Botswana
Initial National Communication to the United Nations Framework Convention on Climate Change

Ministry of Works, Transport and Communications
2001

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Foreword

Botswana was among the countries which signed the United Nations Framework Convention on Climate Change at the United Nations Conference on Environment and Development (UNCED), the "Earth Summit" that was held in Rio de Janeiro, Brazil in June 1992. Botswana's delegation to UNCED was headed by the then President, Sir Ketumile Masire, which reflects the high level of support afforded by this country to the principle of sustainable development. Botswana went on to ratify the United Nations Framework Convention on Climate Change on 27 January, 1994. The Convention came into force on 27 April, 1994.

Botswana only contributes about seven percent of Africa's total greenhouse gas emissions while Africa itself contributes only about five percent of the global total. The country is, therefore, a minor contributor to the problem of global warming and climate change. However, Botswana, like many of the developing countries, will be significantly impacted by climatic change. The country is not well endowed with abundant surface water resources so water scarcity is a key concern. The availability and quality of water, which may become more seriously affected under the predicted climate change scenarios, are thus Botswana's developmental challenges.

The Initial National Communication is an assessment of the country's present status with respect to climate change, and also is itself a useful tool on which to base decisions concerning climate change and future national development. It also offers opportunities for policy refinement and development, and poses the greater challenge of achieving a lasting balance between improved living conditions for Batswana and economic, social and environmental needs.

Botswana's Initial National Communication to the UN Framework Convention on Climate Change currently reflects the best available information. It should be viewed as a living document that will continually improve as information is refined and uncertainty on the impact of climate change is reduced. It is a first step, and is submitted in the knowledge that some aspects will require further attention.

Finally, Botswana's Initial National Communication also presents itself as a marketing document. It must sell the country as a partner in development to investors within and outside the country. Botswana is already undertaking a number of mitigative programmes and projects relating to climate change. We are committed to the sustainable use of natural resources and, in particular, to renewable energy resources through the use of solar energy technology. These actions demonstrate our recognition of the need to safeguard the environment and atmosphere against further deterioration.

I have pleasure in presenting to you the Botswana Initial National Communication which represents the commitment of the Government of Botswana and its people to address the issue of global warming and climate change. It contains the greenhouse gas inventory for Botswana as well as the main findings of studies which assessed the possible impact of, and vulnerability to, climate change of various economic sectors. The possible impact of global warming and climate change on agriculture, woodland resources, the prevalence of pests and diseases such as malaria, cholera, various fevers, increased flooding and other concerns were investigated. These concerns are some of the critical issues for Botswana. Additional studies are still necessary to identify remaining socio-economic activities that may be affected.

Pula.

D. N. MAGANG
MINISTER OF WORKS, TRANSPORT AND COMMUNICATIONS

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Acknowledgements

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Abbreviations, Acronyms and Glossary

BPC	Botswana Power Corporation
BRIMP	Botswana Range Inventory and Monitoring Project
BWP	Botswana Pula: the Botswana currency, equal to USD 0.2163 in 1999
CBNRM	Community Based Natural Resource Management
CH_4	Methane, a greenhouse gas
CO_2	Carbon dioxide
COP2/10	Decision 10 of the Second Conference of Parties of the UNFCCC
CSO	Central Statistics Office
DM	Dry matter (the weight of plant material after drying)
DMS	Department of Meteorological Services
DOC	Degradable Organic Content
ENSO	El Nino Southern Oscillation
GACMO	Gas abatement costing model
GCM	Graphic climate model
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Gigagram ($1x10^9$ g), equivalent to 1 kiloton
GHG	Greenhouse gas
GWP	Global warming potential
ha	Hectare (equivalent to 10 000m^2)
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
kt	Kiloton (one thousand tons, $1x10^9$ g)
LPG	Liquid petroleum gas
Mg	Megagram ($1x10^6$ g) also known as a metric ton
Mt	Megaton (one million tons, $1x10^{12}$ g)
MW	Megawatt ($1x10^6$ watts or $1x10^6$ J/s)
N_2O	Nitrous oxide, a greenhouse gas
NCCC	National Committee on Climate Change
NDP8	National Development Plan 8
non-annex 1	Countries not listed in annex 1 at the UNFCCC
PV	Photo-voltaic
RIIC	Rural Industries Innovation Centre
SADC	Southern African Development Community
t	Ton (one metric ton, $1x10^6$ g)
TJ	Terajoules ($1x\ 10^{12}$ Joules); a measure of energy
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Purpose of the Report

There is scientific evidence that the climate may change during the next century, both globally and locally, due to increased concentrations of greenhouse gases in the atmosphere. The increase in these gases is due mainly to human activities, such as the use of fossil fuels and change in the land surface through agriculture. The UN General Assembly adopted a Resolution “Protection of the Global Climate for Present and Future Generations of Mankind” during its 45th Session to establish an Intergovernmental Negotiating Committee with the task of negotiating a convention on climate change. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in New York on 9 May 1992. The objective of the Convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Botswana was a founding signatory of the UNFCCC in 1992 and ratified the Convention on 27 January 1994. It therefore entered into force for Botswana on 27 April 1994. This initial national communication by Botswana to the Conference of Parties to the UNFCCC is delivered in accordance with Articles 4 and 12 of the Convention, and follows the guidelines laid out in the Decision 10 of the Second Conference of Parties. The emissions of greenhouse gases from the territory of Botswana for the year 1994, the specified “base year” for signatory countries not listed in Annex 1 of the Convention, form part of this communication, along with summaries of the anticipated impacts of climate change and a statement of the actions taken and planned by Botswana to avoid and respond to climate change, and the needs of Botswana in this regard.

National Circumstances

Botswana is a landlocked, arid to semi-arid country in southern Africa. It covers a land area of 581 730 km^2 between approximately 20˚ and 29˚ E and 18˚ and 27˚ S. The principal land cover is natural grassland, shrubland and woodland, a quarter of which is conserved in parks or reserves. Much of the country consists of the Kalahari, a vast, dry sandy area of sparse population but abundant wildlife. The wetlands of the Okavango Delta and Chobe River in the north are of international importance for the conservation of biodiversity, as recognised under the RAMSAR Convention.

The current population of Botswana is 1.5 million, of which half live in rural areas. The per capita GDP in 1994 was US$ 2 800. Botswana is a developing country, with a proud record of steady improvement in the quality of life of its people, and a stable democratic political system. The economy is based on mining, (particularly diamonds, but also copper-nickel, coal and soda-ash), light manufacturing, tourism and livestock. Contributions of the various sectors to the GDP are: mining 35.7%, general government 15.6%, banks, insurance and business 10.1%, trade, hotels and restaurants 8.3%, construction 6.5%, manufacturing 4.6%, agriculture 4.4%, transport and communication 3.7%, water and electricity 2.2%, and social and personal services 4.3%.

Emissions of Greenhouse Gases

Botswana is believed to be a net sink for greenhouse gases, since emissions resulting from the burning of fossil fuels in Botswana in 1994 were small and were more than balanced by a net increase in the size and number of trees. The greenhouse gases reported here are carbon dioxide, methane and nitrous oxide. Excluding the uptake of carbon dioxide through tree growth in Botswana, the climate-changing effect of the emissions are 52% due to carbon dioxide, 33% due to methane and 16% due to nitrous oxide, and the sum is equivalent to about 0.02% of the global anthropogenic emission (IPCC, 1995). The sectoral origin of the CO_2 equivalent emissions in 1994 was as follows: 57% agriculture, 17% electrical power generation, 10% mining and industry, 8% transport, 3% domestic heating and cooking and 1% government.

The carbon dioxide emissions originate from a single coal-fired electrical power station; a soda ash plant; a copper-nickel smelter; a small amount of coal, paraffin and liquid petroleum gas (LPG) burned for domestic cooking and heating; and the petrol, diesel and aviation fuel used in the transport sector. One quarter of the electricity consumed in Botswana in 1994 was imported from the southern African power pool. Nationally, the largest source of energy is fuelwood (58% of the total), harvested by hand from the savannas, woodlands and forests which cover most of the country. While there are local examples of fuel-wood harvesting exceeding the natural re-growth rate, at a national scale the best available evidence is that the growth in biomass stocks exceeds the amount harvested by an amount substantially greater than the carbon emissions from fossil fuels. The aridity, poor soils and low population combine to limit the degree to which the land is transformed for crop agriculture. Botswana is thus a net sink of atmospheric carbon dioxide, the principal greenhouse gas. There is large uncertainty surrounding the magnitude of the suggested uptake of CO_2 by the land as a result of tree biomass increase.

Nearly 50% of methane emissions from Botswana originate from enteric fermentation in live-stock. The remainder is contributed by coal mining, domestic combustion of wood, and power generation. Nitrous oxide emissions are very small, given the low rate of fertiliser use and the absence of significant nitrous oxide emitting industries. The largest single source of nitrous oxide is savanna burning followed by explosives used by the mining industry.

Energy demand in Botswana is increasing in response to a growing population and a rapidly growing economy, which is diversifying from diamond mining into several other commodities and industrial products. Energy demand is projected to increase at a rate of 5.6% and 4.6% for the commerce and transport sectors respectively, but less than 2% for the other sectors. Emissions of greenhouse gases from fossil fuel combustion are therefore projected to grow at around 4% per annum for the next decade.

Summary of greenhouse gas emissions (positive) and removals (negative) in 1994.

Greenhouse gas source and sink categories	CO_2 (Gg/year)	CH_4 (Gg/year)	N_2O (Gg/year)	CO_2 equivalent (Gg/year)
All energy	3038	25	1	3 866
Industrial processes			0.7	211
Agriculture		169	5	5 067
Land use change and forestry	-38 734			-38 734
Waste		8		172
Total (net national emission/removal)	**-35 697**	**126**	**7**	**-29 418**

Notes: One Gg is equal to a billion (10^9) grams, or a thousand tons.
Methane and nitrous oxide have been converted to their equivalent climate effect, expressed as CO_2.
Values have been rounded to the nearest Gg, thus the column totals may not exactly equal the sum of the values given.

Vulnerability

The welfare of the people of Botswana, the performance of the economy, and the state of the environment in Botswana are all very closely linked to the climate. The available climate change projections and the impact studies which have been done suggest that Botswana is highly vulnerable to climate change.

Temperatures are predicted to rise by 1 to 3˚C during the next hundred years, as a result of global warming caused by the release of greenhouse gases. Future trends in rainfall in Botswana are less certain, but may decline by as much as 25% or increase by 10%. The overwhelming majority of general circulation models predict a rainfall decrease in Botswana. The predicted impact on various sectors is as follows:

Grazing and livestock**:** Livestock production, a socially and culturally important activity in Botswana, has been severely affected by recurrent droughts during the past century, which would become deeper, longer and more frequent under a drying scenario. Desertification is a major concern in Botswana.

Crops: Under a scenario of a hotter, drier future potential crop yields are predicted to be reduced by about 30% for both maize and sorghum.

Woodlands and forests**:** Under a dry future scenario, thorn and shrub savanna is predicted to expand at the expense of grasslands and moister forests and woodlands. There is great uncertainty with these predictions, not only with respect to future climates but also the effects of rising CO_2 on plant growth responses.

Water resources**:** Water supply is a critical issue for the future of Botswana, regardless of climate change, but will become an even greater challenge if the future climate is warmer and drier.

Human health**:** A warmer climate, especially if it is also wetter, will lead to a doubling of the population exposed to malaria by 2021, to over a million people. Several other diseases (Dengue fever, rickettsia, yellow fever and bilharzia) could be affected by climate change as well.

Policies and Measures

There is no dedicated policy to respond to climate change in Botswana, but the potential for future climate change and the associated environmental threats is acknowledged in the National Development Plan. Climate change issues are addressed in a combination of different policy areas. Underpinning all policy development in Botswana is the recognition that long term growth must be sustainable. Specific climate adaptation and mitigation policies are already in place in some sectors, such as the strong Governmental support for solar energy technologies in the energy sector.

Climate change considerations in Botswana are championed by the National Committee on Climate Change. Representatives from government departments and ministries, non-governmental organisations and the private sector regularly meet to discuss climate change issues and the possible impacts in various sectors.

Actions Taken in Support of the Convention Objectives

The National Committee on Climate Change has orchestrated a range of studies specifically dealing with issues and impacts of climate change. In addition, a number of National policies are already in place that support climate change considerations and demonstrate the high level of concern for environmental issues in Botswana.

- Botswana has conducted studies on the emissions of greenhouse gases from its territory for the years 1990 and 1994.

- Studies of the vulnerability and adaptive capacity of the livestock (rangeland), crop agriculture, forest, health and water resources sectors have been completed.

- Studies on mitigation options for the energy and some non-energy sectors (land use and forestry, agriculture, waste and industry) have been conducted.

- A process of national awareness-raising with respect to climate change has commenced.

- The possibility of climate change is acknowledged in the National Development Plan (NDP8).

- Botswana maintains a system of systematic observations of the climate and key indicators in the affected sectors.

- Several major research projects aimed at reducing uncertainties regarding global environmental change are hosted in Botswana, and involve Botswana scientists.

Areas of Need

The climate change action agenda in Botswana will continue to require support from the international community if it is to become firmly established. In particular, assistance is needed in:

- ***Capacity-building*:** The development of highly skilled human capacity, particularly in relation to the understanding of complex human-environment systems such as climate change is needed. Specifically, capacity support is needed to improve understanding of Botswana's vulnerability to climate change, understand the interaction between economic activities and emissions of greenhouse gases, improve models and observations specifically suited to Botswana, and finally to enhance the ability of policy makers to support a sustainable development pattern that takes climate change into account. Increasing awareness of climate change in the general public is an additional capacity-building activity that is currently conducted through radio programmes, through school and university programmes and general awareness campaigns. Financial support is needed to promote and further the progress that has already been made in capacity building at all ages and levels of Botswana society.

- ***Research and systematic observations*:** Considerable research is still needed to reduce uncertainties in the emissions inventory, particularly in the land use change and forestry sector. The investigations of the vulnerable sectors identified so far revealed a common need for baseline information to be improved. A comprehensive investigation into the proposed mitigation options is also suggested in which costs, benefits, feasibility and cultural acceptance are carefully considered. Support for systematic observations which provide climate information is also needed.

- ***Technology needs***: Access to technology, specifically regarding predictive models, remote sensing and adaptation, is needed – especially in the agriculture, livestock, water supply and health sectors. Energy efficient technologies in the mining, industrial, energy, housing and transport sectors are also called for. Skills in technology assessment must be developed to enable decision-makers to select and promote technologies that are feasible, practical and meet the needs of both climate change considerations and human development.

1. National Circumstances

The purpose of this section is to establish the context in which Botswana exists, especially as it relates to the vulnerability to climate change and Botswana's capacity to respond to likely impacts. The obligatory information in terms of COP 2/10 is summarised in Table 1.2.

Geography and Geology

Botswana is a landlocked country in southern Africa that neighbours Zimbabwe, South Africa, Namibia and Zambia (Figure 1.1). The total land area is 581 730 km^2, between 20 and 29.4˚ E and 17.8 and 26.8˚ S. The country lies entirely within the shallow basin formed by the high-lying interior plateau of southern Africa. Three-quarters of the land surface is covered by the Kalahari sands, which fill the basin to a depth of up to several hundred meters. Only in the south east, and in isolated inselbergs in the northwest, does the underlying bedrock approach the surface to form low hills, and slightly more clayey and fertile soils. As a result, the land surface is nearly flat, with a mean altitude of 1 000 m above sea level. The lowest point in Botswana is at the confluence of the Limpopo and Shashe rivers at an altitude of 537 m. The highest point is found at the Otse Hill in the south east, at 1 491 m (personal communication Department of Surveys and Mapping, 2000; National Development Plan 8; CSO, 2000).

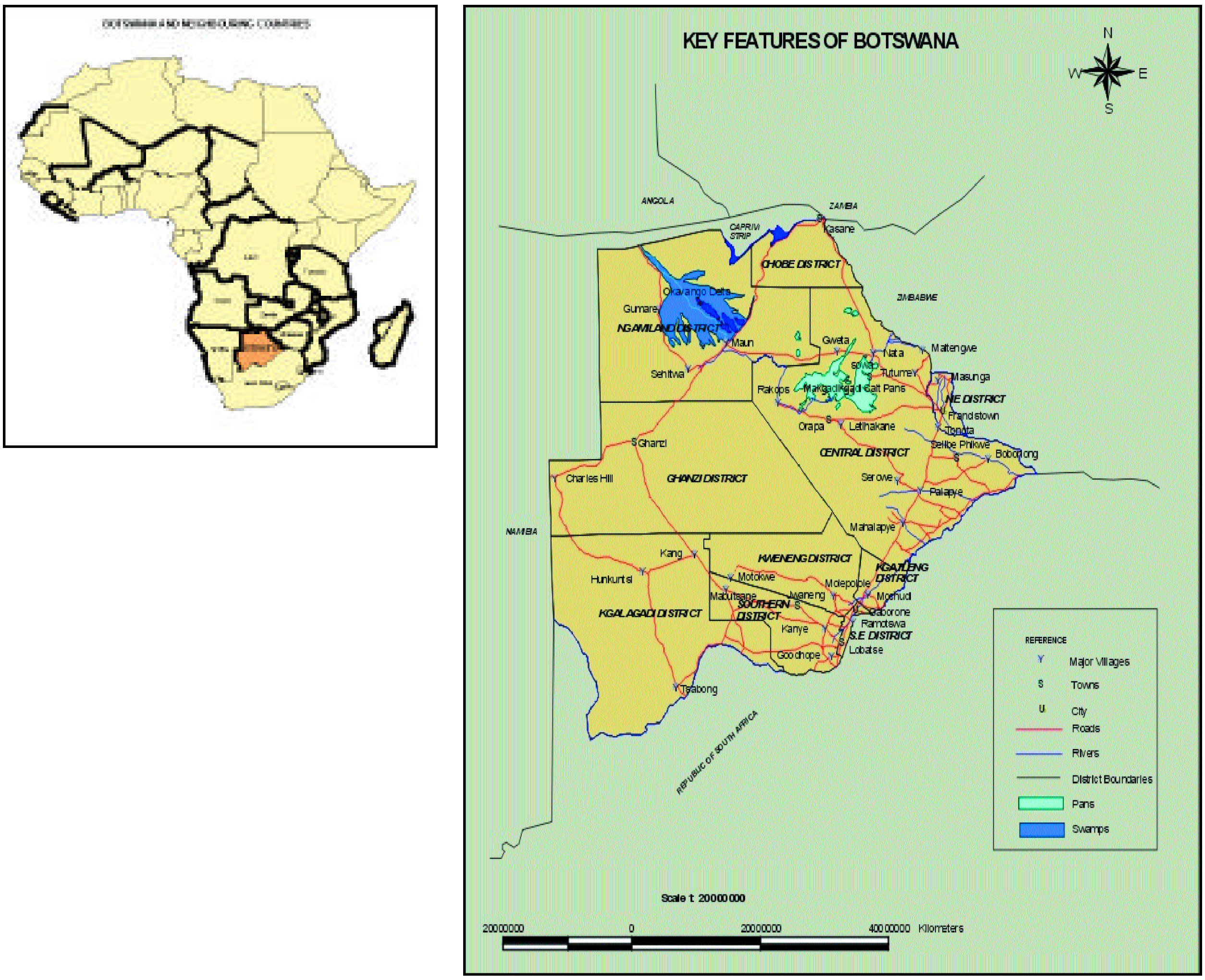


Figure 1.1. Key features of Botswana (Map provided by Department of Surveys and Mapping).

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

Climate

The country is arid to semi-arid with highly erratic rainfall. The mean annual rainfall ranges from over 650 mm in the north-east to less than 250 mm in the south west. The national average rainfall is 475 mm per year, which is half of the global average annual rainfall. Most rain occurs in the months from October to April, and falls as localised showers and thunderstorms (Department of Meteorological Services in CSO, 2000).

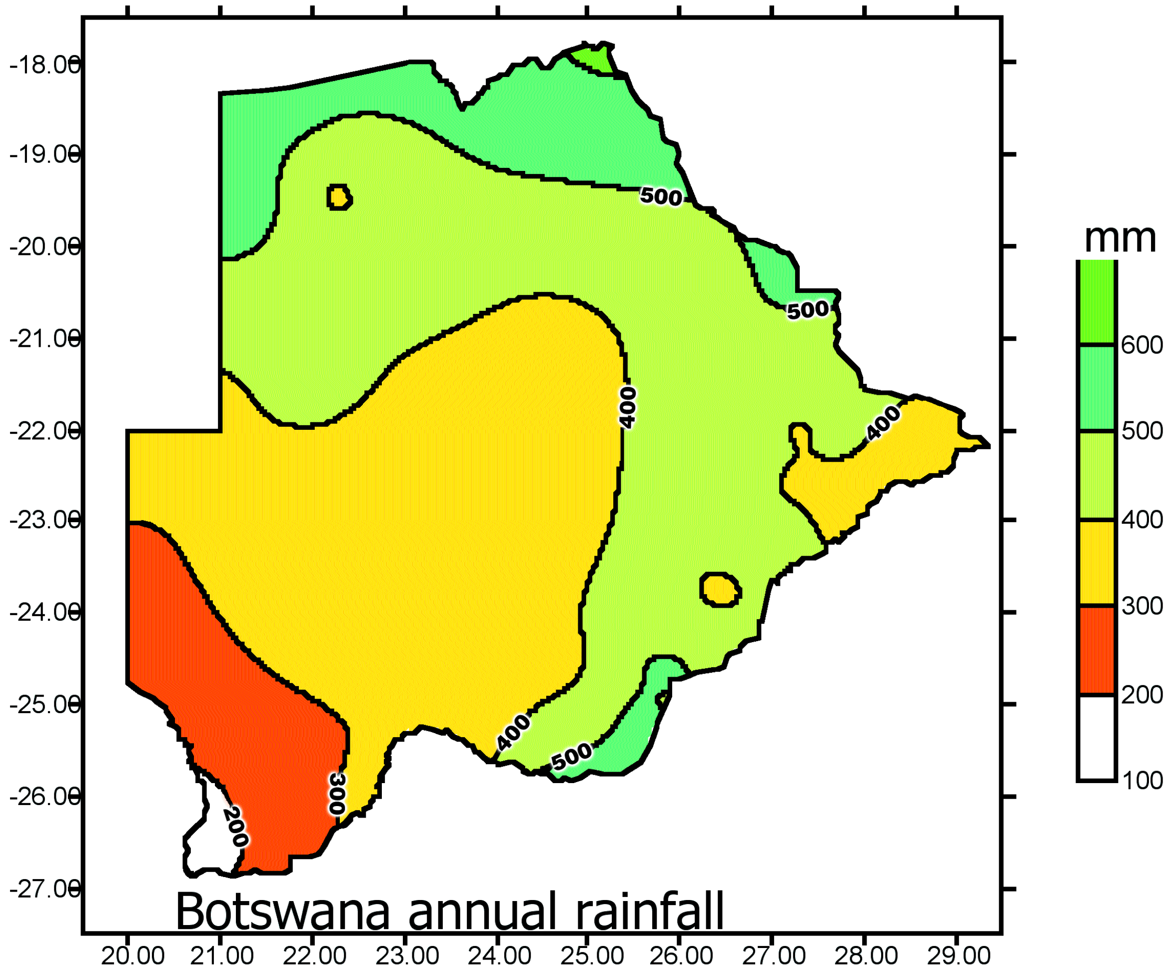


Figure 1.2. Average annual rainfall for Botswana (Map provided by Department of Meteorological Services).

The main features of the climate are determined by Botswana's inland location, astride the subtropical high-pressure belt. During the summer months, the Inter-Tropical Convergence Zone (ITCZ) moves southward to about 20˚ S to bring moisture to the northern parts of the country. The rest of the sub-continent is influenced by a thermal low pressure cell. Moist air associated with the ITCZ, and the moist air which is fed in to the eastern parts of the country from the Indian Ocean, is warmed by the intense sunshine, leading to convective storms. The air becomes progressively drier westwards as most of the moisture is shed over the eastern and northern parts of the country. Between May and September the stable high pressure cell displaces the ITCZ and its associated thermal lows to the north, resulting in drier conditions in winter. Once every few weeks during the dry season, westerly waves displace the cell northward, drawing in cold air from the south and causing light frontal clouds (Botswana Department of Meteorological Services, 2000 personal communication; Bhalotra, 1987; Preston-Whyte and Tyson, 1988).

The daytime air temperatures are generally warm to hot due to the high insolation, but because of the low humidity night-time minimum temperatures regularly drop to near freezing in winter. The mean monthly maximum temperature ranges from 29.5 to 35˚C in summer, and 19.8 to 28.9˚C in winter. Mean monthly minimum temperatures range from 14.6 to 20.8˚C in summer, and 2.9 to 11.6˚C in winter (Department of Meteorological Services in CSO, 2000). The high solar radiation, low humidity and high temperatures lead to very high evaporation rates, ranging from 1.8 to 2.2 m annually for surface water. The sparse and highly variable rainfall, the high evaporation rate and the virtual absence of permanent surface water over large parts of the country combine to ensure that water is a scarce resource in Botswana. Drought is a recurring feature of the climate, and desertification is a national concern. Responses to drought are planned for in advance: for instance, sustainable water yields are calculated on the basis of long term hydrological analysis which includes drought years (National Development Plan 8). Botswana is highly vulnerable to climate change effects because of the variable nature of the country's rainfall frequency and magnitude.

Botswana is also susceptible to variations in climate induced by global sea-surface temperature (SST) anomalies. In particular, El Nino events in the East Tropical Pacific lead to negative departures from the norm in respect of rainfall over arable land in the country, while La Nina events tend to enhance rainfall amounts. There are preliminary indications that the Okavango discharges might be directly influenced by July-August-September SST anomalies in the Nino 3.4 region (i.e. lon 130-175W, lat 20S-25N) (Adedoyin, 1999). The inter-annual coefficient of variation of rainfall is very high, ranging from 25% in the north to 45% in the southwest and extreme east (Moyo *et al.*, 1993 in CSO, 2000). Rainfall in Botswana is highly correlated with the global El Nino-Southern Oscillation (ENSO) phenomenon. During strong 'El Nino' years, the rainfall over most of Botswana is severely depressed. These conditions may persist for several years in succession, bringing great hardship. The persistence of drought always bring a host of social problems like famine, diseases etc.: for instance, the combination of drought and rinderpest in 1896/97 nearly wiped out the cattle population in Botswana (Prah, 1978). The drought of the 1960's was probably the worst (Cambell, 1978), and farmers were forced to move their livestock into the sandveld with the help of borehole drilling schemes. In response to drought, some groups engaged in the gathering of veld products or the hunting of wildlife (Hitchcock, 1978). Drought has a direct effect on the cattle population in Botswana; Figure 1.3 illustrates annual cattle population and mortality from 1979 to 1996. The trend in the 1980's was that of an increase in mortality and a decrease in number.

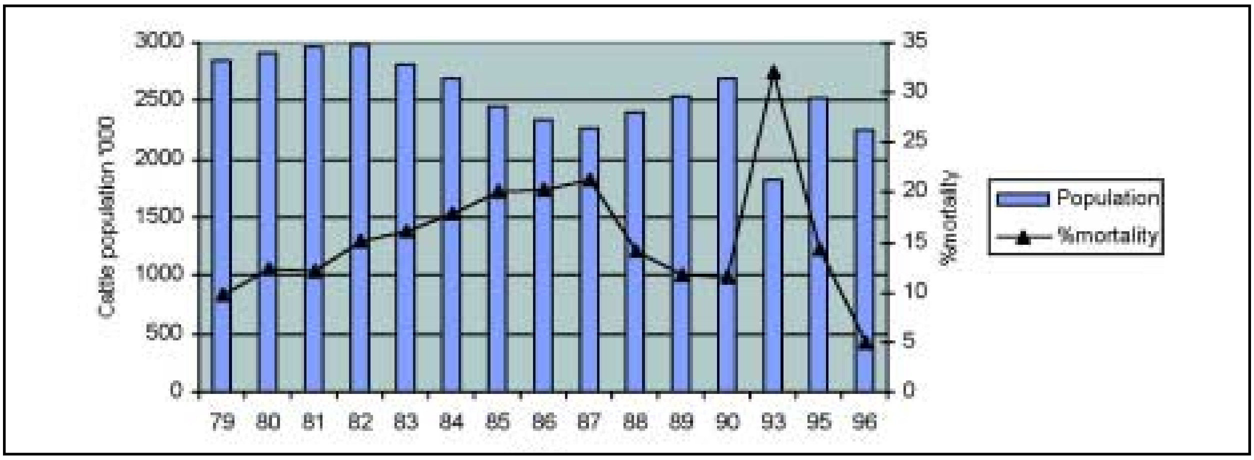


Figure 1.3. Cattle population and mortality (Source: Central Statistics Office, 1996).

There is a clear link between drought, low agricultural production and poverty, and this is recognised and catered for by drought relief programmes which are implemented by the Botswana Government (Midterm Review of NDP8, 2000). Conversely during 'La Nina' years, flooding can be experienced in the east. Floods lead to water logging of soils, leaching of soil nutritions and the proliferation of pests. During the 1999/2000 rainfall season the outbreak of pest (in particular quelea birds) and diseases caused a 50% reduction in crop yields.

Natural Resources

Botswana's natural resource base comprises range and arable land, woodlands, a large wildlife population and a variety of mineral deposits. Less than 5% of the land area is suited to cultivation. Beef production is the most common land use (CSO, 2000). Four-fifths of the country has sufficient tree cover to meet the criteria of a 'forest' in the Food and Agriculture Organisation classification system, but only about one-fifth is sufficiently tall and dense to be called a forest in the sense in which that term is used in southern Africa. Gazetted forest reserves occupy 4 555 km^2. The total above ground woody standing stock is estimated as 1 277.4 million tons, and the mean annual increment as 40.8 million tons (CSO, 2000). The wildlife population, which is one of the largest in Africa, was estimated at around 778 thousand head in 1996, although eastern Botswana was not included (Department of Wildlife and National Parks in CSO, 2000).

Vegetation

The major plant communities found in Botswana include shrub savanna, tree savanna, closed tree savanna on rocky hills, semi-arid shrub savanna, grass savanna, aquatic grassland, dry deciduous forest and woodland. The land cover is dominated by savannas (mixed tree and grass systems) of various forms (Table 1.1) With only 2 600 to 2 800 plant species (Table 1.2), Botswana is reported to have the lowest level of floral endemism in the southern African region (World Conservation Monitoring Centre - quoted in CSO, 2000). The southwestern part of the country is characterized by shrub savanna. The extreme south

Figure 1.4. The Kalahari sand dunes found over Southwestern Botswana. (Photo: Fonsag)

west is the driest region with sparse vegetation and rolling sand dunes. The vegetation becomes denser towards the north and east, changing to open tree savanna, then woodlands and dry forest. There are special habitats such as the aquatic grassland of the Okavango Delta, the grass savanna of the Makgadikgadi Pans and the deciduous forests in the northeastern corner of the country in the Chobe district (Botswana Handbook, 1999). Climate change could cause changes in some or all of these habitats which, in turn, may impact on Agriculture especially on livestock production, biodiversity and tourism.

Table 1.1. Land cover of Botswana in 1994 (Chanda *et al.*, 2000), based on Landsat TM interpretation. The total is 553 103 km^2, 95% of the surface area of Botswana (the image mosaic did not cover the entire country).

Cover type	Area (km^2)
Dense mainly broadleaved and *Acacia* savanna forest	114 477
Moderately dense mainly broadleaved and *Acacia* savanna forest	207 302
Sparse mixed savanna woodland and grassland	85 728
Floodplains and bare soils	35 159
Mixed savanna, including bush encroachment	37 141
Dark soils including pan grasslands	26 277
Very sparsely vegetated woodland and bare soils including burn scars	28 592
Agricultural fields	1 337
Flooded areas, hills and dark soils	17 089

Table 1.2. Levels of Endemism and Estimates of Flora in Southern Africa.

Country	Species of flora	Number of endemics
Angola	5 000	1 260
Botswana	2 700	17
Mozambique	5 500	219
Namibia	3 159	d.u[a]
South Africa	23 000	d.u[a]
Zambia	4 600	211
Zimbabwe	5 428	95

Note: a) d.u = data unavailable.

Water Resources

Water is the scarcest resource in Botswana, affecting many aspects of the nation's development. Water conservation and demand management are key priorities in the National Water Master Plan. In 1994, over 93% of Batswana had access to safe drinking water (piped). At least 90% of people were within 2.5 km of a source of drinking water. There are disparities in access to safe water: in urban areas all households have access to safe portable water compared with only 69% of households in rural areas. In Ngamiland North, access to piped water is limited to 38% of households, but in other districts this figure is at least 50% (Botswana Human Development Report, 1997). In 1990, surface water comprised 36% (41.9 million cubic meters) and groundwater 64% (75.7 million cubic meters) of the consumed water resources in Botswana. The groundwater resources are mostly of fossil type, so their exploitation must be carefully managed if the wellfields are not to be exhausted. Supply from surface water is expected to rise to 57% of consumption in 2020. Although access to water has improved through the development of new pipelines and dams, water supply is limited. Surface water studies which aim at meeting demands beyond 2020 are being done and will be completed in 2002. The Limpopo and Zambezi Rivers are viewed as potential sources to meet future water needs. The possibility of cross-border supply from South Africa to augment water supply in

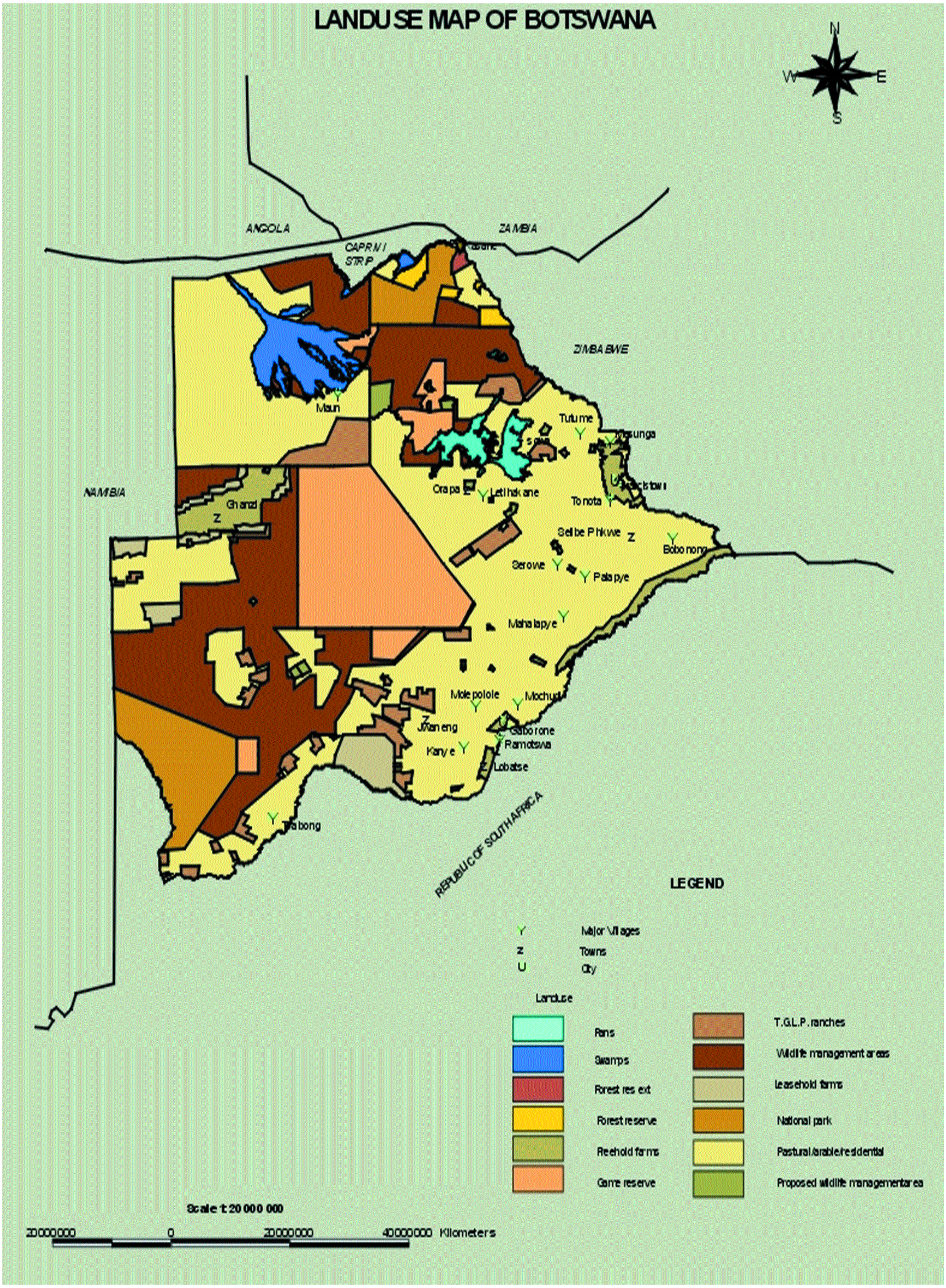


Figure 1.5. Land tenure classification (Map provided by Department of Surveys and Mapping).

the southern part of the Kgalagadi district is also under discussion (Mid-term Review of NDP8, 2000). Waste water is recognised as an important water resource that could be used more extensively. The ephemeral nature of the surface water supplies, and Botswana's increasing dependence on these sources, increases the country's vulnerability to drought and to climate change (National Development Plan 8; Zhou and Masundire, 1998).

Rivers and Wetlands

The perennial rivers all either occur on the borders, or originate outside of Botswana. The Zambezi River touches the extreme northeast of the country, forming a wetland area at its confluence with the Chobe river. The Okavango River enters from Namibia in the northwest, and spreads into the large inland delta known as the Okavango Swamps before evaporating and disappearing into the sands. Depending on the time of year and the rainfall in the main catchment area in Angola, the wetted area ranges from 5 000 to 14 000 km^2 (Ashton, 1999). Together with the swamps associated with the Kwando, Linyanti and Chobe Rivers, it forms a wetland of international importance and a major tourism attraction due to its exceptional scenery and wildlife.

Figure 1.6. Botswana's wetlands are internationally renowned for their beauty and biodiversity (Photo: Illustrative Options).

The Limpopo drainage in the southeast, shared with South Africa, is not perennial. Other ephemeral rivers include the Shashe in the northeast and the Boteti, connecting the Okavango to the Makgadikgadi systems. The Kalahari is threaded with numerous 'fossil'drainage lines, remnants of prehistoric wet periods. Many thousands of years ago, the water of the Okavango emptied into an inland lake in what is now north-central Botswana. The remnant is a very extensive saline depression, the Makgadikgadi Pans, which contains shallow water during exceptionally wet periods. Soda ash is mined at Sowa, on the eastern part of this system. There are hundreds of small, circular pans dotted across the Kalahari sand sheet, particularly in the southeast, which briefly hold water after rains.

Land Use

State land (which includes national parks, some game reserves and wildlife management areas, and all the forest reserves) covers 25% of Botswana's total land area (Figure 1.4). Freehold farms make up 5% while the balance of 70% is communal or tribal land which includes 17% made up of wildlife management areas (personal communication, Department of Lands, 2000). The proportion of land set aside for conservation management (18%) is the highest in the world, and together with the communal and freehold land supports the large mammal population. Wildlife, hunting and the wilderness experience are major tourist attractions. Wildlife also contributes to the subsistence economy of the country.

Culture and History

The majority of the people of Botswana share the Setswana language and culture. Setswana and English are the official languages, the latter being the main language in Government. About 40% of the population can read and speak English while Setswana is spoken by over 80% of the population. The major tribal groups include Baherero, Bahurutshe, Bakalanga, Bakgalagadi, Bakgatla, Bakgothu, Bakhurutshe, Bakwena, Balete, Bambukushu, Bangwaketse, Bangwato, Banyambzya, Barolong, Basarwa, Basubiya, Batawana, Bateti, Batlokwa and Bayei. There are also a number of citizens of Asian and European descent (Botswana Handbook,1999;Botswana Human DevelopmentReport, 1997,National Development Plan 8).

The Basarwa or San people, who occupied all of southern Africa for many thousands of years, are now semi-nomadic remote area dwellers in the Kalahari. Setswana-speakers had established kingdoms in eastern Botswana and northwestern South Africa by the 13th century. To avoid being overrun by European (Boer) settlers in the nineteenth century, they requested protection from Great Britain. The Protectorate of Bechuanaland was formed in 1885, with its administration in Mafeking in present-day South Africa. It became the independent Republic of Botswana on 30 September 1966, with Gaborone as the capital city (Botswana Handbook, 1999).

The post-colonial political system is a parliamentary democracy. Legislative powers belong to the Parliament of Botswana which consists of the President and the National Assembly. In addition to the President, the members of the National Assembly consist of 40 elected members from constituencies and four specially elected members, the Speaker and the Attorney-General. Elections are held every five years. In addition, there is a House of Chiefs, consisting of 15 members, to advise on matters affecting custom and tradition (National Development Plan 8). Nine elections have been held since independence. Botswana is regarded as a model of African democracy and the rule of law. The constitution upholds the principles of non-racial democracy, freedom of speech, freedom of the press, and freedom of association. All citizens have equal rights. Information on government policy is disseminated during open hearings or "*kgotla* meetings" where the public may comment on government policy (Botswana Human Development Report, 1997; A long term vision for Botswana, 1997).

Population

The population at the time of the most recent national census (1991) was 1 327 000. Projections for 2001 estimate the population to range between 1 667 000 to 1 716 000 (National Development Plan 8). Most of the population is concentrated along the railway line in the east of the country (see Figure 1.3). The population distribution is related to both historical factors, and to the availability of water and arable soils. The population is young: about 43% of the people are less than 15 years of age (1991 data). In the 1980's population growth was estimated to be 3.5%, but has been recently revised to 2.5% (National Development Plan 8). The possible mortality due to HIV/AIDS is a significant uncertainty with respect to future population trends. In 1995, 23% of the population aged 15 to 49 years was estimated to be HIV positive, and 3 450 cases of AIDS had been reported (Botswana Human Development Report, 1997).

The population is becoming increasingly urbanized. Currently, 46% of the people live in urban settlements, and the annual rate of urbanization is 8%. Increasing urbanization and the reliance on fuel wood for household energy, result in localized forest depletion in areas adjacent to towns and settlements (National Development Plan 8).

Socio-economic Profile and Development

The monetary unit is the Pula, which was worth an average of US$ 0.2163 in 1999 and US$ 0.3607 in 1994 (1 Pula = 100 thebe). Annual inflation has declined from 10.2% in 1994 to 6.7% in 1998/1999. Inflation for 2000 was projected to range between 8% and 9.5% (Mid-Term Review of NDP8, 2000). The GDP per capita, estimated as US$ 3 135 at present, places Botswana in the category of a middle-income developing country. Expressed in Purchasing Power Parity terms, this was equivalent to US$ 5 611 in 1995. Botswana is ranked 97th out of 171 countries (4th in sub-Saharan Africa, and well above the average for developing countries) on the Human Development Index (UNDP, 1998), which incorporates measures of life expectancy, adult literacy, educational enrollment and GDP per capita. Botswana has shown a 44% improvement on this index since the 1960's. The economy grew at an average rate of 6.6% per year between 1994 and 2000.

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

Unemployment was reported to be 21% in 1994. The private sector is the largest formal sector employer (57.0%) followed by Government (37.1%) and the parastatals (5.9%). Agriculture is responsible for a significant proportion of informal sector employment. About 38% of Botswana's households were living in poverty in 1993/94. In 1985/86 the proportion of poor and very poor households was 49% (National Development Plan 8).

The current development priorities of Botswana are focused on diversifying the economy, creating employment, reducing poverty, providing infrastructure and recovering its cost, developing human resources, rural development, improving environment and land use policy, and policy reform in the public sector (National Development Plan 8).

Energy

The profile of Botswana's energy supply is similar to most developing countries, particularly the Southern African Development Community (SADC) countries, and is dominated by fuelwood which contributes 58% to the total primary energy supplied. The fuelwood is mainly collected by hand, by individual households, resulting in local depletion. At a national scale, the supply due to tree growth is greater than the harvest.

Table 1.3. Primary and net energy supply for 1994/5 (Source: CSO, 2000).

Energy supply	Primary energy supply		Net energy supply[a]	
	TJ	%	TJ	%
Coal	21 906	23.70	4 338	5.53
Fuelwood	54 116	58.54	54 116	69.00
Renewable energy (solar and biogas)	36	0.04	36	0.05
Electricity	1 054	1.14	4 971	6.34
Petroleum products	15 324	16.58	14 969	19.09
Total	92 436	100	78 430	100

Note: a) Excludes energy lost in the transformation process.

Fuelwood is used in the residential sector, government institutions and in small to medium commercial enterprises, especially in rural areas. Annual national wood demand is estimated to be 1.8 million tons. Liquid petroleum gas (LPG) and electricity are used in medium and high-income households. LPG is steadily gaining in popularity in the low-income households because of convenience, and because of localised fuelwood scarcity. The water and electricity supply sectors together contributed 2.2% to the 1994 GDP.

The Botswana Power Corporation (BPC), a parastatal (a statutory corporation), uses coal mined at Morupule to generate electricity at the Morupule power station. The installed capacity is 132 MW. A coal-fired power station at Selibe Pikwe was decommissioned in 1995/6. Botswana Ash generates 20 MW for its own use. In the rest of the country diesel generators are estimated to supply over 20 MW of energy to villages, rural schools, hospitals, police stations and prisons. Solar photovoltaic and wind-generated electricity contribute a fraction of one percent to the total energy supply, but occupy an important niche in satisfying needs in remote areas, and are promoted by the national energy policy (Zhou and Masundire, 1999). Solar and photovoltaic technologies are used in schools, for rural street lighting, and in some homes and government buildings. In 1994, 75.1% of the electricity supply in Botswana was generated in the country, and 24.9% was imported from the Southern African Power Pool (CSO, 2000).

Nearly 100% of the petrol, diesel and paraffin fuel marketed in Botswana (except for small amounts from Namibia for the Ghanzi district) is imported by the five multinational oil companies (BP, Shell, Caltex, Total and Engen) from South Africa (National Development Plan 8). The transport sector is the main consumer of petrol and diesel. A combined total of 435 million liters of petrol and diesel was consumed in 1994.

Mining and Industry

Botswana has several important mineral deposits. Diamonds were first discovered in Botswana in 1967 and are currently mined at Orapa, Letlhakane and Jwaneng. The output in 1996 was 17.7 million carats. The diamond mining industry was a key factor in the rapid economic and social development of the country. The Botswana diamond company, Debswana, is jointly owned by De Beers Centenary AG and the Botswana government. In the period between 1980 and 1995, diamond exports contributed between 50% to 70% of foreign exchange earnings (CSO, 2000). Copper-nickel reserves have been exploited at Selibe Pikwe since 1973. Since 1984 production has been relatively constant at 49 000 tons of matte. Sale of copper-nickel contributed between 5% to 9% of total exports. Coal has been mined at Morupule since 1976, with 900 778 tons extracted in 1994. Coal reserves in Botswana are estimated to amount to 212.8 billion tons. Extensive reserves of salt and soda ash are found at Sowa Pan; production in 1995 was 208 and 211 thousand tons of each. Other minerals are known to occur, including gold, manganese and semi-precious stones, but are not mined in significant quantities. Crushed stone, sand and clay are quarried for construction purposes; the level of production depends on the building industry and large infrastructure projects. The mining sector dominated the economy in 1994 (36% of the GDP) and continues to do so at present (CSO, 2000; Annual Economic Report).

Botswana has one heavy industrial process - the copper-nickel smelter at Selibe Pikwe. Botswana’s industry is predominantly focused on light manufacturing and assembly (textiles, garments, leather products, foot wear, light engineering, wood and paper products, rubber and plastic, furniture, food products and information technology) (Statistical Bulletin, 1999). In 1994/1995, vehicles replaced copper-nickel matte as the second major export commodity, but vehicle assembly ceased in 1999. Manufacturing contributed 4.6% to the 1994 GDP (Annual Economic Report, 2000; National Development Plan 8). The Botswana government is actively encouraging a shift away from the economic reliance on mining to a more proactive reliance on other natural resources.

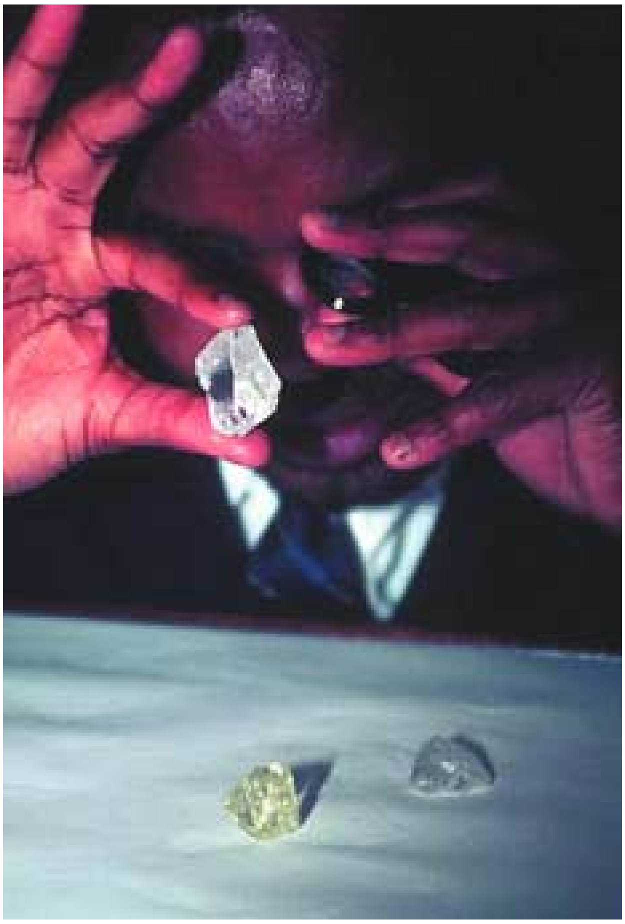


Figure 1.7. Export earnings from diamonds contributed between 50 and 70% of the Gross Domestic Product between 1980 and 1995 (Photo: Illustrative options).

Tourism

Tourism is an important and growing economic sector in Botswana, with a shift towards promoting the use of permanent accommodation facilities rather than casual camping (Tourism Policy, 1990). Most tourism is based on the spectacular wildlife resource and wilderness character of the landscape, particularly in the northern part of the country. The Okavango Delta, Chobe, Moremi, Makgadikgadi and Nxai Pan offer tourists a diversity of attractions and activities focused on wildlife appreciation. Effective wildlife conservation is thus essential to support further growth opportunities for tourism. The majority of tourists are from Europe. In 1995, the number of tourist visitors to national parks and game reserves stood at 50 000, a twofold increase over the 1994 figure. Over 27 000 people are estimated to be employed in tourism-related activities (e.g. hotels, airlines, safari companies, hand crafts) (National Development Plan 8). Trade, hotels and restaurants contributed 11.8% to the GDP in 1994. Within this, the tourism industry contributes approximately 3% to the GDP annually (Tourism Development Guide of June 1995, quoted in National Development Plan 8; CSO, 2000; National Development Plan 8; Annual Economic Report, 2000).

Figure 1.8. Wildlife viewing is an increasingly important contributor to tourism and the national economy (Photo: Illustrative Options).

Agriculture and Forestry

Botswana's climate is marginally suited to crop agriculture, except in areas where irrigation is possible. Changes in temperature or rainfall attributable to climate change would influence the vulnerability of this sector. Agriculture contributed 4.4% to the GDP in 1994, of which most came from livestock production. In 1993, total production from both traditional and commercial farms amounted to 16 527 tonnes of sorghum, 4 254 tonnes of maize, 1 546 tonnes of millet, 718 tonnes of beans or pulses, 327 tonnes of sunflower and 123 tonnes of groundnuts (CSO, 2000).

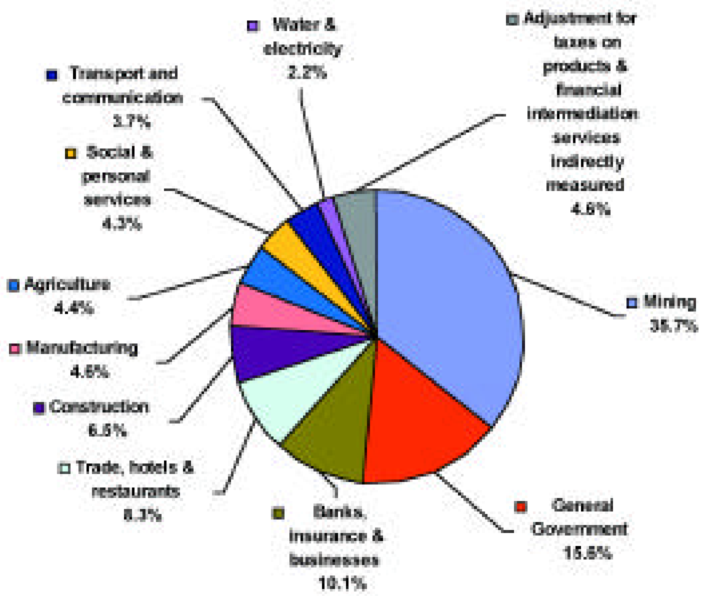
Forestry is the responsibility of the Department of Crop Production and Forestry within the Ministry of Agriculture. Commercial forestry is thus included within the agricultural sector although estimates of timber production or contribution to the GDP are not distinguished from the rest of the agricultural sector. Wood resources in the forest reserves are only exploited when Government issues permits to do so. The main timber species are *Baikiaea plurijuga* and *Pterocarpus angolensis*. Harvesting from the Chobe Forest Reserve was suspended in 1993 due to fears that the resource was not being sustainably harvested (CSO, 2000).

The contribution to GDP from agriculture has declined from 40% at Independence, largely due to the rapid development of the mining sector and increasing urbanisation. Despite this decline, the agricultural sector remains an important source of food, income, employment and capital formation for the majority of the population living in the rural areas (National Development Plan 8; Annual Economic Report, 2000).

Figure 1.9. Cattle ranching, once the mainstay of the Botswana economy, has been replaced by diamond mining as the top export earner (Photo: Illustrative Options).

Other Economic Sectors

The contribution of other economic sectors to the GDP in 1994 was as follows: local and national government 15.6%; financial services 10.1%; construction 6.5%, transport and communication 3.7%, personal and social services 4.3%.



The sum of the sectors is slightly more than 100% due to a 'dummy sector' introduced to account for bank service charges (Annual Economic Report, 2000). The development of a supportive financial services sector is an important priority in promoting economic growth. The Botswana government is thus encouraging a greater diversity of financial instruments and institutions, as well as revising several monetary, fiscal and exchange rate policies to ensure that they operate in a supportive manner (National Development Plan 8).

Economic Outlook

The real growth rate of GDP during the 1999/2000 national accounts year is forecast to be around 10%, which would be more than double the growth rate estimated for 1998/99. The primary reason for this expected acceleration is a substantial growth of around 15% in GDP from the mining sector, due in turn to the doubling of production at the Orapa mine following the completion of the expansion project. The fall in the growth rate in 1998/99, from 8.0% of the preceding year to 4.5%, was also due mainly to a contraction in the mining sector GDP by over 4%. This shows that despite the economic diversification taking place in the economy, the overall growth and prosperity of the country are still crucially dependent on the fortunes of the mining sector, which contributes around a third of the country's GDP. While the growth rate of the mining sector is thus likely to go through some oscillations, the growth rates of other major sectors such as Manufacturing, Construction, Trade, Finance and Services are likely to continue at an average rate in the range of 6 to 7%.

Table 1.4. Key Indicators of National Circumstances.

Criteria	Units	1994	Most recent year	Source[a]
Population (estimated from 1991 census with average growth rate of 2.5%)	Number	1 425 398	1 533 000 (1997)	1
Land area	km^2	581 730		2
GDP[b]	US$ billion	4.2	5.0 (1998)	3
GDP per capita	US$	2 800	3135 (1998)	4
Share of informal sector in GDP	%	No data		
Share of agriculture in GDP[c]	%	4.4	2.8 (1998)	4
Share of mining in GDP	%		35.7 35.0 (1998)	
Share of manufacturing in GDP	%	4.6	4.7 (1998)	
Share of water and electricity in GDP	%	2.2	1.9 (1998)	
Share of construction in GDP	%	6.5	5.9 (1998)	
Share of trade, hotels and restaurants in GDP	%	8.3	11.8 (1998)	
Share of transport and communication in GDP	%	3.7	4.1 (1998)	
Share of banks, insurance and business services in GDP	%	10.1	10.5 (1998)	
Share of general government in GDP	%	15.6	16.0 (1998)	
Share of social and personal services in GDP	%	4.3	3.9 (1998)	
Land area used for agricultural	km^2			3
• Beef production		450 000		
• Major cereals		2 750		
• Horticultural production km^2		6.6		3
Urban population as percentage of total population (urban areas defined as settlements of > 5000 people in which < 25% indulge in agricultural activities)	%	45.7		3
Livestock population (1993 data)[d]				
• Cattle	Million	1.8		
• Goats		1.8		
• Chickens		1.0		
• Sheep		0.25		
• Donkeys & horses		0.26		
• Pigs	Thousand	4.0		2
Forest area (dense, broadleafed and *Acacia* savanna)	km^2	114 477		5
Population in absolute poverty (households)	% 3	8		3
Life expectancy at birth	years	66.1	65.3 (1996)	3/6
Literacy rate (adult)	%	68	Not available	3

Notes:

a) Information sources 1. CSO, 1996 in Zhou, 1999 c, Botswana Country Study; 2. CSO 2000; 3. National Development Plan 8; Annual Economic Report, 2000. 5. Ringrose *et al.*, 1997. 6. Botswana Human Development Report (1997).

b) The GDPis for the year 1994, but expressed in current (i.e. year 2000) US$ terms.

c) Classification of economic activities follows that of the BSIC Rev. 2 Adaptation (Annual Economic Report, 2000).

d) The average for 1990, 1993 and 1995 was used to represent the baseline in the inventory. There was no livestock census in 1994, and there is high inter-annual variation due to drought (especially in 1992/93).

2. Inventory of Anthropogenic Greenhouse Gases

This section reports on the quantity of climate-change causing gases that were produced (or taken up) by Botswana in 1994, the agreed base year adopted under the UNFCCC process for non-annex 1 countries. The detailed contributions from each sector are given in Appendix 1.

Introduction

Article 4.1(a) of the Convention requires Parties to periodically share information about the emissions from sources, and uptakes by sinks, of the gases believed to be causing climate change. To ensure international comparability and transparency, these national 'inventories' are conducted according to a methodology developed by the Intergovernmental Panel on Climate Change (IPCC) (see Box 1). The values reported in this chapter for Botswana have been calculated using the Revised 1996 IPCC methodology (IPCC, 1997). The information source for this chapter is the 1994 Greenhouse Gas Emissions Inventory for Botswana (Zhou, 1999a).

The reporting requirements for non-annex 1 countries, such as Botswana, are given in decision 10 of the second Conference of Parties. Non-annex 1 countries are required to report emissions and removals of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) for the base year 1994. These countries may report other greenhouse gases mentioned in the IPCC guidelines if they so wish and data are available. Emissions of carbon monoxide (CO), nitrogen oxides (NO_x) and sulphur hexa-fluoride (SF_6) were included in the 1994 Botswana inventory.

In order to assess the combined global warming effect of the different gases, they are converted to 'CO_2 equivalents', by making use of standard Global Warming Potentials (GWP, Table 2.1). The GWP is the ability of each greenhouse gas to trap heat in the atmosphere relative to carbon dioxide. It takes into account the different radiation absorption properties of the gases, and also the different lifetimes. By convention, the standard GWPs are integrated over a 100-year period. For example, one ton of CH_4 has 21 times the warming effect of a ton of CO_2.

Table 2.1. Global warming potentials of some of the greenhouse gases (not all greenhouse gases are considered in the Initial National Communication).

Greenhouse Gas		Global Warming Potential
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Nitrogen oxides	NO_x	40
Carbon Monoxide	CO	3
Sulphur Hexafluoride	SF_6	23900

The IPCC guidelines provide default emission factors for the various activities contributing to GHG emissions. Countries are encouraged to use locally-specific emission factors where they are available and can be documented. IPCC default values have been used in this inventory unless stated otherwise. Similarly, countries are free to develop variations of the methodology if they believe that their approaches are more appropriate to the local circumstances, provided that the methods used are clearly described.

Overview

Botswana was estimated to be a major net sink for CO_2 emissions in 1994 due to the large uptake of carbon by trees (the 'Land Use and Forestry' sector). The amount of carbon estimated to be taken up by the natural vegetation in Botswana in 1994 constitutes about one percent of the total net uptake by land ecosystems throughout the world (IPCC, 2000).

The uncertainty in the Land Use and Forestry sink has several sources which are discussed below in the Land Use and Forestry sector. Reducing this key uncertainty is a high priority for future research. Because of the large size of the Land Use and Forestry sink, and the high uncertainty associated with it, the statements which follow regarding the fractions contributed to the emission inventory by various sectors of gases *exclude the Land Use and Forestry sink.*

The contributions by the main economic sectors to CO_2, CH_4 and N_2O emissions in 1994 (excluding CO_2 removals in the Land Use Change and Forestry sector) are given in Table 2.2.

The total greenhouse gas emissions (CO_2, CH_4 and N_2O) from Botswana in 1994 *excluding forest regrowth and non-fuel wood use* were estimated to be equivalent to 10 227 Gg CO_2 (Table 2.3). Carbon dioxide is the largest contributor to this total (52%), followed by methane (33%) and nitrous oxide (16%), on a per capita basis this is 7.2 t CO_2 equivalents per person.

Table 2.2. Percentage contribution to national emissions by various economic sectors.

Economic Sector[a]	CO_2	CH_4	N_2O	All gases GWP	Main sources of emissions
Power generation (total electricity generated in the country)	53	0	7	19	Coal-fired power station
Households	2	6	1	4	Fuelwood
Transport	24	0	4	9	Petrol
Mining and Industry	16	6	12	11	Explosives
Government	4	0	1	1	Petrol and diesel
Agriculture[b]	1	84	75	55	Savanna burning Enteric fermentation from cattle
Trade and Hotel	0	0	0	0	LPG and paraffin

Notes:

a) The IPCC sector categorisation (Table 2.3) is different. For this table, the emissions associated with various economic sectors as defined in Botswana have been grouped together. The columns do not all sum to 100% due to minor contributions from other sectors (Zhou, 1999a). The land use sink term has been excluded from this analysis due to its large uncertainty.

b) Added agriculture (energy) + agriculture.

The overall uncertainty associated with the Botswana national greenhouse gas emissions inventory, *excluding the CO_2 sink term estimated for the Land Use Change and Forestry sector*, is estimated to be 20% on a CO_2 equivalent basis. This overall estimate is arrived at by expert judgement, based on the uncertainties attributed to the main sources. In the 1994 Botswana inventory, the CO_2 emissions calculated by the reference approach differs by less than 1% from the emissions calculated by the sectoral approach. This exceptionally good agreement is partly due to the availability of accurate total national supply and sectoral demand data for all fuel types in Botswana (except fuelwood).

Table 2.3. National greenhouse gas emissions (positive) and removals (negative) in 1994 (Gg/year). (Zhou, 1999a)

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	CO_2 equivalent
Total (Net) National Emission (Gigagram per year)	-35696.730	201.862	6.577	-29418.861
1. All Energy	**3037.600**	**25.185**	**0.965**	**3865.532**
Fuel combustion (Reference approach)	*3037.600*			*3037.600*
Fuel combustion (sectoral approach)	*3014.497*	*13.115*	*0.965*	*3588.959*
Power Generation	1605.489	0.215	0.447	1748.524
Households[a]	69.983	11.791	0.090	345.370
Agriculture	36.065	0.003	0.013	40.070
Industry	473.684	0.064	0.140	518.285
Trade and Hotels	3.920	0.001	0.001	4.407
Transport	713.457	0.694	0.236	801.264
Social Services	0.633	0.090	0.001	2.763
Government	111.267	0.257	0.037	128.276
Fugitive fuel emission	*12.070*			*253.470*
Solid Fuels: coal mining	12.070			253.470
Other	*2348.460*			*2348.460*
Aviation Bunkers[b]	NA	NA	NA	NA
Fuelwood	2348.456			2348.456
2. Industrial Processes			**0.680**	**210.800**
Explosives			0.680	210.800
3. Agriculture		**168.727**	**4.914**	**5066.607**
Enteric fermentation		92.636		1945.356
Manure management		0.091		1.911
Savanna burning[c]		76.000	4.700	3053.000
Fertilisers			0.214	66.340
4. Land Use Change and Forestry	**-38734.330**	**0.020**	**0.001**	**-38733.600**
Forest Changes	*-39646.500*			*-39646.500*
Biomass Regeneration	-42364.047			-42364.047
Wood Uses[a]	2717.550			2717.550
Forest Conversion	*912.166*	*0.020*		*912.586*
On Site Burning	19.305	0.020	0.001	20.035
Biomass Decay	170.528			170.528
Soil Carbon	722.333			722.333
5. Waste		**7.930**	**0.017**	**171.800**
Solid waste landfilled		7.830		164.430
Domestic and commercial Waste water		0.100		2.100
Pit latrines[d]			0.017	5.270

Notes:

a) The CO_2 emissions from the sustainable use of fuelwood are only noted for reporting purposes but not included as part of the total CO_2 emissions. The CO_2 emissions reported for wood uses are related to the non-energy use of wood.

b) Data were not available for international aviation fuel usage, as it is not reported separately from national aviation fuel usage.

c) Carbon dioxide emissions from the burning of savannas and agricultural residues are assumed to be net zero emissions because carbon released to the atmosphere is reabsorbed during the next growing season or between burning cycles.

d) The IPCC Guidelines only provide methodology for calculating N_2O emissions from human sewage.

Box 1: The IPCC Guidelines for National Greenhouse Gas Inventories

The guidelines are designed to estimate and report on national-level inventories of anthro-ogenic greenhouse gas emissions and removals. The term 'anthropogenic' refers to emissions and removals that are a direct result of human activities, or are the result of natural processes that have been affected by human activities in a way which is different in type or degree to the human effects prior to the Industrial Era (i.e. since 1750). The 'Revised Guidelines' (IPCC, 1997) were used for the Botswana 1994 inventory.

National inventories include all emissions and removals taking place within the national territory. They do not include the emissions associated with energy or goods that are imported. Emissions from fuel sold to aircraft departing on international flights are listed separately ('international bunker fuels').

The Guidelines provide step-by-step instructions for calculating CO_2, CH_4, N_2O and some other trace gas emissions. For CO_2 emissions from the energy sector two calculation methods are used, which act as a check on one another. The *Reference Approach,* also known as the 'top down'approach, multiplies the total quantity of energy used in the country by the carbon content per unit energy for each fuel type. The *Sectoral Approach*, also known as the 'bottom-up' approach, adds up the emissions for each individual emission-generating process. The emissions for each process are calculated by multiplying an 'activity level'(i.e. how much of that process occurs) by an 'emission factor' (the gas emitted per unit of activity). For gases other than CO_2, only a sectoral approach is possible. Within the sectoral approach, three levels of increasing detail and accuracy are offered (Tier 1, 2 and 3). Countries are expected to choose the level that matches the availability of data in their country. Botswana used Tier 1 methods in their 1994 inventory.

A single year estimate is required for most source and sink sectors, except for agriculture and land use change and forestry. For these, three-year averages (with the base year in the middle) are preferred. This is to compensate for cases where the reference year was an 'abnormal'year for a specific activity, for instance a drought year.

Energy

Emissions from the Energy sector are divided into combustion and fugitive emissions. 'Fugitive emissions' (i.e. unintentional gas leaks from a process, which are not emitted from the smoke stack or exhaust pipe) are estimated for coal mining and post-mining activities. All coal in Botswana is mined using underground mines rather than open pits (CH_4 emissions per kg of coal are greater from underground mines than from open pits). There were no oil, natural gas and petroleum refining activities in Botswana in 1994, and thus no fugitive emissions from these sources. The IPCC Tier 1 methodology and default emission factors were used throughout, except for the CO_2 emission factor for coal. An emission factor of 92 t CO_2/TJ was used instead of the IPCC default value of 95 t CO_2/TJ, based on the characteristics of the coal mined in Botswana. The energy content of the coal is low (24.0 MJ/kg), as is the carbon content, at 53.9% (CSO, 2000, pg 80).

For the *Sectoral Approach*, energy consumption per sector could only be disaggregated to the level reported in the national energy balance (i.e. fuel-mix and consumption per sector). The same average emissions factor per gas species per fuel type was applied to all the different demand sectors. The non-CO_2 emission factors are derived from international databases reporting emissions from combustion devices similar to the ones used in Botswana (Zhou 1999a). In the *Reference Approach*, no carbon sequestered in coal and petroleum by-products such as lubricants and bitumen was deducted from the total amount of carbon consumed, since these products are only used and not produced in Botswana.

Energy-related CO_2 emissions in Botswana in 1994 were low in absolute terms (3 014 Gg CO_2 per year) and on a per capita basis (2.68 Mg CO_2 person/year). This is because the Botswana society and economy has an intrinsically low energy intensity (there is little industry, low transport density and relatively few buildings are air conditioned or centrally heated), and the overwhelming majority of household energy needs are provided by a renewable source, fuelwood. The CO_2 emitted when fuelwood is burned is not considered to add to the atmospheric burden provided that the wood is sustainably harvested, since it is taken up again by regrowing trees. However, this is not true for the emissions of CH_4 and N_2O from fuelwood burning. Although there are localised examples of fuelwood depletion in Botswana, the national balance between tree growth and wood use appears to be strongly positive (see Land Use and Forestry sector).

Figure 2.1. Fuelwood from Botswana's forests and woodlands is the main energy source for rural households (Photo: Illustrative Options).

The uncertainty for CO_2 emissions from the energy sector is estimated to be between 5 and 10% because accurate coal and petroleum products supply and demand data are available. The uncertainty for non-CO_2 combustion and fugitive emissions is estimated to be between 10 and 20% due to the lack of locally applicable emission factors. These uncertainty estimates are mainly based on the uncertainty levels noted in the IPCC guidelines for the various sources of energy related GHG emissions.

Industry

All the greenhouse gas emissions that are not related to energy but are the result of the chemical or physical transformation of materials are reported in this category. Nitrous oxide emissions from the usage of explosives (0.68 Gg of N_2O (211 Gg of CO_2 equivalents) was the only source in the sector in 1994. The uncertainty for the N_2O emissions from the industrial sector is estimated to be between 10 and 15%. This is mainly due to the lack of a locally applicable N_2O emission factor for explosive usage, since the quantity of explosives used is well documented.

Cement is packaged in Botswana, but there was no cement-producing kiln in 1994, and therefore no emissions from this source. No CO_2 emissions were attributed to the soda ash manufacturing process because the CO_2 source in this case is already completely accounted for under energy emissions. The original source is the flue gas from the power plant. Over 70% of the CO_2 in this process is recycled; the net emissions from soda ash usage were estimated to be insignificant.

The energy-related emissions from the copper-nickel smelter are already accounted for in the estimates for the energy sector.

Agriculture

The IPCC methods and default values were used except in the following cases:

- A locally-derived emission factor for the CH_4 emissions from manure management was used on emission factors of 0.018 kg. CH_4/kg dung was estimated based on the following: 1000kg of fresh cow dung was estimated to produce 50 - 60m^3 of biogas at 35°C with a CH_4 content of 70%. These figures were adapted to 25% (Zhou, 1999a).

- Regionally-applicable emission factors for the non-CO_2 emissions from the burning of savannas were used instead of the IPCC methodology and default values (Scholes, 1995, Delmas *et al.,* 1995).

Botswana is a beef exporting country. The CH_4 emissions from enteric fermentation in livestock is the dominant source of CH_4 emissions from the agricultural sector, contributing more than 90% to the total CO_2 equivalent emissions from the sector, and 74% to the methane emissions from the country. A simplified Tier 1 method was used, in which the number of animals of each livestock type in the country was multiplied by a default emission factor for animals in developing countries in Africa (kg CH_4/head/year). The traditional Tswana cattle are typically small-statured, free-ranging, drought tolerant and consume a relatively low-quality diet compared with exotic breeds. The number of cattle in 1993 (the year nearest to 1994 for which data were available) was 1.8 million.

Methane emissions occur when manure decomposes under anaerobic conditions. In addition, during the storage of manure, some manure nitrogen is converted to N_2O. Nitrous oxide emissions from anaerobic lagoons, liquid systems, solid storage and dry lots are reported as part of ‘Livestock’emissions. Methane emissions from manure management were only estimated for dung collected at abattoirs. Almost all Botswana cattle are free-range. As a result, most of the dung is thinly spread over the rangelands and rapidly dries out. Conditions that are favourable for CH_4 production are most unlikely to occur.

The emissions from the burning of savannas involve multiplying the area that burns by the mean fuel load and then by an emission factor derived for African savannas for each of the gases that are emitted, (Delmas *et al.,* 1995). Only non-CO_2 emissions from savanna burning are given since CO_2 emissions from the burning of savannas and agricultural residues are assumed to be balanced by regrowth in subsequent seasons.

Although on average 15% of the land area of Botswana burns annually (Zhou, 1999a, quoting regional analyses based on satellite imagery), and virtually all of this is in savannas, very little could be described as ‘prescribed burning’. Some of the fires are probably ignited by humans (no accurate statistics exist). The average grass and litter fuel load is estimated at 3.6 t DM/ha (tons of dry matter: Zhou, 1999a). Crop residues are not burned in Botswana; They are left on the fields to serve as fodder for cattle, and any remnants are ploughed into the soil. The uncertainties in estimates of savanna burning emissions are around 40%, largely associated with uncertainties regarding fuel load.

Agricultural soils are potential sources of CH_4 and N_2O emissions. Soils that have anaerobic zones (typically as a result of waterlogging) emit CH_4. The arid, sandy soils of Botswana are effectively never anaerobic. No significant area of paddy rice is grown in Botswana. When nitrogenous fertilisers are applied to soils, a fraction of the applied nitrogen is lost to the atmosphere as N_2O. The IPCC methodology for agricultural N_2O emissions is based on the annual usage of nitrogen-containing fertilisers of all forms (including fertiliser, crop residues, biological nitrogen fixation and manure). It was assumed that all the nitrogen fertiliser used in Botswana was applied to agricultural land, and no other sources of nitrogen input were calculated.

Figure 2.2. Agricultural activities such as ploughing and fertilizing influence emissions of greenhouse gases (Photo: Illustrative Options).

The uncertainties associated with the CH_4 and N_2O emissions from enteric fermentation and manure handling are estimated to range between 15 and 25%, mainly due to the lack of locally applicable emission factors. The uncertainty associated with the emissions from savanna burning is estimated to be between 20 and 25%, since the activity data are not monitored regularly.

Land Use Change and Forestry

The IPCC methodology was applied to calculate emissions from Land Use Change and Forestry, using locally-determined biomass regeneration rates for the different vegetation types occurring in Botswana instead of the IPCC default values (Energy Resources Ltd, 1985). The areas of various vegetation cover types were estimated by the ETC Foundation (1987) and more recent interpretations of satellite thematic mapping imagery and field surveys (Ringrose *et al.*, 1997, cited in Zhou 1999a). The human-induced deforestation was derived from a map of degraded lands (Ringrose *et al.*, 1997, cited in Zhou, 1999a).

Botswana is estimated to be a significant sink of carbon due to the growth of trees exceeding the quantity harvested by a large margin. When this difference is multiplied by the large extent of the area covered with trees, a substantial sink is indicated. The area of the various vegetation types is known with reasonable accuracy (± 20%) and the growth rate of the trees, while very variable between years and sites, averages around 3.2% of the woody standing stock per annum (CSO, 2000), with a range from 2 to 6% (i.e. an uncertainty of 50%). The aboveground woody biomass standing stock in Botswana is reported as 1 277 million tons (CSO, 2000). Wood consumption rates have been widely surveyed in Botswana and elsewhere in southern Africa (CSO, 2000; Gandar, 1994), and vary principally in relation to wood availability and the climatically-determined need for heating. The range is about 240 to 1100 kg/person/year, with the average for Botswana for rural and peri-urban dwellers likely to be around 400 kg/person/ha.

Botswana woodlands, like other woodlands in Africa, are not undisturbed. There have been changes in land use and in particular increases in grazing pressure and reductions in fire frequency, which have been widely shown in Botswana and neighbouring countries to lead to an increase in woody biomass (i.e. a carbon sink; see van Vegten, 1983; Scholes and Archer, 1997). The biomass of trees in savannas can increase dramatically, over a period of a few decades, following changes in grazing and fire management. The soil carbon stores increase at the same time. As tree density increases, grazing potential is suppressed. There is thus a potential tradeoff between grazing and carbon storage.

Forest conversion to croplands is the only major source of emissions in this sector. When land that has been under natural vegetation for an extended period of time is converted to crop agriculture, the carbon content of the topsoil typically declines, over a period of several decades, to a new equilibrium level. This carbon is lost from the soil as CO_2. The area of 'forest' converted to cropland in the 1993 to 1995 period was estimated to be 24 000 ha per year in total, or 13 000 ha per year when only considering conversion of vegetation which had not previously been converted in recent decades (Eskeli, 1989). The soil carbon content is estimated to vary between 11 t/ha and 37 t/ha. For undisturbed savanna lands a soil carbon content of 21 t C/ha was assumed, which declines to 11 t C/ha some years after ploughing. The biomass removed during destumping is used for fuel wood and bush fencing or is burnt on site (35, 53 and 12% respectively). Locally applicable emission factors for the non-CO_2 emissions from on site burning were used (Delmas *et al.*, 1995). The uncertainties associated with the emissions from the conversion of forests are estimated to be 20-30%. The main source of uncertainty is associated with the soil carbon emission factor, which varies about 70% when comparing different areas in the country.

The area under plantation forest (non-indigenous trees, including woodlots) has been constant at around 650 ha since the 1970s and does not contribute a significant amount to the overall carbon sink in Botswana. Although non-indigenous plantations have not increased, the area of plantations of indigenous trees is increasing.

Waste

Emissions from solid waste landfills contributed to almost all the CH_4 from the waste sector. The IPCC methodology was generally followed and locally applicable data were included where available. The number of people living in urban and rural areas, together with a per capita waste production rate that differs between rural and urban inhabitants, were used to calculate total solid waste amounts. Landfill sites are generally not covered with soil in Botswana, so they do not generate methane. Only the CH_4 emissions from reasonably well-managed landfill sites in Gaborone and Lobatse were calculated. Methane emissions from waste water were only determined for urban areas, where it is collected and treated in sewerage plants. Nitrous oxide emissions from human waste deposited in pit latrines were determined for rural areas. A Degradable Organic Content (DOC) of 0.13 (instead of the IPCC default value of 0.15) was used for the solid waste disposed of in landfills. This value was calculated for the waste collected in Gaborone, and is assumed to be more representative of the local conditions.

Following the IPCC Guidelines, only the N_2O emissions from human sewage are calculated. Nitrous oxide emissions from pit latrines are most probably higher than calculated because of the amount of meat consumption, which leads to a higher nitrogen content in the sewage. No locally applicable data on the annual protein consumption per capita are available. The number of pit latrines in 1994 was estimated by projecting the number of pit latrines documented in the 1991 Population and Housing Census Reports (CSO, 1994). Only the rural and village pit latrines were considered. The N_2O emissions from pit latrines are insignificant. Only N_2O emissions from human sewage are calculated following the IPCC methodology.

No waste is incinerated for energy purposes in Botswana. Emissions from the incineration of medical waste are not included as no data on actual amounts are currently available.

The uncertainty associated with the total emissions from the waste sector was estimated to be between 5 and 15%. The largest uncertainty is the N_2O emissions from pit latrines (between 10 and 25%).

Difficulties Encountered in the Inventory

- The internal capacity for conducting greenhouse gas inventories requires further development and support. This is expanded on in the section on 'Financial and Technology Needs'.

- Some minor changes in the way national statistics are collected are needed, for instance the separate recording of aviation bunker fuels.

- The IPCC methodology for estimating the changes in forest biomass carbon stocks as the difference between mean annual increment and harvest rate does not take into account natural mortality and decay on lands which have not been transformed, and could lead to a substantial overestimate of the land sink term where most of the natural mortality goes unharvested.

- The greatest single uncertainty relates to the Land Use and Forestry Sector. Documented changes in forest biomass and soil carbon are required for a representative sample of the land area. Further details are given in the chapters on 'Research and Observations'and 'Financial and Technology Needs'.

- The non-CO_2 emissions from savanna burning are of the same order of magnitude as industrial emissions and have higher uncertainties. Fuel load data, collected through the same process that is developed to support Land Use and Forestry, would narrow the uncertainty.

- Savanna fires are not known to have changed in frequency or extent over the period for which rises in greenhouse gases have been documented. They are generally not prescribed, although they are neccessary for the maintenance of biodiversity and productivity. If not ignited by humans, the land scapes would burn sooner or later as a result of lightning. On what basis are they considered 'anthropogenic emissions', whereas fires in other biomes are not?

3. Policies and Measures

This section contains information regarding the actions being taken or envisaged by Botswana to deal with climate change. These activities will reduce the impact of climate change, and will also reduce greenhouse gas emissions.

Policy Context

The long-term vision document for Botswana, Vision 2016, re-emphasises the national principles of Democracy, Development, Self-Reliance and Unity. These principles have always underpinned the National Development Plans, but a fifth has recently been added. The fifth principle, *Botho*, refers to the concept of a well-mannered, courteous, caring and disciplined people who realise their potential for both themselves and for their community.

A National Development Plan for Botswana (NDP) is produced every six years. The eighth NDP summarises Botswana's policies, development progress and plans for the period 1998 to 2003.

Broad priorities to be addressed during implementation of the National Development Plan 8

- Economic diversification
- Employment creation
- Poverty reduction
- Policy reform in the public sector
- Provision of infrastructure and cost recovery
- Human resource development
- Rural development
- Environment and land use policy

Sustainable Development

Botswana acknowledges that long-term growth must be sustainable and consider population growth (including the impact of HIV/AIDS), environmental effects and the rate at which resources are extracted. The Botswana government aims to pursue a policy of sustainable economic diversification in order to achieve long-term economic growth. Direct private sector investment in Botswana will be actively encouraged.

Botswana has a strong tradition of broad consultation in shaping policy. Consultation includes national, district and local government, the private sector, farmers, traders, industrialists, professional and other associations, trade unions, employers, academics and non-governmental organizations.

Co-ordination of Climate Change Activities

Botswana was a founding signatory of the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro in June 1992. Botswana ratified the Convention on 27 January 1994 and it came into force for Botswana on 27 April 1994. The Department of Meteorological Services (DMS), housed within the Ministry of Works, Transport and Communications, is the national focal point responsible for consideration of climate change and for meeting Botswana's obligations under the UNFCCC. The Director of DMS chairs the National Committee on Climate Change (NCCC), which is an advisory body with representation from non-governmental organizations, government departments and ministries and private sector organizations (see Appendix 2). In line with the consultative approach, the NCCC has representatives from 16 institutions. Each representative has an alternate. The Climate Change Secretariat, consisting of four professional officers, is located in the DMS. The organisational structure is shown in Figure 3.1.

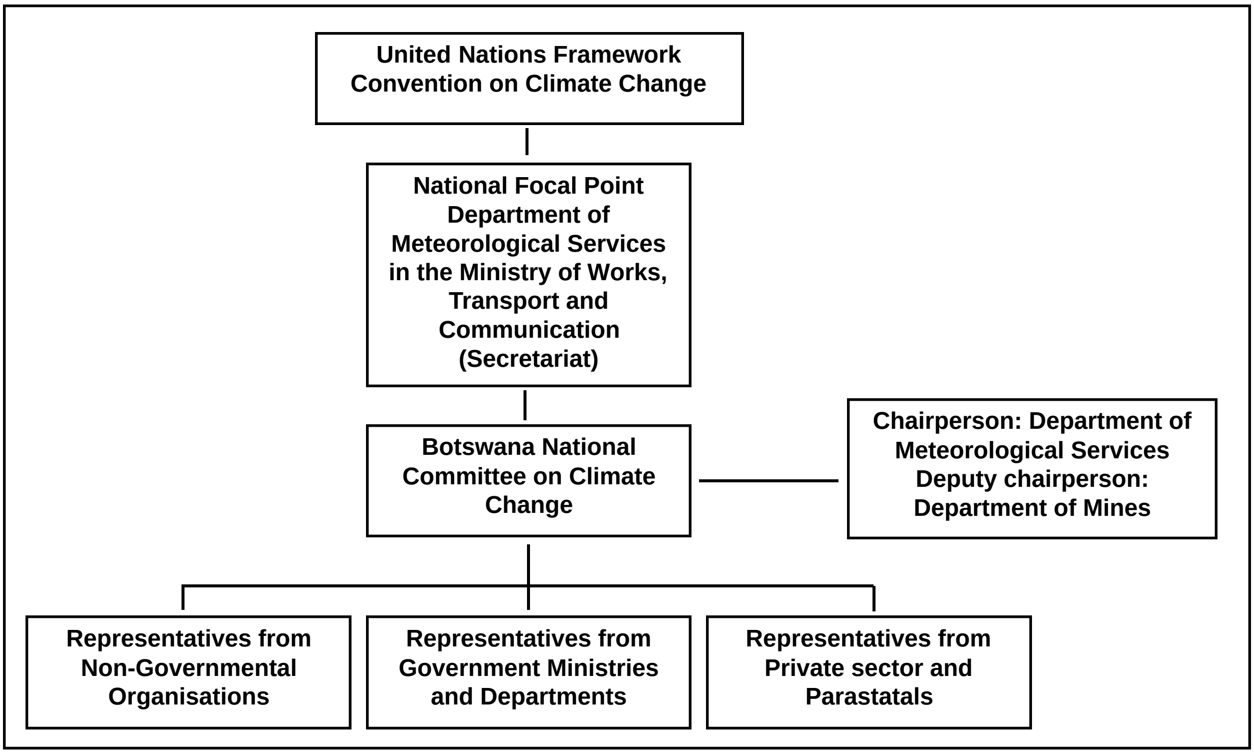


Figure 3.1. Institutional arrangements to deal with climate change issues in Botswana.

The roles of the Climate Change Secretariat include planning and coordination of the elements and activities of the climate change project, communication with stakeholders, public awareness raising and management of the project. Technical reports are reviewed by appropriate experts before the reports are accepted by the NCCC.

International Environmental Conventions and Policy

Botswana has already signed and/or ratified several international conventions and agreements, demonstrating the country's sense of responsibility with respect to international environmental concerns (CSO, 2000).

Botswana's commitment to international environmental conventions

- Wetlands of International Importance (RAMSAR Convention 1971)
- Convention on Biological Diversity (1992)
- The Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES 1973)
- The Vienna Convention on the Protection of the Ozone Layer (1985)
- Montreal Protocol on Substances that Deplete the Ozone Layer (1987)
- Convention to Combat Desertification (1994)
- Convention for the Protection of World Cultural and Natural Heritage (1998)

There is no dedicated policy to respond to climate change in Botswana, but the potential for future climate change and the associated environmental threats is acknowledged in the NDP8, the highest-level national planning document. Climate change issues are addressed in a combination of different policy areas. Within different policy sectors, varying emphasis is placed on environmental considerations and specifically on climate change. Similarly, the obligations under the Montreal Protocol, the Vienna Convention and the Convention to Combat Desertification are being addressed under various national action programmes.

Regional Co-operation

Botswana is a member of the Southern African Development Community (SADC) and the Southern African Customs Union (SACU). There are opportunities for regional cooperation in the development of infrastructure and in harnessing energy and water resources. Both are important as Botswana is a water scarce country and currently imports about 40% of its electricity, and all its liquid fuels (Mid-term Review NDP8, 2000).

In 1994, Angola, Botswana and Namibia signed an agreement to form the permanent Okavango River Basin Commission (OKAKOM). Together these three river basin countries advise on matters relating to the conservation, development and utilization of the Okavango basin. These countries are committed to the negotiation of all transboundary water issues through the commission. Issues addressed include ensuring the long term yield from all potential water resources, and the equitable allocation and sustainable use of water resources in the Okavango catchment Commissions of OKACOM are appointed by the respective governments (CSO, 2000).

Botswana is already a party to an Agreement of the Action Plan for the Environmentally Sound Management of the Common Zambezi River System (ZACPLAN) and the Limpopo River Basin Committee. In addition Botswana supports several environmental SADC Protocols such as the Shared Watercourse Systems (1997), Protocol on Energy (1996), Protocol on Transport, Communications and Meteorology (1997), Protocol on Health (2000), Protocol on Mining (1997), Protocol on the Development of Tourism (1999), and the Protocol on Wildlife Conservation and Law Enforcement (2000).

Botswana has also participated in two SADC studies dealing with energy efficiency and conservation in industry. The Industrial Energy Conservation Pilot Project aimed to promote self-sustaining economic development through activities that would enhance improved energy usage within SADC industries. Following on the success of the pilot project, the SADC Industrial Energy Management Project was initiated. The primary objective of this project was to develop energy management expertise within industry, consulting engineers and technical educational institutions (Zhou and Masundire, 1999).

Overview of Relevant National Policy and other Regulatory Mechanisms

The national *Energy Policy* is coordinated by the Ministry of Mineral Energy and Water Affairs (MMEWA). The Botswana Power Corporation (BPC), a parastatal (i.e. a company created by an act of Parliament and completely owned by the state), is responsible for electricity generation and supply. The implementation of energy-related activities is shared with numerous other ministries, parastatals and NGO's. The Botswana Energy Master Plan sets out the appropriate policies, regulatory mechanisms and institutions to guide the energy sector in reaching national economic and social goals. One of the policy goals is to maintain an appropriate level of engagement with international developments involving global environmental impacts of the energy sector. In order to meet this goal, the Energy Affairs Division participates in Botswana's policy development regarding greenhouse gas emissions and abatement. Apart from this involvement, climate change is not explicitly addressed within the energy policy, although aspects of policy will have a direct bearing on climate change considerations. Within the Energy Master Plan, further policy recommendations include promoting the efficient use of energy, diversification of energy supplies, and the inclusion of social and environmental costs in the price of energy. National energy programmes include, among others, the Rural Electrification Project which promotes the use of solar energy, and the Expanded Coal Utilisation Programme. The latter programme is supported by an active policy to exploit Botswana's large coal reserves in lieu of exploiting the natural woodlands. The public and Government institutions are encouraged to use coal wherever technically feasible and economically sound. The net effect may be an increase in greenhouse gas emissions. There are also plans to continue explorations for gas and oil in the Nossop-Ncojane Basin, and to assess the hydrocarbon potential of the Ngamiland region.

Botswana aims to achieve a balance between the import of electricity from the southern African power pool and its local generation. In 1994, the ratio of local electricity generation to import was 75:25 and was expected to shift to 44:56 in 2000; in fact, however, Botswana presently imports 40% of her power supply requirements (Mid-term Review of the NDP8, 2000). Within the NDP8, environmental concerns related to energy are not perceived as posing a serious threat. This perception will be regularly assessed.

The ***Revised Industrial Development Policy*** was approved by Parliament in December 1997 and aims to foster a core manufacturing capacity in Botswana that is export oriented, efficient, competitive and sustainable. It is envisaged that small and medium scale component and supplier firms will support the larger core enterprises. Sustainable exploitation of the natural resource base and control of emissions from industry are not explicitly considered.

As Botswana becomes more affluent, industrial and urbanized, control of vehicle emissions is recognized as an emerging issue. The importation of second-hand vehicles has increased because of a reduction in import duties and may result in an increase in vehicle emissions. Provision to control vehicle exhaust emissions has been made through the ***Road Traffic Act*** (revised 1987). There are also suggestions that air pollution may be controlled through the introduction of metered parking in certain urban areas. There is no policy to promote the use of mass transit transport or non-motorised transport. The transport sector is the largest consumer of petroleum products, all of which are imported from neighbouring countries.

The ***Waste Management Act of 1998*** requires that waste management plans be prepared, and where possible that waste be recycled. Local authorities are obligated to license all landfills, most of which will need rehabilitation or to be closed and redesigned. Ground water pollution will also be reduced by replacing the ventilated improved pit latrines with dry compost technology. This new on-site sanitation technology is currently being assessed and piloted (Mid-term Review NDP8, 2000).

The ***Atmospheric Pollution (Prevention) Act*** regulates the emission of gases into the atmosphere. Registration certificates are also issued before certain industrial processes may be conducted. Air pollution control is the responsibility of the Department of Mines and is focused on major industrial sources. Intensive air quality monitoring takes place in some locations such as Gaborone and Selibe Pikwe. There are plans to establish a national environmental laboratory and to expand the air pollution network by establishing stations in major settlements.

The ***Mines, Quarries, Works and Machinery Act (1978)*** ensures the sustainable management and control of the mining industry. The safety, health and welfare of persons involved in prospecting, mining and quarrying operations are addressed in the regulations. Precautions with respect to harmful toxic and inflammable gases, fire prevention and underground fuel storage are stipulated. The ***Mines and Minerals Act (1999)*** requires that mining areas be rehabilitated and that wasteful mining practices be avoided. Regulations are in place to ensure protection of the environment; these include restoration of top soil after mining. Further, a requirement for Environmental Impact Assessments of planned projects was introduced in the Mines and Minerals Act (Mid-term Review NDP 8, 2000).

The ***National Conservation Strategy*** (NCS) is a multi-sectoral policy that addresses all aspects of the environment. Co-ordination of the strategy across government departments and other organizations is the responsibility of the National Conservation Strategy Agency. The NCS is aimed at pursuing policies and measures to increase the effectiveness of natural resource use and management, and to integrate the work of the many sectoral Ministries and interest groups throughout Botswana. Fulfillment of development and conservation goals requires that development be designed so as to minimize environmental costs and to enhance environmental quality. Issues addressed within the NCS include:

- Growing pressure on water resources;
- Degradation of rangeland pasture resources;
- Depletion of wood resources;
- Overuse or exploitation of some natural veld products; and
- Pollution of water, air, soil and vegetation resources.

The intention to reduce local emissions of gases such as CO_2 and NO_x will also reduce global emissions. The National Conservation Strategy aims to reduce rangeland and pasture degradation, the depletion of wood resources and the dumping of waste - all of which will ultimately impact on climate change.

Expanding livestock and wildlife herds, drought-coping strategies, and unsustainable woodland forestry are important issues for the conservation of the natural resource base and the alleviation of rural poverty. The ***Rural Development Policy*** aims to address poverty through increasing agricultural incomes and through employment creation. The policy is currently undergoing a review with the intention of improving project planning and productivity as well as creating employment and increasing opportunities for income generation. Major challenges include halting environmental degradation, the review of drought relief programmes, and supporting development in rural areas (Mid-term Review NDP8). Government also recognizes the need to review existing resource-use practices and to identify appropriate strategies for promoting sustainable use and management. An approach based on ***Community-Based Natural Resource Management (CBNRM)*** is advocated in that it encourages communities to manage their own resources through Community Based Organisation (CBO's). Natural resources such as fuelwood, flora and fauna and various veld products are used sustainably to ensure that these resources are not depleted, but are instead valued. CBNRM is both a conservation and rural development strategy, involving community mobilisation and organisation, institutional development, training, enterprise development and monitoring of the natural resource base. Protection of woodland resources, and the continued sustainable use of biomass fuels, are important for maintaining Botswana's current favourable greenhouse gas emission status.

The ***Forest Act of 1980*** provides for the better regulation and protection of forests and forest produce in Botswana. The Act prohibits the setting of fires, stock grazing, crop cultivation and the damage or removal of forest produce within State-proclaimed forest reserves. Government is currently developing a new forest policy which will amend the existing legislation. The new policy which is intended to regulate the development and use of natural forests will also increase the potential for Botswana to be a carbon sink (Zhou and Masundire, 1999).

Crop cultivation, livestock grazing and watering, vegetation clearing and afforestation are regulated within the ***Agricultural Resources (Conservation) Act.*** The maximum number of stock per stock class that may be kept in an area is also controlled under this legislation.

The ***National Settlement Policy*** aims to reduce the demand for land by encouraging intensive farming practices and promoting land use planning. The policy also promotes the upgrading of villages to urban status and a resultant shift from agricultural activities to other enterprises.

The increasing importance of environment and development is illustrated by the inclusion for the first time of a separate chapter on environmental conservation and land use in the NDP8. Government recognises the conflicts between different legislation which governs land use. During implementation of the NDP8, government aims to streamline the Land Use Policy to reduce the conflict between population growth and environmental degradation. There are policies and programmes, amongst others, to combat overgrazing, deforestation and indiscriminate waste disposal, all of which partly address climate change issues.

Mitigation Options

The objective of the UNFCCC is to stabilize the concentration of greenhouse gases in the atmosphere to a level that will prevent human interference with climate systems. Identifying ways and means of reducing the rate of greenhouse gas emissions is thus a priority - particularly for developed countries. In Botswana, a number of policies and measures are already in place which incidentally take climate change issues into consideration, and as a consequence will bring about a reduction in greenhouse gas emissions. Furthermore, many Acts are currently under review, and will be revised to take climate change considerations into account. Through the implementation of existing policies and the development of new policies, an enabling environment exists for inclusion of relevant mitigation options.

Scenarios in which GHG emissions are reduced or mitigated relative to a baseline case were analysed for both the energy and non-energy sectors (Zhou, 1999b, c) up to the year 2030 (long term scenario), with a short term scenario considered for the period 1994 to 2005. The baseline scenario was constructed using the Macro-Economic Model of Botswana, the Botswana Energy Master Plan, and the Long Range Alternative Planning (LEAP) model.

Population and economic factors were considered to be the main drivers of growth in both the energy and non-energy sectors. The short term economic projection was based on Botswana's 7th and 8th National Development Plans, whereas the long term projection was based on the Vision 2016 development plan. Population growth will directly impact on the future energy demand. The annual average population growth rate is estimated at 2.5% between 1994 and 2005 and about 2.1% until 2030. These estimates take into consideration the impact of the HIV/AIDS epidemic on the population as derived by the CSO (CSO 1996, Zhou, 1999c). Projected population figures used in the mitigation study are shown below.

Table 3.1. The projected *de facto* populations for Botswana (used to estimate growth rates, emissions, and abatement costs for the energy and non-energy sectors).

1991 (census year)	1994	2005	2030
1 326 796	1 425 398	1 963 891	3 689 793

The cost of introducing a new technology as a mitigation option must be discounted to the present value to enable decision-makers to make informed choices. An assumed discount rate of 6% was used for both the energy and non-energy sectors. This rate is also applied to Government development projects.

In mitigation analysis, the preferred costs or prices are the factor costs (these exclude taxes and subsidies). However, relating local prices to factor costs is difficult so was not attempted in either the energy or non-energy sector mitigation study. This approach is justified as it provides the consumer perspective and is based on the insight that investment decisions are made on the basis of actual costs. In Botswana, there are no major subsidies and import tax is about 10%. An additional 10% is added if goods are imported from outside the SACU. Thus if factor costs are required, the final costs of GHG reduction per tonne could be reduced by as much as 20% (Zhou, 1999b and c).

Energy Sector

A portfolio of abatement options was identified for the energy sector. The greenhouse gas abatement costing model (GACMO) was used to calculate the abatement costs and the potential reduction in GHG emissions from the abatement options. The cost of GHG reduction per ton and the total reduction potential for each option were sequenced in a cost curve for both the short and long term scenarios. Of the twenty options considered, nine could be implemented at negative cost (in other words, it would be profitable in the medium to long term to implement them, regardless of greenhouse gas reduction benefits).

Most of the negative-cost mitigation options can be implemented in households with limited financial resources. The cost of mitigation options in the transport sector relates to savings in diesel and responds to economies of scale. Thus, as is evident in Table 3.2, transport costs change over the long term scenario. The cost of establishing a pipeline shifts from a positive cost of 184.82 BWP/ton in 2005 to a negative cost of 301.5 BWP/ton in 2030 when fuel demand has increased sufficiently to warrant the pipeline.

Table 3.2. Abatement options, costs and potential for the reduction of greenhouse gas emissions in the energy sector (Zhou 1999c).

Mitigation option	Description and rationale	2005 scenario		2030 scenario	
		Cost of GHG reduction (BWP/ton CO_2)	Cumulative GHG reduction (CO_2 equivalent Mt/year)	Cost of GHG reduction (BWP/ton)	Cumulative GHG reduction (CO_2 equivalent Mt/year)
Paved roads	Less fuel consumed on paved roads	-660.4	0.30	-660.4	0.30
Conversion of road freight to rail freight	Rail is less energy intense and less road maintenance will be necessary	-501.7	0.38	-501.7	0.46
Efficient lighting	Use of compact fluorescent lamp (CFL) instead of incandescent bulbs	-495.3	0.45	-495.3	0.63
Zero-tillage	No diesel Tractors used – direct broadcast of seed	-493.2	0.46	-381.8 to -493.2	0.64
Pre-payment meters	Electricity conservation through awareness of costs	-111.2	0.54	-111.2	0.73
Geyser time switches	On switch is timed for when hot water is needed.	-84.4	0.71	-84.4	1.02
Solar home systems	Use of solar power for lighting and light electrical appliances	-67.9	0.71	-67.9	1.45
Power factor correction	Results in reduction of power loss	-47.6	0.74	-47.6	1.46
Efficient boilers	Boilers fitted with economizers to reduce coal consumption	-36.7	0.75	-36.7	1.49
Differential fuel pricing	Diesel vehicles have a lower fuel intensity	0.0	0.77	0.0	1.52
Efficient motors	Saving on electricity consumption	2.4	0.85	2.4	1.52
Biogas from landfills	CH_4 from waste used to generate electricity	0.0 to 5.4	0.98	0.0	1.67
Vehicle inspection	Promote roadworthiness and better fuel efficiency	3.2 to 8.7	1.48	3.2	2.16
Solar geysers	Use of solar energy for water heating	27.2	1.48	27.2	2.47
Biogas for rural households	Use of cattle dung in biogas plants for cooking, lighting, water heating	55.1	1.57	55.1	2.48
Central photovoltaic electricity	Centralised solar power plants to replace coal-based electricity	44.6 to 85.3	1.57	44.6	2.70
Pipeline for petroleum products	Shift from road and rail transport will produce savings in diesel costs	184.82	1.61	-301.5	2.84
Solar photovoltaic water pumps	Use of solar energy for pumping groundwater	223.3	1.65	223.3	2.91
Reforestation	Replacement of depleted fuelwood reserves	342.1	1.72	342.1	2.98
Diesel to electric rail	Electric locomotives can carry more than diesel locomotives	4 080.1	1.75 1	784.5	3.04
Total baseline emissions			**7.32**		**11.74**
GHG reduction (%)			**24**		**26**

All of the mitigation options were then considered in conjunction with the development plans of Botswana and their possible impacts on the economy. Each mitigation option was assessed against the following criteria and scored for its positive impacts.

Implementation aspects	Macro economic impact assessment criteria
• Institutional capacity • Difficulty in organising and the required lead time • Transaction costs not included in cost analysis • Short and long term effects and sustainability • Government position or policy	• Impact on balance of payments • Revenue collection • Employment loss or creation • Savings on energy consumption and avoided fuel import bills or deferred investments • Improvement in economic efficiency • Cross-sectoral linkages • Improvement in health aspects • Improvement of social standards • Land rehabilitation

The total number of positive impacts for each mitigation option determined the final ranking of the mitigation options and their sequencing as shown in Table 3.3.

This sequence ranking of options could form the basis of the strategic abatement framework for Botswana. The sequence of implementation could be adapted to suit financial circumstances. For example, the implementation of solar photovoltaic pumps will require a large capital expenditure which will not be immediately affordable, even with strong governmental support and subsidies. Some of the options that are not highly ranked, such as zero-tillage agriculture, could be immediately implemented once appropriate policies are in place. However, before any implementation programmes are initiated, a rigorous assessment of each abatement option is warranted. Feasibility, practicality, cost and cultural acceptance must be fully investigated.

Table 3.3. Re-prioritisation of GHG abatement options based on national development interests (Zhou, 1999c).

Ranking	Description of abatement option	Cost of reduction (BWP/ton) for 2005[a]
1	Vehicle inspection	8.7 (3.18)
2	Prepayment meters	-111.2
	Solar home systems	-67.9
3	Efficient lighting	-495.3
	Landfill gas for power generation	0.0 to 5.4
	Paved roads	-660.4
4	Biogas for rural households	55.1
	Solar photovoltaic pumps	223.3
5	Efficient boilers	-36.7
	Geyser time switches	-84.4
	Power factor correction	-47.6
	Efficient motors	2.4
	Reforestation	342.1
6	Solar geysers – water heaters	27.2
7	Zero tillage in agriculture	-493.2
8	Conversion of road to rail freight	-501.2
	Fuel switch from petrol to diesel through differential pricing	0.0
	Central photovoltaic plants	85.3
	Pipeline for petroleum products	184.82 (-301.5)
	Electrification of the railway line	4 080.1 (1784.8)

Note: a) Cost values in parenthesis are given for the long term (2030) scenario where these differ from the short term (2005) scenario.

Non-energy Sector

The study of mitigation options for the non-energy sector focussed on land use and forestry, agriculture, waste and industry. As in the energy sector, both a short term and long term scenario were considered. Nine mitigation options for the non-energy sector were identified (Table 3.4).

Table 3.4. GHG mitigation options, costs and reduction potential for the non-energy sector in Botswana. (Zhou, 1999b)

Mitigation option	Description and rationale	Cost of GHG reduction (BWP/ton)	Cumulative GHG reduction (Mt/yr) 2005	2030
Cooking stoves	Replacement of open fires with fuelwood stoves to improve fuel use efficiency	-237.3	0.183	0.268
Natural woodlands management	Meet the increasing need for forest products	-14.9	3.262	3.106
Solid waste	Use of CH_4 from solid waste landfills as energy source	-4.1	3.562	3.780
Substitute wooden poles with steel fencing	Reduce demand on forest resources for wooden poles	7.7	3.918	4.224
Afforestation	Establishment of woodlots to supply fencing and fuelwood needs	44.4	4.303	5.071
Veld fire guarding	Reduce emissions from veld fires	1.4.8	4.413	5.167
Cattle feed	Cattle feed boosts beef production and reduces grazing pressure	316.2	4.418	5.182
Replace SF_6 circuit breakers with air blasts	Reduce release of SF_6 to atmosphere	374.6	4.418	5.183
Manure biogas	Manure at abattoirs used in biogas plants to generate energy	4483.3	4.423	5.201
Baseline total emissions			**-34.6Mt**	**-30.3Mt**
% GHG reduction			**13%**	**17%**

Three of the nine options can be implemented at negative cost. These are the preservation of forests through the use of cooking stoves, management of natural woodlands, and the use of solid waste to generate methane as an energy source.

As for the energy sector, these mitigation and abatement options were assessed against the national development priorities. The options were then ranked according to the number of positive impacts that would be derived if that mitigation option were implemented (Table 3.5).

Table 3.5. Prioritisation of GHG mitigation options for the non-energy sector based on national development interests (Zhou, 1999b).

Ranking	Mitigation option	Cost of GHG reduction (BWP/ton)
1	Solid waste	-4.1
2	Afforestation	44.4
	Veld fire guarding	104.8
3	Wood cooking stoves	-237.3
	Natural woodlands management	-14.9
4	Substitute wooden poles with steel fencing	7.7
5	Manure biogas	4 483.3
6	Cattle feed	316.2
7	Replace SF_6 circuit breakers with air blasts	374.6

Selection of Mitigation Options

There is a significant potential to reduce GHG emissions in Botswana by applying a number of mitigation options in both the energy and non-energy sectors (Table 3.6). The non-energy sector is already a net sink of carbon and this capacity can be further increased by adopting some or all of the suggested mitigation options.

Table 3.6. Reduction potential of GHG emissions for both the energy and non-energy sectors.

Scenario	2005 emissions (Gg CO_2 equivalent)	2030 emissions (Gg CO_2 equivalent)
Energy sector		
Baseline	7 317	11 739
Mitigation	1 750	3 070
Reduction	24%	26%
Non-energy sector		
Baseline	-34 621	-30 332
Mitigation	-39 044	-35 534
Reduction	13%	17%

Appropriate government policies to implement mitigation options are needed if the further reduction of GHG emissions is to be achieved. Raising awareness of climate change mitigation options within non-governmental organizations, the private sector, government and other stakeholders is essential to ensure that implementation is timely. It must be noted that the adoption and implementation of abatement options must be performed with due care. National development priorities have already been used to identify abatement options that can be implemented. Nevertheless, each option should be scrutinized carefully with regard to its appropriateness, cost and possible cumulative effects if adopted.

A rigorous assessment of suggested mitigation measures must be performed to select those that are relevant and appropriate. The adoption of measures that are feasible elsewhere, even within southern Africa, may not be suited to conditions prevailing in Botswana.

As a first step, a “no-regrets” philosophy should be adopted to identify mitigation options that will be of benefit to the country regardless of climate change considerations. Examples would include vehicle inspections which would lead to a reduction in vehicle-related deaths due to poor maintenance. More efficient lighting, boilers and motors would also be beneficial because they would lead to cost savings.

Once mitigation options have been identified and implemented on the "no-regrets" basis, attention can then be focused on options where the benefits and costs must be weighed. Considerations of risk and transaction costs must be analysed together with the conditions under which the measures could be implemented.

A number of the mitigation options described for both the energy and non-energy sectors are already being implemented at various scales in Botswana. The Rural Industries Innovation Center (RIIC) introduced biogas technology to Botswana in the 1970's but commercial use for water pumping only started in the 1980's. The use of biogas is however limited as animals are seldom gathered together in pens, thus the collection of animal manure is difficult. There is potential to apply biogas technology on a small scale at abattoirs such as in Maun and Francistown. Opportunities to generate methane from urban landfills and sewage ponds for use in households is a possibility that requires further investigation (CSO, 2000). The RIIC also provides a National Photo-voltaic Innovation scheme to promote the photovoltaic form of energy supply. Loans are provided which are repayable over a four-year period. Pre-paid meters to conserve electricity have been installed in 9 000 households. More efficient lighting systems, such as compact fluorescent bulbs, are in use by some hotels and new government buildings (Zhou, 1999c). Solar power is also in use – particularly in rural areas which are located far from the national power grid. A small mini-grid photovoltaic station is currently operating at Motshegaletau.

Actions Taken in Support of the Convention

Botswana is fulfilling its obligation to the UN FCCC through the following actions:

- Reports on greenhouse gas emissions for 1990 and 1994;
- Adaptive or mitigation strategies identified for key sectors (energy, land use and forestry, waste, agriculture and industry);
- Impacts and vulnerability studies for forestry, crops, health, water and livestock;
- A process of public awareness-raising has been initiated; and
- Observation and research networks in support of climate change information are maintained.

Recommendations

Botswana is actively encouraging growth in all sectors of its economy. An increase in demand for water, land and energy to meet the needs of both a growing population and economy is anticipated. The resultant increase in energy needs will lead to an increase in greenhouse gas emissions, which must be balanced against the international need to limit climate change. These features will strongly influence Botswana's position in the climate change policy arena. Botswana is a net sink of GHG, but is also highly vulnerable to climate change. Several mitigation options are available to permit development at a lower trajectory of emissions provided the necessary policies, incentives and technology are in place. A rigorous assessment of the suggested mitigation options is a priority area for further investigations.

4. Projected Impacts and Vulnerability Assessment

This section summarises the studies which have been done on the vulnerability of people, agriculture and ecosystems in Botswana to climate change, and how they may adapt.

Magnitude of Change

A variety of climate simulation models agree that Botswana will be, on average, 1-3˚C warmer by around 2050 than it is at present (Figure 4.1 and 4.2). The models are less unanimous regarding future trends in rainfall. Most predict that the mean annual rainfall will be about 10% to 25% less by that time, while some predict an increase in rain of about 10%. The assessments, given below, of climate change impacts for specific sectors cover this range of uncertainty, and were based largely on predictions of the U.K. Meteorological Office model (UKTR), the Canadian Climate Centre model (CCC), and the Oregon State University model (OSU) as they stood in the mid 1990s. Since that time, the models have improved and many more are available. On balance, they show greater warming and a decrease in rainfall.

The historical trends in mean annual temperature over Botswana are shown in Figure 4.3. There has been an increasing trend over the period of observation of about 1.0°C. The historical trend in rainfall amounts shows no overall trend (Figure 4.4) but shows periods of above and below average rainfall which usually coincide with ENSO events.

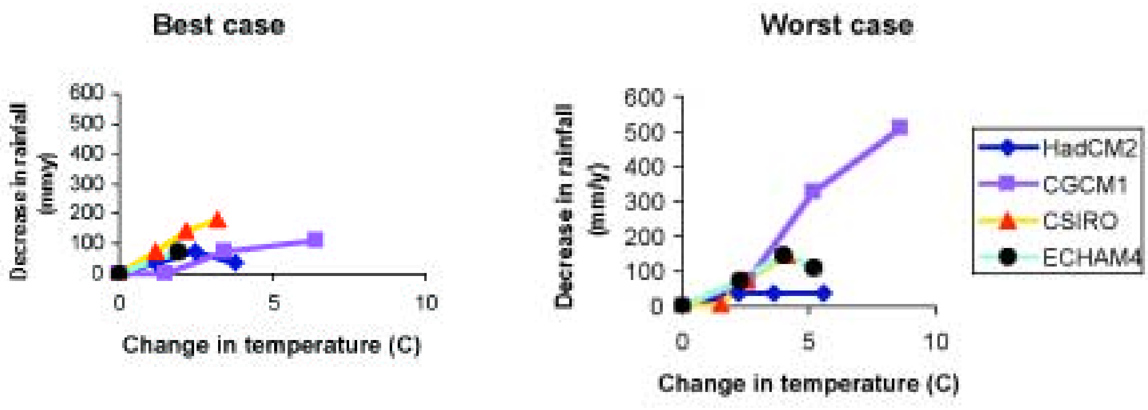


Figure 4.1. Changes in mean annual temperature and mean annual rainfall relative to the 1961-1990 average for the Botswana region, as predicted by a selection of global circulation models.

The 'Worst Case' scenario is the 1992a emission scenario with no sulphate aerosols, and the 'Best Case' scenario is the 1992d emission scenario, with the inclusion of sulphate aerosols. The first marker on the trajectory is the 1990 prediction, the second is the change predicted for 2020, the third is for 2050 and the last marker is for 2080. HadCM2 is the Hadley Centre model from the U.K., ECHAM4 is the European climate change model, CSIRO comes from Australia, and CGCM1 is the Canadian model. Source: IPCC Data Distribution Centre, Nov 2000 (http://ipcc-ddc.cru.uea.ac.uk).

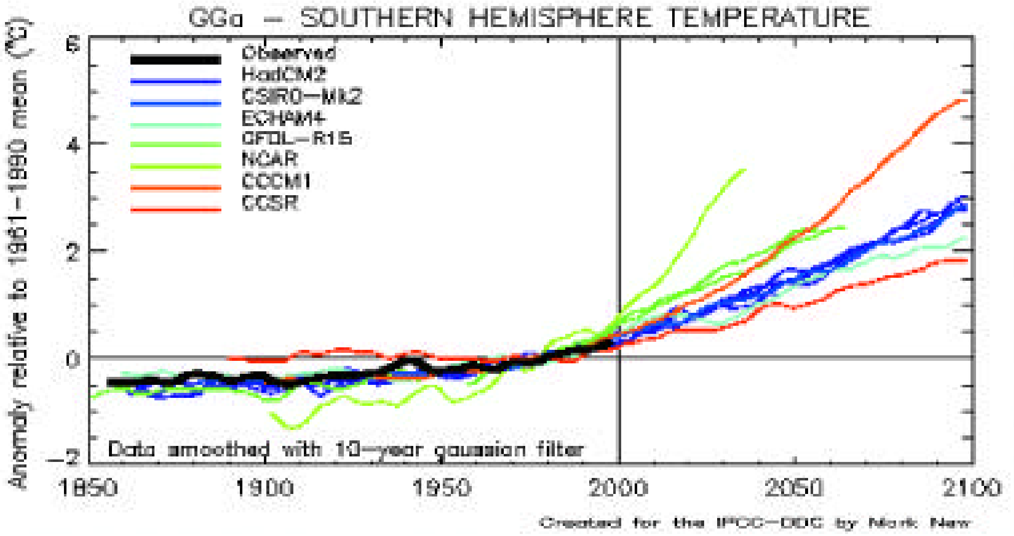


Figure 4.2. Predictions of future temperature change in the southern hemisphere by a variety of models, driven by the 1992a emissions scenario, without sulphate aerosols. Temperature rise in Botswana would be expected to be slightly higher than the southern Hemisphere average. Source: IPCC Data Distribution Centre, Nov 2000 (http://ipcc-ddc.cru.uea.ac.uk).

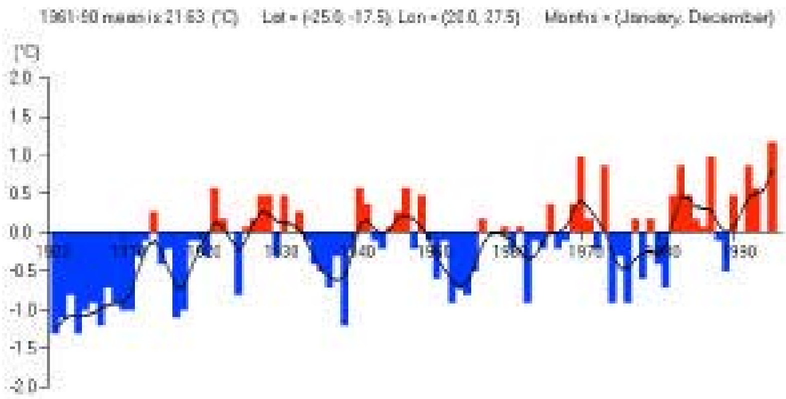


Figure 4.3. Long-term temperature trend for Botswana. Source: IPCC Data Distribution Centre, Nov 2000 (http://ipcc-ddc.cru.uea.ac.uk).

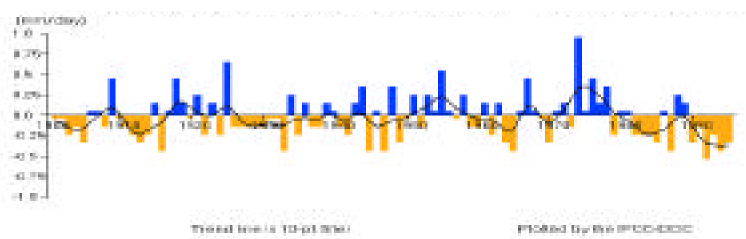


Figure 4.4. Long-term rainfall trend for Botswana. Source: IPCC Data Distribution Centre, Nov 2000 (http://ipcc-ddc.cru.uea.ac.uk).

Climate Change Scenarios for Botswana

The warming projection that is used by the IPCC (Intergovernmental Panel on Climate Change) is usually taken to be the central emission scenario for the 21st century (Legget et al., 1992) for most global warming studies. This warming projection was used for the Botswana climate scenarios as discussed below. The global temperature rise with this mid-range scenario is 1.7°C and the CO_2 concentration associated with it lies between 530 and 590 ppmv. The IPCC scenario as described above projects world population at 10 billion by 2050 and takes into account energy consumption by different energy mixes. Included also are emissions from other greenhouse gases such as methane and nitrous oxide and from halocarbons (Ozone Secretariat, 1997) as agreed upon under the Montreal protocol and its amendments.

Climate change experiments that have been conducted with GCMs (Graphic Climate Model) will now be presented to show how the IPCCs mid-range scenario translates into recognizable patterns of climatic change over Botswana. Possible changes in climate over southern Africa, which includes Botswana, have been studied using a variety of models put together in the Scenario Generator (SCENGEN) software by Hulme *et al.* (1996).

Climatic variables of interest (temperature and rainfall in this report) are simulated on a monthly basis using the 1961-90 climate base period. Due to the different philosophies used in the GCMs, results of climate change simulations are not always the same between two or more models. In this report, results of the UKTR GCM are considered to be the primary scenario for making adaptive and other preparatory measures for a changed climate in Botswana. This is because the UKTR model is a coupled ocean atmospheric model which according to Hulme *et al.* (1996) and Joubert (1995) attempts to simulate ENSO-like events that bring about rainfall variability across southern Africa. In order to represent the range of extremes that may take place in rainfall, two other models, which show greater drying or wetting, are also reported. These are simulation results from the Oregon State University (OSU) GCM (Schlesinger and Zhao, 1989) and the Canadian Climate Centre (CCC) GCM (McFarlene *et al.,* 1992) respectively. This approach of using a variety of GCMs that span the range of precipitation changes in an area has been used elsewhere (Conway *et al.,* 1996) and is now becoming one option of resolving the uncertainty in precipitation simulation.

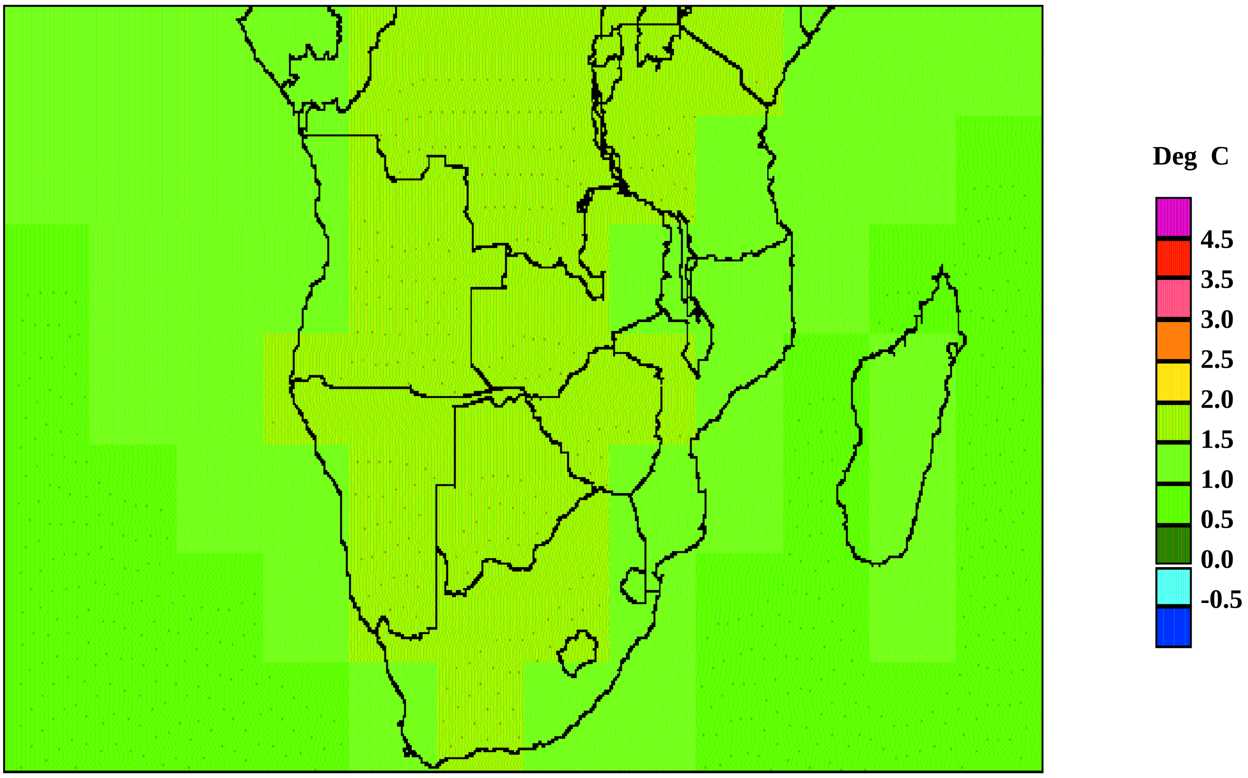
With respect to temperature (and using the core scenario experiment), Botswana and surrounding countries may warm by 2°C by 2050 (Figure 4.5). This projection represents a rate of warming of about 0.27°C per decade (calculated from 1976 to 2050 with the temperature change expressed on decadal basis) which is about four times the rate of warming that has been experienced in the region during the present century. A comparison of this warming trend to the drought/warm decade of 1985-95 which was 0.3°C more than the 1961-90 average temperatures clearly indicates that some of the projected warming in Botswana may have taken place already. It should be noted that the expected annual rise in temperature will be modified by other factors such as cloud on a monthly basis (note the temperature changes during the peak rain season in the lower half of Figure 4.5 which indicates a temperature decrease by a few tenths of a degree Celsius due to cloudiness). The decrease in temperature during the rainfall season is most pronounced in the southeastern half of the country. Projected temperature increases as shown in Figure 4.5 are likely to lead to increased open water and soil/plant evaporation. The exact magnitudes of the increase depend on several factors including physiological changes in plant biology, atmospheric circulation and land use patterns. The manner in which high temperatures will affect physiological processes of plants however is highly uncertain.

Even though there are problems in modelling rainfall due to the poor representation of internal and external factors which bring about rainfall variability, the core scenario (Figure 4.6) shows annual decreases of down to 5% for much of the northern and western districts of Botswana. Southeastern districts have a slight increase of 5% in annual rainfall. On a monthly basis (lower half of Figure 4.6), there is an increase of rainfall during the peak rainfall months of December, January and February of between 10 and 20%. The rest of the months experience reduced rainfall (not shown in the map) and this generally brings about reduced annual rainfall as depicted in the top map of Figure 4.6. The monthly description of rainfall suggests that the rainfall season will be shorter or less reliable by the 2050s in comparison to the base period of 1961-90.

The rainfall change as simulated using the core scenario (a transient model) represents a gradual evolution of climate as the atmosphere is subjected to gradual increases of atmospheric greenhouse gases. Natural variability can therefore obscure changes in rain due to greenhouse forcing. Since natural variability is difficult to separate from greenhouse gas-induced changes, only qualified conclusions can be made regarding simulated changes in rainfall due to greenhouse gas increases alone.

Climate scenario results as presented above using the core scenario may be realized earlier or later depending on the sensitivity of the climate system. If the system is not extremely sensitive, changes may be delayed until much later than the simulation period (2050s). If the climate system is very sensitive, then climate change under the core scenario could occur earlier than 2050. The timing of the core scenario can thus be represented as alternative patterns of climate change. In the case of a delayed response, this may be represented by the OSU GCM, in which annual rainfall increases of up to 20% or more may be expected across northern Botswana and increases of between 10 to 20% for the rest of the country (Figure 4.7). The main rainfall months of December, January and February (lower half of Figure 4.7) have rainfall increases of 20% for much of the country. When the response of the climate system is rapid, this could result in rapid warming and this is represented by the CCC GCM where annual rainfall may decrease by 5 to 10% in the eastern half of the country and by 0 and 5% for the rest of the country (Figure 4.8). Rainfall does not increase during the peak rainfall months in Botswana with this scenario.

Climatic change scenarios as discussed above do not address land cover changes which could come about due to natural or human activities. This realization complicates further climate change scenario interpretation and use in vulnerability assessments. In spite of these difficulties, GCMs are the recommended vulnerability assessment tools because they provide the best source of information about regional climate change (Smith *et al.,* 1997).



Change in mean temperatures in Southern Africa from December to February

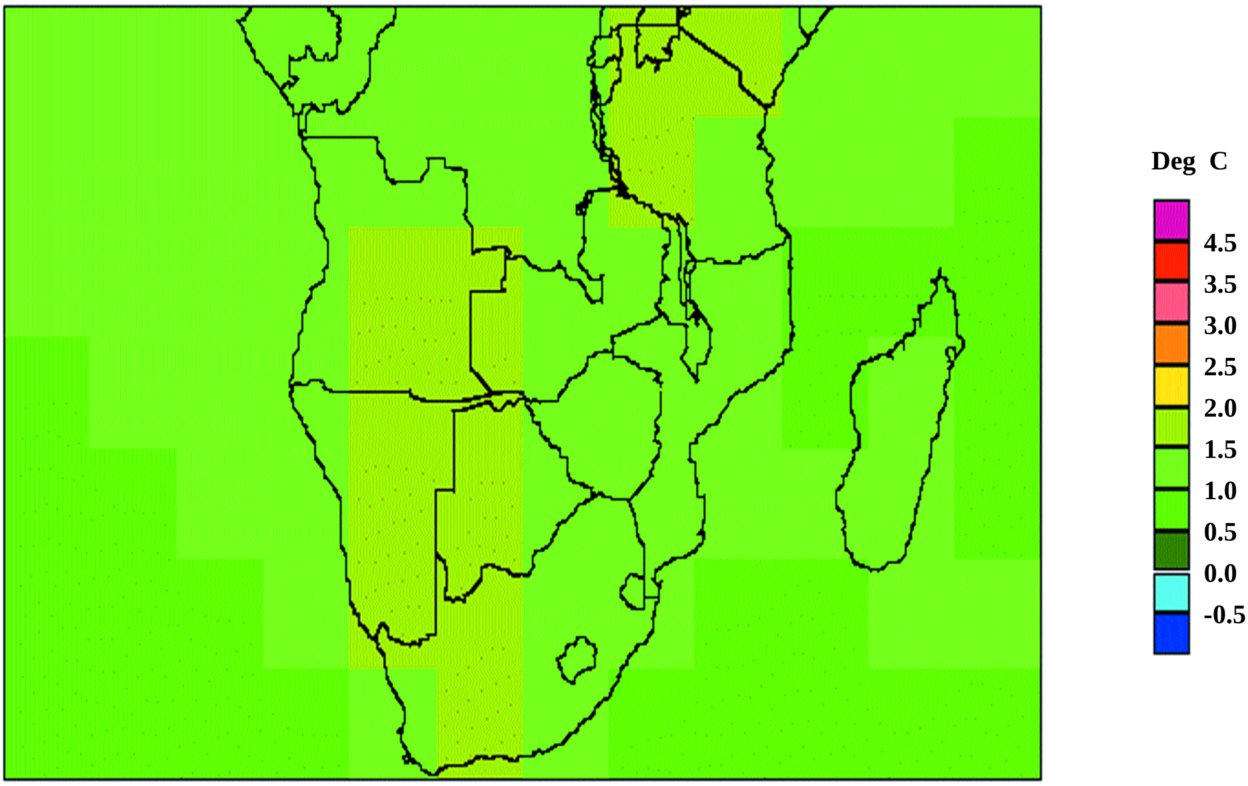
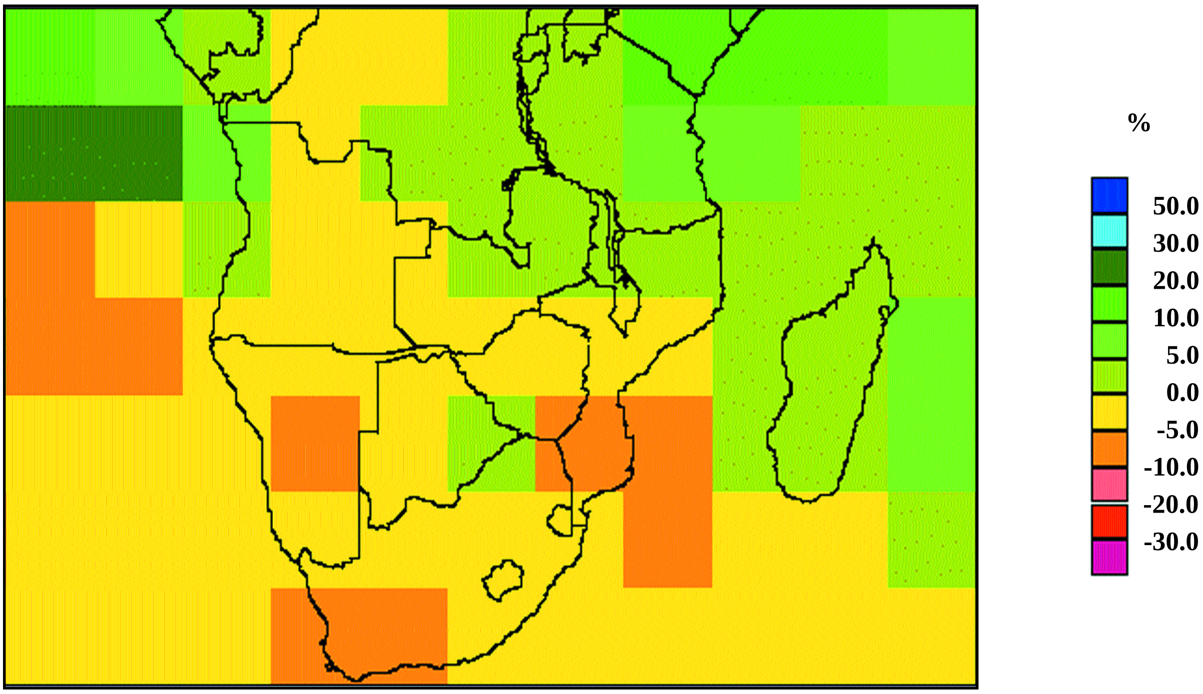


Fig.4.5. Simulated change in mean temperatures in Southern Africa using the UKTR GCM, core scenario (IS92A).



Precipitation over Southern Africa from December to February

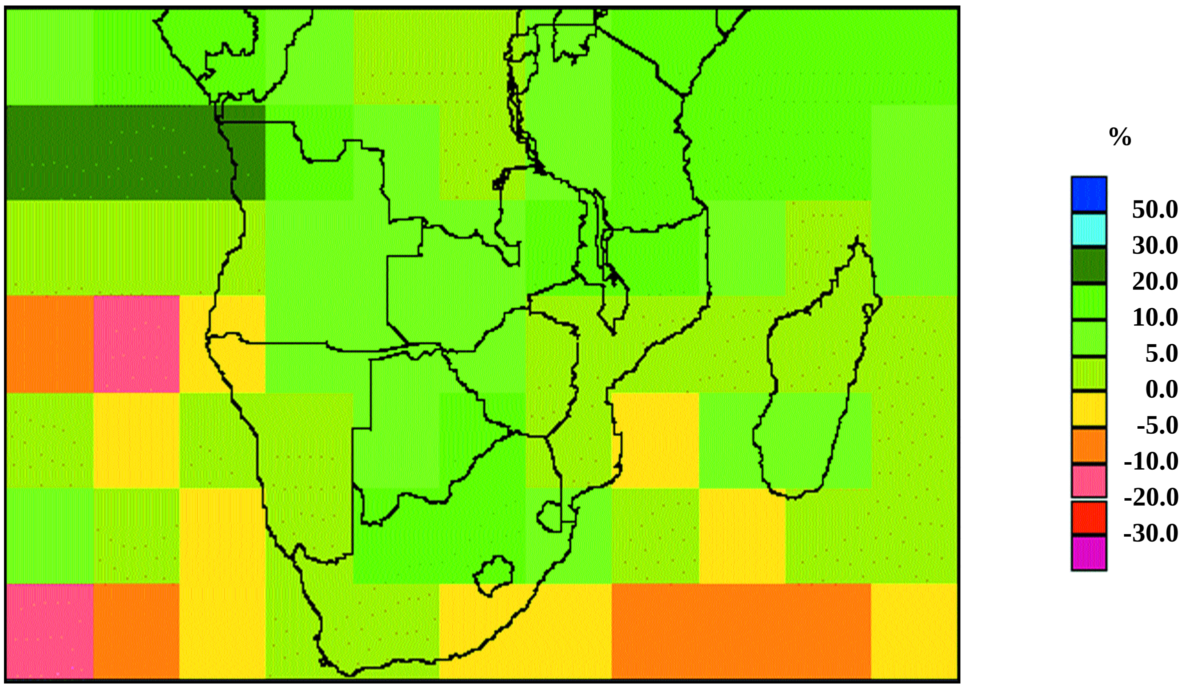
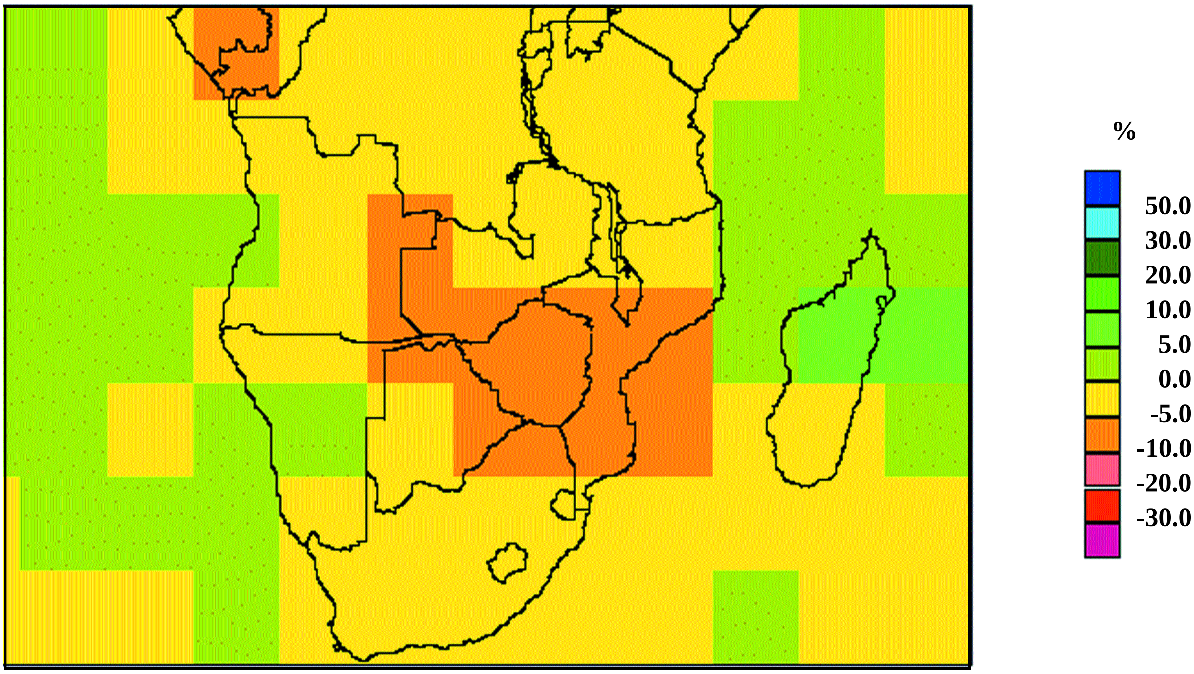


Fig. 4.6. Simulated percentage change in mean annual precipitation over Southern Africa using UKTR GCM, core scenario (IS92A).



Percentage change in mean precipitation from December to February

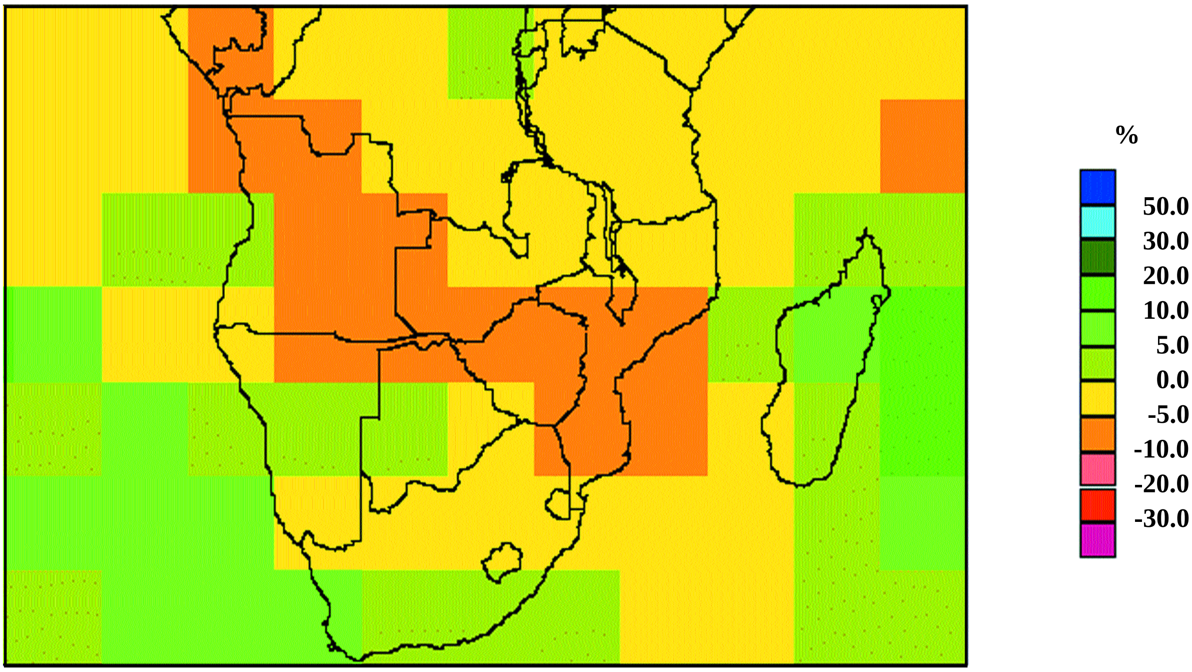
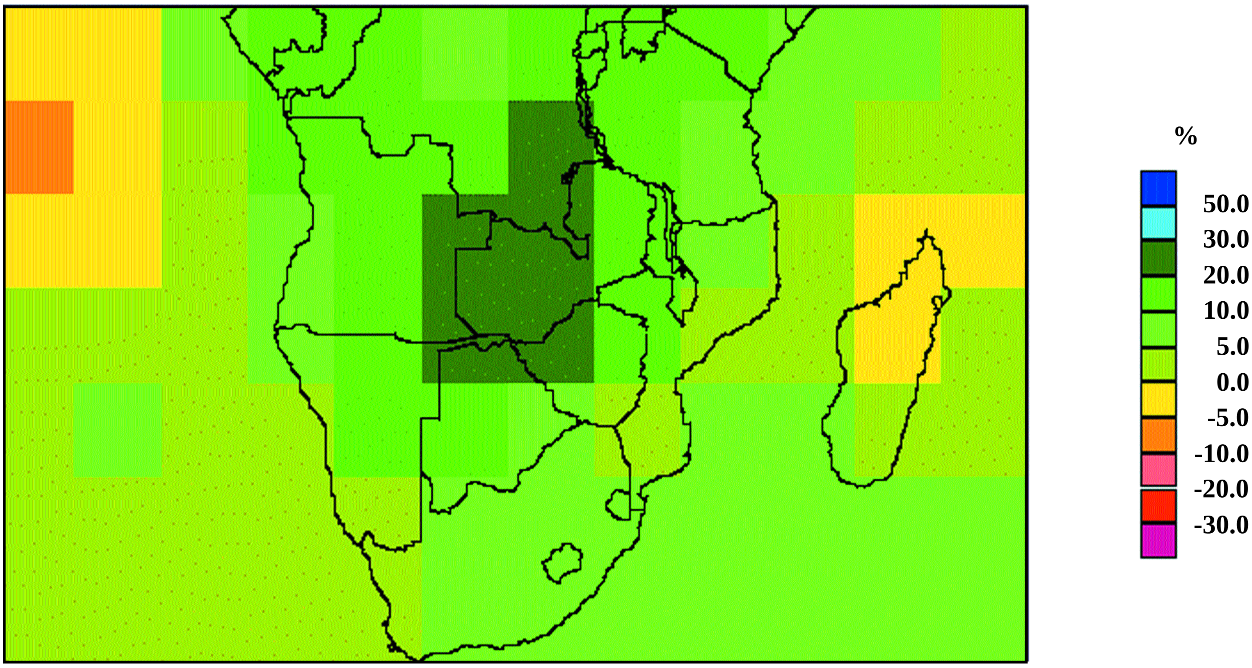


Figure 4.7. Simulated percentage change in mean annual precipitation using the 'drying' scenario CCC GCM, (IS92A).



Percentage change in mean precipitation from December to February

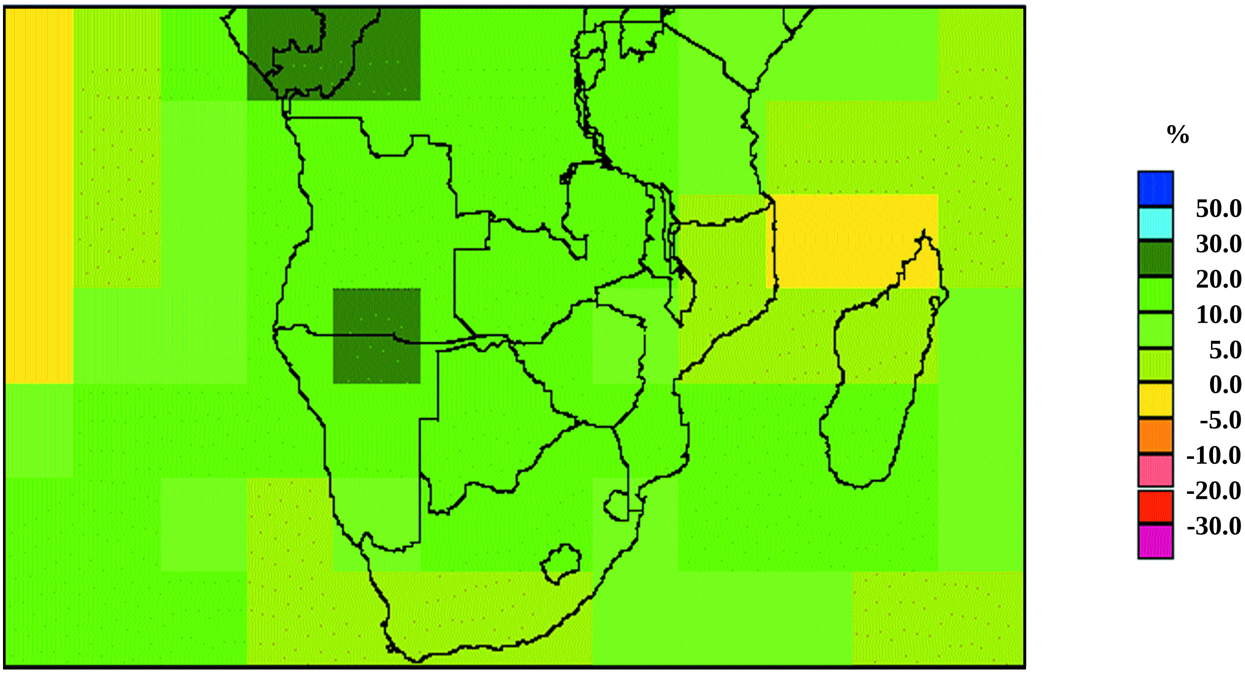


Figure 4.8. Simulated percentage change in mean annual precipitation using the 'wetting' scenario OSU GCM (IS92A).

Human Health

The vulnerability study for the health sector adopted a desktop approach involving literature reviews and interviews with Botswana's health professionals. The diseases most likely to be affected by climate change were identified (malaria and paediatric diarrhoea) and epidemiological data used to identify areas and populations most at risk. In future studies, vulnerability models such as TARGET and MIASMAcould be applied in areas where disease susceptibility is greatest.

Malaria, caused by the parasite *Plasmodium falciparum* and carried by the mosquito *Anopheles arabiensis*, has historically been confined to the northern districts of Botswana (Figure 4.9). Malaria transmission is known to be sensitive to both temperature and rainfall. In years of high rainfall, outbreaks occur further south, and the area at risk appears to be moving southward. Malaria has a seasonal pattern in Botswana. In the 1996/7 season 86 000 cases were reported in Botswana, resulting in 209 deaths. The trend in confirmed cases is upwards, which is partially due to growing resistance by the parasite to the drugs which have been used for prophylaxis and treatment.

A southern shift in the 'endemic malaria' region would be consistent with the predictions of climate-driven models of malaria given the predicted climate changes in the twenty first century. The population living in malaria-prone areas in Botswana is predicted to double, to just over a million people, by 2021. So far, control measures have been effective because of the small affected population. If the disease burden doubles, large scale control may be more difficult and more emphasis may be placed on community and personal involvement (Ndzinge and Bagwasi, 2000, based on data collected by the Health Statistics Unit, Ministry of Health, Botswana).

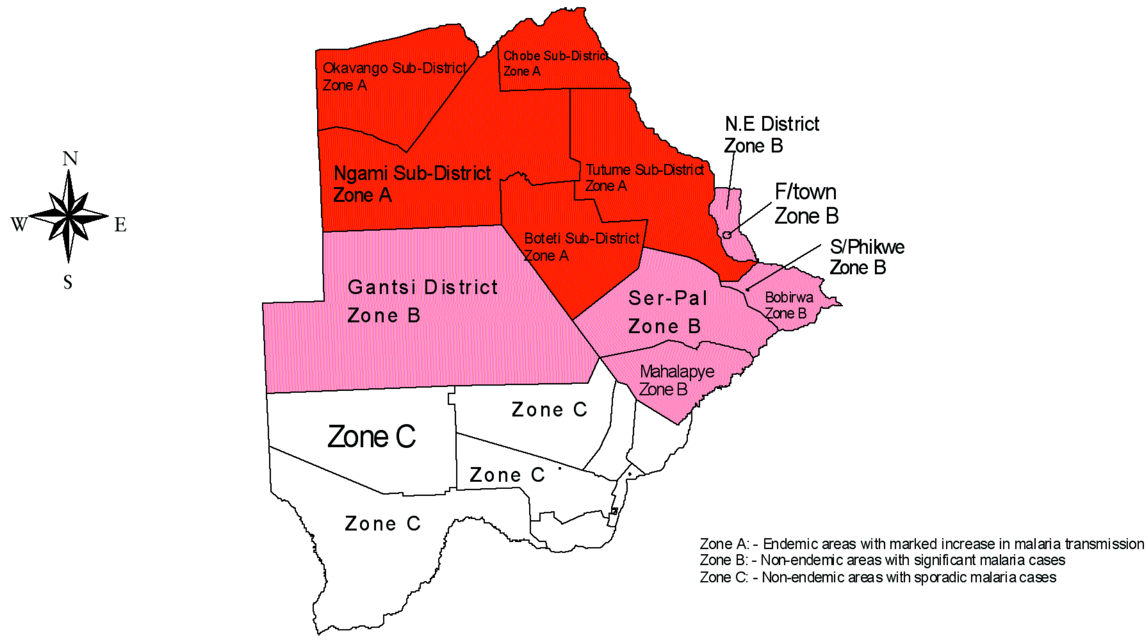


Figure 4.9. The current districts of Botswana in which malaria is endemic (i.e. present in all years), and non-endemic but occasionally or rarely present. Source: Health Statistics Unit, Ministry of Health.

Diarrhoea, caused by a variety of water-borne viruses, bacteria and parasites, is responsible for 5% of all visits to clinics and hospitals in Botswana (130 000 cases in 1994). Children below the age of 5 years are the victims in about 60% of cases, resulting in around 30 child deaths per year. Poor sanitation, unclean water and lack of hygiene contribute to the occurrence of the disease. Water supply systems and water-borne sewerage systems are generally considered together in order to facilitate water supply planning.

Responsibility for the operation and maintenance of sanitation facilities falls on the Town Councils in urban areas and the District Councils in rural areas (NDP8). In 1999, water supply and sanitation measures were completed at Mochudi, Kanye and Molepolole as part of an ongoing upgrade of water supply and sanitation facilities (Mid-term review, 2000). Nationally, 13% of people have flush toilets and 35% use pit latrines (Ndzinge and Bagwasi, 2000; Zhou, 1999 quotes a value of 26% for pit latrines in 1994). In rural areas, two thirds of the population have no access to sanitary disposal, and 31% have no access to piped water. Diarrhoea has been noted to be more prevalent during the early rainy season. Climate change leading to either more contamination of water supplies, or more use of contaminated water, is expected to increase the prevalence of diarrhoea.

The diseases Dengue Fever, Rickettsia, Cholera, Yellow Fever and Bilharzia may potentially be affected by changes in temperature and water availability, as may be respiratory diseases (such as asthma) and heat stress, but the relationship between these illnesses and the future climate has not been investigated in Botswana. The actions needed to adapt to climate change-induced diseases include general improvement of the health care system, disease surveillance and public awareness. For malaria, a variety of vector control techniques are being used and may need to be expanded. For diarrhoea, the strategy could include upgrading of drinking water supplies and sanitation, improved drainage and poverty alleviation.

Water Resources

Groundwater accounted for 64% of all the water consumed in Botswana in 1990. Eighty percent of the population, and most of the livestock, relies on boreholes and wellfields. The volume of groundwater is large but saline in places, expensive to develop, and unsustainable at extraction rates above about 3 mm/year, which is the national annual average recharge rate. Recharge of the resource is sensitive to climate change, but no detailed analysis of potential impacts has been undertaken.

Figure 4.10. Water for livestock is primarily sourced from boreholes (Photo: Illustrative Options).

The current water resources of Botswana are inadequate to supply the projected increase in demand by the year 2075 in all the catchments on the southeastern side of the country, by a large margin (332% deficit in water supply). This is true even if the climate does not change. A warmer, drier future climate makes the shortfall more severe, but only by a relatively small percentage (about 10%) and a warmer, wetter future does not prevent the shortage (Zhou and Masundire, 1998).

For the vulnerability assessment in the water sector, a water balance model was used to determine water supply through surface run-off once evapotranspiration losses, soil moisture and groundwater had been taken into account. Pitman's Water Resources Simulation Model (WRSM90) was used to simulate basin discharge. Runoff under different climate scenarios was then estimated using predicted rainfall and temperature and compared with anticipated water demand.

The main adaptation strategies in the water sector include inter-basin water transfers (for instance, from the Okavango and Zambezi rivers in the north, which have a large supply but are shared with several other countries, to the main area of demand in the southeast), water purchase from neighbouring countries and a doubling of internal recycling. Water conservation has the potential for a 10% to 25% saving. Adaptation costs are estimated at BWP7 to 10 per m^3 of water. Given a climate change-induced shortfall which may reach 30 million m^3/y, this could add BWP 300 million to the annual water supply costs in Botswana (Zhou and Masundire, 1998).

Woodlands and Forests

Over 81% of the land surface of Botswana has a significant tree and shrub cover, but less than 20%, mostly in the north east, is tall and dense enough to be considered a forest. Fuelwood from forests and woodlands accounts for 69% of net energy supply in Botswana. The sustainable use of biomass energy emits no net CO_2 to the atmosphere, and very small quantities of other greenhouse gases. Furthermore, woodlands which are increasing in biomass take up more CO_2 than they release. The woodlands of Botswana are therefore the main reason for the favourable greenhouse gas emission situation in Botswana.

Nine percent of all dwellings in Botswana use poles cut from local woodlands for their walls, and 41% use poles in their thatched roofs. Tree and woodland products, including medicines, fruits and wild foods are an important part of rural livelihoods. This dependency on woodlands is highest in rural areas and is predicted to decline in the future with poverty alleviation.

Vegetation models driven by the projected climate changes in Botswana during the twenty-first century predict an expansion of thorn and shrub savanna, at the expense of grasslands and moister forests and woodlands under a 'dry future'scenario. If the future is wetter than the present climate, the forests and woodlands will expand southwards.

There is great uncertainty associated with these predictions, relating not only to uncertainty regarding future climates but also the effects of rising CO_2 on plant growth and future trends in land use. The best available information is that Botswana is a net sink for carbon; in other words, the amount of carbon dioxide taken up by the thickening of the savannas exceeds the losses from clearing plus the emissions from fossil fuels.

The vulnerability assessment of the woodlands and forest sector to climate change made use of the following methodology: analysis of recent whole country satellite data showing the distribution of forests (in terms of species content and overall density), how these changed over the past decade. and how these changes have varied spatially. Results of previous surveys commissioned by the Botswana Government (1994 being the base year) in conjunction with those of local scientists were extensively used. Results of the BIOME model as reported by Hulme *et al*. (1996) were used to infer how the forest distribution could change under different climatic scenarios well into the 21st century. Analyses of forest products, the extent to which major stakeholders depend on them and what constraints they face were made using available research results (vulnerability analysis). A review of existing adaptive strategies was made and feasible recommendations were suggested in the face of climate change (adaptation analysis). Key forestry policies were identified on the basis of how they impact on the sustained use of forest products currently. Recommendations were made on how these policies (and their implementation) could be modified to enhance the continued sustainable use of forest products under a changed climate.

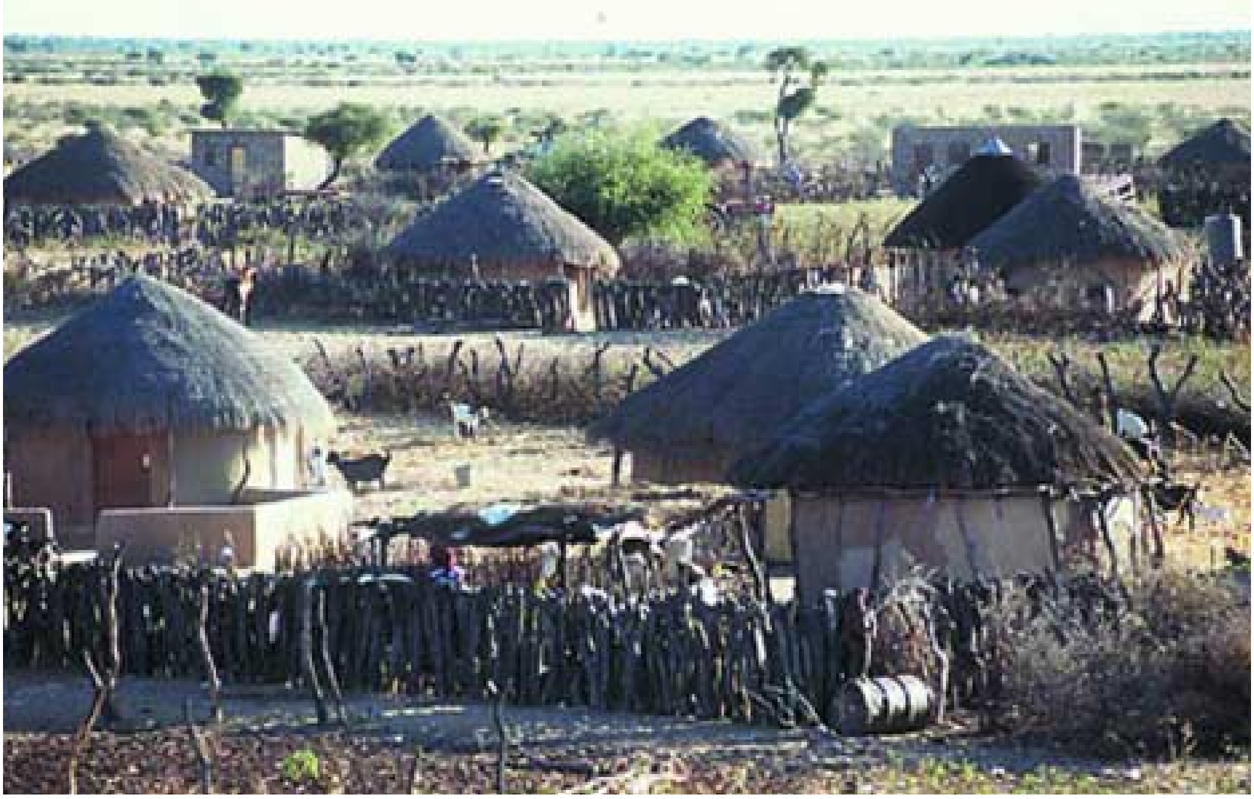


Figure 4.11. Tree and woodland products are used for building in rural settlements (Photo: Illustrative Options).

Adaptive Mechanisms

The foregoing sections suggest that climate change in Botswana will cause significant changes in prevalent vegetation and rangeland cover, and that this will consequently affect species types, composition and their distribution, as well as those who depend on them. This conclusion is arrived at after recognizing that many of the vegetation stands in Botswana are growing in a ‘fragile’ environment and further desiccation of the climate could therefore be expected to degrade the current stands.

A number of adaptive strategies designed to prevent further deterioration of the vegetation cover are being implemented in Botswana to some degree. These include control of deforestation; improved rangeland management; expansion of protected areas; and sustainable management of vegetation stands. The Government of Botswana through several chapters in the Eighth National Development Plan pledged to encourage natural resource management countrywide. Environmental non-governmental organisations have always done natural resource management of some kind. Adaptive strategies that have been employed by the different stakeholders and suggestions for improvements include the ‘Around the Home Tree Planting’ programme run by the Forestry Association of Botswana; Community Based Natural Resource Management leading to sustainable use of woodland resources, such as the programmes run by several NGOs; and the development of alternate sources of energy and building materials (Chanda *et al*., 2000).

Grazing and Livestock

While only 5% of Botswana households depend entirely on cattle, sheep and goats for cash income, 49% rely on their livestock for in kind income such as food, draught, milk and skins. Cattle are not only economically important but are also an important feature of Botswana culture, with strong cultural symbolism and value. The livestock sub-sector remains an important although declining source of employment. It accounts for about half of the agricultural GDP, which in 1994 was 4% of the national GDP. The sector is based entirely on the grazing of natural rangeland and is very sensitive to climate variability. The national herd decreased by about one third during the severe drought episodes of the 1930's, 1960's, 1980's, and 1991/2, all of which were associated with strong El Nino events. Stock mortalities are often the result of dehydration rather than starvation due to the dependence on ephemeral water resources in parts of the country. Successive droughts also lead to progressive degradation as the ability to recover from drought events is hampered. Animal diseases, such as the outbreak of 'lung disease' (*Contagious Bovine Pleuro-Pneumonia*) in 1995, have also led to large regional variations in stock numbers.

The National Early Warning Unit was set up in 1983 in response to this climate sensitivity. The strategies for alleviating drought impacts have focused on assistance to people, and may not have contributed to sustainable livestock management. These interventions can consume half of the agricultural GDP in drought years.

A simulation model (APSBRAM) was used to assess the rangeland and livestock production system in Botswana. Baseline data on climate, livestock production, soils and vegetation were used to predict herbage and livestock parameters. These were in turn used as indicators of the vulnerability of each system. The drawback of the APSBRAM model is that it is only applicable to cattle and does not apply to other major ruminant species such as goats, sheep and wildlife.

A future increase in temperature and decrease in rainfall would lead to more frequent and more extended droughts and less moisture in the soil, resulting in less growth of grass. If the frequency of droughts increases, the cumulative impact on range degradation could be more severe than the small change in temperature and rainfall would suggest, since the grasses would be unable to recover from one severe event before the next occurred. A wetter, warmer future (which currently appears unlikely) may result in fewer, shorter and less intense droughts. The uncertainty is high due to the current inability to predict future rainfall trends with confidence, and to the paucity of scientific understanding of the effects of higher future levels of CO_2 in an arid, tropical environment on largely infertile soils.

The potential adaptation strategies include Community-Based Natural Resource Management leading to more sustainable grazing practices; policy incentives for sustainable herd management (for instance, marketing and slaughter support for strategic destocking); regulatory control of animal numbers and grazing reserves; and diversification of the breeds and species used, including greater use of managed wildlife (Setshwaelo, 2000).

Crops

Botswana has a harsh climate and poor soils for crop agriculture. Crop damage by pests and wildlife and low levels of crop management inputs further contribute to an average rain-fed cereal yield in the traditional ('subsistence') farming sub-sector of 250 kg/ha, which is sufficient to meet only half of the national demand. The area planted varies greatly between years since farmers do not plant unless the spring rains have been good, and the area harvested may be a quarter of the area planted if the summer rains do not result in a crop which justifies the harvesting effort. For instance in 1993 (a dry year), 138 394 ha of sorghum was planted by traditional farmers, and 66 562 ha was harvested, yielding 10 797 tons of grain; 83 956 ha of maize was planted but only 22 185 ha was harvested, yielding 2 976 tons of grain. Production per hectare from the small area of commercial, irrigated cropland in the northeast is substantially larger and less variable. To illustrate this, an area of 5 924 ha was planted with sorghum in 1993, of which 5 821 ha was harvested, yielding 5 730 tons of sorghum; 1301 ha was planted to maize and 1 197 ha harvested, yielding 1 278 tons of maize (CSO, 2000). Botswana imports a large part of its grain needs.

A dynamic model, CERES (Crop Estimation Through Resource And Environment System) was used to simulate crop growth and development under future climate change scenarios. Input data included climate parameters, soil and management interventions such as the date of planting, seeding rates and fertiliser applications; processes that were simulated on a daily basis are the water balance, phenelogy or crop development stages, and plant growth.

Figure 4.12. Agricultural products such as sorghum are produced by both traditional and commercial farmers (Photo: Illustrative Options).

The major crops by area planted are sorghum and maize. A much smaller area of millet is planted, exclusively by traditional farmers (about 15 106 ha), as well as beans (27 202 ha in 1993 by all sectors combined), groundnuts (1 559 ha, all sectors) and sunflowers (2 721 ha, all sectors). There is high inter-annual variability in production, related almost entirely to variations in rainfall and the area planted, but little overall trend in yield per hectare over the period 1968-1994 can be established. Production per hectare is around 10% of the agronomic potential predicted by the CERES model, given the soil and climate circumstances. Under a scenario of a drier, hotter future climate, potential crop yields are predicted to be depressed by around 30% for both maize and sorghum. A wetter, warmer future would lead to slight increases in sorghum production, and less so for maize. The differential response is because sorghum is a crop much more suited to the low rainfall and high temperature conditions which prevail in Botswana.

Adaptive strategies have included national programmes aimed at increased food security, the development of a capacity for drought early warning, the import of cereals, and relief packages for rural people. At a local scale, there are traditional mechanisms for coping with poor crop years, including shifting to other activities and the sharing of yields. Future adaptations could include wider use of minimum tillage farming methods, which conserve soil, water and carbon; wider use of varieties with a short growing season; strategic analysis of optimum planting dates; and a focus on solving the problems which keep actual yields far below potential yields (Chanda *et al*., 1999).

5. Research and Systematic Observations

Climate Observation System

Climate observations have been made in Botswana since 1909. The Department of Meteorological Services currently operates a network of about 400 rainfall stations and 14 full weather stations ('synoptic stations', which include temperature, humidity, pressure and wind measurements taken hourly). Daily upper air observations are conducted at four locations, and provided to the international community for purposes of weather forecasting. Botswana has a National Early Warning System, and collaborates with the SADC initiatives on drought monitoring and prediction.

Environmental Observations

River flows are recorded at several points along major river courses. Three stations are linked via satellite to the HYCOS southern Africa network. The depth to the water table is automatically monitored in 17 wellfields (increasing to 30) and reported via satellite. The Botswana Range Inventory and Monitoring Project (BRIMP) has mapped and established monitoring plots for the vegetation of about a fifth of the country and continues to expand. Wildlife and livestock numbers are counted annually from the air. Air quality is monitored by the Department of Mines in the Ministry of Minerals, Energy and Water Affairs. Sulphur dioxide is extensively measured, but not the major greenhouses gases. The SO_2 monitoring system could be expanded to include measurements of greenhouse gases. Energy statistics are collected by the the Energy Affairs Division of the Ministry of Minerals, Energy and Water Affairs. In future these need to be collected at a level which allows them to be analysed in terms of the IPCC sectors. The Health Statistics Unit, part of the Central Statistics Office but housed in the Ministry of Health, collects data relating to the incidence of diseases. Crop yields, the total area planted and harvested, livestock numbers and livestock production data are surveyed by the Agricultural Statistics Unit, housed in the Ministry of Agriculture.

Global Change Research

Botswana has contributed significantly to research into global environmental and climatic change, given the small size of the national scientific capacity. Botswana has had a Global Change Research Committee affiliated to the International Geosphere-Biosphere Programme (IGBP) since 1995. The Sustainable Rangeland Livelihood project, based largely in Botswana and contributing to both the IGBP and the International Human Dimensions Programme, aims at understanding how pastoralists cope with an unpredictable and varying climate. The 'Kalahari Transect', which runs for a large part through Botswana, is one of a set of IGBP global transect studies aimed at understanding the links between climate and ecosystem structure and function, in order that future changes may be predicted more confidently. Botswana is a participant in the SAFARI 2000 experiment which aims to understand land-atmosphere interactions within the southern African region, and particularly the effects of vegetation fires, clouds, dust and trace gases on the earth's radiation balance. International participants include NASA, the Universities of Virginia, Washington, Maryland and Zimbabwe, the CSIR, Eskom, and the South African Weather Bureau. The University of Botswana, in collaboration with the Max Plank Institute of Germany, measures the uptake and release of CO_2 from woodlands in the vicinity of Maun.

Need for Enhanced Interpretive Capacity

A framework for environmental observations exists in Botswana, but there remain gaps and weaknesses. In particular there is a need to enhance the capacity to interpret the information that is collected in ways which help to support decision-making. Studies of the vulnerability of Botswana to climate change revealed a need for both the transfer of technology relating to predictive modelling, and the development of human capacity in the area of the interpretation of complex datasets and interactive human-environment systems.

Key Research Issues

The reduction of uncertainties regarding the direction and magnitude of changes in future rainfall in Botswana is of great importance. It is not possible for Botswana to undertake global climate modelling by itself; therefore the international community needs to direct more effort into improving the reliability of precipitation predictions in tropical and sub-tropical regions. In particular more detailed climate change scenarios are needed for Botswana. When the improved predictions are available, the research community in Botswana will need help in converting them into impact assessments, using the best available modelling technology.

In conjunction with climate change, the effects of elevated CO_2 concentrations in the atmosphere on the recharge of groundwater aquifers is critical for Botswana. A clearer understanding of the carbon balance of woodlands and savannas under various forms and intensities of use, within the context of a changing atmosphere and climate, is necessary to reduce uncertainties in the greenhouse gas emissions inventory and to plan a mitigation strategy for Botswana.

Expansion, repetition in time, and fine-tuning of the BRIMP work for purposes of carbon management and forest inventories is necessary to confirm the magnitude of the land use and forestry carbon sink.

Future studies in the health sector should apply vulnerability models such as TARGET and MIASMA in areas where disease susceptibility is high. Research on mosquito control, predictive malaria models and potential vaccines is proposed as part of an adaptation strategy.

Figure 5.1. The vulnerability of Botswana's wildlife to climate change requires further investigation (Photo: Illustrative Options).

No study has been undertaken specifically looking at the effects of climate change on Botswana's exceptional bird and animal life, nor on the future of the important wetlands of the Okavango delta and Chobe/Linyanti rivers. This is a key sector requiring further research. The rangeland impact study and the forest impact study both suggest that wildlife would be impacted through changes in food availability and habitat. The sensitivity of mammal species in southern Africa to climate variables has been shown in a SADC-wide study (Hulme, 1996). Local extinction of some species is possible. A study on the impacts of future climate change on elements of biodiversity, such as wetlands, indicator plant species, mammals and birds is thus required.

Finally, considerable research is needed to assess the full impact of the proposed mitigation options for both the energy and non-energy sectors. Although the suggested mitigation options have been prioritised according to national development needs, the feasibility and economic implications of some options would warrant more detailed consideration.

Public Awareness and Training

Information for Decision-makers

Workshops and information sessions regarding climate change and variability have been held for local and district councils for several years. The potential for climate change is recognised in the Botswana National Development Plan 8. Awareness of climate change impacts and possible mitigation and adaptation solutions at all levels of development must be promoted amongst the public and decision-makers in particular. Decision-makers and stakeholders also need to be made aware of policy and economic instruments which could yield specific joint benefits to both sustainable development and the reduction of climate change effects.

Radio Outreach

Over 90% of Batswana have access to radio broadcasts, whereas national television was only launched in August 2000 and currently reaches less than a sixth of the population. A Radio Listener Research study is being conducted by the Ministry of Health to determine listener patterns. A series of radio round-table discussions, including climate change experts, development NGOs and sceptics, has been broadcast nationally. Once a sufficient level of public awareness and information has been achieved, an on-air phone-in discussion, known as 'Maokaneng' and based on the traditional forum for discussing important issues, will be the next step.

Schools

A senior secondary school art competition on the topic of climate change has been held. The winners have attended the Youth Forum of the UNFCCC sixth Conference of Parties held in the Hague, the Netherlands, and have acted as communicators of the key issues to the nation, and especially the youth, on their return. Teachers have been provided with climate change interpretive material to incorporate into their syllabi. A workshop for teachers also focused on climate change issues in Botswana. A video programme on climate change in Botswana, aimed for television broadcast as well as use in schools, is currently being prepared.

Public

License and bumper stickers, and posters carrying climate change messages have been used as a way of sensitizing the public to the issue of climate change. A workshop for the media was held to familiarize them with climate change issues. Public awareness raising on the issue of climate change is ongoing.

University

The development of advanced skills in the area of climate change is seen as a key challenge for the University of Botswana and other higher learning institutions. The mechanism will be through post-graduate training and involvement in global change research projects, most of which involve collaboration by university teaching and research staff at regional and international institutions. The Harry Oppenheimer Okavango Research Center (HOORC) is leading climate change research at the University of Botswana.

7. Financial and Technology Needs

Key Technology Transfer Needs

The transfer of and access to environmentally sound technologies that are relevant to climate change is addressed in the UNFCCC and more recently in the Kyoto Protocol. Technology transfer to developing countries is emphasized, but steps must be in place to ensure that such technologies are environmentally sound and of a high standard so that a reduction of GHG emissions results.

Support to Date

The climate change secretariat, housed in the Department of Meteorological Services, has received an enabling grant from the Global Environment Facility/UNDP in support of studies leading to a national inventory of greenhouse gases, and to assessments of vulnerability and adaptation to climate change. The government of Denmark contributed to a study of emission mitigation in the industrial sector, while the United States Country Studies Programme contributed to the first study of the national inventory (base year 1990), as well as assessment studies of vulnerability and adaptation to climate change on crops, water resources and livestock.

Cross-cutting Needs

There are three major socio-economic challenges facing Botswana at present. These are strengthening human capacity (education and training), broadening the economic base through industrialization, and enhancing land utilization for such industries as agriculture and tourism under the harsh desert and semi-arid ecosystems which make up the bulk of Botswana's territory. Botswana is fortunate in that it is a young but vibrant economy which still has scope to choose a sustainable development path without commitment to any major historical development paradigm. To this end it can orient its human resources development path, industrial development policies and land use programmes to suit a sustainable and climate sensitive perspective.

To make such a choice, Botswana needs support in the following critical areas:

- Understanding its national circumstances in terms of vulnerability to climate change;
- Assessing present and future relationships between economic activities and the emission of GHGs;
- Enlisting policy makers' support for a climate sensitive development path. There must be greater awareness of policy instruments which could yield specific joint benefits to climate change considerations and to sustainable development;
- Gearing education and training programmes towards establishing capacity to assess and administer climate change considerations in a manner that enhances sustainable development;
- Generating and utilizing models and observation equipment for specifically studying desert and dry land ecology; and
- Developing and assessing the effectiveness of various policy options and policy instruments for combining climate change goals with sustainable development goals.

Capacity Building in Climate Change Studies

The capacity to undertake modelling of future climate change is not available at an internationally comparable level anywhere in Africa. There is a need for the leading global climate modeling groups to:

- Focus more attention on improving the reliability of the models with respect to Africa in general and Botswana in particular;

- Involve experts from Africa (including Botswana) in the setting up, running and interpretation of the models; and
- Transfer the model technology to suitable groups in Africa with regional mandates.

The infrastructure already exists in Botswana for running predictive models with lower computational demands, for instance in the areas of hydrology, crop production and human health, but advanced training is needed in their application.

In addition, greater understanding of climate change issues is needed in government ministries and departments. The internal capacity to conduct greenhouse gas inventories is not yet sufficient or self-sustaining, and further capacity building and support is required.

Capacity building, whether through programmes that increase public awareness or through focussed academic programmes at tertiary institutions requires ongoing financial support.

Sectoral Technology Needs

In its industrial expansion effort, Botswana will face a significant influx of new industrial and energy technologies. Botswana has shown through its high receptivity for clean energy technologies such as solar photo-voltaics and Solar Home Water Heaters that it is willing to adopt appropriate technologies in its development programmes. The technology influx will require advanced skills in technology assessment and technology trade or contracting. Addressing this need must be an integral part of any climate change support programme for Botswana.

Energy - The energy sector requires technology support to initiate demand-side management programmes, and to improve on energy efficiency and conservation, particularly within the mining sector. Renewable energy strategies such as the use of photo-voltaic cells and “modern biomass” to generate energy also require further support. The use of indigenous resources in an efficient manner should also be promoted.

Mining and industry - Technologies for improved water-use efficiency are needed in the mining sector (particularly the diamond mining sub-sector). Smelting technologies that reduce greenhouse gas emissions are also required.

Transport - The transport sector needs technology to enable rationalisation of the freight haulage system with a view to increasing efficiency. Use of mass transport and rail should be promoted. Methods to test and monitor vehicle emissions are also required. The scale of such testing would be determined by the ultimate costs and benefits that such a programme would entail.

Health - The health sector needs technology for the control of malaria-carrying mosquitoes, including engineering solutions, such as drainage and mosquito-protected dwellings, as well as options for biological control. An effective malaria vaccine and prophylactic drugs remains a high priority. Modern equipment such as spray pumps is needed to control mosquitoes. The upgrading of water supply and sanitation facilities is also required. Water testing technology to detect pathogens is needed to protect public health. Awareness of climate change issues within the health sector needs to be improved, both amongst the health professionals and the general public.

Water - Since water is a scarce resource in Botswana, there is a need for technology which allows water conservation, water treatment for reuse, recycling of wastewater for reuse, and water harvesting and industrial cooling. Studies to investigate the social acceptability of waste water recycling are needed. The reliance on groundwater requires that borehole monitoring systems be expanded and automated to ensure that water use is regulated. Technologies to assess ground water quality as well as feasible desalination technologies are needed. Demand management and appropriate water pricing will be key strategies to ensure that the development and social needs of the nation are met; policy support in this regard is required.

Agriculture - The location, testing and deployment of drought-tolerant crop cultivars and heat-tolerant livestock breeds are a necessary part of adaptation within the agricultural sector. Strategies to implement effective rangeland and livestock management are needed. Methods to reduce methane production from livestock should be further pursued. Public participation, particularly concerning issues of land conservation, is important and is being promoted through the CBNRM approach. Tillage technology which maximizes the storage of carbon and efficient use of water is required.

Land use change, forests and woodlands - The level of uncertainty surrounding the contributions of GHG from land use change needs to be addressed. Technology for the detection and quantification of land-based carbon stocks, such as in woodlands, is needed for refinement of the inventory and the assessment of options under the Clean Development Mechanism of the Kyoto Protocol. Affordable and applicable access to remote sensing (both from satellites and aircraft) is an important part of this technology. Technologies such as remote sensing analysis, geographical information systems, modelling and baseline inventory techniques need to be transferred to the appropriate institutions in Botswana.

Housing - Technologies to reduce domestic energy demand in the future are needed (e.g. insulation, passive climate design of houses). They should be promoted through revised building regulations and standards which address climate change considerations. Improved insulation and new solar power technologies for water heating, pumping and lighting could be applied and supported by government policies.

Climate Change Projects

There have been a number of initiatives to develop projects and programmes to address climate change concerns in Botswana and in particular to reduce greenhouse gas emissions from various developmental activities. For example, there is an initiative between the Governments of Japan and Botswana (JICA Project) to evaluate the potential of solar photo-voltaic technology in satisfying the rural electrification policy of the Government of Botswana, to disseminate solar PV technology in rural areas through replication of the Manyana pilot project and to formulate a Master Plan which will provide a basis for the future development of solar PV electrification in Botswana.

Botswana and the GEF are developing a project *Identifying and Overcoming Barriers to Widespread Adoption of Renewable Energy-Based Rural Electrification* which will be implemented alongside the JICA Project.

Furthermore, the following Climate Change Project concepts were also submitted to UNDP/GEF for review:

- Generation of Energy from Botswana Meat Commission abattoir waste;
- Power Generation options for Botswana from mixing and hybrids of renewable energy resources (solar, wind and waste);
- Large Scale power generation from solar energy;
- Utilisation of organic residues from food processing plants for energy generation;
- Economic and environmental benefits of energy efficiency and conservation at the Bamangwato Concession Limited - Copper/Nickel Mine;
- Coal Bed Methane Investigations;
- Coal Gassification;
- Substitution of fuel-wood in rural areas through promotion and use of residues;
- Efficient lighting programme;
- Residential and Commercial Energy Efficiency Building codes; and
- Fuel efficiency in transport.

While the above mentioned projects and programmes address the concerns relating to greenhouse gas emission reduction, other project concepts were developed to specifically address the issues relating to non-energy strategies for greenhouse gas emissions.

The project concepts submitted included the following:

- Species Diversity of Indigenous Leafy vegetables (*Amaranthus, Cleome and Cochorus species*) in Botswana;
- Eco-geographic distribution, diversity and collection of indigenous and cultivated watermelon landraces and their weedy relatives in Botswana;
- Establishment of Grapple Plant (*Harpogophytum procumbens*) Gene Bank in Botswana;
- Environmental Conservation in Rural Income Generation (ECRIG);
- Management of Pans and Grazing areas around the Pans in Northern Kgalagadi;
- Establishment of a National Inventory on Forests, Fisheries and Veld Products to monitor and evaluate utilization of these resources;
- Rehabilitation of Rangeland Resources in Tubu Area;
- Indigenous Rhizobia in Botswana Soils;
- Botswana Secondary School Pilot Project:
- Integrated Alternative Livelihoods;
- Eco-tourism Awareness Project for Rural Communities;
- Utilization of Indigenous Plants and their Conservation and Utilization in Livestock Ethno-Veterinary Medicine;
- Protecting Wild-Harvested Phytomedicinal Plants in Botswana;
- Improving Economic Utilization of Dryland Botanical Resources;
- Makopong Communal Range Management Project; and
- Developing Ways of Identifying the Spatial Distribution of Degraded Areas in the Bobirwa Subdistrict.

The above project concepts are not exhaustive. These lists will have to be systematically reviewed from time to time.

Research Funding

The need for focussed research activities is detailed for each of the vulnerable sectors that were investigated. A common need across these included the improvement of baseline information on which decisions can be made. An assessment of the vulnerability of Botswana's wildlife to climate change should also be done.

A comprehensive investigation into the proposed mitigation options is also needed. The initial prioritisation of mitigation options against the country's development needs should be strengthened with more robust information. Costs, benefits, feasibility and cultural acceptance need to be carefully considered before mitigation options are supported by government policy.

Finally, continued financial support for climate observations is needed as well as support to upgrade computing facilities.

Future Financial Support

The major need is for support to institutionalise the mechanisms which have begun to develop in Botswana for reporting on, understanding, quantifying and adapting to climate change. These mechanisms involve elements of the public sector, non-governmental organisations, civil society and the private sector, and have not yet reached a critical mass. The skills developed in conducting the 1990 and 1994 greenhouse gas emissions inventories and the vulnerability, adaptation and mitigation studies need to be built upon, improved and sustained. The need for greater capacity in the interpretation of climate change issues has been noted above. The public awareness programme has been initiated and will be a long-term project requiring ongoing support.

The effort invested in developing the Botswana national communication is such that this document and its subsequent versions can become a major aspect of future economic planning activities. It is important that Botswana be given significant financial and technical support in the development of subsequent national communications sufficient to raise the local and international credibility of the document and its relevance to national economic development needs.

8. Conclusions

Botswana's Contribution to Climate Change

The best available information suggests that Botswana had a net uptake of greenhouse gases in 1990 and 1994. Energy-related CO_2 emissions are relatively small (2.68 Mg CO_2 equivalent per capita per year) due to the high reliance on biomass energy and the low degree of industrialisation. Emissions are believed to be more than balanced by uptake of CO_2 in woodlands, although the uncertainty around the latter estimate is large.

Botswana's Vulnerability to Climate Change

Botswana is extremely vulnerable to climate change, for better or worse. Fluctuations in annual rainfall already have a clear effect on the Gross National Product, human welfare and the state of the environment. The major shortfall of water supply relative to projected demand will be exacerbated by warming and drying, and slightly relieved if the future is wetter than the present. The population exposed to malaria is projected to double, and increases in a variety of other climatically linked diseases are possible. The national cattle herd has suffered mortalities of one-third at least four times in the past seventy years because of drought. Crop agriculture is a marginal activity in Botswana which could become more precarious, particularly for subsistence farmers who are reliant on the land.

Actions Taken in Support of the Convention

Through this document, Botswana is fulfilling its obligation to report its emissions, climate change action plan and national circumstances, in terms of Articles 4(a) and (j) and Article 12 of the Convention. Key adaptive strategies (Articles 4(b), (d), (e) and (f)) are either already in place or are planned, and a process of public awareness-raising (Article 4(i) and Article 6) has begun. Botswana continues to support the observation and research networks (Articles 4 (g) and (h), Article 5) needed to understand and quantify climate change.

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Appendix 1

Greenhouse Gas Emissions Inventory Calculations

Energy Sector
Combustion Emissions

Table 1. Emission coefficients for the different fuel types used in Botswana.

Energy carrier	Fraction oxidised	CO_2 t/TJ	CH_4 t/TJ	N_2O t/TJ
Coal	0.98	92.00	0.012	0.025
LPG	0.99	63.07	0.001	0.030
Av gas	0.99	69.30	0.030	0.022
Jet A	0.99	71.50	0.000	0.022
Petrol	0.99	69.30	0.100	0.022
Paraffin	0.99	71.87	0.023	0.022
Diesel	0.99	74.07	0.002	0.026
Fuel Oil	0.99	77.37	0.002	0.026
Wood[a]	0.00	0.00	0.563	0.003

Note: a) A zero CO2 emission factor is used because it is assumed that wood consumption is sustainable on a national level.

Table 2. Greenhouse gas emissions in 1994 from the different sectors based on the types and amounts of fuel used and emission factors per fuel type for each gas species.

Sector	Carriers[a]	TJ	CO_2(t/1994)	CH_4 (t/1994)	N_2O (t/1994)
Transformation	Coal	17568.0	1583930.9	214.5	439.2
	Diesel	294.0	21557.8	0.5	7.6
	Sub Total	17862.0	1605488.7	214.9	446.8
Households	Coal	50.0	4508.0	0.6	1.3
	LPG	496.0	30968.3	0.4	14.9
	Paraffin	485.0	34506.8	10.9	10.7
	Wood	20940.0	-	11778.8	62.8
	Sub Total	21971.0	69983.0	11790.7	89.6
Agriculture	Petrol	18.0	1234.9	1.8	0.4
	Diesel	475.0	34829.9	0.8	12.4
	Sub Total	493.0	36064.8	2.6	12.7
Industry	Coal	4069.0	366861.0	49.7	101.7
	LPG	34.0	2122.8	0.0	1.0
	Av Gas	2.0	137.2	0.1	0.0
	Jet Fuel	9.0	637.1	0.0	0.2
	Petrol	119.0	8164.2	11.9	2.6
	Paraffin	1.0	71.1	0.0	0.0
	Diesel	1305.0	95690.4	2.1	33.9
	Sub Total	5539.0	473684.0	63.8	139.6
Trade and Hotels	Coal	5.0	455.4	0.1	0.1
	LPG	27.0	1685.8	0.0	0.8
	Paraffin	25.0	1778.7	0.6	0.6
	Wood	1.0	-	0.6	0.0
	Sub Total	58.0	3919.9	1.2	1.5
Transport	Av Gas	65.0	4459.5	1.9	1.4
	Jet Fuel	193.0	13661.5	0.0	4.2
	Petrol	6871.0	471398.7	687.1	151.2
	Diesel	3054.0	223937.6	4.8	79.4
	Sub Total	10183.0	713457.3	693.9	236.2
Social and Private Services	LPG	9.0	561.9	0.0	0.3
	Paraffin	1.0	71.1	0.0	0.0
	Wood	160.0	-	90.0	0.5
	Sub Total	170.0	633.	90.0	0.8
Government	Coal	216.0	19474.6	2.6	5.4
	LPG	31.0	1935.5	0.0	0.9
	Petrol	739.0	50700.6	73.9	16.3
	Diesel	534.0	39156.1	0.8	13.9
	Wood	320.0	-	180.0	1.0
	Sub Total	1840.0	111266.7	257.4	37.4
Total		**58116.0**	**3014497.4**	**13114.5**	**964.7**

Note: a) No CO_2 emissions from wood combustion are calculated because it is assumed that wood consumption is sustainable on a national level.

Fugitive Emissions

Table 3. Methane emissions from coal mining and post mining activities using the IPCC methodology and default emission factors.

		A Amount of coal produced (Mt)	B Emission factor (m^3 CH_4/t)	C Methane Emissions (million m^3) C = (A x B)	D Conversion factors (0.67 Gg $CH_4/106m^3$)	E Methane Emissions (Gg CH_4) E = (C x D)
Underground Mines	Mining	0.901	17.500	15.764	0.670	10.562
	Post Mining	0.901	2.500	2.252	0.670	1.509
Surface mines	Mining	0.000	1.200	0.000	0.670	0.000
Stock Pile	Post Mining	0.000	0.100	0.000	0.670	0.000
Total						**12.070**

Industrial Sector

Only the N_2O emissions from the usage of explosives are included.

Table 4. Nitrous oxide emissions from the usage of explosives.

	Activity-tonnes (t)	Emission factor (t N_2O/t explosives)	N_2O (Gg)
Total Industry	A	B	C=A*B/1000
Explosives	1242.43	0.55	0.68
Total			**0.68**

Agricultural Sector

The following processes contribute to greenhouse gas emissions from the agricultural sector:

- Domestic livestock:
  - Enteric fermentation
  - Manure management
- Fertiliser usage
- Veld burning

Table 5. Methane emissions from domestic livestock.

Livestock Type	A Number of Animals[a]	B Emissions Factor for Enteric Fermentation	C Emissions from Enteric Fermentations	D Livestock Slaughtered	E Manure/ Carcas	F Emissions Factor for Manure Management per cow[c]	G Emissions Factor for Manure Management	H Total Annual Emissions from Domestic Livestock
	1000s	kg/head/year[b]	Gg/year		kg	kg	Gg	Gg
	A	B	(C= A x B)/1000				G=D*F	H = C +G
Dairy Cattle[d]	-	-	-	-	-	-	-	-
Non-Dairy Cattle	2 349.000	32.000	75.168	195 295.000	25.000	0.018	0.090	75.258
Sheep	301.333	5.000	1.507	6 109.000	5.000	0.018	0.001	1.507
Goats	2 184.667	5.000	10.923	3 962.000	5.000	0.018	0.000	10.924
Camels	0.200	46.000	0.009	-	-	-	-	0.009
Horses	33.333	18.000	0.600	-	-	-	-	0.600
Mules and Asses	230.667	10.000	2.307	-	-	-	-	2.307
Swine	2.500	1.000	0.003	1 594.000	5.000	0.037	0.0003	0.003
Poultry	2 120.000	1.000	2.120	-	-	-	-	2.120
Total			**92.636**				**0.091**	**92.728**

Notes:

a) An average number was calculated for 1994 based on the 1990, 1993 and 1995 values except for swine numbers that were only based on the 1993 and 1995 data (data were unavailable for 1994). Swine numbers declined after 1990.

b) IPCC default values.

c) The CH_4 emission factor for manure was calculated as follows: 1000kg of fresh dung is estimated to produce 50-60 m^3 of biogas which has 70% CH_4 at 35ºC (Swaneng Hill School & RIIC 1976).

d) It was assumed that the number of dairy cattle was insignificant.

Table 6. Nitrous oxide emissions from the use of fertilisers.

Fertilizers (tonnes)	Activity (tonnes)	Emission Factor[a] (%)	N_2O(Gg)
	A	B	C = A x B
Inorganic nitrogenous only	17002.098	0.013	0.213
Organic (Animal and Vegetable)	102.722	0.013	0.001
Total	**17104.820**		**0.214**

Note: a) IPCC default values.

Table 7. Greenhouse gas emissions from savanna fires.

Vegetation Type Burned	Area Burned (Mha/year) A	Biomass burnt (t/ha) B	Emission factora (kg/t dm) C	CO_2 (Gg) D= AxBxC	EF[a] CH_4(kg/t dm) E	CH_4 (Gg) F= AxBxE	EFa N_2O (kg/t dm) G	N_2O (Gg) H= AxBxG
Sparse Vegetation/Grasslands	6.697	3.60	1 640	39541	2.4	57.9	0.15	3.6
Tree Savanna Woodlands	2.094	3.60	1 640	12368	2.4	18.1	0.15	1.1
Total				**51909[b]**		**76.0**		**4.7**

Note:
a) Regionally applicable emission factors (EF) based on a study by Delmas *et al.* (1995) were used instead of the IPCC default values.
b) Note that the CO2 emissions are not carried forward, since they are not considered net emissions. The CO_2 is taken up again by the vegetation in subsequent years.

Land Use Change and Forestry

Table 8. Amount of carbon uptake due to forest regeneration.

Vegetation Type	Area of vegetation type (kha in 1994)	Annual Growth Rate (t/ha)	Annual biomass Increment (Gg)	Carbon Fraction of Dry Matter	Total Carbon Uptake Increment (Gg)
Dense broad leaved Savanna woodlanda	11447.7	1.3	14882.01	0.45	6696.90
Dense mixed savanna including bush encroachment	3714.1	1.0	3714.10	0.45	1671.35
Moderate mainly broadleaved savanna woodland	20730.2	0.3	6219.06	0.45	2798.58
Sparse mixed savanna woodland and grasslandb	8572.8	0.1	857.28	0.45	385.78
Degraded Lands- flood plains, hills/dark soils/bare soils	10711.7	-	-	-	-
Fields	133.7	-	-	0.45	-
Woodlots	0.65	4.2	2.73	0.45	1.23
Total	**55310.85**		**25675.18**		**11553.83**

Notes:
a) Regeneration rate weighted for Dense forests: 2.1 t/ha for an area of 3 336 kha + 629.7 kha and Woodlands: 1t/ha for an area of 8340.7 kha.
b) Estimated to be between moderate savanna and degraded lands.

Table 9. Total amount of carbon removed or emitted from the forestry sector.

	H	I	J	K	L	M
Harvest Categories	**Commercial Harvest ($1000m^3$ roundwood)**	**Biomass Conversion/ Expansion Ratio (t dm/ m^3)**	**Total Biomass Removed in Commercial Harvest**	**Total Traditional Fuelwood Consumed (kt dm)**	**Total Other Wood-use (kt dm)**	**Total Biomass consumption (kt dm)**
			J =H x I			**M=J+K+L**
Timber						0
Fuelwood				1338	309	1647

Table 9. ***continued***

	N	O	P	Q	R	S
Harvest Categories	**Wood Removed from Forest Clearing (kt dm)**	**Total Biomass Consumption from Stocks (kt dm)**	**Carbon Fraction**	**Annual Carbon Release (kt C)**	**Net Annual Carbon Uptake (+) or release (-) (kt C)**	**CO_2 Annual Emission (-) or Removal (+) (Gg)**
		O = M - N		**Q = O x P**	**R = Total Carbon uptake - Q**	**S = R x (44/12)**
Timber		0	0.45	0		
Fuelwood		1647	0.45	741.15	-10812.7	-39646.5

Table 10. Carbon dioxide emissions from forest conversion: Carbon from soils cleared for agricultural purposes.

Vegetation type	**Annual amount cleared (kha)**	**Carbon soil content[a] (t/ha)**	**Total Soil carbon (Gg C)**	**Fraction of carbon released over 25 years**	**Carbon Release from soil (Gg C)**	**Total Carbon (Gg C)**
	A	**B**	**C=A x B**	**D**	**E=C x D**	
Savanna - ploughed land	11	11	121	0.5	60.5	
Savanna - virgin land	13	21	273	0.5	136.5	197.0

Note: a) Values were derived from a study done by Ringrose *et al*. (1998).

Table 11. Carbon from forest conversion.

	Area[a] (kha) A	**Biomass (t/ha) B**	**Total biomass Total biomass (Gg) C = A x B**
Savanna woodlands	13	15	195

Note: a) Area destumped per year was deduced from Eskeli (1989). About 40 000 ha were destumped between 1985 and early 1988 (period of 3 years).

Table 12. Carbon from on-site burning.

	Fraction burnt on site H	Total biomass (Gg) I=C x H	Fraction Oxidised J	Biomass Oxidised (Gg) K=I x J	Carbon Fraction L	Amount of Carbon (Gg Carbon) M=K x L
Savanna woodlands	0.12	23.40	0.5	11.70	0.45	5.27

Table 13. Carbon from off-site burning.

	Fraction burnt off site[a] N	Total biomass (Gg) O=C x N	Fraction Oxidised P	Biomass Oxidised (Gg) Q=O x P	Carbon Fraction R	Amount of Carbon (Gg Carbon) S =Q x R
Savanna woodlands	0.35	68.25	0.5	34.13	0.45	15.36

Note: a) Based on survey by Eskeli (1989). Offsite burning of firewood was 35%.

Table 14. Carbon from biomass decay.

	Area (kha) A	Biomass change (t/ha) B	Average annual loss of biomass C=A x B	Fraction/fence left to decay[a] D	Amount of biomass left to decay (Gg/year) E=C x D	Carbon Fraction F	Amount of carbon (Gg/year) G=E x F
Savanna woodlands	13	15	195	0.53	103.35	0.45	46.51

Note: a) Based on survey by Eskeli (1989).

Table 15. Non-CO_2 emissions from the delayed decay of biomass.

Amount of carbon released from on-site burning (Gg carbon) A	Non-CO2 greenhouse gas types C	Trace Gas Emission factors[a] (t/kt C) D	Trace Gas Emissions (kt C) E =Ax D	Conversion Ratio F	Non-CO_2 from burning of forests (Gg) G =E x F
5.27	CH_4	2.2	0.012	16/12	0.015
5.27	N_2O	0.15	0.001	44/28	0.001

Note: a) Based on values from the Delmas *et al*. (1995) study. Values were averaged for savanna fires and woodburning as both stems and branches are burnt. Only on site burning was considered.

Waste

Table 16. Waste production by settlement types.

District/Town/ City Council (1994)	Estimated population	Estimated waste disposed (t/year)	Gg MSW/ 10^6 persons/ year	kg/person/ day	Gg MSW/ year	Fraction land filled	Gg MSW land filled/ year
Towns/Cities							
Gaborone	156 724	135 897	867.11	3.10	135.90	0.8	108.72
Francistown	75 960	18 092	238.18	0.80	18.09	0.8	14.47
Lobatse	27 891	10 670	382.56	1.20	10.67	0.8	8.54
Selebi Phikwe	42 580	7 693	180.68	0.60	7.69	0.8	6.15
Orapa	9 534	11 451	1 201.04	1.00	11.45	0.8	9.16
Jwaneng	12 915	592	45.88	0.20	0.59	0.8	0.47
Sowa	2 661	1 189	446.86	1.60	1.19	0.8	0.95
Districts							
Central District	434 392	23 941	55.11	0.15	23.94	0.8	19.15
Ghanzi District	26 232	5 072	193.37	0.53	5.07	0.8	4.06
Kgalagadi District	32 846	1 795	54.65	0.15	1.80	0.8	1.44
Kgatleng District	60 052	2 982	49.66	0.14	2.98	0.8	2.39
Kweneng District	180 869	9 740	53.85	0.15	9.74	0.8	7.79
North East District	43 876	3 259	74.27	0.20	3.26	0.8	2.61
North West District	114 296	5 560	48.65	0.13	5.56	0.8	4.45
South East District	48 463	3 324	68.58		3.32	0.8	2.66
Southern District	155 034	7 770	50.12	0.14	7.77	0.8	6.22
Total	**1 424 636**	**257 526**	**180.77**	**0.50**	**257.53**	**0.8**	**206.02**

Table 17. CH_4 from solid waste.

District/Town/ City Council	Estimated population	kg/ person/ day (1994)	MSW land filled/ year	Fraction DOC (Gg/year)	Annual DOC land filled (Gg)	Fraction which actually degrades[a]	Annual carbon released as biogas	Fraction C-CH_4 to C-biogas	Annual carbon released as CH_4 (Gg C)	Conversion ratio	Annual released CH_4 (Gg/year)
	A	B	C	D	E	F	G	H	I	J	K
		A*B*365/ 1000 000			C x D		E x F		G x H		K=I x J
Towns/Cities											
Gaborone	156 724	2.38	108.72	0.13	14.13	0.77	10.88	0.5	5.44	1.33	7.26
Francistown	75 960	0.65	14.47	0.13	1.88	0	0.00	0.5	0.00	1.33	0.00
Lobatse	27 891	1.05	8.54	0.13	1.11	0.77	0.85	0.5	0.43	1.33	0.57
Selebi Phikwe	42 580	0.50	6.15	0.13	0.80		0.00	0.5	0.00	1.33	0.00
Orapa	9 534	3.29	9.16	0.13	1.19		0.00	0.5	0.00	1.33	0.00
Jwaneng	12 915	0.13	0.47	0.13	0.06		0.00	0.5	0.00	1.33	0.00
Sowa	2 661	1.22		0.13	0.00		0.00	0.5	0.00	1.33	0.00
Districts											
Central District	434 392	0.15	19.15	0.13	2.49		0.00	0.5	0.00	1.33	0.00
Ghanzi District	26 232	0.53	4.06	0.13	0.53		0.00	0.5	0.00	1.33	0.00
Kgalagadi District	32 846	0.15	1.44	0.13	0.19		0.00	0.5	0.00	1.33	0.00
Kgatleng District	60 052	0.14	2.39	0.13	0.31		0.00	0.5	0.00	1.33	0.00
Kweneng District	180 869	0.15	7.79	0.13	1.01		0.00	0.5	0.00	1.33	0.00
North East District	43 876	0.20	2.61	0.13	0.34		0.00	0.5	0.00	1.33	0.00
North West District	114 296	0.13	4.45	0.13	0.58		0.00	0.5	0.00	1.33	0.00
South East District	48 463	0.19	2.66	0.13	0.35		0.00	0.5	0.00	1.33	0.00
Southern District	155 034	0.14	6.22	0.13	0.81		0.00	0.5	0.00	1.33	0.00
Total	**1 424 636**		**206.02**		**25.77**		**11.74**		**5.87**		**7.83**

Note: a) It was assumed that there were no anaerobic conditions at dumping sites except at Gaborone and Lobatse.

Table 18. Nitrous oxide emissions from sewage deposited in pit latrines.

A Region	B Per capita protein consumption/yr (kg/person/yr)	C Pit latrine population	D Fraction of nitrogen in protein fraction (kgN/kg Protein)	E Emission factor kgN_2O-N/kgsewage-N produced[a]	F Total Annual N_2O (Gg N_2O/year) F= BxCxDxEx44/28
Total Botswana 1991	17.5	347 095	0.16	0.01	0.0153
Total Botswana 1994[b]	17.5	392 346	0.16	0.01	0.0173

Notes:
a) IPCC default value.
b) The 1991 values were adjusted for 1994 assuming the same ratio for the number of pit latrines.

Table 19. Methane emissions from domestic and commercial wastewater treatment.

District/Town/ City Council	Estimated population (1994)	Waste BOD value (Gg BOD_5/ 1000 persons/ year[a])	Annual BOD (Gg BOD_5)	Fraction of Waste Water anaerobically treated (Gg BOD_5)	Quantity of BOD from Anaerobically treated wastewater	Methane emissions factor (Gg CH_4/ Gg BOD_5)	Total annual CH_4 emissions (Gg CH_4)
	A	B	C C = A x B	D	E E = C x D	F	G G = E x F
Towns / Cities							
Gaborone	156.724	0.0135	2.12	0.1	0.21	0.22	0.05
Francistown	75.960	0.0135	1.03	0.1	0.10	0.22	0.02
Lobatse	27.891	0.0135	0.38	0.1	0.04	0.22	0.01
Selebi Phikwe	42.580	0.0135	0.57	0.1	0.06	0.22	0.01
Orapa	9.534	0.0135	0.13	0.1	0.01	0.22	0.00
Jwaneng	12.915	0.0135	0.17	0.1	0.02	0.22	0.00
Sowa	2.661	0.0135	0.04	0.1	0.00	0.22	0.00
Districts							
Central District	434.392	0.00	0.00	0.1	0.00	0.22	0.00
Ghanzi District	26.232	0.00	0.00	0.1	0.00	0.22	0.00
Kgalagadi District	32.846	0.00	0.00	0.1	0.00	0.22	0.00
Kgatleng District	60.052	0.00	0.00	0.1	0.00	0.22	0.00
Kweneng District	180.869	0.00	0.00	0.1	0.00	0.22	0.00
North East District	43.876	0.00	0.00	0.1	0.00	0.22	0.00
North West District	114.296	0.00	0.00	0.1	0.00	0.22	0.00
South East District	48.463	0.00	0.00	0.1	0.00	0.22	0.00
Southern District	155.034	0.00	0.00	0.1	0.00	0.22	0.00
Total	**1 424.636**		**4.43**		**0.44**		**0.10**

Note: a) The IPC default value was used. A value of 0.0175 was westimated for Gaborone.

Appendix 2

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