCF). Total methane emission was the sum over all animal types and all manure systems.

1.5.3.2 Methodology, Activity Data and Emission Factors

There are a number of equations used for calculating emissions due to biomass burning. These incorporates both CO_2 and non-carbon dioxide gases whereby calculations are made separately for each greenhouse gas, using the appropriate emission factor. These equations are as follows;

CH_4 Emissions = (carbon released) ● (emission ratio) ● 16/12

CO Emissions = (carbon released) ● (emission ratio) ● 28/12

N_2O Emissions = (carbon released) ● (N/C ratio) ● (emission ratio) ● 44/28

NO_x Emissions = (carbon released) ● (N/C ratio) ● (emission ratio) ● 46/14

As indicated in the equations, these non-carbon dioxide emission gasses used here are methane, carbon monoxide, nitrous oxide, nitrates and nitrites emitted in combination. In this project, these equations' major component is the quantity of greenhouse gas (GHG) released due to fire (L_{fire}) measured in tonnes of carbon. The equation is as follows:

L_{fire} = A ● B ● C ● D ● 10^{-6}; where area burnt (A) calculated in hectare is multiplied by mass of 'available' fuel (B) weighed in kilograms per dry matter per hectare (d.m. ha^{-1}) and that multiplied by combustion efficiency (C) or fraction of the biomass combusted, dimensionless (Table 3A.1.14) and the result multiplied by the emission factor (D) measured in gram per kilogram per dry matter (g $(kg\ d.m.)^{-1}$)

1.5.4 LAND USE AND LAND USE CHANGE AND FORESTRY (LULUCF)

Annual biomass loss is a sum of losses from commercial round wood fellings, fuelwood gathering, and other losses and was calculated using Equation 3.2.6 of the 2003 IPCC Good Practice Guidance. Details of other calculations are in Appendix 1. Forest and vegetation distraction by elephants also forms a substantial amount of loss, although this project does not take loss by animal destruction into consideration.

1.5.5 WASTE

The data obtained from the various sources were in units of either weight (or mass, i.e. metric tonnes).. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors.

1.6 KEY CATEGORY ANALYSIS

Identification of key categories followed the 2003 IPCC Good Practice Guidance; especially with the inclusion of Agriculture, Forestry and Land Use (AFOLU) emissions. This Good Practice Guidance recommended the Tier 1 level for trend assessment, which was adopted throughout the study. Hitherto, the Energy Sector has always been presumed to be the major source of emissions in Botswana but the inclusion of Land Use, Land Use Change and

Forestry (LULUCF) in the current study revealed the importance in LULUCF, which had largely been excluded in previous studies. The participation of Botswana in a project conceived to strengthen the capacity of Eastern and Southern African countries to improve the quality of their national GHG inventories and encourage the development and setting up of sustainable inventory management systems helped in this revision of GHG inventory studies.

1.7 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) PROCEDURES

1.7.1 Sectorial Roles and Responsibilities

The sectorial teams were provided with templates for Quality Assurance/Quality Control and Uncertainty Analysis. These include:

- A checklist of QA/QC procedures;
- Review of checklists for completeness;
- Delivery of online documentation to an agreed database;
- Technical reviews to ensure conformity with national and international standards.

1.7.2 Implementation of QC Procedures

The Tier 1 level of trend assessment as recommended by the 2003 IPCC Good Practice Guidance followed these procedures:

- Emission data were reported in manners consistent with calculation tables for ease of transference to BURS (Biennial Update Reports) and National Communications;
- Confirmation that the total GHG emissions equaled the sum of individual sectorial emissions;
- IPCC software and Agriculture and Land Use National Greenhouse Gas Inventory Software Program (ALU), were used independently for computations of national greenhouse gas inventories for the Agriculture and Land Use, Land Use Change and Forestry sectors for the purposes of ensuring consistency and accuracy;
- Assurance that data in sectorial inventory tables are consistent with text entries in the report;
- Creation of back-ups for all documentations in both hard and soft copies;
- Selection and application of estimation methods are consistent with 2006 IPCC Inventory Software.

1.7.3 Internal and External Review Processes

The GHG Team constituted itself into an internal review party for all sectorial inventory reports. In addition, the Botswana National Climate Change Committee (NCCC) made elaborate inputs into the inventory report at its meetings scheduled for the purpose. In addition to these, the report was subjected to external review by the NCCC secretariat. The external reviewers were from the office of the UNDP (United Nations Development Programme) Global Support Program for National Communications and Biennial Update Reports.

1.7.4 Uncertainty Assessment

Most of the activity data were from primary sources in all categories of the study. This is one of such unique instances for a Non-Annex 1 country. In virtually all instances, therefore, the study had access to uncertainty ranges. In the few instances where the primary source could not be corroborated independently, expert judgement was used to eliminate inherent uncertainties.

ENERGY

2.0 ENERGY

2.1 INTRODUCTION

It is estimated that wood-fuel accounts for as much as 34% of the country's total energy consumption, while petroleum products account for about 45%. The total CO_2 emissions from this sector in 2011 were estimated at 6894.49 Gg.

2.2 BACKGROUND

The major energy consumers in Botswana are residential, transport and industry at 42, 27 and 23% respectively (SNC, 2011). For the base year 2011, the percentage of wood-fuel and petroleum products will be accounted for under the land-use change and forestry sector. Botswana also has one of the lowest per capita energy consumption in the world with commercial energy utilisation accounting for about 10% of the total energy consumption. This low level of commercial energy consumption, coupled with the country's over dependence on wood-fuel, implies that Botswana is not expected to be a major net contributor of GHGs into the atmosphere, on the basis of fossil fuel combustion alone. There is, however, indication of systematic reduction in the carbon dioxide sink due to continued deforestation.

2.3 DATA SOURCES

All raw energy data used in the estimation of GHG emissions were obtained from local sources (MoEWT, 2012). These sources are listed hereunder in accordance with the nature of emissions:

a. Estimation of CO_2 emissions from petroleum products: Data on annual sales of petroleum products;
b. Estimation of GHGs from mobile combustion: Data on
- Road transport and agricultural machinery;
- Non-road transport: Botswana Civil Aviation Authority;
- Estimation of GHGs from non-mobile combustion.

2.4 METHODOLOGY

The data obtained from the various sources were in units of either weight or volume (litres) of fuel. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors. For bio-fuels combustion, GHG Team experts determined specific emission factors.

2.5 CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION ACTIVITIES

2.5.1 Background

All fossil fuels consumed in Botswana are secondary forms of petroleum. Botswana's own reserves of crude oil and peat are of unknown potential and are not yet exploited. Apart from lubricants and plastics, the imported petroleum products are all used for energy production in the transport, household, industry and commercial sectors. The petroleum importation is carried out by several multinational oil companies, although the Government also procures its own strategic stocks of gasoline (petrol), gas oil (diesel) and kerosene. The Government stocks have been used on loan basis, by the oil companies, whenever there is a shortage.

2.5.2 Estimation of CO_2 Emissions – Energy Industries

The total CO_2 emissions from **Energy Industries** sub-sector is 3657.59 Gg (Table 1), as derived from Appendix 1, with the main activity being electricity and heat production. The absence of significant contributions from heat plants limited the sources of GHG to combustions from lignite, motor gasoline and diesel oil which respectively contributed 27%, 30% and 36% to the estimate given above. Combustions from the avaition industry and residueal fuels make up the balance of 7% in this segment of the ENERGY Sector (IPCC GHG Reference Manula, 1991).

TABLE 1. SUMMARY INVENTORY OF GHG EMISSIONS FROM ENERGY SECTOR

Inventory Category	CO2 Emissions (Gg)
Energy Industries	3657.592
Manufacturing Industries and Construction	1235.519
Transport	1985.097
Fugitive emissions from fuels	16.28565

2.5.3 Estimation of CO_2 Emissions – Manufacturing Industries and Construction

The total CO_2 emissions from Manufacturing Industries and Construction sub-sector is 1235.52 Gg (Table 1) with the main activity being mining (82% of CO_2 emissions). The balance of about 18% came from non-specified industry, construction and food processing, beverages and tobacco sub-sectors.

2.5.4 Estimation of CO_2 Emissions – Transport

The total CO_2 emissions from Transport sub-sector amount to 1985.10 Gg (Table 1) with the main activity being road transportation which contributed 98% of these emissions. The balance of about 2% came from the domestic aviation sub-sector. The data available did not sub-categorise road transportation into passenger cars or light trucks, heavy-duty trucks or motorcycles. There is no international water-borne navigation in land-locked Botswana and domestic water-borne navigation is limited to tourists' cruises in the Okavango Delta.

2.6 CARBON DIOXIDE EMISSIONS FROM FUGITIVE EMISSIONS FROM FUELS

2.6.1 Background

Fugitive emissions from fuels are limited to the mining sector because Botswana has no oil or natural gas and no associated pipeline activities.

2.6.2 Estimation of CO_2 Emissions – Solid Fuels

The total CO_2 emissions from Solid Fuels sub-sector is 16.29 Gg (Table 1) with the main activity being the underground mining of coal (92% of CO_2 emissions). The balance of about 8% came from post-mining seam gas emissions.

2.7 CARBON DIOXIDE EMISSIONS FROM BIOMASS BASED FUELS

2.7.1 Data Sources

Various data sources on wood-fuel utilisation are scrutinised. It was found that there were significant variations in these data sets. The following assumptions have been made to estimate wood-fuel utilisation. The urban population, including those with facilities for electricity/LPG, use wood for domestic cooking. All rural people use firewood. The percentage of urban people using other fuels (electricity/ LPG) is offset by that of rural people using wood.

2.7.2 Total Wood-fuel Consumption

By the 2011 census, the population of Botswana is 1,986, 701 with an estimated 64.0% living in urban centres. Botswana's per capita charcoal consumption in 2011 is estimated at 0.41 MT in the urban areas, which brings total charcoal consumption to 520 Gg. On the other hand, per capita consumption of air-dry biomass is estimated at 1.36 MT. Given a rural population of 36%, total consumption of firewood becomes 972.69 Gg. These figures are inclusive of dry-biomass used in biomass burning industries.

TABLE 2. CARBON RELEASED IN COAL/WOOD FUEL COMBUSTION

TYPE OF BIOMASS	TOTAL BIOMASS CONSUMED (Gg)	BURNING EFFICIENCY (%)	BIOMASS BURNED (Gg)	C-CONTENT OF BIOMASS (Kg C/Ton)	TOTAL C RELEASED (Gg)
Wood	1,363.0	87	1,185.81	0.50	592.91
Coal	249.2	30	74.76	0.70	52.33
Total	**1,612.2**	**117**	**1260.57**	**1.20**	**645.24**

2.7.3 Emission Factors and Error Margins

Country specific figures for the carbon content, nitrogen content, C/N and N/C ratios were determined experimentally. These figures have been used in the emissions calculations (Ref. Table 3). It should be noted that there is quite a wide range in both the carbon and nitrogen contents. Both these figures have been used in the determination of the emissions to arrive at a reasonable margin of error. It has been found that the range is quite big, in excess of +/-20%, for the total emissions due to bio-fuels combustion.

TABLE 3. CALCULATION OF TRACE GAS EMISSIONS FROM CARBON EMISSION ESTIMATES FROM WOOD-FUEL

TOTAL C RELEASED (Gg)	NITROGEN CONTENT OF BIOMASS (kgN/Ton)	TOTAL N RELEASED (Gg)	TRACE GAS EMISSION RATIO	TRACE GAS EMISSIONS (Gg C or N)	CONVERSION FACTORS	TRACE GAS EMISSIONS (Gg GAS)
592.91			(CH_4) 0.01	(CH_4) 5.93	16/12	(CH_4) 7.91
			(CO) 0.10	(CO) 59.30	28/12	(CO) 138.37
	0.004	2.37	(N_2O) 0.007	(N_2O) 0.02	44/28	(N_2O) 0.03
			(NOx) 0.1210	(NOx) 0.29	30/14	(NOx) 0.62
NOTE: CO_2:C = 44:12 Then, CO_2 emission is given by 592.91 x 44/12 = 2174.00 kt						

TABLE 4. CALCULATION OF TRACE GAS EMISSIONS FROM CARBON EMISSION ESTIMATES FROM COAL

TOTAL C RELEASED (Gg)	NITROGEN CONTENT OF BIOMASS (kgN/Ton)	TOTAL N RELEASED (Gg)	TRACE GAS EMISSION RATIO	TRACE GAS EMISSIONS (Gg C or N)	CONVERSION FACTORS	TRACE GAS EMISSIONS (Gg GAS)
52.33			(CH_4) 0.0014	(CH_4) 0.073	16/12	(CH_4) 0.098
			(CO) 0.060	(CO) 3.140	28/12	(CO) 7.326
	0.01	0.5233	(N_2O) 0.007	(N_2O) 0.004	44/28	(N_2O) 0.006
			(NOx) 0.1210	(NOx) 0.063	30/14	(NOx) 0.136
NOTE: CO_2:C = 44:12 Then, CO_2 emission is given by 52.33 x 44/12 = 191.88 kt						

2.7.4 Emissions from other Biomass

In Botswana, other types of biomass combusted for energy include agricultural wastes and biogas from cow-dung. The statistics on the latter are not available.

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

3.0 INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

3.1 COUNTRY INDUSTRIAL BASE

Botswana is not heavily industrialised. This section will therefore be discussed within the bounds of limited number of industries that produce and use of solvents in industries that offer services.

3.1.1 INTRODUCTION

There are two main industrial processes in Botswana that contribute meaningfully to the national GHg inventory. These are the soda ash production plant and the limited production of cement. They both contribute 540.72 Gg of CO_2 emissions with soda ash production contributing 98.6% of this value (Table 6).

3.1.2 BACKGROUND

All GHG inventories up to this point have always assumed that the coiuntry is not industrialised, and that all other industrial processes have been taken care of under other inventory sectors. The inclusion of emissions from cement and soda ash productions are done for the first time.

3.1.3 DATA SOURCES

The industries provided the data in Table 6.

3.1.4 METHODOLOGY

The data obtained from the various sources were in units of either weight (or mass, i.e. metric tonnes) or volume (litres) of fuel. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors.

3.2 CO_2 FROM INDUSTRIAL PROCESSES

3.2.1 Cement Production

Production of cement started in Botswana in October 2009 by the Matsiloje Portland Cement Company. The daily production was 65 tonnes of the commodity during the last quarter of 2009. This increased to 100 tonnes a day in the year 2010. The implication of this is that the GHG emissions the production of cement during the period 2000-20010 is limited to the two years 2009 and 2010. Given that the production level was maintained in the year 2011, it can be projected that the CO_2 emission in 2010 from cement production is at the level of 7.67 Gg while for the year 2009, projection would be 1.25 Gg.

3.2.2 Soda Ash Production

The emissions of GHG from soda ash production was estimated from the amount of trona (T-brine) utilized between 2000 and 2010. Table 5 is a summary of the amount of trona utilized in the country during this period. and up to 2011.

TABLE 5. AMOUNT OF TRONA UTILIZED IN THE CEMENT INDUSTRY FROM 2000-2011

YEAR	AMOUNT OF TRONA (T-BRINE) UTILIZED (m^3)
Jan 2000 – Dec 2000	4 071 142
Jan 2001 – Dec 2001	5 729 234
Jan 2002 – Dec 2002	5 974 482
Jan 2003 – Dec 2003	5 047 167
Jan 2004 – Dec 2004	6 114 261
Jan 2005 – Dec 2005	5 847 160
Jan 2006 – Dec 2006	6 453 923
Jan 2007 – Dec 2007	5 779 079
Jan 2008 – Dec 2008	5 672 386
Jan 2009 – Dec 2009	5 209 403
Jan 2010 – Dec 2010	5 258 885
Jan 2011 – Dec 2011	5 581 318

TABLE 6. SUMMARY INVENTORY OF GHG EMISSIONS FROM INDUSTRIAL PROCESSES SECTOR

Inventory Category	CO2 Emissions (Gg)
Mineral Industry	7.67243724
Chemical Industry	533.051181

3.3 SOLVENTS

3.3.1 INTRODUCTION

Most of the dry cleaning companies and hotels are in the urban centres. The main solvent used is Perchloroethylene.. Data on national consumption of this product is not directly available and difficult to decipher from national statistics; hence, NMVOC emissions from the chemical is almost impossible to estimate. From the Botswana Statistics, the total imports of chemicals from 2001 – 2011 are in Table 7.

It has not been possible to distill Perchloroethylene as a component from available data.

TABLE 7. BOTSWANA IMPORT OF CHEMICALS

YEAR	IMPORT (10^3) BWP
2001	1,090,334
2002	1,712,326
2003	1,480,248
2004	1,812,029
2005	1,983,537
2006	2,352,267
2007	3,140,020
2008	3,641,389
2009	3,581,160
2010	4,174,620
2011	4,834,031

3.3.2 CONCLUSION

A more detailed survey and data collection should be carried out in the future which will make it possible to divide the sources in the categories proposed in the IPCC guidelines and also to determine country specific emission factors.

AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

4.0 INTRODUCTION

Botswana was one of the countries that benefit from a project conceived to strengthen the capacity of Eastern and Southern African countries to improve the quality of their national GHG inventories and encourage the development and setting up of sustainable inventory management systems. Specifically, the Project aims to accomplish the following in each of the participating countries:

- Strengthen the institutional arrangements and inventory management systems, its functions, and ability to sustainably oversee the compilation of regular national GHG inventories for submission to the UNFCCC;
- Enhance the technical capacity of designated personnel to produce a complete Tier I level, if Tier 2 level is not achievable, well documented/transparent inventory for the Agriculture and LULUCF sector of the national GHG inventories, due to the unique challenges in producing high quality inventories for sources in this sector and relatively large proportion of emissions that come from these sources in many developing countries;
- Improve national methodologies, activity data and emission factors through a combination of hands-on training designed to meet the individual needs of the countries, use of GHG inventory management tools specifically designed for the Agriculture and LULUCF sectors, assistance from experts with specific knowledge on these source/sink categories, guidance on developing land use maps and regional networking.

Institutions that provided resources for Project include:

- Thünen Institute (TI)
- Coalition of Rainforest Nations (CfRN)
- US-Environmental Protection Agency (USEPA)
- US-Agency for International Development (USAID)
- Colorado State University (CSU)
- Global Earth Observation (GEO)

Under the Project (Adedoyin *et al.*, 2014), participating countries were introduced to the **Agriculture and Land Use National Greenhouse Gas Inventory Software Program (ALU)** developed at Colorado State University to conduct national greenhouse gas inventories for the Agriculture and Land Use, Land Use Change and Forestry sectors.

Key inventories generated for the Agriculture using ALU are in Tables 8-10:

Table 8. METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT

	MODULE	**AGRICULTURE**				
	SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK**				
		ENTERIC FERMENTATION AND MANURE MANAGEMENT				
	WORKSHEET	**4-1**				
	SHEET	**1 OF 2 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC**				
		FERMENTATION AND MANURE MANAGEMENT				
	SESSION	**Botswana**				
	YEAR	**2011**				
	STEP 1			**STEP 2**		**STEP 3**
Livestock Type	A Number of Animals	B Emissions Factor for Enteric Fermentation (kg/head/yr)	C Emissions from Enteric Fermentation (t/yr)	D Emissions Factor for Manure Management (kg/head/yr)	E Emissions from Manure Management (t/yr)	F Total Annual Emissions from Domestic Livestock (Gg)
			C = (A x B)/1000		E = (A x D)/1000	F = (C + E)/1000
Dairy Cows	6666*	36	239.976	1	6.666	0.246642
Non-Dairy Cattle	2554364	32	81739.648	1	2554.364	84.294012
Buffalo	0	0	0	0	0	0
Sheep	295894	5	1479.47	0.21	62.13774	1.54160774
Goats	1769811	5	8849.055	0.22	389.35842	9.23841342
Camels	0	0	0	0	0	0
Horses	40000	18	720	2.2	88	0.808
Mules & Asses	351000	10	3510	1.2	421.2	3.9312
Swine	5000	1	5	2	10	0.015
Poultry	1499000	0	0	0.023	34.477	0.034477
Totals			96543.149		3566.20316	100.1093522

- Moreki *et al., 2011*

Table 9. NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS

MODULE	**AGRICULTURE**		
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK**		
	ENTERIC FERMENTATION AND MANURE MANAGEMENT		
WORKSHEET	**4-1**		
SHEET	**2 OF 2 NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION**		
	EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS(AWMS)		
SESSION	**Botswana**		
YEAR	**2011**		
	STEP 4		
Animal Waste Management System (AWMS)	A Nitrogen Excretion Nex(AWMS) (kg N/yr)	B Emission Factor For AWMS EF3 (kg N2O-N/kg N)	C Total Annual Emissions of N2O (Gg)
			C=(AxB)[44/28]/1 000 000
Anaerobic lagoons	39996	0.001	0.062850857
Liquid systems	359964	0.001	0.565657714
Daily spread	0		
Solid storage & drylot	80000	0.02	2.514285714
Pasture range and paddock	252584368		
Other	899400	0.019	26.85351429
Totals	253963728		29.99630857

Table 10. INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING

MODULE	AGRICULTURE						
SUBMODULE	AGRICULTURAL SOILS						
WORKSHEET	4-5						
SHEET	5 OF 5 INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING						
SESSION	Botswana						
YEAR	2011						
	STEP 7					STEP 8	STEP 9
	I Synthetic Fertiliser Use NFERT (kg N/yr)	J Livestock N Excretion NEX (kg N/yr)	K Fraction of N that Leaches FracLEACH (kg N/kg N)	L Emission Factor EF5 (kg N2O-N/kg N)	M Nitrous Oxide Emissions From Leaching (Gg N2O-N/yr)	N Total Indirect Nitrous Oxide Emissions (Gg N2O/yr)	O Total Nitrous Oxide Emissions (Gg)
					M = (I + J) x K x L/ 1 000 000	N = (H + M)[44/28]	O = (G + C + N)(G from Worksheet 4-5, sheet 2, Step 4; C from Worksheet 4-5, sheet 3, Step 5; N from Worksheet 4-5, sheet 4, Step 6, N from Worksheet 4-5, sheet 5, Step 8).
Total	0	201979219.6	0.3	0.007	0.424	1.301	9.706

METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT

From Table 8, the methane emissions from domestic livestock enteric fermentation and manure management total 100.1093522 Gg which translates to about 2502.73 Gg of CO_2.

NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS

From Table 9, nitrous oxide emissions from animal production emissions from animal waste management systems total 29.996 Gg which translates to about 8938.81Gg of CO_2.

INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING

From Table 10, indirect nitrous oxide emissions from leaching total 9.706 Gg which translates to about 2892.39Gg of CO_2.

These figures give a total GHG emission of **14333.928 Gg of CO_2** from the Agriculture Sector.

There are some reservations as regards this figure. We have used the IPCC defaults in estimating these values but in reality, these could be over-estimating the GHG emissions because the climate of the country is Tropical Dry. Animal waste may then dry up very quickly before the biological processes that enhance GHG emissions commence. This development is informing the consideration of Tier 2 methods of estimates in subsequent inventories.

The study, for comparative purposes and for the reason adduced above, embarked on manual estimates of GHG from Agriculture Sector directly from IPCC guidelines and formulae. The summaries of results are:

- **The 2011 estimate of methane emitted from enteric fermentation was computed to be 83.25 Gg which converts to 2081.17 Gg of CO_2**
- **The 2011 estimate of CO_2 from livestock manure was computed to be 22.28 Gg**
- **The 2011 estimate of CO_2 from burning of crop waste was computed to be 0.00573 Gg**

The results from domestic livestock enteric fermentation and manure management from these separate studies are of the same order of magnitude.

4.1 METHANE EMISSIONS FROM LIVESTOCK

4.1.1 BACKGROUND

Of domesticated animals, ruminant animals (cattle, camels, donkeys, sheep and goats) are the major source of methane emissions with cattle being the most important source globally. Methane is produced as part of the normal fermentative digestive process of animals. Ruminant animals are characterized by a large "fore-stomach" or rumen. Within the rumen microbial fermentation breaks down feed into soluble products which together with the digestion products are utilized by the animal. The microbial fermentation that occurs in the rumen enables ruminant animals to digest complex plant carbohydrates which monogastric animals including humans cannot digest. Methane is produced in the rumen by bacteria as a by-product of the fermentation process. This methane is eructated and exhaled by the animal.

There are a variety of factors that affect methane production in ruminant animals based on the scientific information available such as the physical and chemical characteristics of the feed; the feeding level and schedule; the microbial mix within the rumen including the population densities of protozoa; the use of feed additives to promote production efficiencies and the health and activity of the animal. Of these factors, the feed composition and characteristics and feeding level have the most influence.

4.1.2 EMISSION INVENTORY METHOD

In order to estimate emissions of methane from livestock, IPCC procedures recommend the following steps:

a. Enumerate the number of animals by species.
b. Characterise the population of each animal species and divide the population into reasonably homogeneous categories, e.g. age, size, feeding and production level; and management system.
c. Estimate methane emission factors for each category of animal by:
i. estimating the animal feed energy intake for each animal representative of the category.
ii. estimating the portion of the feed energy intake that will be converted to methane.
iii. estimating the emission factor by multiplying the feed intake by the portion of the feed energy converted to methane.
d. Estimate total methane emissions by multiplying the emissions factor by the number of animals for each category and summing across categories.

4.1.2.1 Enumeration

National Census (Statistics Botswana, 2013) gave the cattle numbers as **2,634,683** and **2,554,364** for **2010** and **2011** respectively. Projections for other domestic animals were as follows:

TABLE 11: CENSUS OF DOMESTICATED ANIMALS (2011)

YEAR	SHEEP	GOATS	DONKEYS*	HORSES*	CHICKEN*	PIGS*	OSTRICHES*
2010	279,237	1,937,931	339,000	41,000	1,761,000	3,000	2,000
2011	295,894	1,769,811	351,000	40,000	1,499,000	5,000	-

*To the nearest '000

4.1.2.2 Domestic Animals Categorisation

Botswana's national herd mainly comprises of indigenous cattle. The average mature weight is 220 kg and the average milk production is two litres per day.

4.1.2.3 Estimation of Methane Emission Factors

Efforts are being made to get country specific factors required to determine methane emission factors of Botswana cattle. This report contains default factors which will be replaced as soon as country specific factors are determined.

4.1.2.3.1 Feed Intake Level

Estimate of daily feed intake as a percentage of live weight using the internationally-acceptable method (OECD, 1991) for cattle consuming straw with 50 percent digestibilities are given as follows:

100 kg live weight: 2.2 percent of live weight
200 kg live weight: 1.9 percent of live weight
300 kg live weight: 1.9 percent of live weight
400 kg live weight: 1.6 percent of live weight

Assuming that Botswana's national sward is also of 50 percent digestibility and taking the average live weight to be 220 kg, the average daily feed intake should be 1.9 percent of 220 kg per animal which is close to 4 kg. Because the cattle that consume mostly low quality forage in tropical regions have relatively low rates of growth and milk production, estimates of the efficiency of energy retention for growth or milk production do not contribute significantly to the estimate of total feed intake. Using more recent work performed in Australia, the following activity factors are recommended for the energy required for grazing.

Confined Animals (pens and stalls); no addition NE_m.

Animals grazing good quality pasture; 17 percent of NE_m and

Animals grazing over very large areas 37 percent of NE_m.
(where NE_m is the net energy required for maintenance in Megajoules (MJ/day)).

Botswana's cattle fall in the category of grazing over very large areas.

NE_m is estimated by the following equation: NEm (MJ/day) = 0.322 x (weight in kg)$^{0.75}$

NE_m (MJ/day) = 0.322 x $(220)^{0.75}$ = 18.4

Because of grazing over very large areas 37 percent of NE_m will be required which is (37 x 18.4)/100 = 6.8 MJ/day

Total net feed energy required will be 18.4 + 6.8 = 25.2 MJ/day.

The gross-feed energy intake is estimated from the net-feed intake above, using the following equation:

$GE = [\{NE_m + NE_f\}/NE/DE + NE_g/(NE_g/DE)]/DE\%/100$

where:

GE = Gross-feed energy intake

NE_m = 18,4 MJ/day, net energy required for maintenance

NE_f = 6.8 MJ/day, net energy required for grazing

NE/DE = 0.298 + 0.0035 x DE%

DE = 60% (default value)

Therefore: NE/DE = 0.508

NE_g = Net energy required for growth (negligible)

Therefore, ignoring the term NE_g, the above equation gives: GE = 87.18 MJ/day.

4.1.2.4 Conversion of feed intake to methane

Statistical relationship developed by experts to estimate the portion of feed intake that will be converted to methane in well balanced forage diets and mixed with forage/grain diets as found in temperate agriculture systems. To simplify matters somewhat for poor quality tropical agriculture diets, a general assumption that 6.0 percent of feed energy is converted to methane is used. Therefore:

(6.0 x 84.19)/100 = 5.05 MJ/day gives the energy converted to methane.

The Methane Emission factor in kg/head/year is therefore estimated as:

4.96 MJ/day x 365 days = 1810.6 MJ/head/year.

55.65 MJ is equivalent to 1 kg of CH_4.

i.e. 1810.6 x 0.018 = 32.59 kg CH_4 /head/year.

Given a cattle population of 2,554,364 in 2011, the annual estimate of methane produced was computed to be 83.25 Gg which converts to 2081.17 Gg of CO_2.

4.1.3 METHANE EMISSIONS FROM RUMINANT AND PSEUDO RUMINANTS

The simple method based on emission factor per animal has been adopted here. An emission factor for cattle in Botswana has been calculated as above. Emission factors as calculated by Crutzen *et al* (1986) from mean animal masses and mean intake of feed will be used for goats, sheep and pigs.

4.2 METHANE EMISSIONS FROM LIVESTOCK MANURE

4.2.1 BACKGROUND

Manure is primarily composed of organic material and therefore the potential for methane emissions is great. The portion of this emission potential which is actually realised is a function of the manure management system. Anaerobic conditions will result in much methane production whereas manure kept in contact with oxygen (e.g. spread on fields) produces little amounts of methane. Other principal determinants of methane production from livestock manure are characterisation of the manure and the climate.

Botswana's national herd mainly comprises of indigenous cattle and the manure management system is by deposits on pastures and ranges. The exotic cattle population is considered insignificant compared to the indigenous cattle. The composition of livestock manure which is primarily a function of the animal species and diet, determines its maximum methane producing capacity. In the tropics cattle are mainly fed on roughage diet which will produce less biodegradable manure containing more complex organic substances such as hemi-cellulose, cellulose and lignin. On the other hand however, because of fewer digestibility of the pastures, cattle will take in a lot and produce much manure. The climatic parameters like temperature and rainfall will affect both the rate and total amount of methane production in manure. A warm and moist environment promotes methane production.

4.2.2 METHODOLOGY FOR ESTIMATING EMISSIONS FROM LIVESTOCK MANURE

Reports are from major steps of the methodology recommended in IPCC 2006 as follows:

a. Estimate the amount of volatile solid produced for each animal type (VS) using published statistics on animal populations, animal sizes and manure generation rates.
b. Estimate the maximum methane producing capacity for the manure from each animal type (B_0).
c. Define the manure management systems in use and for each system estimate its methane producing potential (MCF).
d. Estimate methane emissions for each animal type and manure management system (TM) by multiplying the amount of volatile solids produced by the animal type (VS) by the methane producing capacity of the manure B_0 and by the methane producing capacity potentials of the manure management system (MCF).
e. Total methane emission will be the sum over all animal types and all manure systems.

4.2.3 Calculation of Emissions

Total Methane emissions for each animal type for one year may be calculated with the following formula:

$TM = VS \times B_0 \times MCF \times 365 \times \text{Density of } CH_4 / 109$

The estimates of VS, B_0, MCF were recently modified by the US Environment Protection Agency EPA 1993.

Owing to lack of country specific data for those parameters, the EPA modified estimates will be used.

TABLE 12. ESTIMATES OF VS, B_0 AND MCF AND METHANE EMISSION (2011)

DESCRIPTION	SHEEP	GOATS	DONKEYS	HORSES	CHICKEN	PIGS	POULTRY (including ostriches)
VS kg/head/day	0.37	0.49	1.70	1.70	0.02	0.41	0.02
B_0 (m^3 CH_4/kg/VS)	0.13	0.13	0.10	0.10	0.24	0.29	0.24
Manure Management System	PRP	PRP	PRP	PRP	PRP	Solid Storage and Dry Lot	PRP
MCF at 30^0C	2%	2%	2%	2%	2%	5%	2%
TM (10^{-3})	2.1	2.8	7.5	7.5	0.21	13.2	0.21
Methane Emission (kg)	620.17	4976.58	2642.70	290.70	314.63	65.94	-

Total methane emitted was therefore estimated at **8910.72 kg = 22.28 Gg of CO_2**

In the final draft of Greenhouse Gas Inventory workbook, the Manure Management Emissions Factors are given as:

Cattle	1.00 kg/head/year
Donkeys	1.00 kg/head/year
Sheep	0.21 kg/head/year
Goats	0.22 kg/head/year
Poultry	0.023 kg/head/year
Pigs	2.00 kg/head/year

These figures are for developing countries with warm climates.

4.3 NITROUS OXIDE EMISSIONS FROM FERTILIZER USE

4.3.1 FERTILIZER CONSUMPTION IN BOTSWANA

It is considered from our study that majority of Botswana farmers have not taken use of fertilizers seriously.

4.4 CARBON DIOXIDE RELEASED DUE TO BURNING OF AGRICULTURAL CROP WASTES

4.4.1 BACKGROUND

The basis for the determination of greenhouse gas emissions from burning of agricultural wastes is on the amount of carbon burned and the emission ratios of CH_4, CO, N_2O and NOx to CO_2 measured in the smoke fires (Crutzen and Andrea, 1990). To determine the total carbon burned in agricultural wastes, six parameters for each crop type were determined through both field, and laboratory experiments and measurements:

- Amount of crops produced with residues that are commonly burned
- Ratio of crops produced with residues that are commonly burned
- Fraction of residue burned
- Dry matter content of residue
- Carbon content of the residue
- Nitrogen/Carbon ratio of the residue

4.5 NON-CO2 GASES FROM BIOMASS BURNING

4.5.1 Category description

This category reports the non-carbon greenhouse gas emissions from burning activities including wild fires in managed forests as well as fires related to land use changes and land management. In the case of Botswana, only emissions associated with wild fires are reported, since burning is uncommon in association with deforestation and shifting cultivation has not been considered in this inventory. Most natural fires in Botswana are started by lightning strikes or inadvertently by human causes.

4.5.1.1 Methodology, Activity Data and Emission Factors

There are a number of equations used for calculating emissions due to biomass burning. These incorporates both CO_2 and non-carbon dioxide gases whereby calculations are made separately for each greenhouse gas, using the appropriate emission factor. These equations are as follows;
CH_4 Emissions = (carbon released) ● (emission ratio) ● 16/12
CO Emissions = (carbon released) ● (emission ratio) ● 28/12
N_2O Emissions = (carbon released) ● (N/C ratio) ● (emission ratio) ● 44/28
NO_x Emissions = (carbon released) ● (N/C ratio) ● (emission ratio) ● 46/14
As indicated in the equations, these non-carbon dioxide emission gasses used here are methane, carbon monoxide, nitrous oxide, nitrates and nitrites emitted in combination. In this project, these equations' major component is the quantity of greenhouse gas (GHG) released due to fire (L_{fire}) measured in tonnes of carbon. The equation is as follows:
$L_{fire} = A \bullet B \bullet C \bullet D \bullet 10^{-6}$; where area burnt (A) calculated in hectare is multiplied by mass of 'available' fuel (B) weighed in kilograms per dry matter per hectare (d.m. ha^{-1}) and that multiplied by combustion efficiency (C) or fraction of the biomass combusted, dimensionless (Table 3A.1.14) and the result multiplied by the emission factor (D) measured in gram per kilogram per dry matter (g (kg d.m.)$^{-1}$)

The area burnt was taken from Statistics Botswana (2013) table 5.4d. The figure of 4 387 879 ha comprises the forest areas burnt in protected areas in forest reserves, wildlife management areas, game reserves and national parks. In that year 38% of the entire forest area was burnt. That percentage was applied to all forest subcategories and age ranges in order to derive the burnt areas. The available fuel is equivalent to the standing biomass in the forest (Table 3A.1.2 for natural forest and 3A.1.3 for plantations). Default values were adjusted down to only 5% to account for the low intensity of typical fires in Botswana. For combustion efficiency we selected 0.9 from Table 3A.1.14 – the lowest value allowed by the range provided in the table, once again, to reflect the low intensity fires of Botswana's forest ecosystems.

4.6 DETERMINATION OF CARBON BURNED

The total carbon burned from all crops was determined from total carbon burned (tonnes C) = (P_c * R_c * B_c * DM_c * C_c) where:

P = Crop Production (tonnes)
R = Residue/Crop Ratio
B = Residue Burned (%)
DM = Dry Matter Content (%)
C = Carbon Content (tonnes C/tonnes DM)
C = Crop Type

It should be noted however that some of the agricultural residues could be burnt for energy purposes. In such cases, the fraction burnt for energy purposes should be determined and its emissions estimated under the energy sector. The results are shown in Table 13 below.

TABLE 13. CARBON DIOXIDE RELEASED FROM BURNING OF AGRICULTURAL CROP WASTES

CROP TYPE	CROP PRODUCTION (TONNES)	RESIDUE/ CROP RATIO	RESIDUE BURNED (%)	DRY MATTER CONTENT (%)	CARBON CONTENT (TONNES C/TONNES DRY MATTER)	TOTAL CARBON BURNED (TONNES C)	CO_2 RELEASED = 0.9 x TOTAL CARBON BURNED (t-C)
Sorghum	32,591	1.2	40.0	80.0	0.792	3.557	3.203
Maize	35,322	1.0	30.0	75.0	1.543	2.612	2.354
Millet	2,511	1.1	20.0	8.5	0.306	0.153	0.138
Beans/Pulses	4,700	0.7	5.0	80.0	0.639	0.039	0.035
					TOTAL	**6.361**	**5.730**

TABLE 14. METHANE/CARBON MONOXIDE RELEASED FROM BURNING OF AGRICULTURAL CROP WASTES

CO_2 RELEASED (t-C)	CH_4-C Emissions (t-C)		CH_4 Emissions (tonnes)		CO-C Emissions (t-C)		CO Emissions (tonnes)	
	Low	High	Low	High	Low	High	Low	High
5.730	0.005	0.013	0.007	0.017	0.073	0.145	1.022	2.044

TABLE 15. NITRUOS OXIDE RELEASED FROM BURNING OF AGRICULTURAL CROP WASTES

N_2O-N Emissions (t-N)		N_2O-N Emissions (tonnes)		NO_x-N Emissions x 10^3 (t-N)		NO_x Emissions (tonnes)	
Low	High	Low	High	Low	High	Low	High
0.20	3.08	0.32	1.57	3.78	50.65	8.11	108.53

4.6.1 GREENHOUSE GAS EMISSION RATIOS

The emissions of CH_4, CO, N_2O and NOx were calculated based on the methodology in Crutzen and Andrea (1990). In the calculation of CH_4 and CO emissions due to crop residue burning, the amount of carbon burning is multiplied by 0.9 to account for approximately 10% of the carbon that remains on the ground (Seilar and Crutzen, 1980; Crutzen and Andrea, 1990 - cited IPCC Methodology). The resulting figure which is the amount of CO_2 released instantaneously measured in units of carbon, was then multiplied by the ratios of emissions of CH_4 and CO relative to CO_2 to yield emissions of CH_4 and CO in units of carbon. The emissions of CH_4 and CO are then multiplied by 16/12 and 28/12, respectively, to convert to full molecular weights.

The emissions of N_2O and NOx due to burning of crop residue were calculated by multiplying the total carbon burned by the N/C ratio of the fuel by weight to calculate the total amount of nitrogen released. A range of 0.02 - 0.17 was adopted to give the low and high emission scenarios based on the laboratory results of the crop-type N/C values.

The total N released was multiplied by the ratios of emission of N_2O and NOx relative to the N content of the fuel to yield emissions of N_2O and NOx in units of N. The emissions of N_2O and NOx were converted to full molecular weights by multiplying their emissions by 44/28 and 30/14 respectively.

Summary of calculations of CH_4, CO, N_2O and NOx emissions from burning of Agricultural Wastes:

CH_4 - C emissions (low)	= (carbon burned) x (0.90) x (0.003)
CH_4 - C emissions (high)	= (carbon burned) x (0.90) x (0.007)
CH_4 emissions (low, high)	= CH_4 - C emissions (low, high) x 16/12
CO - C emissions (low)	= (carbon burned) x (0.90) x (0.04)
CO - C emissions (high)	= (carbon burned) x (0.90) x (0.08)
CO emissions (low, high)	= CO - C emissions (low, high) x 28/12
N_2O - N emissions (low)	= (carbon burned) x (0.02) x (0.005)
N_2O - N emissions (high)	= (carbon burned) x (0.17) x (0.009)
N_2O - N emissions (low, high)	= N_2O - emissions (low, high) x 44/28
NOx - N emissions (low)	= (carbon burned) x (0.02) x (0.094)
NOx - N emissions (high)	= (carbon burned) x (0.17 x (0.148)
NOx - emissions (low, high)	= NOx - N emissions (low, high) x 30/14

TABLE 16. EMISSION RATIOS FOR BIOMASS BURNING CALCULATIONS (from Crutzen and Andrea, 1990)

COMPOUND	RATIOS
CH_4	0.003 – 0.007
CO	0.04 – 0.08
N_2O	0.005 – 0.009
NO_x	0.094 -0.148

a. Ratios for CH_4 and CO are mass of Carbon Compound released in units of C relative to mass of CO_2 released from burning (in units of C).
b. Ratios for N_2O and NOx are expressed as the ratios of emissions relative to the nitrogen content of the fuel.

The total CO_2 emissions from Biomass Burning in 2011 was estimated as **0.00573 Gg** (Table 13)

4.7 LAND-USE CHANGE AND FORESTRY

4.7.1 Introduction

Land-use changes affect the chemical composition of the atmosphere. CO_2 is the major gas released as a result of land-use change. Other gases such as Methane, Nitrous Oxide, Carbon Monoxide, etc. are also released due to changes in land-use. All these emissions lead to concentrations of greenhouse gases. The removal of CO_2 is done by photosynthetic activity of plants. If the vegetation is cleared this important process is curtailed. In this chapter the estimation of CO_2 emissions and removals are presented.

The first part of this chapter gives an account of the methodology adopted in the estimation of GHGs in the Forestry sector. During the assessment, a wide range of literature reviews were made and comparisons between the data were critically made in order to filter out the most reliable data.

There has been a gradual but serious reduction of the forest estate both within and outside gazetted areas and the rate of deforestation in Botswana is currently not known except for estimates made by various institutions both in and outside the country.

Given the definition of land management as the use and development of land resources for variety of purposes, it cannot be considered that all land is managed in Botswana.

4.7.2 Land representation

The Botswana vegetation cover map was used to derive the areas for the land use categories. This map was compiled in early 1990s by expert field investigators from FAO and Ministry of Agriculture, and digitized about the year 2000. The topographical baseline data of this map was derived from the Department of Surveys and Mapping 1: 1,500,000 scale map. This map was then utilized in this project to give values for forest land, grassland, cropland, and wetland. Unfortunately the map did not provide sufficient information on settlements; because where this information was given it was found to be insufficient as data was collected at very small scale and essential details were inevitably lost.. Subsequent to that data was taken from RMCRD and Botswana 2000, and 2010 Land Cover Maps and 2000 to 2010 Land Cover Change Maps. A difference in land cover change investigation of 10 years was chosen because land cover change is normally a slow process which takes hundreds of years for its effects to be felt. However, other processes are rapid, more especially those with destructive results; lately, there has been an avalanche of natural disasters which have caused devastating damage and great loss of life, accelerating changes on the land. Causes of such changes have been many of which the El Niño is one and fire is another. Also, for these reasons; it would be difficult or at most imposable to predict the land cover change; that is why the changes for yearly or after two years changes were not used as only the calculated results could be authentic.

The Botswana Vegetation Cover Map (shape files) was used as the basis for the land representation. The map had localized Botswana land use classification legend. This classification was different from IPCC land use categories (FL, CL, GL, WL, S, and OL). Therefore it was imperative to make some assessment and analysis as to what these map classes meant when translated to IPCC terms of reference. Further, the map was providing the following land use subcategories: FL- Dry Deciduous Forest (DDF), FL-woodlands (WL); CL- Vegetables (VE), CL-Field Crops (FC), CL-Orchards (OR); GL- Open Grassland (OG), GL-Savannah (SA). The following changes were made to utilize the vegetation map.

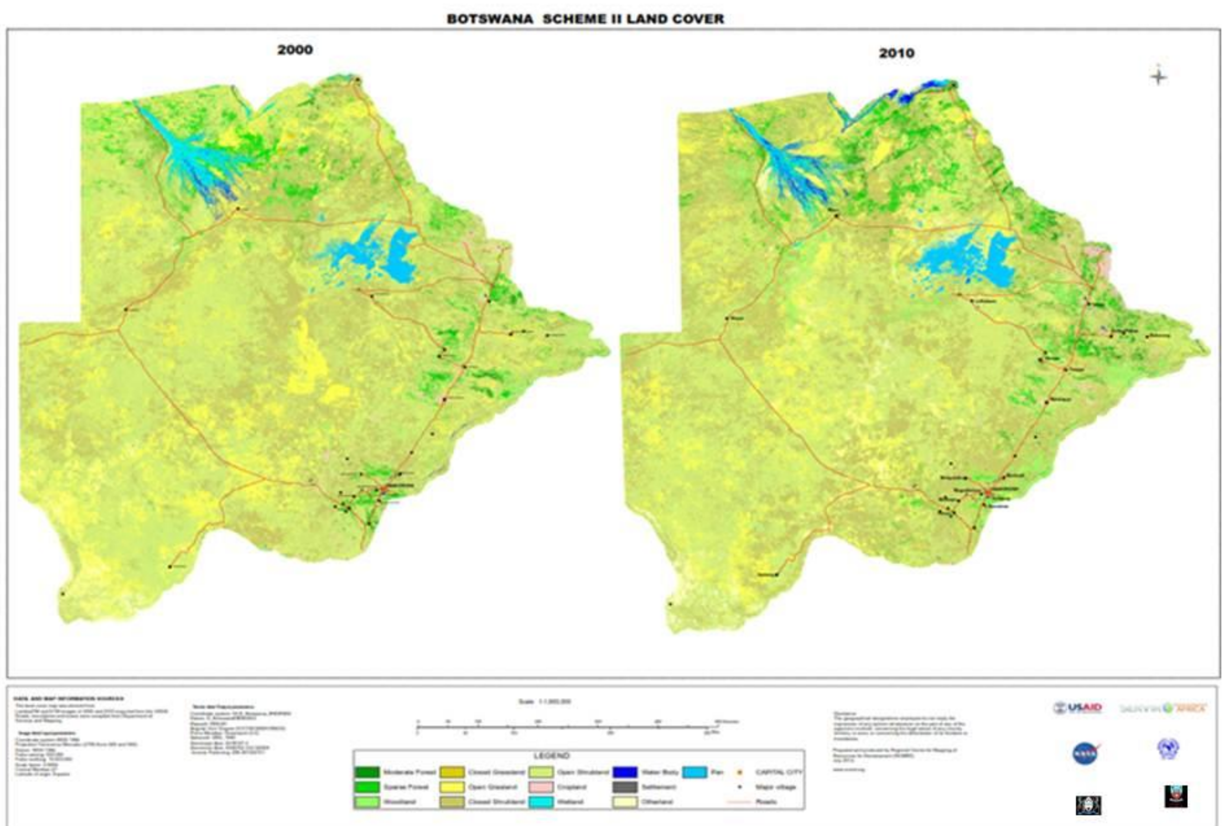


Figure 1: Land Cover Maps Botswana
a) 2000 and b) 2010

Fig. 1 2000 and 2010 land cover maps for Botswana

From Fig. 1, we obtain a land use category map of the country as in Table 17.

TABLE 17. LAND USE CATEGORY MAP FOR BOTSWANA

FAO CODE	Land-Use Category	Year 2000	Year 2010	Net Change 2010-2000
		(Ha)	(Ha)	(Ha)
6661	**A. Forest Area**	4,769,656.11	7,509,620.70	2,739,964.59
6620	**B. Arable Land and Permanent Crops**	497,262.06	748,258.20	250,996.14
6655	**C. Permanent meadows and pastures**	53,534,701.44	50,833,352.16	-2,701,349.28
6698	D.1 Wetlands	1,747,993.23	1,840,346.01	92,352.78
6697	D.2 Settlements	81,288.18	120,623.76	39,335.58
6699	D.3. Other land	811,197.99	406,937.52	-404,260.47
6601	**Total Land Area**	**61,442,099.01**	**61,459,138.35**	**17,039.34**

Botswana 2000- scheme 1	
Land_Cover	Area_Ha
Forestland	4769656.1100
Grassland	53534701.4400
Cropland	497262.0600
Wetland	1747993.2300
Settlement	81288.1800
Otherland	811197.9900

Botswana 2010- scheme 1	
Land_Cover	Area_Ha
No Data	42777709.11000
Forestland	7509620.70000
Grasssland	50833352.16000
Cropland	748258.20000
Wetland	1840346.01000
Settlement	120623.76000
Otherland	406937.52000

Botswana 2000- Scheme II	
Moderate Forest	618804.09000
Sparse Forest	3625197.66000
Woodland	525654.36000
Open Grassland	3702903.39000
Closed Shrubland	19577939.13000
Open Shrubland	30253858.92000
Annual Cropland	497262.06000
Wetland	756048.87000
Water Body	136853.73000
Settlement	81288.18000
Otherland	811197.99000

Botswana 2010- Scheme II	
No Data	42777709.11000
Moderate Forest	1592480.43000
Sparse Forest	5120075.25000
Woodland	797065.02000
Open Grasssland	2999654.46000
Closed Shrubland	19227185.28000
Open Shrubland	28606512.42000
Annual Cropland	748258.20000
Wetland	652472.10000
Water Body	265132.71000
Settlement	120623.76000
Otherland	406937.52000
Pan	922741.20000

Table 18 was obtained from two different GIS Schemes which used different land categories (as presented below the Table. The equipment and techniques used in 2010 also were more up-to-date than those in 2000. This is the reason why some pixels are not classified in 2010 as they did not qualify within the digital number choice.

The analysis had shown that only 30% of cropland in the Francistown environment has not changed, the rest was converted into grassland. Also 66% of cropland located in and around the upper reaches of the Limpopo basin remain unchanged. The rest of the CL had been converted to GL.

The adapted map was combined with the FAO climate map and the FAO soil map in order to assign the corresponding climate and soil to each of the land use categories, and the subcategories.

This resultant map data were conveyed into a form analytic pivot table containing the proportions in percentage form and in hectares.

The forest was subdivided into three subcategories. Dry Deciduous Forest (DDF) represents dense tree cover whose height are greater than 15m. Woodlands (WL) are Mopane and acacia trees whose heights are less than 15m. Plantations (PL) mainly comprise of Eucalyptus. That subcategory was not contained in the vegetation map, and therefore its area was estimated by expert knowledge.

Additionally, expert knowledge was utilized in the estimation of the total areas for these land cover/land use categories as thus: the total area of forest in Botswana is 20 %: this was distributed to the two soil classes by expert knowledge resulting in 60 % forest land (FL) for High Activity Clay Mineral (HAC) and 10% FL for Sandy Mineral (SAN) (average weighted by area of soil classes results in 20 %). The remaining area was distributed to other land use categories based on pivot table and expert knowledge.

4.7.3 Changes in Woody Biomass Stocks

4.7.3.1 Category description

Botswana's forests are endowed with natural resources that people and ecosystems depend on. They also provide habitats and food for the wildlife, upon which the country depends to a large extent, especially through tourism revenue. The largest consumer of energy in Botswana is the household sector, which is dominated by a dependence on fuelwood. Fuelwood is the primary household energy source in Botswana, especially for rural households. To a smaller extent the people harvest timber for making furniture and building materials. A major threat to forests in Botswana is that presented by wild fires. Wild fires destroy forests and disrupt ecological balances. This presents threats to biodiversity. Wild fires also destroy livestock and the grazing resources they depend on.

4.7.3.2 General Methodological Approach: Gain-Loss Method

Annual biomass loss is a sum of losses from commercial round wood felling, fuelwood gathering, and other losses and was calculated using Equation 3.2.6 of the 2003 IPCC Good Practice Guidance. Details of other calculations are in Appendix 1. Forest and vegetation distraction by elephants also forms a substantial amount of loss, although this project does not take loss by animal destruction into consideration.

Table 18 (derived from Appendix 1) shows GHG emissions and carbon dioxide removals per category.

TABLE 18. GHG EMISSIONS AND CO_2 REMOVALS (Gg)

Source/Sink Category	**Gg (gas) yr $^{-1}$**		
	CO_2	**CH_4**	**N_2O**
Conversions to Forest	-46186.19971		
Conversions to Cropland	745.688346		
Conversion to Grassland	22363.24739		
Conversions to Wetland	0		
Conversions to Settlements	396.81829		
Conversions to Other Lands	-4840.110092		
Net gas emissions (Gg CO2-eq yr-1)	**(27520.555776)**		

Table 17 indicates an increase of 57.5% in total forest area of Botswana between 2000 and 2010. Normally, this should translate into a sink category for GHG. However, the devastating fire incident of 2010 almost annulled these forest gains; hence, the net emissions from conversions to forest in Fig. 18 for the year 2011. The conversions to Other Lands and Settlements in Figs. 17 and 18 are consistent in trend.

In 2010, 13,586,774.41 Ha of land was affected by wildfire in Botswana. This translates to 23.4% of the total area of the country. The areas destroyed by fire included the gains in forest land between 200 and 2010 (Fig. 17); and the permanent meadows and pastures. This incident further worsened the loss of permanent meadows and pastures recorded in Fig. 17. The recovery processes, which included fire policy legislation by Government, and the natural process of conversions to grassland resulted in net carbon sinks in 2011 under the category of Conversions to Grassland (Fig. 18). In a tropical dry climate zone, 8.7 tonnes d.m. ha^{-1} is the default for biomass carbon stocks present when land is converted to grassland (IPCC, 2003). In the case of 2011 in Botswana, this translates to about 500,000 Gg of CO_2 sink. However, given the El-Niño event of 2010 and the associated drought in Botswana, we estimate that about one-fifth (20%) of the expected carbon stock would result from the recovery process. The study therefore estimates a carbon-sink-recovery of about 100,000 Gg of CO_2 in 2011 from the extensive wildfire of 2010.

WASTE

5.0 WASTE

The total methane emission from the WASTE Sector is 5.29 Gg (Table 19) with the main activity being the Waste Treatment and Discharge procedures. This translates to 132.25 Gg equivalent of CO_2. The corresponding emission of N_2O is 0.086 Gg (Table 19) which is 25.63 Gg of CO_2. Thus, the Waste Sector emitted **132.34 Gg** of CO_2 in the base year 2011.

Quantities of municipal waste generation were estimated as follows:

Domestic waste	0.8 kg/head/day
Market waste	0.05 kg/head/day
Commercial and Industrial	0.2 kg/head/day
Street sweepings	0.1 kg/head/day
Total	1.15 kg/head/day

Several organisations, including the World Bank, have complained that the rate of 1.15 kg/head/ day is unreliable and most likely too high. A more reliable rate is most likely between 0.6 and 0.7 kg/head/day.

5.1 MANAGEMENT PRACTICES

5.1.1 Estimation of Methane Emissions

Since the Municipal Solid Wastes are virtually not landfilled it is difficult to use some suggested international formulae. Some estimates have however been made based on the conversion factor of 21.5 kg of methane per ton of garbage for Municipal garbage from developing countries. This conversion factor is 50% of the average methane recovery determined for the USA using an empirical model based on landfill gas recovery data. Due to limited basic data from developing countries, the range of default values of 25% to 75% of the USA mean recovery value is suggested for the developing countries. The lower conversion factor for developing countries is due to differences in garbage composition factor and management practices. Most of the landfills in developing countries, including Botswana, are open dumps. This situation tends to suppress anaerobic decomposition while enhancing aerobic decomposition where much of the methane formed is oxidised. However, due to the high content of organic matter in the Botswana garbage, the methane recovery potential is most likely higher than the average value suggested for calculations. Until data becomes available, we limit ourselves to factors in 2006 IPCC Software Inventory.

5.2 DATA SOURCES

All raw data used in the estimation of GHG emissions were obtained from local sources; especially from the Department of Waste Management and Pollution Control.

5.3 METHODOLOGY

The data obtained from the various sources were in units of either weight (or mass, i.e. metric tonnes).. They were then converted to energy units (Giga Joules) using standard conversion factors given in the IPCC 2006 GHG

Inventory Reference Manual. Emission estimates for petroleum combustion were also made using the emission factors contained in the same manual and the GHG Inventory Workbook. It should be noted that Botswana has no country specific emission factors.

5.4 GREENHOUSE GAS EMISSIONS FROM SOLID WASTE DISPOSAL

The Municipal Solid Wastes in the main towns of Botswana are dumped in valleys or shallow pits originally used for extraction of materials for road construction. The wastes end up in relatively shallow, open piles decomposing mainly under aerobic conditions to produce carbon dioxide and a small amount of methane. Further, there is no classification of municipal garbage into the international components of: vegetable matter, paper, plastic, metal, glass, aluminium (empty cans) and debris. GHGs are therefore difficult to estimate by category of waste.

The total methane emissions from Solid Waste sub-sector is 1.15 Gg of methane (Table 19) which is equivalent to 28.75 Gg of CO_2. These are largely from managed waste disposal sites.

5.4.1 Sanitation Facilities

The following sanitation facilities exist in the country:

a. Water borne - use of sewer lines or septic tanks.

b. Straight drop pit latrine - these are the most common in all areas of the country.

The use of pit latrines is the most prevalent in the country, being about 85% in the rural areas. Calculation of methane released from sanitation facilities will at the moment only take into account release from pit latrines.

5.4.2 Methane release from pit latrines

To calculate the methane released from pit latrines the formula recommended (for sewage treatment facilities) in the proceedings of the International IPCC Workshop on Methane and Nitrous oxide in national emissions inventories and options for control was adapted. In this formula,

Emissions (kg CH_4 /year) = Rural Population x kg BOD/Capita/day x 365 x Production Potential kg CH_4 /kg BOD x Fraction anaerobically digested

5.4.3 Fraction Anaerobically Digested

An average pit latrine in Botswana can reasonably be assumed to be about six meters, being generally deeper in the urban areas and shallower in the rural areas. Since anaerobic digestion is expected to take place below a depth of one metre, the greatest fraction of anaerobically digested matter is 5/6(0.833) and the lowest zero. Therefore, the average is 0.417 which is taken as the fraction anaerobically digested. Substituting for these factors, therefore,

Emissions (kg CH_4 /year)

= 715212 x 0.37 x 365 x 0.0227 x 0.417 kg

= 0.091430 x 10^6 kg

= 0.091430 Gg

If calculations are made using a methane production potential of 5 g/l and an average human waste density of 1.464 kg/l, the methane release of about 0.091430 x 10^6 kg /year would imply an average human waste generation of about 120 g/person/day which is not unreasonable.

5.5 GREENHOUSE GAS EMISSIONS FROM WASTE WATER TREATMENT DISCHARGES

The total methane emissions from Solid Waste sub-sector is 4.14 Gg of methane (Table 19) which is equivalent to 103.50 Gg of CO_2. There is a simultaneous emission of 0.086 Gg of N_2O which is 25.63 Gg of CO_2. The country does not biologically treat solid waste and incineration and open burning of waste is illegal.

TABLE 19. SUMMARY INVENTORY OF GHG EMISSIONS FROM WASTE

Inventory Category	CO2 Emissions (Gg)	CH4 Emissions (Gg)	N2O Emissions (Gg)
Solid Waste Disposal	0	1.147096485	0
Wastewater Treatment and Discharge	0	4.141871709	0.085632386

SUMMARYOF GHG EMISSIONS FROM ALL SECTORS AND CONCLUSIONS

6.0 SUMMARYOF GHG EMISSION FROM ALL SECTORS AND CONCLUSIONS

In accordance with the objective of the United Nations Framework Convention on Climate Change (UNFCCC) of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, and in conformity with the commitment of the Government of Botswana, as a signatory, which requires all parties to develop, periodically update, publish and make available to the Conference of Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies, the national greenhouse gas inventory for Botswana for the base year 2011 is presented in this report.

6.1 ENERGY

The total CO_2 emissions from this sector in 2011 was estimated at 7539.74 Gg broken down as:

6.1.1 CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION ACTIVITIES

- **Energy Industries** sub-sector is 3657.59 Gg (Table 1) with the main activity being electricity and heat production.
- **Manufacturing Industries and Construction** sub-sector is 1235.52 Gg (Table 1) with the main activity being mining (82% of CO_2 emissions).
- **Transport** sub-sector is 1985.10 Gg (Table 1) with the main activity being road transportation which contributed 98% of these emissions.

6.1.2 CARBON DIOXIDE EMISSIONS FROM FUGITIVE EMISSIONS FROM FUELS

- **Solid Fuels** sub-sector is 16.29 Gg (Table 1) with the main activity being the underground mining of coal (92% of CO_2 emissions).

6.1.3 CARBON DIOXIDE EMISSIONS FROM BIOMASS BASED FUELS

- The total CO_2 emissions from this sector in 2011 was estimated at 645.24 Gg

6.2 INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

- The total CO_2 emissions from this sector in 2011 was estimated at 540.72 Gg (Table 5)

6.3 AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

The total CO_2 emissions from this sector in 2011 were estimated at **16540.89 Gg** broken down as:

6.3.1 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT

- The methane emissions from domestic livestock enteric fermentation and manure management total 100.1093522 Gg (ALU Software) which translates to about 2502.73 Gg of CO_2. This compares very well with the figure of 96.877734 Gg (IPCC Software) from Appendix 1.

There are some reservations as regards these figures. We have used the IPCC defaults in estimating these values but in reality, these could be over-estimating the GHG emissions because the climate of the country is Tropical Dry. Animal waste may then dry up very quickly before the biological processes that enhance GHG emissions commence. This development is informing the consideration of Tier 2 methods of estimates in subsequent inventories.

The study, for comparative purposes and for the reason adduced above, embarked on manual estimates of GHG from Agriculture Sector directly from IPCC guidelines and formulae. The summaries of results are:

- **The 2011 estimate of methane emitted from enteric fermentation was computed to be 83.25 Gg which converts to 2081.17 Gg of CO_2**
- **The 2011 estimate of CO_2 from livestock manure was computed to be 22.28 Gg**

These figures give a total of 105.53 Gg of CO_2. Within a margin of error of 5%, the figures obtained from manual estimates, ALU and IPCC software are consistent; but the study is of the opinion that they may over-estimate the emissions from domestic livestock enteric fermentation and manure management. A Tier 2 approach in subsequent studies is envisaged to give more realistic figures for the country.

The emissions by category of GHG gas are depicted in Fig. 2

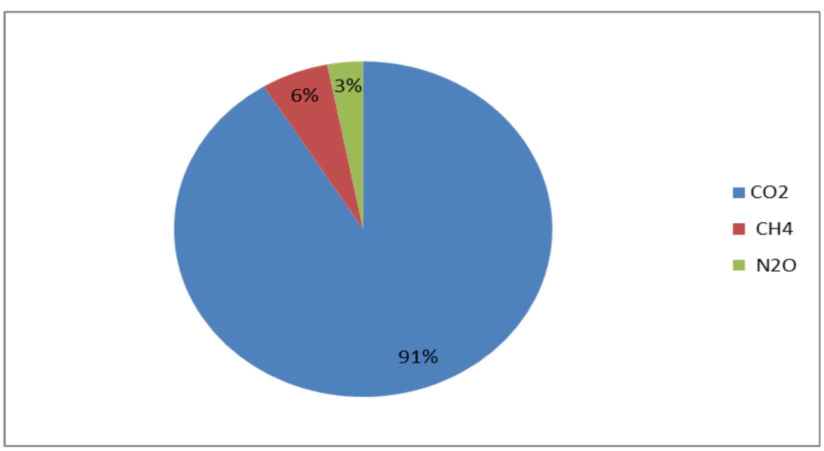


Fig.2 AFOLU Emissions by GHG Gas Category

6.3.2 NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS

- Nitrous oxide emissions from animal production emissions from animal waste management systems total 29.996 Gg which translates to about 8938.81Gg of CO_2.

6.3.3 INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING

- Indirect nitrous oxide emissions from leaching total 9.706 Gg which translates to about 2892.39 Gg of CO_2.

6.3.4 BIOMASS BURNING

- The 2011 estimate of CO_2 from biomass burning was estimated at 91.51 Gg of methane which translates to about 2287.75Gg of CO_2 (Appendix 1).

6.4 LAND-USE CHANGE AND FORESTRY

The total CO_2 emissions/removals from this sector in 2011 were estimated at 27520.56 Gg of CO_2 broken down as:

Source/Sink Category	Gg (gas) yr $^{-1}$		
	CO_2	CH_4	N_2O
Conversions to Forest	-46186.19971		
Conversions to Cropland	745.688346		
Conversion to Grassland	22363.24739		
Conversions to Wetland	0		
Conversions to Settlements	396.81829		
Conversions to Other Lands	-4840.110092		
Net gas emissions (Gg CO2-eq yr-1)	**(27520.555776)**		

The conversion of land to grassland in the table above was limited to events within 2011. The special case of recovery from the extensive wildfires of 2010 was calculated separately. In 2010, 13,586,774.41 Ha of land was affected by wildfire. This translates to 23.4% of the total area of the country. The recovery processes, which included fire policy legislation by Government, resulted in the massive carbon stock through conversion to grassland. In a tropical dry climate zone, 8.7 tonnes d.m. ha^{-1} is the default for biomass carbon stocks present when land is converted to grassland (IPCC, 2003). In the case of 2011 in Botswana, this translates to about 500,000 Gg of CO_2 sink. However, given the El-Niño event of 2010 and the associated drought in Botswana, we estimate that about one-fifth (20%) of the expected carbon stock would result from the recovery process. The study therefore estimates a carbon-sink-recovery of about 100,000 Gg of CO_2 in 2011 from the extensive wildfire of 2010.

6.5 WASTE

The total CO_2 emissions from this sector in 2011 were estimated as 540.72 Gg (Table 18). The emissions by category of GHG gas are depicted in Fig. 3.

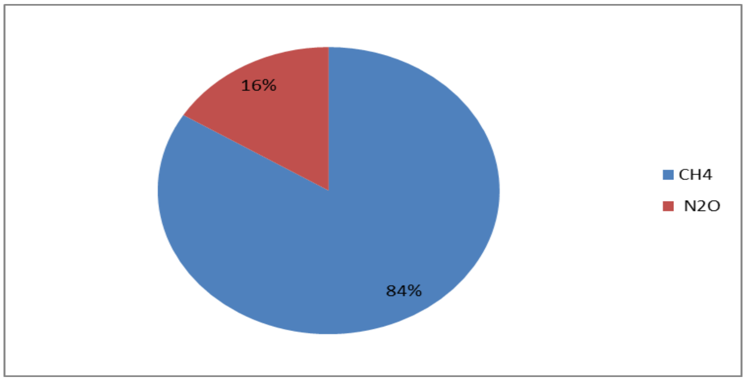


Fig.3 Waste Emissions by GHG Gas Category

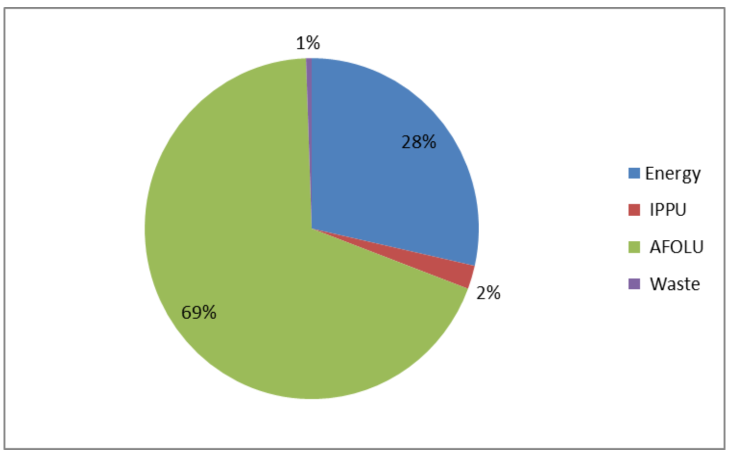


Fig.4 Total GHG Emissions by Source Categories

6.6 CLIMATE ANALYSIS INDICATORS TOOL (CAIT) COMPARISON

One reliable source of climate data is the Climate Analysis Indicators Tool (CAIT). This tool was used to estimate the GHG emissions in Botswana (http://cait.wri.org/profile/Botswana). The values for 2011 are in Table 20. Comparative and corresponding figures from this study have been inserted in a parallel column in the same table. Results are comparable and identical in virtually all the sectors except for LULUCF and Industrial Processes.

For the Industrial Processes sub-sector, this study included the manufacture of cement. This is a recent industrial process in Botswana and could have accounted for the difference between CAIT figures and those in this study. The difference in the figures for LULUCF is difficult to explain. This study employed two independent methods for these estimates namely, ALU and 2006 IPCC Software and arrived at comparable results. The 2000 and 2010 landuse maps for Botswana (Fig. 1) also seem to validate the results from this study.

Table 20. 2011 Climate Analysis Indicators Tool (CAIT) GHG Estimates for Botswana Versus Estimates from Local Studies

		MtCO2e (CAIT)	MtCO2e (Study Estimates)
1	**Total GHG Emissions Excluding Land-Use Change and Forestry - 2011**	**22.81**	**24.19**
2	**Total GHG Emissions Including Land-Use Change and Forestry - 2011**	**33.55**	**47.7**
3	**Energy - 2011**	**5.77**	**6.89**
4	**Industrial Processes - 2011**	**0.01**	**0.54**
5	**Agriculture - 2011**	**16.79**	**16.62**
6	**Waste - 2011**	**0.26**	**0.13**
7	**Land-Use Change and Forestry - 2011**	**10.74**	**23.51**

6.7 FUTURE IMPROVEMENT PLANS

With regard to agriculture the main constraint is lack of national specific factors for livestock which informed the use of southern hemisphere or UNFCC default that are likely to be higher than locals; hence, the need for empirical research to determine national emission factors. The other challenge is lack of empirical evidence to quantify emissions from small scale agricultural farming systems (that are majority of our farmers). Currently, it is assumes that Botswana small-scale farmers use agricultural fertilizer subsidies, which is not necessarily correct. Tillage also plays a major role: animal draught power versus mechanization; but this need to quatified. Lastly, it is known that feeding livestock nitrates reduce their methane emissions, but in Botswana farnmers (especially in winter when grazing is poor) farmers feed Non-Protein Nitrogen (NPN) sources such as winter lick, protein blocks etc. It is yet to be quantified whether or not these can offset methane emission.

7.0 TRENDS IN GHG EMISSION FROM 2000 TO 2010

7.1 CO_2 from Energy Sources (Time Series from 2000-2010)

Fig. 5 is a time series of CO_2 emissions from Energy sources between 2000 and 2010; expressed in Mt (million tons). It is close to a linear increase from the year 2003. These figures are limited to fuel combustion activities from fossil fuels alone and they do not contain contributions from other GHG gases like methane. It therefore makes them comparable to figures obtained for 2011, which is the base year for this inventory studies.

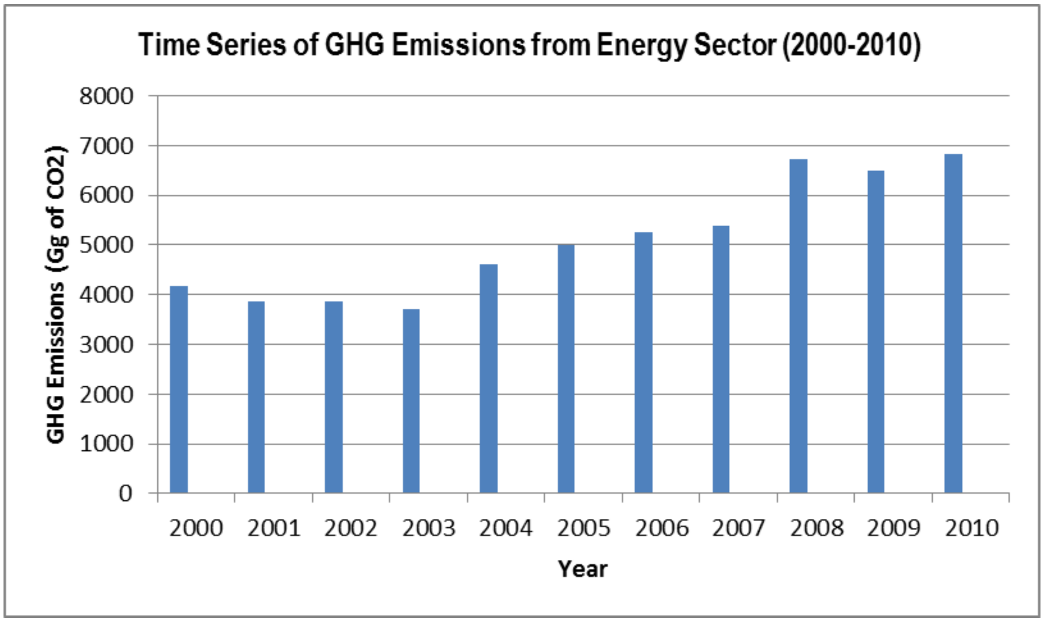


Fig. 5 Time Series of CO_2 (Gg) from (Fossil Fuel Combustion) Energy Sources 2000-2010

7.2 CO_2 from Industrial Processes Sources (Time Series from 2000-2010)

Fig.6 is a time-series of CO_2 (Gg) Emission from Soda Ash Production from 2000-2010.

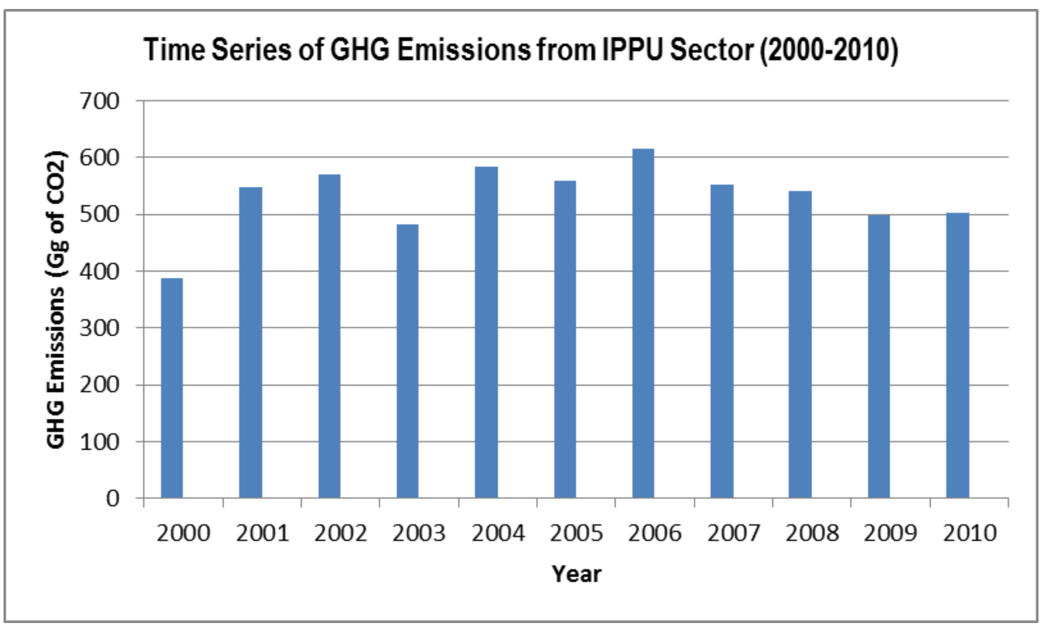


Fig. 6 Time Series of CO_2 (Gg) Emission from Soda Ash Production 2000-2010

7.3 CO_2 from Agriculture Sources (Time Series from 2000-2010)

Fig. 7 is a time-series of the total annual emissions of CO_2 (Gg) from domestic livestock from 2000-2010.

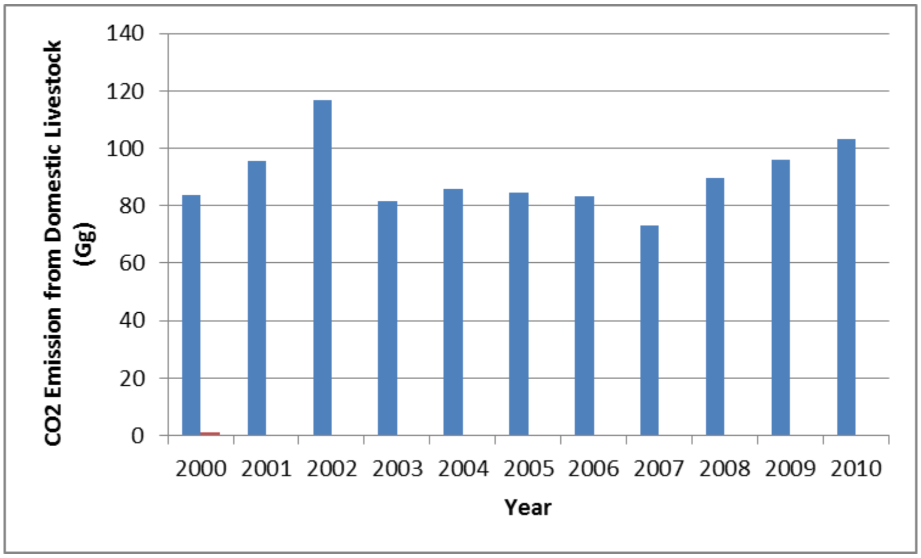


Fig. 7 Total Annual Emissions of CO_2 (Gg) from Domestic Livestock 2000-2010

7.4 CO_2 from AFOLU Sources (Time Series from 2000-2010)

Fig. 8 is a time-series of the total annual emissions of CO_2 (Gg) from AFOLU from 2000-2010.

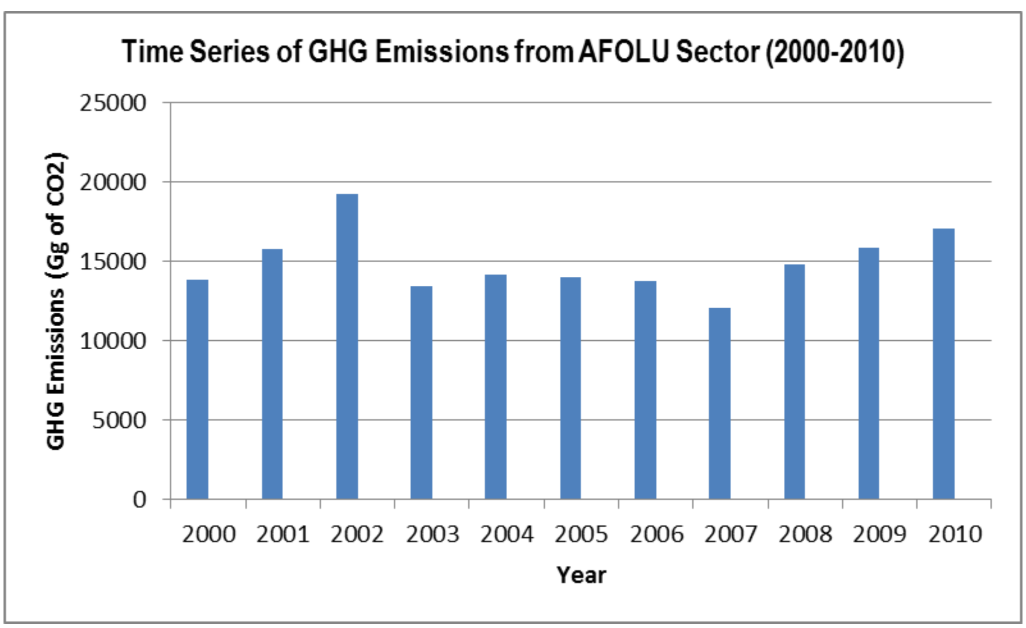


Fig. 8 Total Annual Emissions of CO_2 (Gg) from AFOLU 2000-2010

7.5 CO_2 from Waste Sources (Time Series from 2000-2010)

Fig. 9 is a time-series of the total annual emissions of CO_2 (Gg) from the Waste Sector from 2000-2010. Emissions from waste incineration were not estimated due to lack of activity data

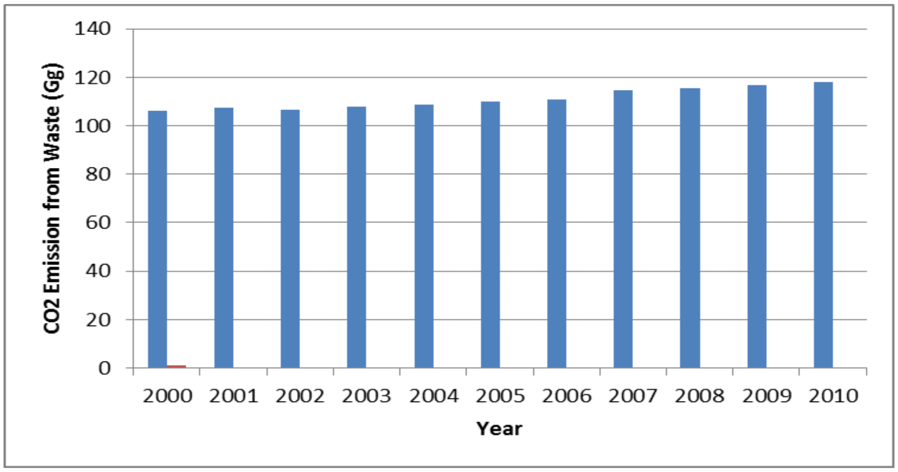


Fig. 9 Total Annual Emissions of CO_2 (Gg) from Waste 2000-2010

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APPENDIX 1

SECTORIAL EMISSION TABLES

ENERGY

Inventory Year: 2011

Categories	Emissions (Gg)						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	6894.493	0	0	0	0	0	0
1.A - Fuel Combustion Activities	6878.207	0	0	0	0	0	0
1.A.1 - Energy Industries	3657.592	0	0	0	0	0	0
1.A.1.a - Main Activity Electricity and Heat Production	3657.592	0	0	0	0	0	0
1.A.1.a.i - Electricity Generation	3657.592	0	0	0	0	0	0
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				0	0	0	0
1.A.1.a.iii - Heat Plants				0	0	0	0
1.A.1.b - Petroleum Refining				0	0	0	0
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries				0	0	0	0
1.A.1.c.i - Manufacture of Solid Fuels				0	0	0	0
1.A.1.c.ii - Other Energy Industries				0	0	0	0
1.A.2 - Manufacturing Industries and Construction	1235.519	0	0	0	0	0	0
1.A.2.a - Iron and Steel				0	0	0	0
1.A.2.b - Non-Ferrous Metals				0	0	0	0
1.A.2.c - Chemicals	0.839147	0	0	0	0	0	0
1.A.2.d - Pulp, Paper and Print	3.402132	0	0	0	0	0	0
1.A.2.e - Food Processing, Beverages and Tobacco	38.20872	0	0	0	0	0	0
1.A.2.f - Non-Metallic Minerals	5.403811	0	0	0	0	0	0
1.A.2.g - Transport Equipment				0	0	0	0
1.A.2.h - Machinery				0	0	0	0
1.A.2.i - Mining (excluding fuels) and Quarrying	1008.513	0	0	0	0	0	0
1.A.2.j - Wood and wood products	0.11359	0	0	0	0	0	0
1.A.2.k - Construction	82.59849	0	0	0	0	0	0
1.A.2.l - Textile and Leather	6.797127	0	0	0	0	0	0

1.A.2.m - Non-specified Industry	89.64279	0	0	0	0	0	0
1.A.3 - Transport	1985.097	0	0	0	0	0	0
1.A.3.a - Civil Aviation	36.88055	0	0	0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	36.88055	0	0	0	0	0	0
1.A.3.b - Road Transportation	1948.216	0	0	0	0	0	0
1.A.3.b.i - Cars				0	0	0	0
1.A.3.b.i.1 - Passenger cars with 3-way catalysts				0	0	0	0
1.A.3.b.i.2 - Passenger cars without 3-way catalysts				0	0	0	0
1.A.3.b.ii - Light-duty trucks				0	0	0	0
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts				0	0	0	0
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts				0	0	0	0
1.A.3.b.iii - Heavy-duty trucks and buses				0	0	0	0
1.A.3.b.iv - Motorcycles				0	0	0	0
1.A.3.b.v - Evaporative emissions from vehicles				0	0	0	0
1.A.3.b.vi - Urea-based catalysts	0			0	0	0	0
1.A.3.c - Railways	0	0	0	0	0	0	0
1.A.3.d - Water-borne Navigation				0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation				0	0	0	0
1.A.3.e - Other Transportation				0	0	0	0
1.A.3.e.i - Pipeline Transport				0	0	0	0
1.A.3.e.ii - Off-road				0	0	0	0
1.A.4 - Other Sectors				0	0	0	0
1.A.4.a - Commercial/Institutional				0	0	0	0
1.A.4.b - Residential				0	0	0	0
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms				0	0	0	0
1.A.4.c.i - Stationary				0	0	0	0
1.A.4.c.ii - Off-road Vehicles and Other Machinery				0	0	0	0
1.A.4.c.iii - Fishing (mobile combustion)				0	0	0	0
1.A.5 - Non-Specified	0	0	0	0	0	0	0
1.A.5.a - Stationary				0	0	0	0
1.A.5.b - Mobile	0	0	0	0	0	0	0
1.A.5.b.i - Mobile (aviation component)				0	0	0	0

1.A.5.b.ii - Mobile (water-borne component)				0	0	0	0
1.A.5.b.iii - Mobile (Other)	0	0	0	0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	16.28565	0		0	0	0	0
1.B.1 - Solid Fuels	16.28565	0		0	0	0	0
1.B.1.a - Coal mining and handling	16.28565	0		0	0	0	0
1.B.1.a.i - Underground mines	16.28565	0		0	0	0	0
1.B.1.a.i.1 - Mining	14.94097	0		0	0	0	0
1.B.1.a.i.2 - Post-mining seam gas emissions	1.344687	0		0	0	0	0
1.B.1.a.i.3 - Abandoned underground mines				0	0	0	0
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	0	0		0	0	0	0
1.B.1.a.ii - Surface mines	0	0		0	0	0	0
1.B.1.a.ii.1 - Mining	0	0		0	0	0	0
1.B.1.a.ii.2 - Post-mining seam gas emissions	0	0		0	0	0	0
1.B.1.b - Uncontrolled combustion and burning coal dumps				0	0	0	0
1.B.1.c - Solid fuel transformation				0	0	0	0
1.B.2 - Oil and Natural Gas				0	0	0	0
1.B.2.a - Oil				0	0	0	0
1.B.2.a.i - Venting				0	0	0	0
1.B.2.a.ii - Flaring				0	0	0	0
1.B.2.a.iii - All Other				0	0	0	0
1.B.2.a.iii.1 - Exploration				0	0	0	0
1.B.2.a.iii.2 - Production and Upgrading				0	0	0	0
1.B.2.a.iii.3 - Transport				0	0	0	0
1.B.2.a.iii.4 - Refining				0	0	0	0
1.B.2.a.iii.5 - Distribution of oil products				0	0	0	0
1.B.2.a.iii.6 - Other				0	0	0	0
1.B.2.b - Natural Gas				0	0	0	0
1.B.2.b.i - Venting				0	0	0	0
1.B.2.b.ii - Flaring				0	0	0	0
1.B.2.b.iii - All Other				0	0	0	0
1.B.2.b.iii.1 - Exploration				0	0	0	0
1.B.2.b.iii.2 - Production				0	0	0	0
1.B.2.b.iii.3 - Processing				0	0	0	0

1.B.2.b.iii.4 - Transmission and Storage				0	0	0	0
1.B.2.b.iii.5 - Distribution				0	0	0	0
1.B.2.b.iii.6 - Other				0	0	0	0
1.B.3 - Other emissions from Energy Production				0	0	0	0
1.C - Carbon dioxide Transport and Storage	0			0	0	0	0
1.C.1 - Transport of CO2	0			0	0	0	0
1.C.1.a - Pipelines	0			0	0	0	0
1.C.1.b - Ships	0			0	0	0	0
1.C.1.c - Other (please specify)	0			0	0	0	0
1.C.2 - Injection and Storage	0			0	0	0	0
1.C.2.a - Injection	0			0	0	0	0
1.C.2.b - Storage	0			0	0	0	0
1.C.3 - Other	0			0	0	0	0

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
Memo Items (3)							
International Bunkers				0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)				0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)				0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)				0	0	0	0
Information Items							
CO2 from Biomass Combustion for Energy Production	0						

INDUSTRIAL PROCESSES

.Inventory Year: 2011

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	540.723618	0	0	0	0	0	0	0	0	0	0	0
2.A - Mineral Industry	7.67243724	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	7.67243724								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	533.051181	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	533.051181								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	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning	0	0	0	0	0	0	0	0	0	0	0	0
2.F.1.a - Refrigeration and Stationary Air Conditioning				0					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

AFOLU

Inventory Year 2011

Categories	(Gg)					
	Net CO2 emissions / removals	Emissions				
		CH4	N2O	NOx	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	-27518.8800998	188.388536	38.350760794	155.1543466	2586.017926	0
3.A - Livestock	0	96.877734	0	0	0	0
3.A.1 - Enteric Fermentation	0	96.877734	0	0	0	0
3.A.1.a - Cattle	0	82.19088	0	0	0	0
3.A.1.a.i - Dairy Cows		0.140576		0	0	0
3.A.1.a.ii - Other Cattle		82.050304		0	0	0
3.A.1.b - Buffalo		0		0	0	0
3.A.1.c - Sheep		1.396185		0	0	0
3.A.1.d - Goats		9.689855		0	0	0
3.A.1.e - Camels		0		0	0	0
3.A.1.f - Horses		0.212976		0	0	0
3.A.1.g - Mules and Asses		3.38513		0	0	0
3.A.1.h - Swine		0.002708		0	0	0
3.A.1.j - Other (please specify)		0		0	0	0
3.A.2 - Manure Management (1)	0	0	0	0	0	0
3.A.2.a - Cattle	0	0	0	0	0	0
3.A.2.a.i - Dairy cows		0	0	0	0	0
3.A.2.a.ii - Other cattle		0	26.85351429	0	0	0
3.A.2.b - Buffalo		0	0	0	0	0
3.A.2.c - Sheep		0	0	0	0	0
3.A.2.d - Goats		0	0	0	0	0
3.A.2.e - Camels		0	0	0	0	0
3.A.2.f - Horses		0	0	0	0	0
3.A.2.g - Mules and Asses		0	0	0	0	0
3.A.2.h - Swine		0	0	0	0	0
3.A.2.i - Poultry		0	0	0	0	0
3.A.2.j - Other (please specify)		0	3.14279428	0	0	0
3.B - Land	74532.06382	0	0	0	0	0

3.B.1 - Forest land	-46186.19971	0	0	0	0	0
3.B.1.a - Forest land Remaining Forest land	-11033.39947			0	0	0
3.B.1.b - Land Converted to Forest land	-35152.80024	0	0	0	0	0
3.B.1.b.i - Cropland converted to Forest Land	-165.2034725			0	0	0
3.B.1.b.ii - Grassland converted to Forest Land	-33697.78795			0	0	0
3.B.1.b.iii - Wetlands converted to Forest Land	-1045.034785			0	0	0
3.B.1.b.iv - Settlements converted to Forest Land	-111.9485508			0	0	0
3.B.1.b.v - Other Land converted to Forest Land	-132.8254802			0	0	0
3.B.2 - Cropland	745.688346	0	0	0	0	0
3.B.2.a - Cropland Remaining Cropland	17.45333333			0	0	0
3.B.2.b - Land Converted to Cropland	728.2350126	0	0	0	0	0
3.B.2.b.i - Forest Land converted to Cropland	58.3924			0	0	0
3.B.2.b.ii - Grassland converted to Cropland	667.3017732			0	0	0
3.B.2.b.iii - Wetlands converted to Cropland	1.5450094			0	0	0
3.B.2.b.iv - Settlements converted to Cropland	0.99583			0	0	0
3.B.2.b.v - Other Land converted to Cropland	0			0	0	0
3.B.3 - Grassland	22363.24739	0	0	0	0	0
3.B.3.a - Grassland Remaining Grassland	0			0	0	0
3.B.3.b - Land Converted to Grassland	22363.24739	0	0	0	0	0
3.B.3.b.i - Forest Land converted to Grassland	21669.98769			0	0	0
3.B.3.b.ii - Cropland converted to Grassland	129.2037853			0	0	0
3.B.3.b.iii - Wetlands converted to Grassland	0			0	0	0
3.B.3.b.iv - Settlements converted to Grassland	7.62729			0	0	0
3.B.3.b.v - Other Land converted to Grassland	556.42862			0	0	0
3.B.4 - Wetlands	0	0	0	0	0	0
3.B.4.a - Wetlands Remaining Wetlands	0	0	0	0	0	0
3.B.4.a.i - Peatlands remaining peatlands	0		0	0	0	0
3.B.4.a.ii - Flooded land remaining flooded land				0	0	0
3.B.4.b - Land Converted to Wetlands	0	0	0	0	0	0
3.B.4.b.i - Land converted for peat extraction			0	0	0	0
3.B.4.b.ii - Land converted to flooded land	0			0	0	0
3.B.4.b.iii - Land converted to other wetlands				0	0	0
3.B.5 - Settlements	396.81829	0	0	0	0	0
3.B.5.a - Settlements Remaining Settlements	0			0	0	0
3.B.5.b - Land Converted to Settlements	396.81829	0	0	0	0	0

3.B.5.b.i - Forest Land converted to Settlements	23.58737333			0	0	0
3.B.5.b.ii - Cropland converted to Settlements	269.9139667			0	0	0
3.B.5.b.iii - Grassland converted to Settlements	103.75233			0	0	0
3.B.5.b.iv - Wetlands converted to Settlements	0.27973			0	0	0
3.B.5.b.v - Other Land converted to Settlements	-0.71511			0	0	0
3.B.6 - Other Land	-4840.110092	0	0	0	0	0
3.B.6.a - Other land Remaining Other land				0	0	0
3.B.6.b - Land Converted to Other land	-4840.110092	0	0	0	0	0
3.B.6.b.i - Forest Land converted to Other Land	-310.9010667			0	0	0
3.B.6.b.ii - Cropland converted to Other Land	-0.0264			0	0	0
3.B.6.b.iii - Grassland converted to Other Land	-4529.129825			0	0	0
3.B.6.b.iv - Wetlands converted to Other Land	-0.0264			0	0	0
3.B.6.b.v - Settlements converted to Other Land	-0.0264			0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land (2)	1.6756762	91.510802	8.354452224	155.1543466	2586.017926	0
3.C.1 - Emissions from biomass burning	0	91.510802	8.354452224	155.1543466	2586.017926	0
3.C.1.a - Biomass burning in forest lands		86.52954276	7.900523469	146.7240073	2445.400121	0
3.C.1.b - Biomass burning in croplands		0.000580815	1.50582E-05	0.000537791	0.019790718	0
3.C.1.c - Biomass burning in grasslands		4.970319803	0.453811808	8.42793358	140.4655597	0
3.C.1.d - Biomass burning in all other land		0.01035862	0.000101888	0.001867948	0.132454491	0
3.C.2 - Liming	1.1916762			0	0	0
3.C.3 - Urea application	0.484			0	0	0
3.C.4 - Direct N2O Emissions from managed soils (3)			0	0	0	0
3.C.5 - Indirect N2O Emissions from managed soils			0	0	0	0
3.C.6 - Indirect N2O Emissions from manure management			0	0	0	0
3.C.7 - Rice cultivations		0		0	0	0
3.C.8 - Other (please specify)				0	0	0
3.D - Other	0	0	0	0	0	0
3.D.1 - Harvested Wood Products	0			0	0	0
3.D.2 - Other (please specify)				0	0	0

WASTE

Inventory Year: 2011

Categories	Emissions [Gg]						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	0	5.288968195	0.085632386	0	0	0	0
4.A - Solid Waste Disposal	0	1.147096485	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	4.141871709	0.085632386	0	0	0	0
4.D.1 - Domestic Wastewater Treatment and Discharge		4.141871709	0.085632386	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

APPENDIX 2

General Methodological Approach: Gain-Loss Method

Annual biomass loss is a sum of losses from commercial round wood fellings, fuelwood gathering, and other losses and was calculated using Equation 3.2.6 of the 2003 IPCC Good Practice Guidance. Details of other calculations are in Appendix 1. Forest and vegetation distraction by elephants also forms a substantial amount of loss, although this project does not take loss by animal destruction into consideration.

$\Delta C_{FFL} = L_{fellings} + L_{fuelwood} + L_{other\ losses}$

Where:
ΔC_{FFL} = annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, tonnes C yr-1
$L_{fellings}$ = annual carbon loss due to commercial fellings, tonnes C yr-1 (See Equation 3.2.7)
$L_{fuelwood}$ = annual carbon loss due to fuelwood gathering, tonnes C yr-1 (See Equation 3.2.8)
$L_{other\ losses}$ = annual other losses of carbon, tonnes C yr-1 (See Equation 3.2.9)

The calculation of annual increase in carbon stocks due to biomass loss in forestland (ΔC_{FFL}) is described in section 3.3.3 of this report. Carbon loss due to commercial fellings/timber harvesting ($L_{fellings}$) is illustrated in section 5.2.3.

Forest Growth

Methodology, Activity data and Emission factors

Estimation of annual increase in carbon stocks due to biomass increment was done using equations 3.2.4 and 3.2.5 of the IPCC 2003 Good Practice Guidance.

$\Delta CFFG = \Sigma ij\ (A_{ij} \bullet G_{TOTALij}) \bullet CF$

Where:
ΔCFFG = annual increase in carbon stocks due to biomass increment in forest land remaining forest land by forest type and climatic zone, tonnes C yr-1
A_{ij} = area of forest land remaining forest land, by forest type (i = 1 to n) and climatic zone (j = 1 to m), ha
$G_{TOTALij}$ = average annual increment rate in total biomass in units of dry matter, by forest type (i = 1 to n) and climatic zone (j = 1 to m), tonnes d.m. ha-1 yr-1
CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)-1

The area (A_{ij}) for the forest subcategories dry deciduous forest, woodlands and plantations was derived from the Botswana Vegetation Cover Map combined with the climate and soil map.

The average annual increment rate in total biomass ($G_{TOTALij}$) was calculated using the case where aboveground biomass increment data are used directly, equation 3.2.5(A):

$G_{TOTAL} = G_W \bullet (1 + R)$

Where:
G_{TOTAL} = average annual biomass increment above and belowground, tonnes d.m. ha-1 yr-1
G_W = average annual aboveground biomass increment, tonnes d.m. ha-1 yr-1
R = root-to-shoot ratio appropriate to increments, dimensionless

The average annual aboveground biomass increment (G_w) values used were for the default African tropical dry forest. For trees younger or equal to twenty years a value of 1.2 was used. For trees older than 20 years a value of 0.9 was used (IPCC 2003, Table 3A.1.5). For the plantations, which mainly consist of the eucalyptus type of trees which are less than 20 years, the default value of 5.1 tonnes d.m. ha-1 yr-1 was used (IPCC 2003, Table 3A.1.6).

The root-to-shoot ratio (R) values used were the defaults from Table 3A.1.8, where the tropical dry forest value for the dry deciduous forest was taken as 0.27, for woodland/savanna the default value of 0.48 was taken and for plantations which are primarily for eucalyptus types of trees the value of 0.45 was used.

Losses Due to Timber Harvests

Methodology, Activity data and Emission factors

For the calculations, information from IPCC Good practice guidance 2003 was used.
Estimation of the annual carbon loss due to commercial fellings is provided in Equation 3.2.7:

$L_{fellings} = H \bullet D \bullet BEF_2 \bullet (1 - f_{BL}) \bullet CF$

Where:
$L_{fellings}$ = annual carbon loss due to commercial fellings, tonnes C yr-1
H = annually extracted volume, roundwood, m3 yr-1
D = basic wood density, tonnes d.m. m-3; Table 3A.1.9
BEF_2 = biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark), dimensionless; Table 3A.1.10
f_{BL} = fraction of biomass left to decay in forest (transferred to dead organic matter)
CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)-1

The value of H is an amount of 105 000 m³ roundwood volume taken from FAO statistics. The source of timber was assigned by expert knowledge as following: 70% from forest land, 20% from savanna/silvipasture and 10% is due to deforestation.

The commercialization of timber harvest was suspended in 1992 due to over-exploitation of timber tree species. Since the moratorium was implemented the DFRR issues harvesting permits as a management tool for domestics harvesting.

The value of *Pterocarpus soyauxii* density (0.84) was taken from IPCC 2003 GPG Annex 3A. 1.9 -2. This plant species used is not found in Botswana; however we have *Pterocarpus angolensis* (Blood Wood), which is not available in the data base. As these species are from the same genus, we opted to use the same value (0.84). *Mopane colophospermum* (Mopane) is another important plant species in Botswana. Mopane density was derived from the following website: www.wood-database.com/lumber-identification/hardwoods/mopane. Then 0.84, which is the average of the two values, was used in the calculations.

The value of BEF_2 (1.5) was taken from IPCC 2003 Good Practice Guidance Annex 3A .1 Table 3A. 1.10. The value of fBL (0) was taken from IPCC Default Biomass Fraction Left after Disturbance. The value of CF (0.5) was taken from IPCC Default Carbon fraction.

Losses Due to Fuelwood Gathering

Methodology, Activity data and Emission factors

This inventory calculates the annual carbon loss due to fuelwood gathering ($L_{fuelwood}$), measured in carbon tonnes for every year investigated. The formula used is based on Good Practice guidelines whereby the measure of fuel wood volume gathered annually (FG) is multiplied by the basic wood density (D) factor, and that multiplied by the dimensionless biomass expansion factor for converting volumes of extracted round-wood (BEF2) and all that multiplied by carbon fraction of dry matter (CF) which is globally estimated as 50% of the total carbon tonne emitted ($L_{fuelwood}$ = FG ● D ● BEF2 ● CF- Equation 3.2.8). *The most important emission factors are: the* basic wood density and the biomass expansion factor.

According to IPCC 2003 GPG Annex 3A. 1.9 -2, the basic wood density is 0.84 for Pterocarpus soyauxii (Mopane) density as taken from: www.wood-database.com/lumber-identification/hardwoods/mopane. This is because generally the mostly harvested and the best fuel wood is Mopane.

The biomass expansion factor was taken as 1.3 as per *IPCC 2003 (Annex 3A.1 Table. 1.10) which has a default of 1.5 with a range of 1.3 to 1.7 for Tropical Broadleaf forests. The lower end of the default range was chosen because of the high efficiency of fuel wood gathering.*

The volume of fuel wood of 2 554 817 m^3 was derived by multiplying the number of households of 555 395 (Census Office, 2011) by the annual fuel wood consumption per household (4.6 m^3). This factor for the annual fuelwood consumption per household is taken from a Namibian study (Barnes et al. 2005), because the conditions in Namibia are expected to be nearly the same than in Botswana.

Losses Due to Disturbances

Methodology, Activity Data and Emission Factors

For losses due to disturbances, only biomass loss from forest fires was considered. Other disturbances are highly uncertain and probably negligible. The calculations employed equation 3.2.9 from IPCC 2003,

$L_{other\ losses} = A_{disturbance} \bullet B_W \bullet (1 - f_{BL}) \bullet CF$

Where:
$L_{other\ losses}$ = annual other losses of carbon, tonnes C yr-1
$A_{disturbance}$ = forest areas affected by disturbances, ha yr-1

B_W = average biomass stock of forest areas, tonnes d.m. ha-1; Tables 3A.1.2, 3A.1.3, and 3A.1.4
f_{BL} = fraction of biomass left to decay in forest (transferred to dead organic matter); Table 3A.1.11
CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)-1

The area affected by fires in 2010 was taken from Statistics Botswana (2013) Table 5.4d. The figure of 4 387 879 ha comprises the forest areas burnt in protected areas in forest reserves, wildlife management areas, game reserves and national parks. In that year 38% of the entire forest area was burnt. That percentage was applied to all forest subcategories and age ranges in order to derive the burnt areas.

The estimations are done using the tier 1 assumption that all aboveground biomass carbon is lost upon disturbance. Hence, f_{BL} is equal to zero. However, since most fires in Botswana are ground fires burning only a small proportion of the biomass, biomass stock values (Bw) from Tables 3A.1.2 and 3A.1.3 were adjusted to only 5% of the given default values. So, instead of using 72 tonnes d.m. ha-1 for natural forests (default for Tropical Dry climates, Table 3A.1.2) and 20 tonnes d.m. ha-1 (default for plantations in Tropical Dry climates, Table 3A.1.3) values of 3.6 tonnes d.m. ha-1 and 1.0 tonnes d.m. ha-1 were used. For the carbon fraction, the IPCC default value of 0.5 was used.

Source Specific Planned Improvements
In order to estimate the biomass increment applying country specific data, diameters and heights surveyed in field studies, as the SADC-GIZ Project collected in 2013, should be utilized to identify an appropriate carbon stock change factor.

Losses due to timber harvest are based on the figure from FAO STAT. The sources of timber have to be verified with the DFRR. It is assumed that this figure does not capture illegally harvested timber. A survey should be conducted to gather this information.

The amount of fuelwood was calculated by multiplying the households with the annual fuelwood consumption. The factor of annual fuel wood consumption per household was taken from Namibia and should be replaced by an appropriate factor applying for Botswana. The figure of household consumption is covering about 95% of fuelwood usage. Only a small percentage of approximately 5 %, e.g. schools, hospitals, clinics (under 5 years health care), is not captured. The Department of Energy Affairs elaborated and designed a fuelwood consumption study, only waiting for funds to get that project started. Whenever the results of this study are available, they should be incorporated.

The figures taken for the burnt area was derived from burnt areas in protected areas (Statistics Botswana 2013). This captures forests burnt as well as grassland burnt, since the protected areas do comprise both land use categories. The figure used seems to be too high. Once the land cover maps are available from RCMRD, they can be overlaid with the burnt scar maps from the DFRR to derive the precise area burnt within each forest sub category and the corresponding age classes.

Forest and Grassland Conversion

Category description

The total forest area in Botswana declined from 23.6 % in 1990 to 19.7 % in 2010 (Statistics Botswana 2013). The main drivers of deforestation in the country are fuel wood harvesting and land clearing for human settlements.

Methodology, Activity Data and Emission Factors

The methodology used for initial change in biomass carbon stocks whereby land is converted to another land employs a formula known as Carbon change conversion equation $\Delta C_{CONVERSION} = \sum_i \{(B_{AFTERi} - B_{BEFOREi}) \bullet \Delta A_{TO\_OTHERSi} \} \bullet CF)$. It takes the sum of biomass stocks on land type before the conversion ($B_{BEFOREi}$) subtracted from biomass stocks on land type immediately after the conversion (B_{AFTERi}), both these parameters are measured in tonnes of dry matter per hector (d.m. ha^{-1}). The result is then multiplied by the area of land use which has been converted to another land-use category in a certain year ($\Delta A_{TO\_OTHERSi}$ ha yr^{-1}). Then all these are multiplied by the carbon fraction of dry matter per carbon tonne (CF) (tonnes d.m.)$^{-1}$. At present the deforestation rate derived from FAO STAT was adjusted to a rate of 0.9% by DFRR by expert knowledge of Mr. Tema & Ms. Phunyuka in May 2013. That rate was applied as percentage to all forest land use subcategories and the corresponding tree age ranges except plantations, assuming that plantations are not subject to deforestation. At present the biomass stocks on land type immediately after the conversion is taken as zero (tier 1 assumption) meaning that the deforestation is total. For previous aboveground biomass stock, default values for Tropical Dry climates were used from Tables 3A.1.2 and 3A.1.3 (IPCC, 2003).

GHG EMISSIONS FROM AGRICULTURE, FORESTRY AND OTHER LAND USES

Background

Conversion of grassland to cultivated land could result in net CO_2 emissions to the atmosphere due to soil disturbance and resultant oxidation of soil carbon and to oxidation of carbon in the vegetation if there is a net reduction in standing biomass.

Similarly, abandonment of cultivated land and subsequent regrowth of natural vegetation could result in net uptake of atmospheric CO_2. Such activities could also affect net N_2O and CO fluxes, although both the direction and magnitude of the effects are highly uncertain.

If managed lands, e.g. croplands and pastures, are abandoned, carbon may re-accumulate on the land and in the soil, although abandoned agricultural land is often too infertile, saline, or eroded for regrowth to occur. In this case, land degradation and associated loss of organic material (i.e. carbon in the biomass and the soils) follows abandonment.

Estimation of CO2 Emissions – Biomass Burning

Greenhouse gas emissions from savanna burning were determined on the basis of the quantity of carbon dioxide released instantaneously due to the burning. Based on the estimate of carbon dioxide emitted, the emissions of CO_2, CH_4, N_2O and NOx to CO_2 were then determined based on the emission ratios in Crutzen and Andrea (1990). The emissions of CO_2 are not included in the inventory because CO_2 released from savanna burning is assured to be re-absorbed during the next growth period.

Carbon dioxide released due to savanna burning

The CO_2 released due to savanna burning was determined by use of the equations below:

a. $B_b = A_s * P_b * (AGB)$ where

B_b = Biomass Burned (t biomass)
A_s = Area of Savanna (ha)
P_b = Portion Burned (%)
(AGB) = Above Ground Biomass Density exposed to burning (t biomass/ha).

b. $(CO_2)_{LM} = B_b * (BE)_{LP} * (LP) * (C\text{-}C)_{LB}$ where

$(CO_2)_{LM}$ = CO_2 released from Live Material (t CO_2 - C)
B_b = Biomass burned (t biomass)
(LP) = Live Portion of Biomass (%)
$(BE)_{LP}$ = Burning Efficiency (%) of Live Portion
(C-C)LB = Carbon Content of Live Biomass (t C/t Biomass)

c. $(CO_2)_{DM} = B_b * (DP) * (BE)_{DP} * (C\text{-}C)_{DM}$ where

$(CO_2)_{DM}$ = Carbon dioxide released from dead material (t CO_2 - C)
(DP) = Dead Portion of Biomass (%)
$(BE)_{DP}$ = Burning Efficiency of Dead Portion (%)
$(C\text{-}C)_{DM}$ = Carbon Content of Dead Biomass (t C/t biomass).

d. Total CO_2 released (t CO_2 - C) = $(CO_2)_{LM} + (CO_2)_{DM}$

Greenhouse gas emission ratios

The emissions of CH_4, CO, N_2O and NOx were calculated based on the IPCC methodology according to Crutzen and Andreae (1990). The total amount of CO_2 - C released due to savanna burning was multiplied by the emission ratios of CH_4 and CO relative to emissions of CO_2 to obtain emissions of CH_4, and CO, each is expressed in units of carbon. The emissions of CH_4 and CO were multiplied by 16/12 and 28/12, respectively, to convert to full molecular weights. The emissions of N_2O, NOx were determined by first multiplying the total CO_2 - C released by the estimated N/C ratio of the biomass (as per results of the biomass characterisation) to yield the total amount of nitrogen (N) released. The total N released was then multiplied by the ratios of emissions of N_2O and NOx relative to the N-content of the biofuel/or biomass to yield emissions of N_2O and NOx, expressed in units of N. The emissions of N_2O and NOx were converted to full molecular weights by multiplying emissions by 44/28 and 30/14 respectively.

Summary of calculations of CH_4, CO, N_2O and NOx emissions from savanna burning is as follows:

CH_4 - C emissions (low)	=	(CO_2 - C Released) x (0.007)
CH_4 - C emissions (high)	=	(CO_2 - C released) x 0.013)
CH_4 - emissions (low, high)	=	CH_4 -C Emissions (low, high) x 16/12
CO - C emissions (low)	=	(CO_2 - C Released) x (0.075)
CO - C emissions (high)	=	CO_2 - C Released) x (0.125)
CO emission (low, high)	=	CO - C emissions (low, high) x 28/12
N_2O - N emissions (low)	=	(CO_2- C released) x (0.0625) x (0.005)

N_2O - N emissions (high)	=	(CO_2 - C released) x (0.0625) x (0.009)
N_2O emissions (low, high)	=	N_2O - N emissions (low, high) x (44/28)
NOx - N emissions (low)	=	(CO_2- C Released) x (0.0625) x (0.094)
NOx - N emissions (high)	=	(CO_2 - C Released) x (0.0625) x (0.148)
NOx emissions (low, high)	=	NOx - N emissions (low, high) x 30/14

APPENDIX 3

GENERAL UNCERTAINTY ASSESSMENT

Uncertainties were assigned to the base source of each activity based on the level of verifiability and reliability using IPCC Good Practices. The uncertainty range input for activity data not otherwise generated from the IPCC 2006 software are in the table below:

Activity Data Source	Uncertainty Range	
	Plus	Minus
Enumeration	4%	2%
National Archives	5%	5%
Facility Level Measurements	5%	5%
Research Results	5%	5%
Expert Judgement	15%	12%
Personal Communication	10%	10%

Base year for assessment of uncertainty in trend: 2011, Year T: 2011

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T
1 - Energy						
1.A.1 - Energy Industries - Liquid Fuels	CO2	2687.582434	5	5	7.0710678 12	0
1.A.1 - Energy Industries - Liquid Fuels	CH4	0	5	5	7.0710678 12	0
1.A.1 - Energy Industries - Liquid Fuels	N2O	0	5	5	7.0710678 12	0
1.A.1 - Energy Industries - Solid Fuels	CO2	725.4693882	5	5	7.0710678 12	0
1.A.1 - Energy Industries - Solid Fuels	CH4	0	5	5	7.0710678 12	0
1.A.1 - Energy Industries - Solid Fuels	N2O	0	5	5	7.0710678 12	0
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CO2	486.5388001	15	15	21.213203 44	0
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CH4	0	15	15	21.213203 44	0
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	N2O	0	15	15	21.213203 44	0
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CO2	748.9800769	13.228756 56	13.228756 56	18.708286 93	0
1.A.2 - Manufacturing Industries and Construction -	CH4	0	13.228756	13.228756	18.708286	0

Solid Fuels			56	56	93	
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	N2O	0	13.22875656	13.22875656	18.70828693	0
1.A.3.a - Civil Aviation - Liquid Fuels	CO2	36.88054524	5	5	7.071067812	0
1.A.3.a - Civil Aviation - Liquid Fuels	CH4	0	5	5	7.071067812	0
1.A.3.a - Civil Aviation - Liquid Fuels	N2O	0	5	5	7.071067812	0
1.A.3.b - Road Transportation - Liquid Fuels	CO2	1948.215972	5	5	7.071067812	0
1.A.3.b - Road Transportation - Liquid Fuels	CH4	0	5	5	7.071067812	0
1.A.3.b - Road Transportation - Liquid Fuels	N2O	0	5	5	7.071067812	0
1.A.3.b - Road Transportation	CO2	0	0	0	0	0
1.A.3.c - Railways - Liquid Fuels	CO2	0	5	5	7.071067812	0
1.A.3.c - Railways - Liquid Fuels	CH4	0	5	5	7.071067812	0
1.A.3.c - Railways - Liquid Fuels	N2O	0	5	5	7.071067812	0
1.A.5 - Non-Specified - Liquid Fuels	CO2	0	5	5	7.071067812	0
1.A.5 - Non-Specified - Liquid Fuels	CH4	0	5	5	7.071067812	0
1.A.5 - Non-Specified - Liquid Fuels	N2O	0	5	5	7.071067812	0
1.B.1 - Solid Fuels	CO2	16.28565367	0	0	0	0
1.B.1 - Solid Fuels	CH4	0	5	0	5	0
1.C - Carbon dioxide Transport and Storage	CO2	0	0	0	0	0
2 - Industrial Processes and Product Use						
2.A.1 - Cement production	CO2	7.67243724	35	0	35	0.149452662
2.A.2 - Lime production	CO2	0	15	0	15	0
2.A.3 - Glass Production	CO2	0	5	0	5	0
2.A.4 - Other Process Uses of Carbonates	CO2	0	0	0	0	0
2.B.1 - Ammonia Production	CO2	0	5	0	5	0
2.B.2 - Nitric Acid Production	N2O	0	2	0	2	0
2.B.3 - Adipic Acid Production	N2O	0	5	0	5	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	0	10	0	10	0
2.B.5 - Carbide Production	CO2	0	5	10	11.18033989	0
2.B.5 - Carbide Production	CH4	0	5	10	11.18033989	0
2.B.6 - Titanium Dioxide Production	CO2	0	5	0	5	0
2.B.7 - Soda Ash Production	CO2	533.051181	5	0	5	14.72240312

2.B.8 - Petrochemical and Carbon Black Production	CO2	0	24.49489743	0	24.49489743	0
2.B.8 - Petrochemical and Carbon Black Production	CH4	0	24.49489743	0	24.49489743	0
2.B.9 - Fluorochemical Production	CHF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH2F2	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH3F	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF3CHFCHFCF2CF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CHF2CF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CHF2CHF2	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH2FCF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH3CHF2	0	1	0	1	0
2.B.9 - Fluorochemical Production	CHF2CH2F	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF3CH3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF3CHFCF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF3CH2CF3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH2FCF2CHF2	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF4	0	1	0	1	0
2.B.9 - Fluorochemical Production	C2F6	0	1	0	1	0
2.B.9 - Fluorochemical Production	C3F8	0	1	0	1	0
2.B.9 - Fluorochemical Production	C4F10	0	1	0	1	0
2.B.9 - Fluorochemical Production	c-C4F8	0	1	0	1	0
2.B.9 - Fluorochemical Production	C5F12	0	1	0	1	0
2.B.9 - Fluorochemical Production	C6F14	0	1	0	1	0
2.B.9 - Fluorochemical Production	SF6	0	1	0	1	0
2.B.9 - Fluorochemical Production	CHCl3	0	1	0	1	0
2.B.9 - Fluorochemical Production	CH2Cl2	0	1	0	1	0
2.B.9 - Fluorochemical Production	CF3 I	0	1	0	1	0
2.C.1 - Iron and Steel Production	CO2	0	10	0	10	0
2.C.1 - Iron and Steel Production	CH4	0	10	0	10	0
2.C.2 - Ferroalloys Production	CO2	0	5	0	5	0
2.C.2 - Ferroalloys Production	CH4	0	5	0	5	0
2.C.3 - Aluminium production	CO2	0	2	0	2	0
2.C.3 - Aluminium production	CF4	0	2	0	2	0
2.C.3 - Aluminium production	C2F6	0	2	0	2	0
2.C.4 - Magnesium production	CO2	0	5	0	5	0
2.C.4 - Magnesium production	SF6	0	5	0	5	0
2.C.5 - Lead Production	CO2	0	10	0	10	0
2.C.6 - Zinc Production	CO2	0	10	0	10	0

2.D - Non-Energy Products from Fuels and Solvent Use	CO2	0	14.14213562	0	14.14213562	0
2.E - Electronics Industry	C2F6	0	14.14213562	0	14.14213562	0
2.E - Electronics Industry	CF4	0	17.32050808	0	17.32050808	0
2.E - Electronics Industry	CHF3	0	10	0	10	0
2.E - Electronics Industry	C3F8	0	10	0	10	0
2.E - Electronics Industry	SF6	0	14.14213562	0	14.14213562	0
2.E - Electronics Industry	C6F14	0	10	0	10	0
2.F.4 - Aerosols	CH2FCF3	0	10	10	14.14213562	0
2.F.4 - Aerosols	CH3CHF2	0	10	10	14.14213562	0
2.F.4 - Aerosols	CF3CHFCF3	0	10	10	14.14213562	0
2.F.4 - Aerosols	CF3CHFCHFCF2CF3	0	10	10	14.14213562	0
2.F.5 - Solvents	CF3CHFCHFCF2CF3	0	10	50	50.99019514	0
2.F.5 - Solvents	C6F14	0	10	50	50.99019514	0
2.F.6 - Other Applications (please specify)	CHF3	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CH2F2	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CH3F	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CF3CHFCHFCF2CF3	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CHF2CF3	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CHF2CHF2	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CH2FCF3	0	10	50	50.99019514	0
2.F.6 - Other Applications (please specify)	CH3CHF2	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CHF2CH2F	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CF3CH3	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CF3CHFCF3	0	10	50	50.99019514	0
2.F.6 - Other Applications (please specify)	CF3CH2CF3	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CH2FCF2CHF2	0	10	0	10	0
2.F.6 - Other Applications (please specify)	CF4	0	10	0	10	0
2.F.6 - Other Applications (please specify)	C2F6	0	10	50	50.99019514	0
2.F.6 - Other Applications (please specify)	C3F8	0	10	0	10	0
2.F.6 - Other Applications (please specify)	C4F10	0	10	0	10	0
2.F.6 - Other Applications (please specify)	c-C4F8	0	10	0	10	0
2.F.6 - Other Applications (please specify)	C5F12	0	10	0	10	0

2.F.6 - Other Applications (please specify)	C6F14	0	10	0	10	0
2.G - Other Product Manufacture and Use	SF6	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	CF4	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	C2F6	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	C3F8	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	C4F10	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	c-C4F8	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	C5F12	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	C6F14	0	60	58.30951895	83.66600265	0
2.G - Other Product Manufacture and Use	N2O	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use						
3.A.1 - Enteric Fermentation	CH4	96.877734	5	5	7.071067812	0
3.A.2 - Manure Management	N2O	26.85351429	5	5	7.071067812	0
3.A.2 - Manure Management	CH4	0	0	0	0	0
3.B.1.a - Forest land Remaining Forest land	CO2	-11033.39947	5	5	7.071067812	0
3.B.1.b - Land Converted to Forest land	CO2	-35152.80024	5	5	7.071067812	0
3.B.2.a - Cropland Remaining Cropland	CO2	-17.45333333	5	5	7.071067812	0
3.B.2.b - Land Converted to Cropland	CO2	728.2050126	5	5	7.071067812	0
3.B.3.a - Grassland Remaining Grassland	CO2	0	0	0	0	0
3.B.3.b - Land Converted to Grassland	CO2	-22363.24739	5	5	7.071067812	0
3.B.4.a.i - Peatlands remaining peatlands	CO2	0	0	0	0	0
3.B.4.a.i - Peatlands remaining peatlands	N2O	0	0	0	0	0
3.B.4.b - Land Converted to Wetlands	N2O	0	0	0	0	0
3.B.4.b - Land Converted to Wetlands	CO2	0	0	0	0	0
3.B.5.a - Settlements Remaining Settlements	CO2	0	0	0	0	0
3.B.5.b - Land Converted to Settlements	CO2	396.81829	5	5	7.071067812	0
3.B.6.b - Land Converted to Other land	CO2	4840.110092	5	5	7.071067812	0
3.C.1 - Emissions from biomass burning	CH4	0	0	0	0	0
3.C.1 - Emissions from biomass burning	N2O	0	0	0	0	0
3.C.2 - Liming	CO2	1.1916762	5	5	7.071067812	0

3.C.3 - Urea application	CO2	0.484	5	5	7.0710678 12	0
3.C.4 - Direct N2O Emissions from managed soils	N2O	0	0	0	0	0
3.C.5 - Indirect N2O Emissions from managed soils	N2O	0	0	0	0	0
3.C.6 - Indirect N2O Emissions from manure management	N2O	0	0	0	0	0
3.C.7 - Rice cultivations	CH4	0	0	0	0	0
3.D.1 - Harvested Wood Products	CO2	0	0	0	0	0
4 - Waste						
4.A - Solid Waste Disposal	CH4	24.08902619	0	0	0	0
4.B - Biological Treatment of Solid Waste	CH4	0	0	0	0	0
4.B - Biological Treatment of Solid Waste	N2O	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	CO2	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	CH4	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	N2O	0	0	0	0	0
4.D - Wastewater Treatment and Discharge	CH4	86.9793059	0	0	0	0
4.D - Wastewater Treatment and Discharge	N2O	26.54603956	0	0	0	0
5 - Other						
Total						
		Sum(C): 23719.391				Sum(H): 14.872
						Uncertainty in total inventory: 3.856

Documentation box

Estimation of GHG emissions has inherent uncertainties. One source of uncertainty is the use of expert knowledge in some circumstances. This inventory has encountered Tier 1 uncertainties in the estimates. Managing and reducing these uncertainties is a recognized IPCC Good Practice. The uncertainties in these estimates are largely from primary sources. The aggregate overall uncertainty in the estimates of GHG for the base year 2011 using IPCC Good Practice Tier 1 methods is 3.856. The need has been identified for a more-complete uncertainty analysis in future studies since IPCC 2006 software default value may not be realistic in all cases even for Tier 1 inventories.

APPENDIX 4

BOTSWANA NATIONAL GREENHOUSE GAS INVENTORY TEAM

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