Zimbabwe

Third National Communication to the United Nations Framework Convention on Climate Change

Ministry of Environment,
Water and Climate
Government of Zimbabwe
2016

Republic of Zimbabwe

Zimbabwe Third National Communication to the United Nations Framework Convention on Climate Change

UNITED NATIONS
FRAMEWORK CONVENTION
ON CLIMATE CHANGE

The Third National Communication of the Republic of Zimbabwe has been prepared in accordance with the United Nations Framework Convention on Climate Change (UNFCCC) Articles 4.1 and 12.1 on the basis of the Guidance for non-Annex I Convention Parties.

The national institution responsible for the preparation of the Third National Communication is the Climate Change Management Department, Ministry of Environment, Water and Climate in collaboration with key Ministries and Agencies.

The following government ministries and agencies participated in the preparation of the Third National Communication of the Republic of Zimbabwe under the United Nations Framework Convention on Climate Change:

- Ministry of Environment, Water and Climate
- Ministry of Health and Child Care
- Ministry of Agriculture, Mechanization and Irrigation Development
- Ministry of Energy and Power Development
- Ministry of Transport and Infrastructure Development
- Ministry of Women Affairs, Gender and Community Development
- Ministry of Industry and Commerce
- Zimbabwe National Statistics Agency
- Zimbabwe Meteorological Services Department
- Agriculture Research Council
- University of Zimbabwe
- Midlands State University
- National University of Science and Technology
- Chinhoyi University of Technology
- Bindura University of Science Education
- Scientific and Industrial Research and Development Centre
- Forestry Commission of Zimbabwe
- Environmental Management Agency

Participant Non Governmental Organisations (NGOs):

› Business Council for Sustainable Development Zimbabwe

› Environment Africa

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Foreword

The world is experiencing unprecedented climate change phenomenon that is likely to lead into crisis of human survival and national development unless urgent steps are taken to curtail human behaviours impelling climate change.

Over the years the Republic of Zimbabwe views climate change as a serious issue. Zimbabwe, through the years, has demonstrated its willingness to preserve the global climate for the good of the present and future generations. Zimbabwe was one of the first countries to sign and ratify the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992. Zimbabwe acceded to the Kyoto Protocol on 28 September 2009. Zimbabwe has made great strides to date through its completion of the National Climate Change Response Strategy, the submission of its Intended Nationally Determined Contributions (INDCs) and the developing of the Climate Policy to ensure that climate change is mainstreamed across all the socio-economic sectors of the country. The country ratified the Doha amendment to the Kyoto Protocol in 2016 as well as signing of the Paris Agreement. In accordance with the UNFCCC commitments, the Republic of Zimbabwe prepared and submitted its Initial and Second National Communication to the UNFCCC in 1998 and 2012 respectively.

Since signing the UNFCCC in March 1992, the Zimbabwean government, private sector, civil society and development partners have also undertaken a number of other initiatives under the climate change portfolio. Some of the initiatives include: US Climate Change Country Studies Programme, GEF/Small Grants Programme, Technology Transfer Needs Assessment, and National Capacity Needs Self-Assessment for implementation of the Multilateral Environmental Agreements, UNDP/GEF Medium Size Project on Coping with Drought and Climate Change, Climate Change Awareness Workshops and Climate Change training workshops for the media.

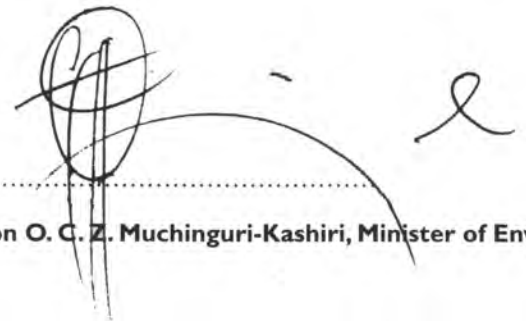
The Third National Communication of the Republic of Zimbabwe to the United Nations Framework Convention on Climate Change is an up-to-date summary of information on climate change issues in Zimbabwe. The major objective of this communication is to inform the Convention Parties, as well as decision-makers, specialists and the public at large of one of the most urgent issues facing mankind in this century. The Communication also provides information of Zimbabwe's emissions of greenhouse gases (GHGs) and information on the interventions undertaken to mitigate and adapt to the adverse impacts of climate change.

It is important to note that the Third National Communication is an original document. However, results and findings from previous research carried out in the country have been incorporated. It is therefore important to refer to the sources and reports that were used by groups of experts. These reports which serve as the basis for this Communication are available in the Climate Change Management Department, Ministry of Environment, Water and Climate.

The results of research conducted within the framework of the Third National Communication revealed that the country's priorities are mainly on adaptation of vulnerable communities and ecosystems to climate change. Developing a low carbon pathway to implement INDCs has been prioritised as an area of intervention under mitigation. Other issues of importance include climate change research and systematic observation at local and regional scales.

The main chapters of the Third National Communication were discussed at workshops and working meetings during the period of 2013-2016 with participation of representatives from more than 15 ministries and agencies, international organizations, civil society and the public at large. More than 30 experts, scientists, academic researchers and staff from different organizations participated in the preparation of this document.

The Ministry of Environment, Water and Climate expresses its gratitude to the authors and editors of chapters of the Third National Communication and National Inventory Report (NIR), members of the National Climate Change Steering Committee, technical support staff, UNEP and National Communication Support Programme (GEF/UNDP/UNEP - NCSP) for financial support and technical guidance.



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EXECUTIVE SUMMARY

INTRODUCTION

Climate change remains a priority on Zimbabwe's socio-economic development agenda since the signing and ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 at the Rio Earth Summit. The motivation behind Zimbabwe's effective participation in the climate change convention and the Paris Agreement hinges upon the need to reduce greenhouse gas (GHG) emissions and the serious impacts caused by global climate change. In this regard the country has developed a National Climate Change Response Strategy and is in the process of concluding the National Climate Policy that will guide the mainstreaming of climate change in national development plans. In addition the country is developing a National Adaptation Plan on climate change.

The Third National Communication (TNC) to the UNFCCC has been prepared in fulfilment of Zimbabwe's obligations to the UNFCCC under articles 4 and 12 of the Convention and builds on the Second National Communication that was submitted in 2013 and several other climate change activities that have been ongoing in the country. The TNC follows the UNFCCC guidelines and includes information on Zimbabwe's greenhouse gas inventory for the year 2006, measures to reduce emissions (mitigation) and adaptation to climate change.

The project was coordinated by the Ministry of Environment, Water and Climate with funding from the Global Environment Facility (GEF), through the United Nations Environment Programme (UNEP).

NATIONAL CIRCUMSTANCES

Geographic Profile and Climate

Zimbabwe is situated in the southern part of Africa between latitudes 15° 30" and 22° 30" south of the Equator and between longitudes 25° 00" and 33° 10" east of the Greenwich Meridian. The country is land locked and is bordered by Mozambique to the East, South Africa to the South, Botswana to the West and Zambia to the North and North-west. Zimbabwe has a total land area of approximately 390 757 square kilometres (km^2) and is divided into ten administrative provinces; Bulawayo, Harare, Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Masvingo, Matabeleland North, Matabeleland South and Midlands. Harare is the capital city and it has the major administrative and commercial functions. In 2012 Zimbabwe had a total population of 13.1 million. The proportion of male and female population was 48 and 52 percent, respectively.

The country's main topographical features include the central watershed, running from southwest to northeast and ranging from 1200m to 1500m above mean sea level. The watershed is 650 kilometres long and 80 kilometres wide. The highest elevation is along the eastern border with Mozambique where mountain peaks range from 2300m to 2500m. The Zambezi and Limpopo River Valleys found in the north and south respectively have the lowest altitude of around 500m.

Zimbabwe has four seasons; cool season from mid-May to August, hot season from September to mid-November, the main rainy season running from mid-November to mid-March and the post rainy season from mid-March to mid-May. The lowest minimum temperatures are recorded in June or July and the highest maximum temperatures in October, or if the rains are delayed, in November. The mean monthly temperature varies from 15°C in July to 24°C in November while the mean annual temperature varies from 18°C on the Highveld to 23°C in the Lowveld.

Natural Resources

The country has abundant natural resources that include beautiful scenery, arable land, forests, minerals, surface and ground water. There are 12 national parks, one trans-frontier park (Trans Zambezi National Park), and other protected areas. The flora in the country is dry miombo woodland, with mopane woodland and other woodland types dominating while high-altitude grasslands and heath is found in the Eastern Highlands. Zimbabwe's forestry resources cover approximately 46% of the total land area (179,748km^2).

The country relies on surface water resources for 90% of its requirements while groundwater supplies the remaining 10%. At present, agriculture uses 60% of all the water in dams. Irrigation efficiencies range between 40% and 60%. In the urban areas, as much as 40% of water is lost during treatment and distribution. There are seven catchments in the country, namely Manyame, Mazowe, Gwayi, Runde, Sanyati, Save and Mzingwane.

Economic sectors

The Country's Gross Domestic Product (GDP) increased gradually, by about a unit percentage, during the period 2010 to 2013. The slight increase is accounted for by the greater performance in the agriculture, hunting and fishing; real estate and health sectors. The other sectors recorded slight increases in their performances. The per capita GDP at market prices has been increasing throughout the 2010 to 2013 period. The per capita year to year growth rates for the period were 20.6%, 10.5% and 26.6%, progressively.

Agriculture: The economy of Zimbabwe is agro-based contributing about 15% each year to the GDP. The country is divided into five Natural Regions on the basis of rainfall, temperature and other factors. Average rainfall ranges from 450mm to above 1050mm per annum. Zimbabwe's agriculture is divided into four major sectors namely; Large Scale Commercial Farms, Small Scale Commercial Farms, Communal and Resettlement Schemes. The country produces a variety of crops in its different sectors and zones. These include grain crops such as *Zea mays* (maize), *Sorghum bicolour* (Sorghum), *Pennisetum americanum* (pearl millet), *Eleusine coracana* (finger millet), *Helianthus anuus* (sunflower), *Arachis hypogaea* (groundnuts) and *Glycine max* (soyabeans) and other industrial crops which include *Nicotiana tabacum* (tobacco), *Gossypiumhirsutum* (cotton), *Phaseolus vulgaris* (edible dry beans) and *Capsicum annuum* (paprika).

Energy: Zimbabwe generates about 1200MW of electricity from thermal and hydro-power plants. In the rural areas, energy needs are met basically with firewood, candles, paraffin and in a few cases, electricity. Energy demand is growing by over 2% annually and local supply does not meet demand. The shortfall is being met with imports of electricity from Zambia, Mozambique and South Africa. The national power utility company, Zimbabwe Electricity Supply Authority (ZESA), also buys electricity from private owned mini hydro power generation plants in the country. However, the country continues experiencing constrained energy supplies, a factor that has adversely affected business and public transport operations. The constrained energy supply has undermined productivity and contributed to a loss of market competitiveness.

With the rising demand for electricity regionally, Zimbabwe has been working on expansion projects of the existing plants and also initiating new hydro-power generation projects particularly in the major rivers that border the country. Solar power and bio-energy projects are also being implemented. Stability in the energy sector, encompassing liquid fuels, and coal and electricity supplies is an indispensable pre-requisite for successful economic growth, as well as for household use.

Mining: The major minerals reserve deposits in Zimbabwe comprise of asbestos, gold, copper, chrome, nickel, diamonds, platinum, coal and iron. The mineral volumes generally showed a decline except for black granite and platinum. Small-scale mining activities have been on the increase. These contribute significantly to employment creation and consequently poverty reduction. However, mining activities have been seen to cause serious environmental problems as a result of the methods used in extracting the ore.The methods are underground and opencast with ancillary operations such as drilling, breaking, milling, cleaning and grading. Opencast methods result in removal of top soil which disturbs the natural environment and the ecological synergies.

Transport: Zimbabwe has a fairly modern transport system which is dominated by road transport. Other predominant forms of transport are railway and air, while boats are used in the man-made dams of the country. Major roads radiate from Harare and Bulawayo (the second largest city) to neighbouring countries. In the year 2012 there was a total of approximately 18,601 km of road designated as state roads in Zimbabwe, of which 9,499km were gravel and earth. There has been a steady increase in the registered vehicle population in the country from 2000 to 2013, with the total number of vehicles rising by about 8.7% over the period.

Tourism: The country is richly endowed with a variety of tourist attractions. Tourism contributes a significant percentage to the country's GDP. It shares with Zambia one of the Seven Wonders of the World and heritage site, the Victoria Falls. The scenic, mystical and beautiful Eastern Highlands is dominated by mountains, waterfalls and forests. The country accommodates a variety of national parks and trans-frontier parks with over 100 animal species and 400 bird species. Hwange National Park is the biggest in the country and among the largest game sanctuaries in Africa. Approximately 12% of the country's surface area was set aside for the National Parks and Wildlife Estates. Among the animal species are the big five: elephant, rhinoceros, leopard, lion and buffalo. The country boasts of tangible and intangible heritage. The tangible heritage consists of stone architectures such as the Great Zimbabwe and Rhodes Matopos monuments while the intangible heritage is dominated by rich cultural diversity, inspiring musical sounds and mesmerising dances.

Trade: Zimbabwe's total trade has increased from US$8.3 billion in 2006 to US$11.2 billion in 2013. A trade balance surplus of US$3.4 billion was recorded in 2006; however it was overturned to a deficit of about US$0.4 billion in 2007 which further grew to US$4.2 billion in 2013.

Environmental protection: Zimbabwe has a National Environmental Policy and Strategies in place since 2009. The country also submitted its Intended Nationally Determined Contributions (INDCs) to the UNFCCC before the advent of COP 21 in Paris in 2015. In addition, the Climate Change Response Strategy document was launched in 2015 and a National Climate Policy is also being concluded in order to enhance Zimbabwe's efforts in combating climate change. The policy compliments the Environmental Management Act (Chapter 20:27) promulgated in 2003, and other complimentary legislation pertaining to environmental protection, monitoring and sustainable management.

Education Development: Zimbabwe achieved the near universal primary education for all in the 1990s which laid a foundation towards the fulfilment of the Millennium Development Goal 2 (MDG 2). The education policy adopted soon after independence in 1980 contributed to increased primary education. The major educational stages in Zimbabwe are Early Childhood Development (ECD), Primary Education, Secondary Education, and Tertiary Education.There has also been a rapid increase and improvement of syllabi and curriculum in the educational institutions. Of late a revision of the curriculum through all the streams has streamlined climate change related subjects to improve awareness on climate issues.

According to the 2012 Population Census 6,717,229 persons are of school going age, i.e. 3 to 24 years. Of this population, females constituted 51 percent. The 2011 Labour Force and Child Labour Survey estimated, for both sexes, a drop in children aged 5 to 9 years who have never been to school from 39 % in 2004 to 26 % in 2011. Generally, the proportion of children who never attended school decreased with increasing age. The scenario resonates with the Government policy towards universal primary education for all by 2018. The 2011 Labour Force Survey estimated the literacy level at 97.2 % with no significant differences across all the 10 provinces.

Healthcare Development: The major health issues in Zimbabwe relate to: nutrition; water, sanitation and hygiene; diseases; morbidity/mortality; health care services and facilities; ante-natal and post-natal care; family planning; vaccination; and fiscal budget allocation and expenditure. The country has a robust health information and surveillance report system, for instance there are weekly disease surveillance reports.

The 2010/11 Zimbabwe Demographic Survey results show that 78.7 % of the households (of which 95.1 % for urban and 68.7 % for rural) were using improved source of drinking water. The sanitation coverage for the country was 64.4 % composed of 93.4 % for urban households and 49.7 % for rural households. In spite of the country's efforts to reduce infant mortality rate it has remained about 6.0 % during the period 2000 to 2012.

Political and Decision Making Structure: Zimbabwe is a unitary, democratic and sovereign state with an elected executive President who serves as both head of state and government. The 2013 Constitution defines the legal system. The Government has three tiers, which are the national Government; Provincial and Metropolitan Councils; and Local Authorities.The parliament consists of the Upper House (Senate) and Lower House (National Assembly). Parliament is elected for a five-year term.

NATIONAL GREENHOUSE GASES (GHGs) INVENTORY

The Third National Communication Greenhouse Gas Inventory for the year 2006 is the third inventory to be prepared for Zimbabwe. The 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines were used to estimate GHG emissions from Energy and Industrial Processes and Other Product Use (IPPU) while the Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste GHG inventories were compiled using the Revised 1996 IPCC Guidelines for National GHG Inventories. It was also based on the Good Practice Guidance and Uncertainty Management in National GHG Inventories (GPG 2000) and the Good Practice Guidance and Uncertainty Management (GPG 2002). The sectors covered in the inventories were: (1) Energy; (2) Industrial Process; (3) Solvents and Other Product Use; (4) Agriculture; (5) Land Use, Land Use Change and Forestry (LULUCF); and (6) Waste. Removals of GHGs were estimated from LULUCF.

Total emissions for the baseline year 2006 amounted to 22,019.566Gg carbon dioxide equivalent (CO_2eq) while removals from LULUCF amounted to 83,000.000Gg CO_2 giving a net sink position of 60,980.434Gg CO_2eq. The sectoral 2006 GHG emissions from the respective sectors were as follows: 10,663.909 Gg CO_2eq for Energy Sector; 906.930Gg CO_2eq for Industrial Processes; 11.184 Gg CO_2eq from Solvents and other Product Use; 9,686.380 Gg CO_2eq from Agriculture; and 752.000 Gg CO_2eq from Waste. Energy Industries (1A1), Other Sectors (1A4), Manufacturing Industries and Construction (1A2), Transport (1A3) as well as Prescribed Burning (4E) and Solid waste disposal (5A) were the key categories exclusive of LULUCF. Key categories with LULUCF were Energy Industries, Other Sectors and Manufacturing Industries and Construction. A summary of the GHG emissions for Zimbabwe in 2006 is presented in Table ES1.

ES 1 Summary of Greenhouse Gas Emissions for Zimbabwe/2006 (Gg)

National greenhouse gas inventory of anthropogenic emissions by sources & removals by sinks of all greenhouse gases not controlled by the Montreal Protocol & greenhouse gas precursors								
Greenhouse gas source & sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Total national emissions & removals	10,995.150	83,000.000	255.418	15.567	1,089.345	264.916	34.107	4.046
1. Energy	10,318.236	NE	11.431	0.201	52.845	203.646	34.107	4.046
A. Fuel combustion (sectoral approach)	10,298.455		4.189	0.201	23.461	91.704	15.820	1.634
1. Energy Industries	5,377.221		0.058	0.085	NE	NE	NE	NE
2. Manufacturing industries & construction	1,438.925		0.021	0.021	4.583	2.037	0.151	0.709
3. Transport	1,277.626		0.261	0.063	12.956	66.498	12.603	0.089
4. Other sectors	2,001.220		3.841	0.030	5.922	20.238	2.466	0.778
Commercial & Institutional	554.034		0.059	0.009	0.255	5.099	0.510	0.214
Residential	72.268		0.010	0.001	1.457	1.214	0.246	0.056
Agriculture	1,374.919		3.773	0.020	4.211	13.925	1.711	0.507
5. Other (please specify) Mining	203.463		0.008	0.002	NE	2.931	0.600	0.058
B. Fugitive emissions from fuels	19.782		NE		NE	0.000	0.000	0.000
1. Solid fuels			7.242		NE	NE	NE	NE
2. Oil & natural gas			NO		NO	NO	NO	NO

National greenhouse gas inventory of anthropogenic emissions by sources & removals by sinks of all greenhouse gases not controlled by the Montreal Protocol & greenhouse gas precursors								
Greenhouse gas source & sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
2 Industrial Processes	665.730	0.000	0.007	0.806	0.000	0.000	0.000	0.000
Mineral products	280.744				NE	NE	NE	NE
Chemical industry	NE		NE	0.806	NE	NE	NE	NE
Metal production	378.789		0.007	NE	NE	NE	NE	NE
Other production	6.196		NE	NE	NE	NE	NE	NE
Production of halocarbons & sulphur hexafluoride								
Consumption of halocarbons & sulphur hexafluoride								
Other	NE		NE	NE	NE	NE	NE	NE
3 Solvents & other product use	11.184			NE			NE	
4 Agriculture			213.900	14.560	1,036.500	61.270	NE	NE
Enteric fermentation			170.290					
Manure management			7.060	0.220			NE	
Rice cultivation			0.040				NE	
Agricultural soils			NE	11.060			NE	
Prescribed burning of savannahs			35.680	3.260	1,008.300	60.500	NE	

National greenhouse gas inventory of anthropogenic emissions by sources & removals by sinks of all greenhouse gases not controlled by the Montreal Protocol & greenhouse gas precursors								
Greenhouse gas source & sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Filed burning of agricultural residues			0.830	0.020	28.200	0.770	NE	
Other			NE	NE	NE	NE	NE	
5 Land-use change & forestry	NE	83,000.000	NE	NE	NE	NE	NE	NE
Changes in forest & other woody biomass stocks	NE	83,000.000						
Forest & grassland conversion	NE	NE	NE	NE	NE	NE		
Abandonment of managed lands	NE	NE	NE	NE	NE	NE		
CO_2 emissions & removals from soils	NE	NE						
Other	NE	NE	NE	NE	NE	NE		
6 Waste			30.080	0.000	0.000	0.000	0.000	0.000
Solid waste disposal on land			25.450		NE		NE	
Waste-water handling			4.630	NE	NE	NE	NE	
Waste incineration						NE	NE	NE
Other (Septic)			NE	NE	NE	NE	NE	NE
Memo items	28.296	0.000	0.000	0.000	0.432	0.361	0.075	0.007
Aviation								
Marine	NA		NA	NA	NA	NA	NA	NA
International Aviation	28.296		0.000	0.001	0.432	0.361	0.075	0.007
CO_2 emissions from biomass								

NE = Not Estimated; IE = Included Elsewhere; NO = Not Occurring

Using global warming potentials of:

(CO_2 =1: CH_4 =25: N_2O =298),

Key Categories

Key category analysis was performed, first without LULUCF (Table ES2) and then with LULUCF (Table ES3). Emissions were from Energy Industries (1A1) 24.75 %, Enteric Fermentation (4A) 19.49 %, Agriculture soils (4D) 15.09 %, Prescribed burning of savannahs (4F) 8.53 %, Manufacturing industries and construction (2A2) 6.62 %, Energy use in Agriculture (1A4) 6.76 %, Commercial and Institutional (1A4), Metal production (2C) and Mineral products (2A).

ES2 Key Category Analysis without LULUCF

IPCC Source Category	Sector	Sub-category	Total GHG (CO_2eq)	Contribution (%)	Cumulative sum (%)
1.A.1	Energy	Energy Industries	5,404.020	24.75	24.75
4.A	Agriculture	Enteric fermentation	4,257.250	19.49	44.24
4.D	Agriculture	Agricultural soils	3,295.880	15.09	59.33
4.E	Agriculture	Prescribed burning of savannahs	1,863.480	8.53	67.87
1.A.4	Energy	Energy use in Agriculture	1,475.280	6.76	74.62
1.A.2	Energy	Manufacturing industries & construction	1,445.775	6.62	81.24
1.A.3	Energy	Transport	1,302.855	5.97	87.21

IPCC Source Category	Sector	Sub-category	Total GHG (CO_2eq)	Contribution (%)	Cumulative sum (%)
6.A	Waste	Solid waste disposal on land	636.250	2.91	90.12
1.A.4	Energy	Commercial and Institutional	558.122	2.56	92.68
2.C.	Industrial Processes	Metal production	378.964	1.74	94.41
2.C	Industrial Processes	Mineral products	280.744	1.29	95.70
4.B	Agriculture	Manure management	242.060	1.11	96.81
2.B	Industrial Processes	Chemical industry	240.188	1.10	97.91
1.A.5	Energy	Other (please specify) Mining	204.177	0.93	98.84
1.B.1	Energy	Energy - solid fuels	181.050	0.82	98.85
6.B	Waste	Waste-water handling	115.750	0.53	99.37
1.A.4	Energy	Residential	72.694	0.33	99.70
4.F	Agriculture	Field burning of agricultural residues	26.710	0.12	99.83
1.B	Energy	Fugitive emissions from fuels	19.782	0.09	99.92
3	Solvents & other Product Use	Solvents and other product use	11.184	0.05	99.97
2.D	Industrial Processes	Other production	6.196	0.03	100.00
4.C	Agriculture	Rice cultivation	1.000	0.00	100.00

With the inclusion of LULUCF, seven categories contributed to the key category. These were LULUCF with 79.17%, followed by Energy industries (5.15%), Enteric Fermentation (4.06%), Agricultural soils (3.14%), Prescribed burning of savannahs (1.78%), Energy use in Agriculture (1.41%) and Manufacturing industries and construction (1.38%).

ES3: Key Category Analysis with LULUCF

IPCC Source Category	Sector	Sub-category	Total GHG (CO_2eq)	Contribution (%)	Cumulative sum (%)
5	LULUCF	Land-use change and forestry (Removals)	83,000.000	79.17	79.17
1.A.1	Energy	Energy Industries	5,404.020	5.15	84.32
4.A	Agriculture	Enteric fermentation	4,257.250	4.06	88.38
4.D	Agriculture	Agricultural soils	3,295.880	3.14	91.53
4.E	Agriculture	Prescribed burning of savannahs	1,863.480	1.78	93.31
1.A.4	Energy	Agriculture	1,475.280	1.41	94.71
1.A.2	Energy	Manufacturing industries and construction	1,445.775	1.38	96.09
1.A.3	Energy	Transport	1,302.855	1.24	97.34
6.A	Waste	Solid waste disposal on land	636.250	0.61	97.94
1.A.4	Energy	Commercial and Institutional	558.122	0.53	98.47
2.C.	Industrial Processes	Metal production	378.964	0.36	98.84
2.C	Industrial Processes	Mineral products	280.744	0.27	99.10
4.B	Agriculture	Manure management	242.060	0.23	99.33
2.B	Industrial Processes	Chemical industry	240.188	0.23	99.56
1.A.5	Energy	Other – Mining	204.177	0.19	99.76
1.B.1	Energy	Energy - solid fuels	181.050	0.82	98.85
6.B	Waste	Waste-water handling	115.750	0.11	99.87
1.A.4	Energy	Residential	72.694	0.07	99.94
4.F	Agriculture	Field burning of agricultural residues	26.710	0.03	99.96
1.B	Energy	Fugitive emissions from fuels	19.782	0.02	99.98
3	Solvents and other Product Use	Solvents and other product use	11.184	0.01	99.99
2.D	Industrial Processes	Other production	6.196	0.01	100.00
4.C	Agriculture	Rice cultivation	1.000	0.00	100.00

MITIGATION ANALYSIS

The mitigation analysis covered the five sectors namely: Energy; Industrial Processes and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry; and Waste. The analysis involved the determination of GHG emission reduction opportunities and the incremental costs of reducing the emissions. A baseline emission growth and the expected impact of the emission reduction options were determined and are presented in subsequent sections. Consultative and modelling approaches based on appropriate software were used. However, a number of challenges such as financial constraints for technology development and transfer as well as lack of technical capacity, need to be addressed for the country to reach its full mitigation potential.

Energy

Zimbabwe's energy industries are responsible for almost 50% of the energy-related emissions. Emissions from energy industries alone are projected to increase by 35% while that of the total energy sector emissions have a projected increase of 73%. The operational mitigation measures identified include improved maintenance of equipment and infrastructure while the capital investment measures involve technology change or fuel substitution. The thermal power plants have surpassed their operational lifespan. Replacing three of the small thermal power plants with one additional hydro power plant would have economic, social and environmental benefits.

Industrial Processes, Solvents and Other Product Use

Greenhouse Gas (GHG) emission sources from industrial processes in Zimbabwe for the year 2006 emanated from mineral production, chemical production, metal production and other production (food and beverages). The GHG emissions from this sector are projected to increase in line with the annual GDP growth rates projected under the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset). Although there are expected reductions in GHG emissions from implementing the proposed mitigation actions, the limiting step remains financial capital. An estimated $528 million (USD) is required.

Agriculture

Mitigation of GHG emissions from Zimbabwe's agricultural sector should be targeted at reducing CH_4 emissions in non-dairy cattle, N_2O emissions from agricultural soils and CO from the burning of savannas. In future, the ability of pastures to compensate primary production of biomass in response to anthropogenic carbon losses will be compromised due to increased rainfall variability in Zimbabwean Savanna rangelands. An integrated, community-based approach could be best in discouraging excessive burning of rangelands. Restoration of grazing infrastructure such as fencing of rangelands in resettlement areas of Zimbabwe presents an opportunity for controlling and optimising grazing and pasture quality. Awareness, training and extension support is required to promote buy-in of good management practices of grasslands including prescribed burning, and on-farm by-products.

Land Use, Land-Use Change and Forestry

The Land Use, Land-Use Change and Forestry sector is a complex sector that calls for both national and international collaboration on knowledge exchange and experience in implementation of forestry related policies. National and international forest policies have the potential to attain climate change mitigation goals. The policies to be considered here are those which will either be used to maintain carbon stocks and/or expand carbon sinks. Such policies include: the Forest Protection and Conservation Policies; policies on shared responsibility for managing existing protected areas between local communities and the other agencies; policies on afforestation and reforestation, and policies on incentives for private ownership of some forest resources. Zimbabwe is finalising the Forest Policy that will also guide climate change mitigation in the forestry sector.

Waste

The largest source of GHG emissions in the Waste Sector is landfill that emits CH_4, followed by wastewater that emits CH_4 and N_2O. The key drivers for emissions from waste sector are population growth, urbanization, affluence and the extent of landfill gas capture. Emissions from waste are projected to increase in line with the anticipated population growth. As a developing country, Zimbabwe needs to pursue waste prevention, reduction or minimisation, re-use and recycle of solid waste. These processes have environmental, social and economic benefits. End-pipe waste disposal methods such as waste to energy for both solid and liquid waste are expensive and therefore pursued after prevention, reduction, re-use andrecycle. This can be achieved through green subsidies, regulatory instruments, voluntary and information based instruments.

Although Zimbabwe is currently a net sink of GHGs, adaptation alone will not be enough. Mitigation measures in the different sectors will present socio-economic benefits, in addition to environmental ones. The various policies, programmes, and strategies that are being implemented are likely to reduce the GHG emissions. International technical and financial support is essential.

IMPACTS, VULNERABILITY AND ADAPTATION

Climate change is an additional constraint to sustainable socio-economic development for Zimbabwe. Zimbabwe is particularly vulnerable to climate change due to its heavy reliance on rain-fed agriculture and climate sensitive resources. In this report, future climate projections based on CSIRO MK3 Global Circulation Model for the 2040s were used. These future climate projections were based on two Intergovernmental Panel on Climate Change (IPCC) Special Reports on Emission Scenarios (Report number four) (IPCC_SRES_AR4) anchored on the A1B (best case) and the A2 (worst case) scenarios. The rationale for adopting climate change scenarios for the 2040s is that they allow for medium term planning for adaptation. Following to this, focus was placed on the vulnerability of Chiredzi District, that relies on the Runde and Save catchments, in Agro-ecological Zone V of Zimbabwe to climate change due to indications that rainfall will mostly decrease in the southern parts of the country compared with other regions of the country. Based on this background, a detailed assessment of vulnerability of Chiredzi District to climate change on the Agricultural and Health Sectors was carried out.

In this report, evidence was provided showing that climate change over Zimbabwe is characterised by high temperature and rainfall variability and extremes. This evidence also showed that the Start of Season (SOS) dates for the five representative meteorological stations in each of the Agro-ecological Zones tend to shift towards late SOS.

Vulnerability and Adaptation in the Agricultural sector in Chiredzi

The study established that the Agricultural sector characterised by cropping and livestock farming are particularly sensitive to variations in rainfall and temperature making the sector particularly vulnerable. Coping strategies in the agricultural sector in Chiredzi include; selling of livestock, vegetable gardening, staggered planting, dry planting, food handouts from donors and consumption of non-timber forest products. Results of the vulnerability assessment imply that adaptation has to be generally long term. For instance, vegetable gardening was for a long time an adaptation strategy that communities relied on, to an extent that the communities involved were able to sustain their families.

Supplementary feeding is one of the adaptation strategies for the livestock subsector that communities indicated as being important. Supplementary feeds supplied by surrounding organizations for example sugar estates have helped communities when the natural pastures are in poor state.There is need to incorporate local knowledge in the designing of adaptation strategies that would be effective in mitigating climate change impacts in the long term.

Vulnerability and Adaptation in the Health sector in Chiredzi

Malaria, schistosomiasis and diarrhoea were used as indicator diseases to assess the potential impact of climate change on the health sector as their distribution and seasonal transmission normally relate with temperature and rainfall. The data used for malaria was from 1990 to 2014. The 2007 data showed a strong relationship between malaria distribution and rainfall. However, schistosomiasis and diarrhoea showed no significant relationship with climate. This therefore suggests that the high prevalence and incidence rates of those diseases could be attributed to non-climatic factors, including limited access to safe water and sanitation, among others. Interventions to reduce these diseases should therefore also target water and sanitation issues. Nevertheless, under a changing climate, this relationship between rainfall, schistosomiasis and diarrhoea may become stronger.

Future Vulnerability in Chiredzi district

An assessment of future cropping vulnerability under both the Best Case Scenario (BCS) and Worst Case Scenario (WCS) indicate that the cropping system is highly vulnerable in the southern and western parts of the region. The vulnerability is more intense under the WCS for Chiredzi District. An assessment of future livestock vulnerability under both BCS and WCS indicates that the livestock system will also be vulnerable to climate change. These vulnerabilities will be exacerbated by shortage of water. The analysis shows that water availability in Runde and Save catchments will decrease with climate change.

SYSTEMATIC OBSERVATIONS AND RESEARCH

Research and Systematic Observations

The Meteorological Services Department (MSD) is a public institution in the Ministry of Environment, Water and Climate, whose mandate is to monitor the state and evolution of the atmosphere, develop and disseminate public, aviation and agrometeorological forecasts and to issue advisories and early warnings on imminent meteorological hazards. Climate and weather information is collected mainly through its network of synoptic and automatic weather stations which comprise of 47 stations that form part of the Global Surface Network (GSN) and Global Upper Air Network (GUAN) as well as at least 300 volunteer rainfall stations. The MSD participates in regional and international data exchange programs within the global observing systems to fulfil international agreements as signed by the government of Zimbabwe. The data is shared regionally and internationally through the Global Telecommunication Systems (GTS). A database management system, Climsoft 3, is used to archive local data. Apart from MSD, other players participate in systematic climate observations, among which are universities, private organisations and the public. Old equipment which experience constant breakdowns hampers data availability; therefore gaps exist within the data.

Systematic observations are also done in agriculture, hydrology, health and forestry sectors. Agriculture sector utilises the same data as collected through the MSD network. Hydrological monitoring is done through the Zimbabwe National Water Authority (ZINWA). At least 340 points are used to monitor and collect run-off data from 7 catchment areas as well as 5 operating automatic hydrologic. The Water Resources System (WRS) is the main database management system used for data storage.

Disease surveillance is done on a daily basis at all health facilities and data on epidemic diseases and deaths is transmitted through the Frontline SMS system. The DHIS2 System, an active computer based system uses internet for compiling and transmitting weekly and monthly reports from District, Province and National Level providing status update on diseases countrywide.

Research and Development

While climate data for the country is available, very little research has focussed on climate sciences due to limited availability of data as the MSD operates on a cost recovery basis. Additionally data paucity sometimes makes the data unusable since methods of triangulation/ interpolation fail where data is unavailable for long periods. Studies have focused mainly on impacts, adaptation and mitigation. Climate projections indicate an increase in areas suitable for small grains.An increase in malaria-risk areas due to projected increases in temperature was predicted. Research within the agriculture sector has focussed on improving small grain traits and breeding of very short season maize varieties. However, there is a strong call to consider indigenous climate science and improving indigenous seeds. In the energy sector, the focus has been on clean energy such as renewable, solar and hydro-electric energy. Research has been done in pockets due to non-collaboration and non-existent linkages among institutions and lack of coordinated funding dedicated for climate change research. To further complicate the situation, there is no mandatory platform providing a reliable database on different research that has been done in the areas of meteorology, greenhouse gas emissions mitigation, vulnerability, adaptation and climate related areas.

Participation in International Programs.

Zimbabwe participates in regional, continental and international programs at different levels. The MSD participates in Global Climate Observing Systems (GCOS) plan through provision of data according to World Meteorological Organisation (WMO) standards and Global Framework for Climate Services (GFCS) activities. At regional level, Zimbabwe participates in Monitoring for Environment and Security in Africa (MESA) and is part of the Meteorological Association of Southern Africa programmes as well as Southern Africa Development Community Climate Services Centre initiatives. Continentally, the Africa Group of Negotiators (AGN) and the African Ministers' Conference on Environment (AMCEN) are the main participation platforms. Internationally, a number of Zimbabwean nationals contribute to the Intergovernmental Panel on Climate Change (IPCC) as lead authors and/or contributors of sections or regional reports and in United Nations Framework Convention on Climate Change negotiation process. ZINWA participates in data sharing programs locally, regionally and internationally. Runoff data is shared through the SADC HYCOS website in line with the SADC Protocol on Shared Water Courses (2003). Surface water data is shared through the Zambezi River Basin Water Resources Managers and Dam Operators (ZAMDO) and through the Zambezi Watercourse Commission (ZAMCOM) platform.

OTHER INFORMATION

Integration of climate change into policies and development planning

Zimbabwe has a National Climate Change Response Strategy (NCCRS) in place and is in the process of concluding the National Climate Policy. Consultations on the development of National Adaptation Plan (NAP) are on-going. The country has submitted its Nationally Determined Contributions (NDCs) to the UNFCCC. Zimbabwe has signed the Paris Agreement. Implementation of the Paris Agreement with respect to the NDCs is under the guidance of the Office of the President and Cabinet (OPC).

Zimbabwe is a member of the Southern African Development Community (SADC) as well as the Southern Africa Power Pool (SAPP). Being a signatory to the Multi-Lateral Environmental Agreements namely, United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD), and United Nations Convention on Biological Diversity (CBD), the country is ready to implement appropriate responses to climate change.

Institutional Arrangements

The Office of the President and Cabinet has the overall responsibility of all decisions around National Climate Policy. The Ministry of Environment, Water and Climate is responsible for coordinating environmental issues in the country including climate change through the

Climate Change Management Department.

The Climate Change Management Department is responsible for the development of the National Communications and is supported by a multi-sectoral National Climate Change Committee for sector-specific and cross-sector implementation, coordination, advice and guidance.

CONSTRAINTS AND GAPS, RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

Several studies that have been conducted in the country revealed some constraints and gaps and related financial, technical and capacity needs.

General Constraints

The level of awareness on climate change in Zimbabwe remains low. This limited awareness negatively affects climate change reporting and implementation of related initiatives.

Data gaps presented a major challenge during the GHG inventory preparation. Inadequacy of data can be attributed mainly to limited capacity (technical and financial) by key institutions to record or collect data. Loss of data from previous initiatives is also a challenge that needs to be addressed. Some of the equipment used to make observations has since reached the end of its useful life span making it obsolete and thus compromising data quality and availability.

Limited understanding of some of the UNFCCC methods and formulas used either in emission estimation amongst other climate change related methodologies remains a challenge.

Suggested solutions to the technological challenges include the need for technical capacity training for local technological institutions on technology adaptation and development. In addition, partnerships were suggested to be forged between local institutions and international technology developers so as to use and produce appropriate technologies.

Limited financial resources have been highlighted as one of the key barriers to successful reporting and implementation of the Convention. The proposed mitigation and adaptation initiatives require funding for successful implementation. Funds should be mobilised both internally and externally to meet climate change needs, especially for climate change adaptation and implementation of Nationally Determined Contributions.

Constraints specific to the Third National Communication

A number of constrains or challenges were identified in different sectors during the preparation of reports and implementation of climate change initiatives reported in the Third National Communication. The critical constraint in preparation of the GHG inventories for National Communications is the expertise in quantification of GHGs and also absence of a functional National Energy Information System (NEIS). The major constraint in reporting vulnerability and adaptation is limited access to and non-availability of data for comprehensive analysis of vulnerabilities. There were constraints to data access for research purposes and limited coverage for systematic observation systems to generate real time data on a continuous basis.

The major limitations to the education, training and awareness sector include limited dialogue on climate change initiatives and lack of funding to implement awareness programmes.

Financial limitations have been highlighted as key by the national consultants in accomplishing their tasks fully. The funds allocated to each section of reporting are not sufficient to ensure national coverage in terms of consultations and data collection. Addressing these constraints will ensure Zimbabwe to set a solid foundation for moving the climate change agenda forward.

POLICY

The development of the National Climate Change Response Strategy (NCCRS) and National Climate Policy in Zimbabwe has been some of the Government of Zimbabwe's key priorities in the climate sector. The two processes are creating an enabling environment for the integration of climate change related issues in Zimbabwe. The NCCRS has action plans and strategies which will require close to US10 billion for implementation in the next 5years, with 50% of the budget going towards water and agriculture related strategies. The country requires US$55.8 billion to reduce its GHGs by 33% towards its NDCs to the UNFCCC.

The country is also realigning its Acts and sector policies with the Constitution of Zimbabwe which was enacted in 2013. However, this realignment may not be achieved in the short term due to lack of financial resources. The implementation of climate change initiatives will require financial resources and innovative interventions if strategies identified in the NCCRS are to be achieved.

Other policies that will be concluded in the near future include disaster risk management, renewable energy, bio-fuel and forestry policy. The Irrigation and Water Resources Management Master Plans are under development.

The Climate Change Management Department (CCMD) was established under the Ministry of Environment, Water and Climate (MEWC) in 2013 in recognition of the importance of effective coordination of climate change issues in the country.

Abbreviations and Acronyms

A'-Level	Advanced Level
ABM	Agent Based Modelling
AGRITEX	Agriculture, Technical and Extension Services
AIDS	Acquired Immuno Deficiency Syndrome
AMCOW	African Ministers' Council on Water
AWMS	Animal Waste Management System
AWOS	Automatic Weather Observing System
BCS	Best Case Scenario / the environmentally conscious scenario (B2a)
BCSDZ	Business Council for Sustainable Development Zimbabwe
BIOCLIM	Biological Climatic Model
BNR	Biological Nutrient Remover
BUH	Botswana Upper High
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CBD	Convention on Biological Diversity
CCMD	Climate Change Management Department
CD	Compact Disk
CDM	Clean Development Mechanism
CDU	Curriculum Development Unit
CH_4	Methane
CIMMYT	International Maize and Wheat Improvement Centre
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of Parties
CPOL	Community Popular Opinion Leaders
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Central Statistical Office
CV	Coefficient of Variation
DCP	Department of Civil Protection
DOC	Degraded Organic Content
DRR	Disaster Risk Reduction
DR&SS	Department of Research and Specialist Services
ECD	Early Childhood Development
ECOCROP	Ecological Crop Requirements Model
EE	Environmental Education

EF	Emission Factor
EFDB	Emission Factor Data Base
EMA	Environmental Management Agency
EPA	Environmental Protection Agency
ESAP	Economic Structural Adjustment Programme
EU	European Union
FAO	Food and Agricultural Organisation
FC	Forestry Commission
GCM	Global Circulation Models
GCOS	Global Climate Observing Systems
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite System
GTS	Global Telecommunication System
GUAN	Global Upper Air Observations
GWP	Global Warming Potential
HadCM2	Hadley Centre Model version 2
HFC	Hydrofluorocarbon
HIV	Human Immunodeficiency Virus
HYCOS	Hydrological Cycle Observing System
IBM	Integrated Behaviour Model
IETC	International Environment Technology Centre
IKS	Indigenous Knowledge Systems
INC	Initial National Communication
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
ITCZ	Intertropical Convergence Zone
IWRM	Integrated Water Resources Management
LAPS	Local Area Prediction Systems
LPG	Liquefied Petroleum Gas
LULUCF	Land-Use, Land Use Change and Forestry
MDG	Millennium Development Goals
MEA	Multilateral Environmental Agreements
MEWC	Ministry of Environment, Water and Climate
MOEPD	Ministry of Energy and Power Development

MOHCC	**Ministry of Health and Child Care**
MSD	**Meteorological Services Department**
MSWDS	**Municipal Solid Waste Disposal Site**
N_2O	**Nitrous Oxide**
NCCC	**National Climate Change Committee**
NCCRS	**National Climate Change Response Strategy**
NCSA	**National Capacity Self Assessment**
NCSP	**National Communication Support Programme**
NEIS	**National Energy Information Systems**
NEP	**National Environmental Policy and Strategies**
NEWU	**National Early Warning Unit**
NGO	**Non-governmental Organization**
NHS	**National Hydrological Services**
NMVOC	**Non-Methane Volatile Organic Compounds**
NOx	**Nitrogen Oxides**
NPP	**Net Primary Productivity**
NTT	**National Task Team for Climate Change**
OPEC	**Organisation of the Petroleum Exporting Countries**
PCGN	**Permanent Committee on Geographical Names**
PFC	**Perfluorocarbon**
PPP	**Public-Private Partnership**
RCZ	**Research Council of Zimbabwe**
SADC	**Southern Africa Development Community**
SAPP	**Southern Africa Power Pool**
SF_6	**Sulphur Hexafluoride**
SHP	**Small Hydro Power**
SIRDC	**Scientific and Industrial Research and Development Centre**
SNC	**Second National Communication**
SO_2	**Sulphur Dioxide**
STEM	**Science Engineering Technology and Mathematics**
SWDS	**Solid Waste Disposal Site**
TB	**Tuberculosis**
TPF	**Timber Producers Federation**
TV	**Television**
UNCCD	**United Nations Convention to Combat Desertification**
UNDP	**United Nations Development Programme**
UNEP	**United Nations Environment Programme**
UNFCCC	**United Nation Framework Convention on Climate Change**

UNITAR	**United Nations Institute for Training and Research**
USA	**United States of America**
WACDEP	**Water, Climate and Development Programme**
WCS	**Worst Case Scenario / the business as usual case (A2a)**
WHO	**World Health Organisation**
WHYCOS	**World Hydrological Cycle Observing System**
WMO	**World Meteorological Organization**
WRSI	**Water Requirement Satisfaction Index**
ZAPF	**Zimbabwe Agricultural Policy Framework**
ZBC	**Zimbabwe Broadcasting Corporation**
ZESA	**Zimbabwe Electricity Supply Authority**
ZFC	**Zimbabwe Fertiliser Company**
Zim Asset	**Zimbabwe Agenda for Sustainable Socio-Economic Transformation**
ZIMSEC	**Zimbabwe Schools Examination Council**
ZINWA	**Zimbabwe National Water Authority**
ZNCPC	**Zimbabwe National Cleaner Production Centre**

Contents

List of Figures

List of Tables

LIST OF APPENDICES

CHAPTER 1

1. NATIONAL CIRCUMSTANCES

1.1 Geographic Profile

Zimbabwe is situated in the southern part of Africa between latitudes 15° 30" and 22° 30" south of the Equator and between longitudes 25° 00" and 33° 10" east of the Greenwich Meridian. The country is land locked and is bordered by Mozambique to the east, South Africa to the south, Botswana to the west and Zambia to the north and north-west. Zimbabwe has a total land area of approximately 390,757 km^2 and is divided into ten administrative provinces; Bulawayo, Harare, Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Masvingo, Matabeleland North, Matabeleland South and Midlands as shown in Figure 1.1. Harare, situated in the northern part of the country is the capital city and it has all the major administrative and commercial functions. Bulawayo is the second largest city and is found in the southern part of the country.

Fig 1.1 Map of Zimbabwe (Source: UN, 2004)

The country's main topographical features, shown in Figure 1.2, include:

The central watershed/plateau, running from southwest to northeast and ranging from 1200m to 1500m above mean sea level. The plateau is 650km long and 80km wide;

i) The central watershed/plateau, running from southwest to northeast and ranging from 1200m to 1500m above mean sea level. The plateau is 650km long and 80km wide;

ii. The mountains along the eastern border with Mozambique where peaks are around 2300m to 2500m; and

iii. The Zambezi and Limpopo River Valleys to the northwest and southeast respectively, with an altitude below 500m.

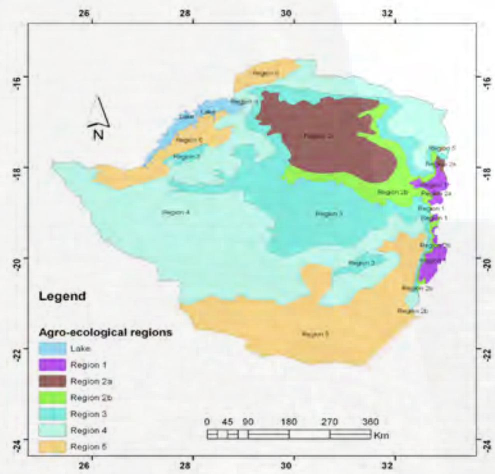

Figure 1.2 Zimbabwe's terrain (Source: Sadalmelik, 2007)

1.2 Climate

The Zimbabwe Meteorological Services Department classifies the seasons of Zimbabwe as follows:

i. Cool season - mid-May to August

ii. Hot season - September to mid-November

iii. Main rainy season - mid-November to mid-March

iv. Post rainy season - mid-March to mid-May

1.2.1 Characteristics of the rainy

Rainfall over Zimbabwe can be as a result of convection, orographic lifting, frontal systems and convergence. Convection accounts for about 90% of the country's rains. The main rainy season stretches from October of one year to March of the following year. The first part of the rainy season (October to December) is characterised by westerly cloud bands as the main rain bearing system while for the second part,January to March, the Intertropical Convergence Zone (ITCZ) is the main rain bearing system. The ITCZ is a migratory axis characterized by semi-permanent low pressure systems over the Caprivi Strip and in the central Mozambique Channel. It oscillates between positions 12°S and 16°S. For a good rainfall season in Zimbabwe 16°S is the preferred position of the ITCZ.

1.2.2 El Niño Southern Oscillation

Significant differences in rainfall amount, temporal and spatial distribution have been observed to occur in the country between opposite extremes in the phase of the El Niño Southern Oscillation (ENSO) (Matarira, 1990). During the warm phase of ENSO, the El Niño phase, the country usually experiences below average rains whilst during the cool phase, La Niña, the country usually receives average to above average rains.

1.2.3 Rainfall Geographical Distribution

Annual rainfall ranges from below 400mm in the south to over 1000mm in the eastern parts of the country. Total rainfall amounts however, exhibit huge spatial and temporal variability from year to year. The mean annual rainfall is as shown below in Figure 1.3.

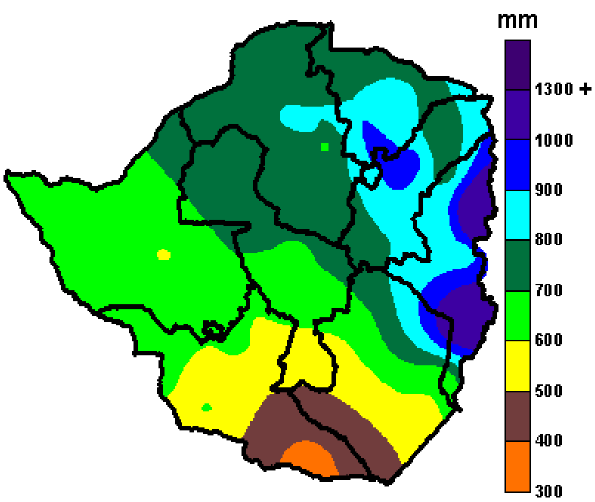

Fig 1.3 Mean Annual rainfall (Source: Zimbabwe Meteorological Services Department)

1.2.4 Tropical Cyclones

Tropical cyclones are an important feature of Zimbabwe's rainfall season. The tropical cyclone season stretches from December to March of the following year peaking in February. Depending on their proximity and relative position, tropical cyclones may induce an extended dry spell (Climate handbook of Zimbabwe, 1981) or give widespread and heavy rainfall within a very short space of time. Examples of tropical cyclones that directly affected the country in recent times are Eline in 2000 and Japhet in 2003.

1.2.5 Dry spells and droughts

During the rainy season the rainfall distribution is such that wet episodes are normally interspersed with dry periods. The most notable dry period during the rainfall season usually occurs from the last week of December to the first or second week of January. It is termed the mid-season dry spell and is caused by a high pressure system that gets established in the middle levels (500 hPa) of the atmosphere over Botswana and is thus termed the Botswana Upper High (BUH). This feature suppresses meaningful cloud development resulting in dry conditions across the country.

The country experiences some relatively frequent drought years. These droughts are of varying duration, intensity and spatial extent and cause impacts in different sectors such as agriculture and water resources. Notable droughts that affected the country within the last 100 years occurred in: 1915/16, 1921/22, 1923/24,1946/47, 1967/68, 1972/73, 1982/83, 1986/87, 1991/92 and 1994/ 95. However, the most devastating drought occurred in 1991/92 season.

1.2.6 Temperature

The lowest minimum temperatures are recorded in June or July and the highest maximum temperatures in October. However, in the case of anomalous years the highest temperatures may be recorded either in Novemberor December. The mean monthly temperature varies from 15°C in July to 24°C in November while the mean annual temperature varies from 18°C in the Highveld to 23°C in the Lowveld.

A combination of a dry south-westerly airflow, overnight clear skies and calm winds in the cool season sometimes results in mild to severe ground frost. The ground frost occurs from about mid-May to early August. There are two peak periods, one occurring around 20 June and another one from mid to end of July with the latter being the more severe.

1.3 Natural Resources

The country has abundant natural resources that include beautiful scenery, arable land, forests, surface water, ground water and minerals such as gold, iron, diamonds, chromium, platinum and asbestos. Zimbabwe is home to Victoria Falls, one of the seven natural wonders of the world.

There are 12 national parks in the country. Three of the national parks lie across international boundaries and are part of the Trans-frontier Conservation Areas (TFCAs). These are Hwange National Park in the Kavango Zambezi (KAZA) TFCA; Mana Pools National Park in the mid-Zambezi TFCA; and Gonarezhou National Park in the Greater Limpopo TFCA.

1.3.1 Soils of Zimbabwe

Zimbabwe's soils can be classified into eight major groups namely the Regosols, Lithosols, Vertisols, Siallitic, Fersiallitic, Paraferralitic, Orthoferralitic and the Sodic (Nyamapfene, 1991). The Fersiallitic soils, mainly formed from granite rocks are the most extensive and are found predominantly in the middle-veld and the central watershed (Figure 1.4)

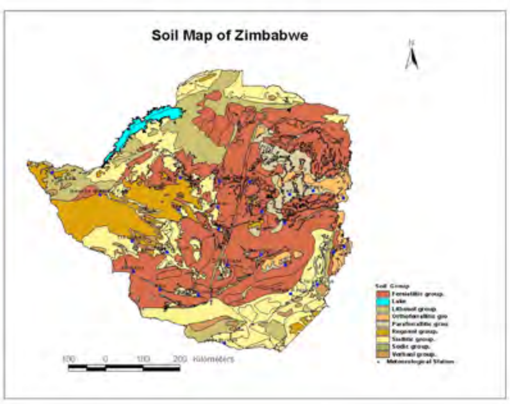

Fig 1.4 Distribution of Major Soil Groups in Zimbabwe (Source: Department of Surveyor General, 1979)

1.3.2 Water resources

Water resources in Zimbabwe are dependent on rainfall which is highly variable across most of the country. The country has over 10,000 small, medium and large dams. The main uses of the dams are domestic, agriculture, mining, fishing, recreation, industrial purposes and hydropower. The country relies on surface water resources for 90% of its requirements while groundwater supplies the remaining 10% (ZINWA). There are seven catchments in the country, namely Manyame, Mazowe, Gwayi, Runde, Sanyati, Save and Mzingwane as shown in Figure 1.5.

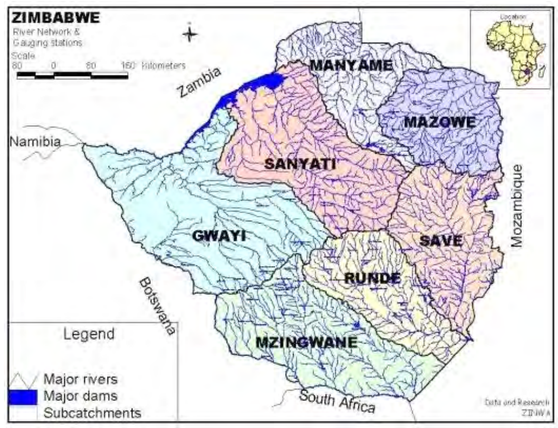

Fig 1.5 Catchments in Zimbabwe (Source: ZINWA, 2014)

Water use in Zimbabwe is governed by the Water Act of 1998 and the Water Policy of 2013. Water use is classified as either primary or commercial. The primary purposes of water use are reasonable use of water for the sustenance of life e.g. drinking, bathing, household cooking and watering small gardens. These purposes do not require a permit. Commercial use of water requires a permit and is basically the use of water by an individual who derives a profit/ benefit out of accessing the water. Catchment Councils, composed of representatives of all categories of people in the catchment area including farmers were formed to ensure that the interests of all water users are represented. Catchment Councils were given the powers to:

› Allocate water permits, with the Administrative
› Court (formerly the Water Court), being the Court of Appeal;

›Supervise the exercise of permits to the use of water within the catchment area; and

› Assist in the preparation of catchment plans in accordance with the Act.

1.3.3 Forestry

Zimbabwe's forestry resources cover approximately 46% of the total land area. Zimbabwe's forest stocks generate a wide range of both timber and non-timber products and services. The products include fuel wood, charcoal, sawn timber, pulpwood, building materials, wood for crafts, fodder, fruits, honey, mushrooms, edible insects, bark for rope, medicines, leaf litter, gum and resins. The services include watershed management, carbon fixation, microclimate stabilization, and the provision of windbreaks, shade, soil stability and wildlife habitat. Over a quarter of the woodland area is found in state lands, namely, national parks, wildlife reserves and forest reserves. Most of the country is covered by mopane/miombo woodland and savanna. About 21 million hectares of the land are under indigenous woodlands, 156,000 hectares under plantations and 12,000 hectares under natural forests. Non-commercial plantations cover 18,000 hectares of land. Commercial plantations, mainly eucalyptus and pine, occupy 120,000 hectares with the biggest area of 108,000 hectares in Manicaland. Commercial timber harvested from indigenous woodlands in communal lands is mainly teak and mukwa species. Sculptors are contributing to environmental damage of the indigenous forests areas by harvesting several species of hardwood to make curios especially in the Hwange and Victoria Falls areas of Matabeleland North. Figure 1.6 below illustrates the distribution of the various types of vegetation commonly found in Zimbabwe.

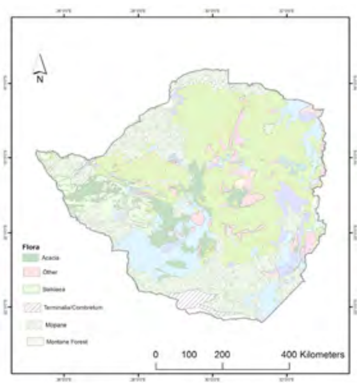

Fig 1.6 Common Vegetation Types in Zimbabwe (Source: Wild and Barbosa, 1967)

The flora of Zimbabwe consists of woodlands, forests and grasslands. Woodlands include Acacia, Biakiaea, Terminalia/Combretum, Miombo and Mopane woodlands. Forests are mainly Montane forests found in the Eastern Highlands of Zimbabwe. Grasslands are mainly found on high altitude areas of the Eastern Highlands of Zimbabwe as well as on serpentine formations along the Great Dyke (Wild and Barbosa, 1967).

Figure 1.7 shows the spatial variations in tree species diversity in Zimbabwe. The changes in diversity follows similar trend to that of rainfall and generally decreases with decreasing annual rainfall.

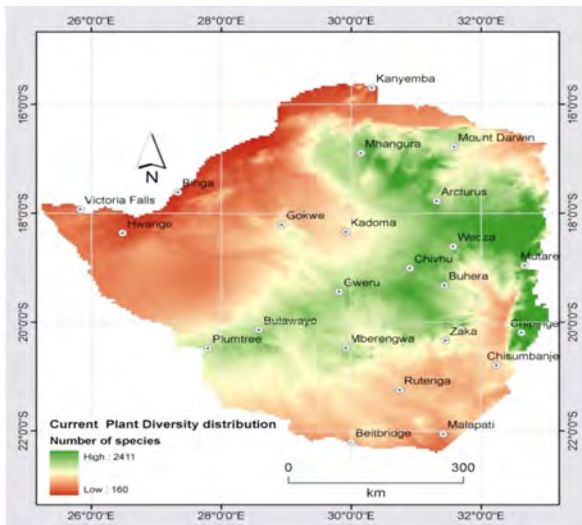

Fig 1.7 Spatial variations in tree species diversity in Zimbabwe (Gwitira et al., 2014)

1.3.4 Wetlands

Zimbabwe became a signatory to the Ramsar Convention in 2011. The country has seven sites that have been designated as Ramsar protected Wetlands. These are:

- Victoria Falls National Park
- Mana Pools National Park
- Monavale Wetland
- Lake Chivero and Manyame
- Driefontein Grasslands
- Chinhoyi Caves
- Cleveland Dam

Wetlands have a number of key functions which include providing a habitat for a variety of wildlife, replenishing groundwater supplies, acting as carbon dioxide sinks, supporting bird species that maintain the ecosystem of the wetlands through seed dispersal and balancing insect populations, providing water for irrigation, aquaculture, supporting recreational activities such as bird watching, and provide a sustainable food source for local communities. They also release clean fresh water which feed into water systems and the grasses remove pollution from runoff thus improving water quality.

Zimbabwe's protection of wetlands is provided for under the Environmental Management Act (EMA) (Ch 20:27) of 2002 with Statutory Instrument 7 of 2007 on Environmental Management (Environmental Impact Assessment and Ecosystem Protection) Regulations, and Government Gazette 380 of 2013.

Section 113 of EMA Act (Ch. 20:27) gives the Minister responsible for the environment powers to declare any wetland to be an ecologically sensitive area. The Minister may impose limitations on development in or around such an area, prohibit the reclamation or drainage, disturbance by drilling or tunnelling in a manner that has or is likely to have an adverse impact on any wetland or adversely affect any animal or plant life therein. Failure to abide by the law is a crime that attracts a fine or imprisonment or both.

Zimbabwe's Wetlands face degradation challenges due to a number of threats that include cultivation, dumping of waste, fires, invasion by alien plants, commercial and residential development and resource extraction.

1.3.5 Wildlife resources

The wildlife of Zimbabwe is mostly located in the national parks, private wildlife ranches, conservancies, sanctuaries and botanical gardens where exotic and indigenous species of trees are protected.

Zimbabwe's parks are home to the African 'big five' (lion, leopard, elephant, buffalo and rhinoceros). The country also has a variety of other animals, such as species of kudu, porcupine, antelope, duiker, impala, roan, gemsbok, bushbuck, sable, eland, wildebeest, zebra, warthog, giraffe, waterbuck, serval, civet, jackal, cheetah, hyena, hippo and the endangered African wild dog.

At the centre of wildlife conservation challenges are issues of increasing wildlife and human populations that now far exceed carrying capacities and wild fires. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) bans trading in endangered species and their products and poaching.

The Zimbabwe Parks and Wildlife Authority is a government department which is responsible for managing and administering game parks and wildlife. The authority also runs Safari areas where controlled hunting is permitted.

Hwange National park is the largest national park in Zimbabwe and boasts of a huge selection of wildlife with over 100 species of mammals, over 400 species of birds and over 100 species of trees and shrubs. The park is also rich in fish species.

1.3.6 Fisheries

The small scale fisheries in Zimbabwe play an important role in income generation and food security at the household level.Commercial fishing occurs mainly in five reservoirs namely Lake Kariba, Lake Chivero, Lake Mutirikwi, Mazvikadei dam and Manyame (FAO, 2007). Kariba fisheries are the largest and contribute 60-70% of Zimbabwe's total fish output. Lake Kariba is located in the north-western part of Zimbabwe on the Zambezi River which forms a border between Zambia and Zimbabwe. It has an area of 5,364km^2, a length of 277km and a mean depth of 29m. The smaller dams, rivers and ponds support small scale (artisanal) fisheries and provide fish for subsistence purposes. Lake Kariba supports pelagic (offshore) and artisanal (inshore) fisheries.

Over 60 fish species have been recorded in Lake Kariba and some of these include; bream, tilapia, nkupe, chessa, catfish, barbel,Cornish jack, Eastern bottlenose, brown squeaker, Nile bream, labeo, vundu and Tiger fish. Other fish species found in other reservoirs in Zimbabwe are Mozambique bream, blue bream, Hunyani salmon, mud sucker, parrot fish, bulldog, spot tail, minnow bass, African mottled eel, rainbow trout, Nyanga trout, Brown trout, and Brook trout.

Lake Kariba, the world's largest man made reservoir which was built in the late 1950s has a vibrant local fishing industry. Some fish farming projects run by some organizations in Kariba have helped locals set up low cost fish farms and provide technical expertise on aquaculture. The sardine (known locally as kapenta) was introduced to Lake Kariba from Lake Tanganyika in the late 1960s and the species spread rapidly through the lake. Commercial sardine fishing began in the early 1970s.

The fish industry has helped small scale fish farmers improve their dietary diversity and nutrition. Kapenta is eaten as fresh or dried and provides a cheap source of protein. Kapenta output has been decreasing over the years and some of the reasons cited for this include; climate change, overfishing, poaching, especially in breeding zones thus affecting the growth of the kapenta reserves, use of banned net sizes which catch small fish, the invasion of the invasive omnivorous Australian Red Claw crayfish which feeds on live or decaying animal or vegetable matter. The influx of cheaper kapenta from Mozambique is also threatening the Kariba fishing industry.

The Parks and Wildlife Act (Chapter 20:14 of 1996), as amended is the principal legislation governing the development, control and management of fisheries in Zimbabwe. The National Parks and Wildlife Management Authority of the Ministry of Environment, Water and Climate is empowered to issue permits, regulate, control, restrict or prohibit fishing in controlled areas.

1.4 Environmental Issues

1.4.1 Climate Change

The country has suffered from the impacts of climate change. These include a shift in the onset of the rainy season, increased duration of the mid-season dry spell, a change in the areal extent of the agro ecological regions, an increase in the intensity and duration of extreme weather events and an increase in temperatures.

1.4.2 Waste management

Non-provision of bins and irregular collection of waste has led to illegal dumpsites mushrooming at undesignated sites in both high and low density suburbs in the country. These dumpsites pose environmental and health hazards because of their attraction of mosquitoes, rats, cockroaches, and flies leading to malaria and cholera outbreaks. They are also a source of bad odours and look unsightly. The country's waste management strategies which focus mainly on the collection, transportation and disposal of waste are failing to cope with the large amounts of waste being generated. The major constraint on proper management of solid waste in cities has been cited as financial constraints.

Most towns and cities in Zimbabwe lack properly designed dumpsites. Landfills, without leachate collection and impermeable liners are the norm. Leachate produced from decomposing waste percolate into the soil and contaminates surface and ground water sources. They are also a source of methane, a greenhouse gas that causes global warming, leading to climate change. Most dumpsites are poorly located. Some of them are near residential and industrial areas, alongside streams with a potential of contaminating the water. They can burn spontaneously after the disposal of waste with burning material and are also a source of windblown litter.

In recent times the amount of electronic waste (e-waste) has also increased. This kind of waste is posing a serious challenge in disposal as some components contain non-biodegradable hazardous substances such as mercury and lead. The Environmental Management Act has regulations that provide for the disposal of hazardous waste.

Some organizations are now promoting waste management strategies such as minimizing production of waste, maximizing use of waste by recycling; composting biodegradable waste, reusing the same product and promoting environmentally sound waste disposal practices.

In an effort to manage waste a number of initiatives are being implemented:

- Programmes that empower communities to engage in waste management as a business.
- The Integrated Solid Waste Management Plan whose framework was developed in 2007.
- Introduction of vehicle litter bins for public and private vehicles.
- Some corporates have placed bins in urban areas.
- Generation of energy in bio-digesters.
- Waste separation at source and colour-coding of bins and liners.

A number of Statutory Instruments are in place to regulate waste management in the country. These include Effluent and Solid Waste Disposal Regulations, Statutory Instrument No. 6 of 2007, and the Hazardous Waste Management Regulations, Statutory Instrument No. 10 of 2007.

1.4.3 Pollution

Zimbabwe is subject to the major types of pollution namely air, water and noise pollution. Sources of pollution include vehicles, industries and open fires. Pollution monitoring is still minimal. While air and water pollution are the most common, noise pollution is rampant in mining areas where heavy trucks are used. Air pollution is increasing due to industries, poor waste management and transportation. Fertilizer manufacturing companies are also contributing to nitrous oxide emissions into the atmosphere. Other sources of air pollution are veld fires, dust raised by graders in mining areas, cement manufacturing companies and burning of fossil fuels in thermal power stations.

Smoke and dioxins from the incineration of used tyres is causing health problems that may include cancer, respiratory infections and birth defects. Indoor air pollution is also prevalent in rural areas because of open fire biomass burning for cooking, lighting and heating.

Emissions are regulated under the Air Pollution Control Regulations Statutory Instrument 72 of 2009 of the EMA Act. There are 8 air pollution monitoring stations in Zimbabwe. Zimbabwe has established the Air Pollution Control Unit (APCU) for Harare and promulgated Regulations for smoke and emission control. The EMA Act provides for pollution control and environmental impact assessment.

Water pollution is a major environmental concern in both urban and rural areas. The main sources of water pollution are the discharge of untreated or partially treated industrial, mining, municipal, domestic waste and washing of agricultural chemicals into water bodies. In urban areas discharge of raw sewage into municipal water supplies has resulted in water borne diseases such as cholera, dysentery and typhoid. Cholera outbreak claimed more than 4 000 lives in Zimbabwe between August 2008 and July 2009. Other problems are water treatment difficulties and clogging of irrigation pipes caused by high content of algae in the lake water. There are a number of legal frameworks that regulate water quality such as the Water Act (Chapter 20:22), the Water (Waste and Effluent Disposal) Regulations (S.1 274/2000), the Public Health Act (Chapter 15:09) and the Environmental Management Act (Chapter 20:27) as well as by-laws passed by local authorities.

1.4.4 Deforestation

Deforestation is one of the major environmental problems the country is facing. A number of drivers have been identified. These include expansion of land for cultivation, wildfires, firewood, tobacco curing, illegal harvesting for wood curio carvings, brick-making, construction poles particularly in rural areas and urban expansion due to the increasing population. A large proportion of Zimbabwe's population is rural and depends on firewood as a major source of household energy. In addition, load-shedding in urban areas caused by the country's power deficit have also led people to turn to firewood as a substitute for electricity. The country has experienced a gradual loss of indigenous trees that take a long time to reach maturity.

The number of registered tobacco growers has increased significantly over the years as tobacco remains the only crop to offer better returns compared with other cash crops. More than 80% of these growers are smallholder farmers. These farmers rely heavily on wood for curing. Zimbabwe is one of the largest flue-cured tobacco producers in the world. According to the Forestry Commission, the national rate of deforestation currently stands at more than 300,000ha per annum, of which approximately 15% is attributable to tobacco production activities. The UN Food and Agriculture Organization (FAO) Global Forest Resources Assessment in its 2010 edition listed Zimbabwe as being among 10 countries that recorded the largest forest cover loss between 1990 and 2010.

The legal instruments used to control deforestation are the Forest Act (Chapter 19:05) and the Communal Land Forest Produce Act (Chapter 19:04). These acts are administered by the Forestry Commission, a statutory body tasked with the conservation of gazetted and non-gazetted forests and the country's vegetation. The instruments make it an "offence to cut, injure, remove, and collect any forest produce without a license and to move firewood from one place to another without a timber movement permit issued by the Forestry Commission." In addition to these two, the Forestry Commission also makes use of Statutory Instrument 116 of 2012 which is the Forest (Control of Firewood, Timber and Forest Produce) Regulations of 2012.This Statutory Instrument controls the movement and trade in both wood and timber in the country and has special emphasis on encouraging the production of flue-cured tobacco on a sustainable basis.

In an effort to address deforestation a number of initiatives have been put in place and these include:

› The National Tree Planting Day which is observed on the first Saturday of December of each year.

› The rural afforestation programme managed by the Forestry Commission.

› A Statutory Instruments that compels tobacco farmers to have a woodlot of fast growing trees.

› Introduction of a rocket barn in an effort to reduce deforestation associated with tobacco curing. A rocket barn decreases wood use while improving the amount and quality of tobacco cured. The rocket barn is said to be 50% more efficient than the conventional barn.

› Research on solar energy and biogas in tobacco curing, which is ongoing.

› The National Forest Policy will address deforestation issues and support sustainable growth in Zimbabwe's forestry sector.

› Establishment of the Sustainable Afforestation Association (SAA) to promote the planting of woodlots for tobacco curing.

1.5 Institutional Arrangements

The Office of the President and Cabinet has the overall responsibility of all decisions around National Climate Policy. The Ministry of Environment, Water and Climate is responsible for coordinating environmental issues in the country including climate change through the Climate Change Management Department. The Climate Change Management Department is responsible for the development of the National Communications and is supported by a multi-sectoral National Climate Change Committee for sector-specific and cross-sector implementation, coordination advice and guidance.

Some of the key players include the Meteorological Services Department (MSD), Department of Civil Protection (DCP), civil society organizations, parastatals, universities, colleges and other private organizations. The MSD is responsible for issuing weather forecasts, advisories and warnings on extreme weather events such as floods, heat waves and tropical cyclones. The CPU coordinates rescue and relief efforts in the event of natural disasters including those of a hydro-climatic nature.

1.6 National Development Programmes

The guiding framework for development programmes is enshrined within the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset). In October 2013 the Government launched the economic blue print that will guide all Government policies and programmes through to December 2018. The economic blueprint's mission is "to provide an enabling environment for sustainable economic empowerment and social transformation to the people of Zimbabwe."

The blueprint identifies four clusters, namely; food security and nutrition, social services and poverty reduction, infrastructure and utilities, and value addition and beneficiation and two sub-clusters; fiscal reform measures and public administration, and governance and performance management.

A number of financing mechanisms for the programme have been proposed, among them, the budget, tax and non-tax revenue, leveraging resources, a Sovereign Wealth Fund, issuance of bonds, accelerated implementation of Public Private Partnerships and securitization of remittances. The country has been under sanctions since 2002. With relaxation of sanctions, the government has embarked on the process of re-engagement with international and multilateral finance institutions and other financial mechanisms.

1.7 Population

The 2012 Zimbabwe Population Census puts the country's total population at about 13.1 million with the average household size of 4 persons. The male population contributed about 48 percent; hence the sex ratio in the country was nearly 93. The annual average inter-censual growth rate for the period 2002 to 2012 was 1.1%. The population distribution was mostly rural with 67% of the total population living in rural areas. On average the population density was 33 persons/km^2. The population density ranged from 9 persons/km2 in Matabeleland North to 2,174 persons/km2 in Harare. The majority of the country's population was in Harare accounting for about 16%, while Bulawayo and Matabeleland South had the least proportions of about 5% each. The average rate of natural increase (the difference between the level of fertility and mortality which does not take account any growth due to migration) for the whole country was 2.2% for the 12-month period preceding the census count. Harare had the highest rate of natural increase of 2.6% while Matabeleland South had the lowest rate of natural increase, 1.4%.

The composition of population by age group and sex is illustrated in Figure 1.8. The proportion of the young population, below 15 years, constituted 41% of the total population and the old population, 65 years and above, contributed to only 4%.

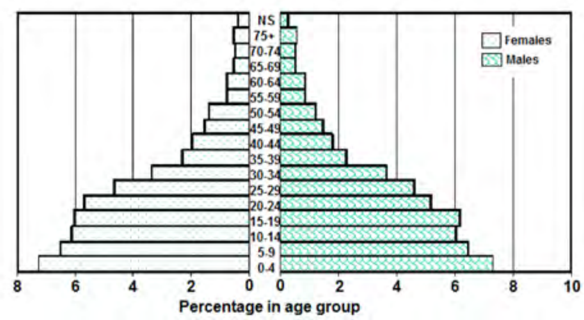

Fig 1.8 Percent Population Pyramid (ZimStat, 2012)

1.7.1 Population Distribution

Zimbabwe is divided into ten provinces with varying population compositions and sizes. In all the provinces males are outnumbered by females. Harare province is almost all urban while Bulawayo is wholly urban. The rest of the provinces have a mix of rural and urban population distribution. There are more people who reside in rural areas than in urban areas. Table 1.1 shows the population distribution by province as of 2012 Population Census.

Table 1.1 Percent Distribution of Population by Province and sex, Zimbabwe

Province	Male	Female	Number	Percent	Sex Ratio
Bulawayo	46.4	53.6	653 337	5.0	87
Manicaland	47.4	52.6	1 752 698	13.4	90
Mashonaland Central	49.2	50.8	1 152 520	8.8	97
Mashonaland East	48.5	51.5	1 344 955	10.3	94
Mashonaland West	49.8	50.2	1 501 656	11.5	99
Matabeleland North	48.2	51.8	749 017	5.7	93
Matabeleland South	47.8	52.2	683 893	5.2	92
Midlands	48.1	51.9	1 614 941	12.4	93
Masvingo	46.5	53.5	1 485 090	11.4	87
Harare	48.3	51.7	2 123 132	16.3	93
Total	48.1	51.9	13 061 239	100.0	93

Source: ZIMSTAT (2012), National Profile 2012 Population Census

1.8 Gender and Climate Change

Climate change presents a significant threat to human security, especially for women who represent 70% of the world's poor. It is widely recognized that climate change will exacerbate the gender dimensions of vulnerability, which arise from existing social inequalities and gendered divisions of labour (Alber, 2009; Brody et al., 2008; Dodman, 2010; WEDO, 2008). Climate change is expected to jeopardize women's livelihoods by reducing economic opportunities, especially for female headed households (Dodman, 2010).

Gender disaggregated data on climate change, its impacts and adaptation strategies in Zimbabwe are still limited. Anecdotal evidence shows that climate change, as evidenced by frequent droughts, floods, and erratic rainfall and extreme temperatures, is negatively affecting smallholder farmers who are mainly women. A study in rural district of Chiredzi, southeast of Zimbabwe, found that the most vulnerable households to climate change included poor households, female-headed and child-headed households as well as those lacking access to irrigation. In Zimbabwe, 70% of women are smallholder farmers dependent on rain-fed agriculture and climate-sensitive resources (Madzwamuse, 2010). Women are therefore particularly vulnerable to the knock-on effects of climate change.

Although women and children are disproportionately affected by climate change, they remain largely absent from decision-making processes on climate change adaptation and disaster risk reduction. It is important to engage them and raise awareness on climate change issues so that they can readily respond to the effects of climate change.

1.9 Economic Development

1.9.1 Industry

Figure 1.9 presents Zimbabwe's Gross Domestic Product (GDP) from 2010 to 2013.The Country's GDP increased gradually, by about a unit percentage, during the period 2010 to 2013. The slight increase is accounted for by the greater performance in the agriculture, hunting and fishing; real estate and health sectors. The other sectors recorded slight increases in their performances. The per capita GDP at market prices has been increasing throughout the 2010 to 2013 period. The per capita year-to-year growth rates for the period were 20.6%, 10.5% and 26.6%, progressively.

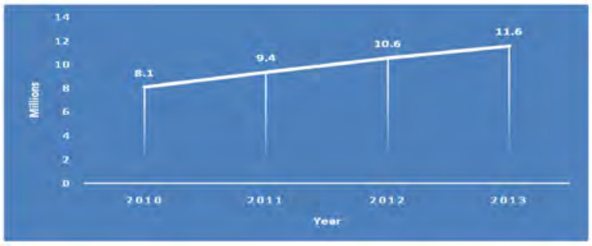

Fig 1.9 GDP trends from 2010 to 2013 Source: Generated from ZIMSTAT National Accounts Statistics

1.9.2 Manufacturing

The Census of Industrial Production (CIP) provides information on the structure and development of the mining, manufacturing, electricity and water and construction industries in Zimbabwe. The CIP of 2013 was carried out when the Zimbabwe Agenda for Sustainable Socio-Economic Transformation 2013-2018 (Zim Asset) an economic blueprint for the nation, was crafted to guide national development for the 5-year period. In this respect, statistics such as value added for mining, manufacturing, electricity and water, derived from the CIP, can be used to monitor growth targets set in Zim Asset. The CIP produce statistics on principal indicators such as gross output, intermediate consumption and value added, gross fixed capital formation, cost of production and raw materials; value of goods produced; inventories, distribution of establishments by economic activity, type of ownership and sector of ownership; employment size and earnings. The four sectors recorded a total of 147,411 employees down from 153,406 in 2012. Manufacturing had the highest number 91,616 representing 62 percent while mining had 15 percent, electricity and water, 1.5 percent and construction contributed 22 percent. Out of the 147,411 employees, only 12,955 were females.

About US$2 billion was spent on materials and supplies, gas, fuel and electricity, water and sewerage services, services and rental payments down from US$2.1 billion in 2012. Of the US$2 billion, US$1.4 billion (63 percent) was spent on materials and supplies only. The least expenditure was on water and sewerage services amounting to US$32.3 million down from US$33.9 million in 2012. Among the sectors, Manufacturing had the highest expenditure of US$1.6 billion (75.7 percent) while Electricity and Water had the least expenditure of US$56 million. The total value of sales of goods produced was US$2.7 billion of which manufacturing had the highest value of US$2.3 billion followed by mining with US$391 million. Out of the US$2.3 billion in manufacturing, US$215 million was exported to customers affiliated to foreign branches of the establishments. The capacity utilisation for the mining sector alone was 74.1 percent. Manufacturing had a capacity utilisation of 46 percent. Electricity and water had a capacity utilisation of 85.6 percent. Gross value for the fixed assets at the end of 2013 was valued at US$2.2 billion of which other machinery and equipment accounted for US$828 million (38 percent). Gross value for intellectual property products at the end of 2013 was valued at US$13 million, and manufacturing had the largest share of US$7 million (53 percent).

1.9. 3 Energy

The Zimbabwe Agenda for Sustainable and Socio-Economic Transformation (Zim Asset) states that energy is key for the country's success. The Government is working towards universal access to cleaner, safer and affordable energy through the Rural Electrification Fund which is built from 6% levies charged on all utility electricity sales. The vision of the Rural Electrification Fund is to achieve universal access to modern energy services by the rural communities by 2030. This will be achieved through grid extension and through alternative energy technologies such as: Grid Connected PV Power generation; Mini grid solar systems for rural institutions & rural households; Mini hydro; Biogas; Biomass Electricity generation; Efficient Cook-stoves and Single Wire Earth Return (SWER).

The access to electricity stands at 13% for the rural population which constitutes about 70% of the national population, and 83% for the urban population. Of the 8,082 rural institutions electrified by June 2015, 471 institutions had 0.84 kW solar systems installed. Business has come up with initiatives that would bring economic, social and environmental dividends such as Energy Efficiency Awards, Green Industry Initiative and Circular Economy, among others. Government, Business and Non-Governmental Organisations including Civil Society Organisations are working together on the sustainable-energy-for- all goal.

The Zimbabwe Electricity Supply Authority (ZESA) is the utility responsible for the generation, transmission and distribution of electricity. ZESA was restructured into strategic business units namely the Zimbabwe Power Company (ZPC) and the Zimbabwe Electricity Transmission and Distribution Company (ZETDC) in order to meet its mandate of electricity generation, transmission and distribution. ZESA has both hydro and thermal power stations (Figure 1.10). Kariba is the major hydro-power station and is jointly owned by ZESA and Zambia Electricity Supply Company (ZESCO). There are four thermal power stations in the country which are Hwange, Munyati, Bulawayo and Harare power stations. To meet the total electricity demand for the nation ZPC imports some of the electricity from neighbouring countries such as Mozambique, Namibia and South Africa. It also buys electricity from private owned mini-hydro power generation plants in the country. However, the country continues experiencing constrained energy supplies, a factor that has adversely affected business and public transport operations throughout the country. The constrained energy supply has undermined productivity and contributed to a loss of market competitiveness.

Several pieces of legislation and policies govern the energy sector. These include:

- Electricity Act (Chapter 13:19)
- Rural Electrification Fund Act (Chapter 13:20)
- Zambezi River Authority Act (Chapter 20:23)
- Petroleum Act (Chapter 13:22)
- Energy Regulatory Authority Act (Chapter 13:23)
- National Energy Policy (2012

Fig 1.10 National transmission grid reinforcement and extension Source: Rafemoyo (2012)

According to ZERA (2012), major sources of electrical energy in Zimbabwe are as shown in Table 1.2.

Table 1.2 Major sources of electricity in Zimbabwe in 2012

Name of Power Station	Technology	Plant Type	Ave MW	Actual GWh
Kariba	Hydro	State owned	608	5387
Hwange	Thermal	State owned	357	3133
Harare	Thermal	State owned	20	60
Bulawayo	Thermal	State owned	30	178
Munyati	Thermal	State owned	20	204
Total			1,035	8,962

Source: ZERA (2012)

The average maximum demand for 2012 was estimated at 2,200 MW, giving a shortfall of 1165 MW. The short-term measures the country is taking to solve the power shortages include:

- Importing power from the neighbouring nations which might have excess,
- Encouraging improvement in the area of energy efficiency and demand management,
- Promoting use of renewable energy as much as possible, and
- Load shedding

The energy and power shortages have affected both the productive and domestic sectors immensely, especially during the 2000 – 2008 period. These shortages, coupled with the country's failure to secure funds for infrastructural development in the energy sector, have presented some business opportunities to some business people. As of year 2012 a significant number of Independent Power Producers (IPPs) are now generating electricity; for own consumption in most cases. Over 40 MW comes from sugar processing (ZERA, 2012).

The Government has adopted coping strategies by blending fuel and allowing firms and individuals to import their own fuel in response to the energy shortages. Stability in the energy sector, encompassing liquid fuels, coal and electricity supplies is an indispensable pre-requisite for successful economic growth, as well as for household use. The country's vision is to ensure self-sufficiency as regards to energy supply, provision of quality data and sustainable consumption of energy with the ultimate aim of reducing GHGs. As a result of joint efforts of the private sector and Government the following are in existence:

- Renewable Energy Association of Zimbabwe
- Annual Energy Efficiency Awards programme
- Government-funded training (Certified Energy Managers training, Handling of Liquefied Petroleum Gas, Power Demand Forecasting and System Development Planning)
- Energy Information System- The system has been installed by the Ministry of Energy and Power Development (MoEPD) and is meant to capture energy data from all sectors of the economy.

1.9.4 Mining

Mining is an important economic activity that constitutes about 10% of the Gross Domestic Product.The major minerals reserve deposits in Zimbabwe are for asbestos (AS), gold (AU), copper (CU), chrome (CH), nickel (NI), iron (Fe), Coal and diamond (Figure 1.11).

The mineral volumes decreased except for black granite and platinum group of metals. Mining activities can cause serious environmental problems as a result of the method used in extracting the ore (either underground or open cast) and the supplementary operations such as drilling, breaking, milling, cleaning and grading. Open cast methods result in removal of top soil which disturbs the natural environment and the ecological synergies. It removes vegetation and spoils arable land.

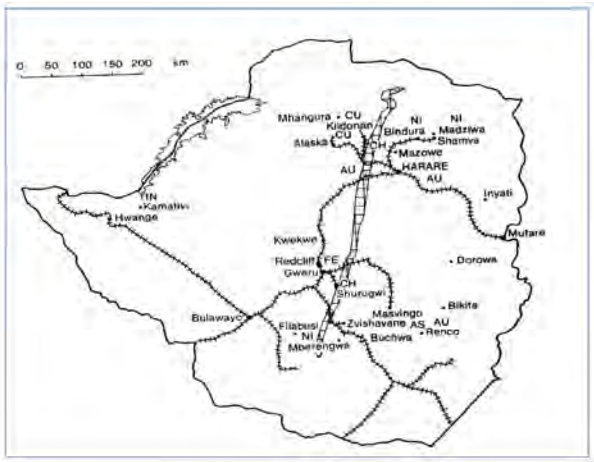

Fig 1.11 Zimbabwe Mineral Reserves by Type (asbestos (AS), gold (AU), copper (CU), chrome (CH), nickel (NI), iron (Fe)
Source: Michie and Nhandara (1999)

1.9.5 Agriculture

Zimbabwe has an agro-based economy with the sector contributing about 15% to the GDP. The country is divided into five Agro-ecological regions commonly known as Natural Regions (NR) based on rainfall, temperature and other factors. The Natural Regions are depicted in Figure 1.12. Regions I and II are suitable for intensive crop and animal production whilst regions IV and V offer opportunities for extensive livestock production and irrigated crops. Rainfall ranges from 650mm to above 1,050mm per annum in regions I to III while in regions IV and V it is below 650mm per annum.

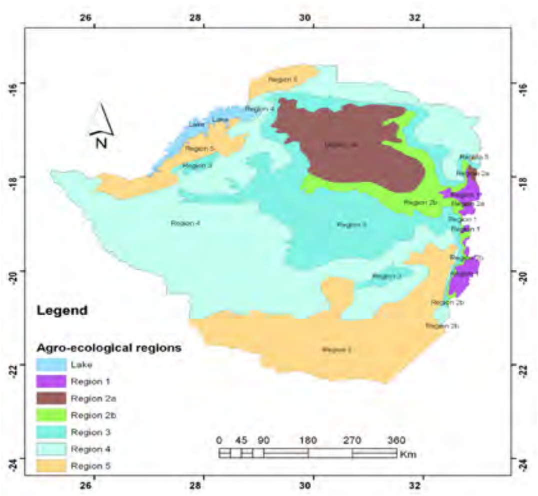

Fig 1.12 Zimbabwe Agro-ecological Zones

Zimbabwean agriculture is divided into four major sectors namely; Large Scale Commercial Farms, Small Scale Commercial Farms, Communal and Resettlement Schemes.

The agriculture land use sectors in Zimbabwe are:

- Communal Lands
- Small Scale Commercial Farming Areas
- Large Scale Commercial Farming Areas
- Resettlement Areas (RA):
- Large Scale Commercial Farms
- Small Scale Commercial Farms
- A1 Farms
- A2 Farms
- Old Resettlement Schemes

1.9.5.1 Cropping

The country produces a variety of crops which include grain crops such as maize, sorghum, mhunga, rapoko, oilseeds (sunflower, groundnuts and soyabeans) and other industrial crops such as tobacco, cotton, edible dry beans and paprika. Table 1.3 presents hectarage and crop production (tonnes) for the years 2005 to 2012 for a few of these crops. Data for 2008 and 2009 were not collected due to hyperinflation experienced by the economy during the period. In terms of market value, the most important crops are tobacco, cotton and maize in that order but in terms of strategic importance maize comes first as it is the staple food.

Table .1.3 Area (hectares) and crop production (tonnes) 2005-2007 and 2010 -2012

Crop	Year	Area (ha)	Production (tonnes)		Crop	Year	Area (ha)	Production (tonnes)
Maize	2005	2,027,268	1,255,822		Rapoko	2005	39,168	10,362
	2006	2,043,941	1,997,403			2006	61,416	24,965
	2007	1,744,615	1,509,210			2007	39,478	16,463
	2010	1,362,563	1,192,399			2010	48,811	12,234
	2011	1,538,577	1,010,473			2011	29,509	6,999
	2012	1,385,161	1,095,954			2012	24,237	7,882
Sorghum	2005	178,421	48,639		Groundnut	2005	200,592	57,754
	2006	288,973	118,229			2006	176,196	83,170
	2007	289,859	96,571			2007	260,518	126,768
	2010	272,679	73,675			2010	319,608	136,719
	2011	222,988	50,549			2011	329,803	97,504
	2012	216,796	44,346			2012	214,266	72,194
Millet	2005	142,491	20,352		Edible bean	2005	47,450	21,482
	2006	188,042	47,347			2006	66,007	30,332
	2007	165,406	33,473			2007	74,115	46,067
	2010	189,471	38,888			2010	79,189	31,248
	2011	183,536	28,544			2011	53,786	16,028
	2012	184,222	28,596			2012	52,123	20,935
Paprika	2005	5,568	3,204					
	2006	5,762	3,821					
	2007	2,965	1,527					
	2010	1,140	685					
	2011	1,742	771					
	2012	1,181	814					

1.9.5.2 Livestock

Meat contributes to the nutritional status of the nation and to the national gross domestic product. The country rears a variety of livestock in addition to its abundant wildlife species. Major domesticated animals are cattle, sheep, pigs, goats and chickens among others. Table 1.4 illustrates the growth patterns in numbers of livestock in the country.

Table 1.4 Numbers of livestock held 2006-2011

Year	Cattle	Sheep	Pigs	Goats
2006	5,048,218	413,871	188,863	3,124,187
2007	5,050,650	391,982	182,796	3,334,224
2008	5,106,673	405,033	207,967	3,210,102
2009	5,330,606	315,193	344,456	4,207,111
2010	5,772,917	309,028	390,686	4,447,903
2011	6,058,388	309,429	396,273	4,719,278

1.9.6 Transport

Zimbabwe is predominantly serviced by road transport despite the availability of other forms of transport that include: air, rail and water transport within the inland water bodies. Most of the international road routes radiate from Harare, the country's capital city and Bulawayo, the second largest city, to neighbouring countries. The main form of public transport is commuter omnibuses which operate within and between cities/towns, rural communities as well as linking other neighbouring states. Zimbabwe mostly accesses the sea either by road or rail transport through ports in South Africa, Namibia or Mozambique. Air Zimbabwe has limited fleet of aircraft that services domestic and regional routes. It is, however, complemented by foreign airlines.

The country has four road authorities (Department of Roads, Urban Councils, Rural District Councils and District Development Fund) responsible for the road types. In the year 2012 the total road network was approximately 81,601km. The state roads lengths were as follows:

Department of Roads	18,000 km
Urban Councils	7,975 km
Rural District Councils	30,626 km
District Development Fund	25,000 km

Fig 1.13 Zimbabwe's Railway network (Source: Gwitira et al., 2016)

1.9.7 Tourism

Zimbabwe is one of the most popular tourist destinations in Africa due its diverse tourist attractions which are easily accessible by road and air transport. The country boasts of the Victoria Falls which is one of the seven natural wonders of the world. Hwange National Park is the biggest in the country and is the fourth largest game sanctuaries in Africa. Approximately 12% of the country's surface area was set aside for the National Parks and Wildlife Estates. Among the animal species in the parks are the Big Five, elephant; rhino; leopard; lion and buffalo.

The Eastern Highlands is the scenic mystical side of the country dominated by mountains, waterfalls and forests. In addition to the magnificent tangible heritage such as the Great Zimbabwe National Monument and the Rhodes Matopos Monument, Zimbabwe has an inspiring and rich cultural heritage. The mighty Zambezi River offers the greatest challenge to white water rafting and Kayting enthusiasts. On the same river lies Lake Kariba, the world's largest man-made lake covering 5,400 km^2 with a stretch of 270km. The lake has emerged as a major tourist attraction; it provides an arena for a diversity of water-based activities that include yachting, sport fishing, canoeing, boating and game viewing.

Zimbabwe has a well-developed tourism infrastructure in the form of accommodation facilities that cater for locals, regional and international tourists. There are simple camping sites in bushes and forests, exclusive safari camps, backpacker lodges and magnificent luxurious hotels within the tourist attractions localities. For those in love with sport there is golfing, walking safaris and bungee jumping. Above all, Zimbabwe has a pleasant climate with sunshine almost all year round and the people are very friendly and hospitable.

1.9.8 Trade

Total trade, sum of exports and imports, is a useful indicator of the level/volume of trading activity (Figure 1.14). Zimbabwe's total trade increased from US$8.3 billion in 2006 to US$11.2 billion in 2013. A trade balance surplus of US$3.4 billion was recorded in 2006; however it was overturned to a deficit of about US$0.4 billion in 2007 which further decreased to US$4.2 billion in 2013. On Zimbabwe's trade direction, the table below depicts total imports and exports for the period 2006 to 2013.

Table 1.5 Foreign Trade Summary in USD millions

Flow Type\Year	2006	2007	2008	2009	2010	2011	2012	2013
Total Exports	5,867	3,169	1,217	2,250	3,245	3,557	3,882	3,507
Imports	2,424	3,538	2,132	6,207	5,865	8,596	7,464	7,704
Trade Balance	3,443	-370	-915	-3,958	-2,619	-5,039	-3,581	-4,197
Total Trade	8,290	6,707	3,349	8,457	9,110	12,154	11,346	11,211

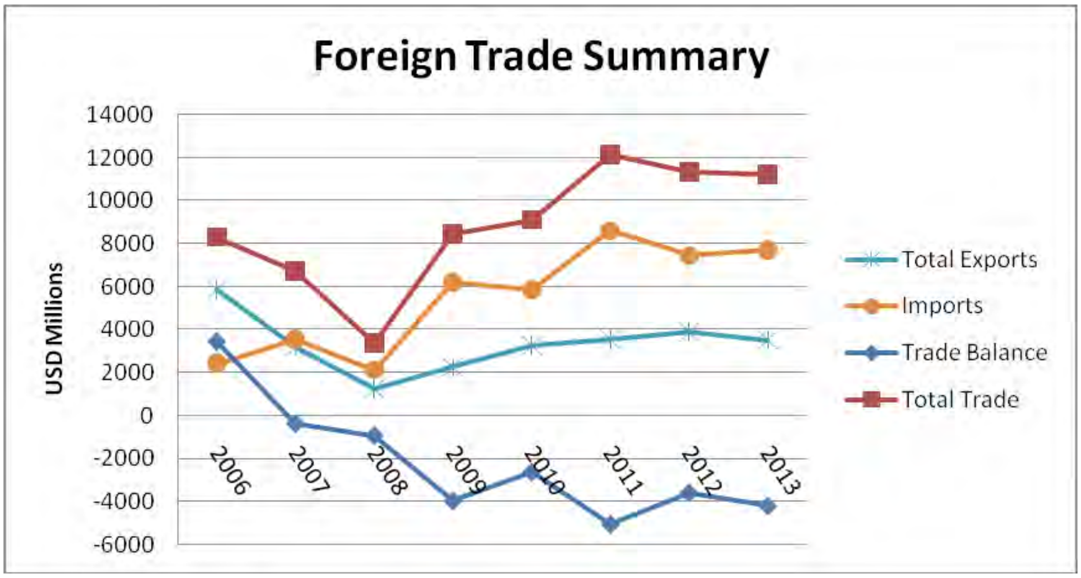

Fig 1.14 Trade Summary in US$ Millions Source: Zimstat (2013, Statement of External Trade)

The three major imported product groups for the entire period under review were mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes (16%), vehicles others than railway or tramway rolling-stock, and parts and accessories thereof (12%) and fertilizers (9%). The three major shareholders of Zimbabwe's export earnings were natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin (16%), tobacco and manufactured tobacco substitutes (14%) and nickel and articles thereof (10%).

1.10 Education Development

Education is pivotal to the socio-economic, political and technological development of Zimbabwe. The country achieved near universal primary education for all in the 1990s putting it on track towards the fulfilment of the Millennium Development Goal (MDG) number 2. The goal sought to achieve universal primary education by year 2015 irrespective of gender.

The education structure in Zimbabwe is categorized into formal and non-formal education. The major educational stages in Zimbabwe are Early Childhood Development (ECD), Primary Education, Secondary Education, and Tertiary Education. The conventional primary school education covers seven years.

The secondary education cycle consists of two years of junior school, two years of middle school and two years of senior school. Tertiary education is offered at institutions of higher learning comprising agricultural colleges, vocational and training colleges, teachers' colleges, polytechnics and universities.

According to the 2012 Population Census 6,717,229 persons are of school going age, i.e. 3 to 24 years. Of this population, females constituted 51%. However in higher and tertiary institutions there are more male than female students. The 2011 Labour Force and Child Labour Survey estimated, for both sexes, a drop in children aged 5 to 9 years who have never been to school from 39% in 2004 to 26% in 2011. In addition, the Government policy endeavours to provide universal primary education to all by 2018. The 2011 Labour Force Survey estimated the literacy level at 97.2 % with no significant differences across all the 10 provinces.

1.11 Healthcare Development

The major health issues in Zimbabwe relate to nutrition; water, sanitation and hygiene; diseases; morbidity/mortality; health care services and facilities; ante-natal and post-natal The country robust health information and surveillance report system, for instance there are weekly disease surveillance reports.

In 2012, 95.1% of children below the age of five weighed equal to or above the expected weight while the remainder were underweight. The common nutritional deficiencies disease/ conditions were kwashiorkor, marasmus (total severe acute malnutrition) and pellagra. During the year, about 0.1 % of the infants were affected by total severe acute malnutrition. During the same year, February experienced the highest total severe acute malnutrition of about 10.7 %.

New cases recorded at the Out-patient desk include nutritional deficiencies, dysentery, schistomiasis (bilharzia), dental conditions, malaria, diseases of the eye, burns and other injuries, skin diseases, diarrhoea and acute respiratory infections (Ministry of Health and Child Care, 2012). The top ten in-patient diseases and conditions were skin and subcutaneous; Acute Respiratory Infections (ARI); direct and indirect obstetric causes; intestinal infections, HIV related/AIDS; TB; malaria; fractures; abortion; and intracranial and internal injuries including nerves. The top five killer diseases reported were HIV related and AIDS epidemic, ARI, TB, intestinal infections and meningococcal and other meningitis.

The 2010/11 Zimbabwe Demographic Survey showed that 78.7% of the households (of which 95.1% for urban and 68.7% for rural) were using improved sources of drinking water. The sanitation coverage for the country was 64.4% composed of 93.4 % for urban households and 49.7% for rural households. In spite of the country's efforts to reduce infant mortality rate, it has remained about 6.0% during the period 2000 to 2012.

Table 1.6 shows the distribution of health facilities by province. The Country has four categories of health services and facilities which are:

1. Primary Level - clinics and rural health centres;
2. First Referral Level - district, mission and rural hospitals;
3. Second Referral Level - provincial hospitals
4. Third Referral Level - central hospitals and infectious diseases.

Table 1.6 Distribution of Health Facilities by Level and Province, 2013

Provinces	Primary Level	First Referral Level	Second Referral Level	Third Referral Level	Total
Harare	470	0	0	7	477
Manicaland	251	66	1	0	318
Mash Central	132	13	1	0	146
Mash East	170	22	1	0	193
Mash West	128	22	1	0	151
Mat North	93	17	0	0	110
Mat South	105	18	1	0	124
Midlands	107	28	1	0	136
Masvingo	172	23	1	0	196
Bulawayo	34	0	0	7	41
Total	1662	209	7	14	1892

1.12 Political and Decision Making Structure

Zimbabwe is a unitary, democratic and sovereign state with an elected executive President who serves as both head of state and government. The 2013 Constitution defines the legal system. The Government has three tiers, which are the national Government; provincial and metropolitan councils; and local authorities. The parliament consists of the Upper House (Senate) and Lower House (National Assembly). The Senate consists of 80 elected members.The National Assembly consists of two hundred and seventy elected members. The National Assembly elects a presiding member regarded as the Speaker of Parliament. Parliament is elected for a five-year term.

The judicial authority is vested in the courts, which comprise of the:

Constitutional Court;

Supreme Court;

High Court;

Labour Court;

Administrative Court;

Magistrates courts;

Customary law courts; andother courts established by or under an Act of Parliament.

CHAPTER 2

2. ZIMBABWE NATIONAL GREENHOUSE GAS INVENTORY REPORT FOR 2006

2.1 Introduction

Zimbabwe has compiled its GHG inventory in compliance with Article 4 of the Convention. In compiling its inventory, the country has considered its national circumstances. The National Inventory Report (NIR) for Zimbabwe contains anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol. Zimbabwe reported on its GHG emissions in the Initial National Communication (INC) to the UNFCCC in 1998. The Second National Communication (SNC) to the UNFCCC was submitted in 2013.

2.2 Structure and Process of Greenhouse Gas Inventory

The inventory team comprised eleven experts from government departments, universities, national research centres and private sector. All the sectors in the Revised 1996 IPCC Guidelines were covered, namely: Energy; Industrial Processes; Solvents and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry (LULUCF) and Waste. The sector experts were organised into teams which were responsible for data collection and analysis. An inventory team leader was assigned to coordinate the NIR process. The inventory team reported to the TNC Project Coordinator in the Ministry of Environment, Water and Climate. Training workshops were held at the beginning of the exercise to familiarise the GHG team members with the IPCC methodologies.

2.3 The Inventory Methodology

The Revised 1996 IPCC Guidelines were used to estimate GHG emissions from Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste, whilst the 2006 IPCC Guidelines were used to compile the GHG inventory for Industrial Processes and Other Product Use (IPPU).

2.3.1 Selection of conversion factors

The 2006 IPCC default conversion factors were used in the Energy, Agriculture and Waste sectors because they were considered to be the most updated. All conversion factors for the Industrial Processes and for the Solvents and Other Product Use were based on the International System of Units as stated in the 2006 IPCC Guidelines for National GHG Inventories. Coal was converted to energy on the basis of analysis made by the coal supplier.

2.3.2 Selection of emission factors

The IPCC default emission factors were used in the computation of GHG emissions for Zimbabwe in all sectors. Emission Factor Database (EFDB) of the IPCC was used in all the calculations of emissions because the country did not have national or plant specific Emission Factors (EFs).

2.3.3 Selection of approach for calculating greenhouse gas emissions

The approach to estimating greenhouse gases was to use manual worksheets. Some data was entered in the 2006 IPCC software for the computation of emissions and removals. However, other sector experts preferred the worksheets hence the IPCC software was not fully utilized. Equation 2.1 was used to calculate the emissions for all sectors.

Equation 2.1:

Emission = Activity Data x Emission Factor

2.3.4 Reference approach

The sectoral and reference approaches were used to determine the 2006 GHG emissions from the energy sector. The reference approach had one factor per fuel while the sectoral approach occasionally had subsector specific EFs, for example there were different CH_4 emission factors for motor gasoline and for road transport. The energy differences between the two methods were also due to statistical differences in the activity data, especially the International Energy Agency (IEA) data.

2.3.5 Completeness of data

The compilation of GHG inventory faced some challenges of data completeness. This was attributed to depressed economic activity countrywide which resulted in the closures of a sizeable number of companies. This rendered the collection of data in many sectors futile. Lack of records and poor record keeping systems at company level has also contributed to data gaps. To ensure accuracy and completeness in data collection; questionnaires, interviews and discussions were conducted with both primary and secondary data source providers. Other reasons that also affected completeness of data relate to restriction due to legislation on disclosure of information by the Census and Statistics Act [Chapter 10:29], 2007. This Act does not allow release of data and information by the national statistical agency in circumstances where there are less than three companies in a sector. To address the data gaps, interpolation was used and surrogate data, e.g. population data where appropriate, was used to estimate the missing activity data.

2.3.6 Data quality and assurance

A number of Quality Assurance and Quality Control (QA/QC) activities were performed during the inventory compiling process. The experts were trained on QA/QC and the IPCC Inventory software. The QA/QC guideline document used was adapted from the United States Environmental Protection Agency (EPA)-USAID QA/QC handbook of 2011 (PA-430-K-11-005). Activity data triangulation was performed in cases where multiple sources of data were available. Some recalculations were performed in cases where emission factors were more applicable or where activity data was found. Peer review meetings and workshops were conducted quarterly. Teams presented their plan and progress to their peers during these meetings. Some experts who were not involved in the compilation of the TNC, but competent on GHG and national inventory processes also attended the review workshops.

2.4 Zimbabwe's Greenhouse Gas Emissions for the year 2006

The summation of GHGs emissions and removals in Zimbabwe was calculated by sector, based on the application of Global Warming Potentials (GWP) from the IPCC Fourth Assessment Report (FAR) as follows: (CO_2=1: CH_4=25: N_2O=298). Table 2.1 shows the GHG emissions and estimated sinks. It can be observed that, Zimbabwe is an emitter of GHGs. This finding includes the major managed forest and not the standing biomass in croplands and urban settlements. Emissions of non-CO_2 gases and their GWP play a critical role in this finding. Given the high uncertainty in N_2O and NMVOC's, this finding can change between inventory years. The GHG removals were estimated to be 83,000.00 Gg for the year 2006.

2.4.1 Major sources of GHG emissions

The major sources of greenhouse gas emissions are Energy, Agriculture, Industrial Processes and Waste. For the base year of 2006, emission of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2) were estimated (Table 2.1). Total emissions from GHG for Zimbabwe in the year 2006 amounted to 22,019.566 CO_2eq. Fuel combustion contributed the largest amount of emissions. Emissions removals were estimated from Land-use-Land use Change and Forestry (LULUCF). For the year 2006, Zimbabwe was a net sink by 60,980.434 Gg CO_2eq.

Table 2.1 Zimbabwe GHG Emissions for 2006

National greenhouse gas inventory of anthropogenic emissions by sources & removals by sinks of all greenhouse gases not controlled by the Montreal Protocol & greenhouse gas precursors								
Greenhouse gas source & sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Total national emissions & removals	10,995.150	83,000.000	255.418	15.567	1,089.345	264.916	34.107	4.046
1. Energy	10,318.236	NE	11.431	0.201	52.845	203.646	34.107	4.046
A. Fuel combustion (sectoral approach)	10,298.455		4.189	0.201	23.461	91.704	15.820	1.634
1. Energy Industries	5,377.221		0.058	0.085	NE	NE	NE	NE
2. Manufacturing industries & construction	1,438.925		0.021	0.021	4.583	2.037	0.151	0.709
3. Transport	1,277.626		0.261	0.063	12.956	66.498	12.603	0.089
4. Other sectors	2,001.220		3.841	0.030	5.922	20.238	2.466	0.778
Commercial & Institutional	554.034		0.059	0.009	0.255	5.099	0.510	0.214
Residential	72.268		0.010	0.001	1.457	1.214	0.246	0.056
Agriculture	1,374.919		3.773	0.020	4.211	13.925	1.711	0.507
5. Other (please specify) Mining	203.463		0.008	0.002	NE	2.931	0.600	0.058
B. Fugitive emissions from fuels	19.782		NE		NE	0.000	0.000	0.000
1. Solid fuels			7.242		NE	NE	NE	NE
2. Oil & natural gas			NO		NO	NO	NO	NO
2 Industrial Processes	665.730	0.000	0.007	0.806	0.000	0.000	0.000	0.000
Mineral products	280.744				NE	NE	NE	NE
Chemical industry	NE		NE	0.806	NE	NE	NE	NE
Metal production	378.789		0.007	NE	NE	NE	NE	NE
Other production	6.196		NE	NE	NE	NE	NE	NE
Production of halocarbons & sulphur hexafluoride								
Consumption of halocarbons & sulphur hexafluoride								
Other	NE		NE	NE	NE	NE	NE	NE
3 Solvents & other product use	11.184			NE			NE	
4 Agriculture			213.900	14.560	1,036.500	61.270	NE	NE
Enteric fermentation			170.290					
Manure management			7.060	0.220			NE	
Rice cultivation			0.040				NE	
Agricultural soils			NE	11.060			NE	
Prescribed burning of savannahs			35.680	3.260	1,008.300	60.500	NE	
Filed burning of agricultural residues			0.830	0.020	28.200	0.770	NE	
Other			NE	NE	NE	NE	NE	
5 Land-use change & forestry	NE	83,000.000	NE	NE	NE	NE	NE	NE
Changes in forest & other woody biomass stocks	NE	83,000.000						
Forest & grassland conversion	NE	NE	NE	NE	NE	NE		
Abandonment of managed lands	NE	NE	NE	NE	NE	NE		
CO_2 emissions & removals from soils	NE	NE						
Other	NE	NE	NE	NE	NE	NE		
6 Waste			30.080	0.000	0.000	0.000	0.000	0.000

National greenhouse gas inventory of anthropogenic emissions by sources & removals by sinks of all greenhouse gases not controlled by the Montreal Protocol & greenhouse gas precursors								
Greenhouse gas source & sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Solid waste disposal on land			25.450		NE		NE	
Waste-water handling			4.630	NE	NE	NE	NE	
Waste incineration						NE	NE	NE
Other (Septic)			NE	NE	NE	NE	NE	NE
Memo items	28.296	0.000	0.000	0.000	0.432	0.361	0.075	0.007
Aviation								
Marine	NA		NA	NA	NA	NA	NA	NA
International Aviation	28.296		0.000	0.001	0.432	0.361	0.075	0.007
CO_2 emissions from biomass								

NE = Not Estimated; IE = Included Elsewhere; NO = Not Occurring

2.5 Dynamics of GHG Emissions per Sector

2.5.1 Key Category Analysis

Key category analysis was performed, first without LULUCF (Table 2.2) and then with LULUCF (Table 2.3). Emissions were from Energy Industries (1A1) 24.75 %, Enteric Fermentation (4A) 19.49%, Agriculture soils (4D) 15.09%, Prescribed burning of savannahs (4F) 8.53%, Manufacturing industries and construction (2A2) 6.62 %, Energy use in Agriculture (1A4) 6.76%, Commercial and Institutional (1A4), Metal production (2C) and Mineral products (2A).

A total of 10,663.72 Gg of carbon dioxide equivalent were emitted from the energy sector in 2006. The main source categories for the energy sector in Zimbabwe in 2006 were the Energy Industries (50.7%), Other Sectors (19.8%), Manufacturing Industries and Construction (13.6%), and Transport (12.2%) which had a total contribution of 96.2% of the total emissions.

Table 2.2 Key Category Analysis without LULUCF

IPCC Source Category	Sector	Sub-category	Total GHG (CO_2eq)	Contribution (%)	Cumulative sum (%)
1.A.1	Energy	Energy Industries	5,404.020	24.75	24.75
4.A	Agriculture	Enteric fermentation	4,257.250	19.49	44.24
4.D	Agriculture	Agricultural soils	3,295.880	15.09	59.33
4.E	Agriculture	Prescribed burning of savannahs	1,863.480	8.53	67.87
1.A.4	Energy	Energy use in Agriculture	1,475.280	6.76	74.62
1.A.2	Energy	Manufacturing industries & construction	1,445.775	6.62	81.24
1.A.3	Energy	Transport	1,302.855	5.97	87.21
6.A	Waste	Solid waste disposal on land	636.250	2.91	90.12
1.A.4	Energy	Commercial and Institutional	558.122	2.56	92.68
2.C.	Industrial Processes	Metal production	378.964	1.74	94.41
2.C	Industrial Processes	Mineral products	280.744	1.29	95.70
4.B	Agriculture	Manure management	242.060	1.11	96.81
2.B	Industrial Processes	Chemical industry	240.188	1.10	97.91
1.A.5	Energy	Other (please specify) Mining	204.177	0.93	98.84
1.B.1	Energy	Energy - solid fuels	181.050	0.82	98.85
6.B	Waste	Waste-water handling	115.750	0.53	99.37
1.A.4	Energy	Residential	72.694	0.33	99.70
4.F	Agriculture	Field burning of agricultural residues	26.710	0.12	99.83
1.B	Energy	Fugitive emissions from fuels	19.782	0.09	99.92
3	Solvents and other Product Use	Solvents and other product use	11.184	0.05	99.97
2.D	Industrial Processes	Other production	6.196	0.03	100.00
4.C	Agriculture	Rice cultivation	1.000	0.00	100.00

With the inclusion of LULUCF, seven categories contributed to the key category. These were LULUCF with 79.17%, followed by Energy industries (5.15%), Enteric Fermentation (4.06%), Agricultural soils (3.14%), Prescribed burning of savannahs (1.78%), Energy use in Agriculture (1.41%) and Manufacturing industries and construction(1.38%).

Table 2.3 Key Category Analysis with LULUCF

IPCC Source Category	Sector	Sub-category	Total GHG (CO_2eq)	Contribution (%)	Cumulative sum (%)
5	LULUCF	Land-use change and forestry (Removals)	83,000.000	79.17	79.17
1.A.1	Energy	Energy Industries	5,404.020	5.15	84.32
4.A	Agriculture	Enteric fermentation	4,257.250	4.06	88.38
4.D	Agriculture	Agricultural soils	3,295.880	3.14	91.53
4.E	Agriculture	Prescribed burning of savannahs	1,863.480	1.78	93.31
1.A.4	Energy	Agriculture	1,475.280	1.41	94.71
1.A.2	Energy	Manufacturing industries and construction	1,445.775	1.38	96.09
1.A.3	Energy	Transport	1,302.855	1.24	97.34
6.A	Waste	Solid waste disposal on land	636.250	0.61	97.94
1.A.4	Energy	Commercial and Institutional	558.122	0.53	98.47
2.C.	Industrial Processes	Metal production	378.964	0.36	98.84
2.C	Industrial Processes	Mineral products	280.744	0.27	99.10
4.B	Agriculture	Manure management	242.060	0.23	99.33
2.B	Industrial Processes	Chemical industry	240.188	0.23	99.56
1.A.5	Energy	Other – Mining	204.177	0.19	99.76
1.B.1	Energy	Energy - solid fuels	181.050	0.82	98.85
6.B	Waste	Waste-water handling	115.750	0.11	99.87
1.A.4	Energy	Residential	72.694	0.07	99.94
4.F	Agriculture	Field burning of agricultural residues	26.710	0.03	99.96
1.B	Energy	Fugitive emissions from fuels	19.782	0.02	99.98
3	Solvents and other Product Use	Solvents and other product use	11.184	0.01	99.99
2.D	Industrial Processes	Other production	6.196	0.01	100.00
4.C	Agriculture	Rice cultivation	1.000	0.00	100.00

2.5.2 Energy

2.5.2.1 Overview of the sector

In Zimbabwe, the major energy sources are biomass, coal and liquid fuels as well as water. Electricity is mainly generated from coal and hydro while other sources like solar and wind's contributions are negligible. The country's energy mix has not changed significantly since 1990. Over the 1990-2000 decade the percentage of biomass energy to total energy has been almost constant just below 50%, coal ranging from 15 to 25%, liquid fuels ranging from 15 to 20% and electricity ranging from 12 to 13% (SADC, 1996). Although it does not appear on the energy mix solar PV is widely used especially in areas that have no grid connections. Unfortunately, the energy output of these solar installations is not quantified and recorded. More Liquefied Petroleum Gas (LPG) is now used in the domestic sector as either an alternative to or substitute for electricity for cooking and heating. Prices of both solar products and LPG are decreasing as a result of Government policy to remove duty on these products.

2.5.2.2 Biomass

Firewood is the major energy source for the domestic sector, mainly the rural and peri-urban population. Although it is discouraged, charcoal is also being used in some households. Agriculture uses firewood as an alternative to coal in crop drying and water-heating. Bagasse is used to generate electricity at the three major sugar milling plants. The three plants generate electricity for own use while the third one exports the excess to the grid. The biogas digesters being constructed in the rural areas and institutions such as schools and hospitals is increasing access to cleaner and sustainable energy. The nation has a target of over 1,250 institutional and domestic biogas plants in the rural areas by 2018.

2.5.2.3 Coal

Zimbabwe is endowed with huge coal reserves and has a relatively big thermal power station (Hwange Power Station) with an installed capacity of 920 MW and three small thermal plants with a total installed capacity of 375MW. Almost 50% of the five million tons of coal mined per annum is for these power plants. The rest is used in the manufacturing, mining and agricultural sectors. Part of the coal is converted to coke. However, the local demand for coke went down in 2008 and most of the product is exported.

2.2.2.4 Liquid Fuels

Diesel constitutes the greatest percentage of the liquid fuels, followed by petrol or gasoline. Other fuels include kerosene, aviation gasoline, jet kerosene, Liquefied Petroleum Gas. Most of the fuels are used in the transport, agriculture, manufacturing and mining sectors. In Zimbabwe's SNC (2013) it was stated that all liquid fuels were imported as finished products. Since 2010, petrol has been blended with ethanol. At the moment (2015) Zimbabwe has the largest ethanol and biodiesel plants in Africa. The vehicle population rose by 19% from 2000 to 2006. The country assembles very few cars and imports most of its vehicle requirements.

The power shortages have seen a sharp rise in the number of standby generators, both petrol and diesel-powered. It is difficult to ascertain the amount of fuel consumed by the generators. The Zimbabwe Energy Regulatory Authority (ZERA) is in the process of registering generators, especially those rated at 100 kW and above. ZERA will monitor fuel consumption and run-hours of such generators in the future.

2.2.2.5 Electricity

Electricity has a relatively small percentage contribution to the energy mix of the country but is the most preferred form of energy because it drives most machines in the productive sector and powers most of the appliances in the household sector. Zimbabwe is failing to meet the power needs of its people and both the productive and domestic sectors are affected by load-shedding. Despite the fact that the thermal plants have a total installed capacity of 1,295 MW the electricity sent out is lower than that of the 750MW Kariba hydropower plant. The major reasons for the low output from the thermal plants include:

- Coal shortages caused by mining and transportation challenges,
- Frequent breakdowns,
- Water problems, and
- Failure by the National Railways of Zimbabwe to transport coal to consumers.

Since 2010 the country has increased hydro-power by 21MW, mainly from Independent Power Producers (IPPs). The extension of the Kariba hydro-power plant which started in 2014 is expected to increase the capacity by 300MW by 2018. However, the utilisation of the extended plant will be restricted to the peak periods otherwise the water will be exhausted before the onset of the rainy season. In the 2015-2016 rainfall season, the power from the major and the mini-hydro power plants decreased due to reduced rainfall. This means that even the power sector is not immune to climate change.

The Zimbabwe Power Company (ZPC) intends to rehabilitate the existing thermal plants and boost supply by about 370MW by 2018. This means that GHG emissions will increase as the nation tries to meet demand for energy. However, there are also hydro, solar and coal-bed methane power projects in the pipeline.

2.2.2.6 Methodology

In estimating GHG emissions both the sectoral and the reference approach were used based on the Revised 1996 IPCC Guidelines. Tier 1 method, which is fuel-based, was chosen due to the nature of activity data obtained from both primary and secondary sources. Higher tiers required subsector disaggregated activity data and technology types for fuel combustion, and this data was not available at national level. In the energy sector the activity data are typically the amounts of fuels combusted. Such data are sufficient to perform a Tier 1 analysis.

The activity data was obtained from various sources (IEA, MoEPD, ZimStat, REA, ZERA), and from some local companies. The data from IEA had no gaps and was the most used data for the 2006 NIR. In cases where data was available from both national sources and IEA, comparisons were made and the difference was below 5%. IEA data was used.

Below are a number of assumptions made in the quantification of the gaseous emissions:

Transport: Petrol and diesel were assumed to be used by road transport while coal was for rail transport. Although diesel is used in rail transport, disaggregated data was not available. Emissions from diesel used in rail transport were therefore not estimated.

Agriculture, Forestry and Fishing: it was assumed that petrol and diesel are used for off-road use and other machinery such as combine harvesters.

The fugitive emissions from coal mining were calculated assuming an average opencast output contribution factor of 90% (HCC, 2005).

Results: Sectoral Approach and Reference Approach

The sectoral and reference approaches gave 10,663.72 Gg CO_2eq and 10,021 Gg CO_2eq, respectively. The percentage difference of the two figures was 6%. The 2000-2012 emissions differences varied from 0.2% to 11%, with a mean of 6.3%. The emissions differences were due to differences in EFs between the reference and sectoral approaches as well as the statistical differences. The reference approach has one factor per fuel while the sectoral approach sometimes has subsector specific EFs. For example, CH_4 emission factor for motor gasoline is 33 kg CH_4/TJ for Road Transport while the EF is 3 kg CH_4/TJ for Manufacturing Industries and Construction and 300 kg CH_4/TJ for Agriculture. The energy difference between the sectoral and reference approaches was smaller than those of emissions and varied from 0.5% to 6.8% with a mean of 3.6%.

Emissions by source categories

Energy Industries (1A1)

The category was responsible for 5,413 GgCO_2eq representing a 50.7% of the emissions from the energy sector in 2006. About 96.8% of the emissions were carbon dioxide, 2.7% methane and 0.5% nitrous oxide. Solid fuels (coal) contributed 99.5% while liquid fuels contributed only 0.5% of the emissions. Of the 3,496 kt of coal supplied (i.e. produced and imported) 43% was used in power generation at the thermal power plants. The 2006 coal figure was actually 36% lower than the 2005 figure, as supported by the decrease in coal-related energy from 4,435 GWh to 2,735 GWh (Figure 2.1). The coal delivery and maintenance challenges at major power stations were the major reasons for lower coal consumption. Otherwise the emissions would have been higher.

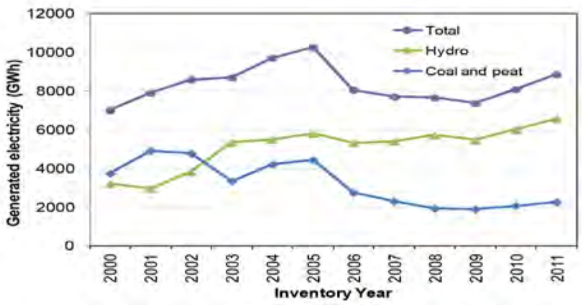

Fig 2.1 Trends of electricity generated using coal and running water

Other Sectors (1A4)

Other Sectors, which emitted a total of 2,106 GgCO_2eq, comprise of Commercial/ Institutional (1.A.4a), Residential (1.A.4b), and Agriculture/Forestry/Fishing/Fish Farms (1.A.4c). Of the 2,106 GgCO_2eq emitted by the Other Sectors, Agriculture contributed 70%, followed by the Commercial/Institutional sub-sector at 27%. The residential sub-sector had the least at only 3%. In the Agriculture sub-sector Stationary equipment contributed 89% of the emissions while off-road vehicles and other machinery contributed 13%. Tobacco curing barns and boilers are some of the stationary equipment.

Solid fuels contributed 82% of the emissions from this sector (i.e.78% as CO_2 and 4% as CH_4). The agricultural activities consumed about 68% of the solid fuels, followed by Commercial/ Institutional facilities at 32%. The increasing number of tobacco farmers partly explains the rise in demand for bituminous coal by the agricultural sector. The residential sector uses very little coal (3%) as shown in Figure 2.2.

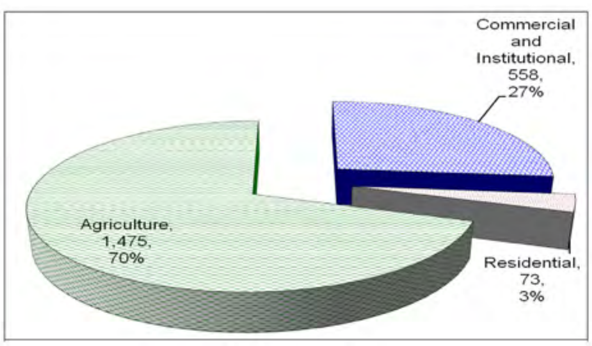

Fig 2.2 GHG emissions (Gg CO_2eq) by Commercial, Institutional, Residential, Agriculture, Forestry, Fishing and Fish Farms

Manufacturing Industries and Construction (1A2)

Emissions from this subcategory amounted to 1,446 Gg CO_2eq. A proportion of 85% of the emissions came from solid fuels while 15% came from liquid fuels. About 79% of the liquid fuels used in industry is diesel. Most steam boilers in industry use coal and a few use diesel. The number of generators to power office equipment and production equipment has been on the rise since 2000 because of power shortages experienced in the country and the SADC region. Figure 2.3 shows liquid fuels used in Zimbabwe in the year 2006. About 13% of the diesel consumed in 2006 was used in industry. LPG, kerosene and diesel are used in industrial ovens to provide the required heat. LPG has substituted electricity and steam in many canteens as the main heat source for heating and cooking. About 75% of the LPG consumed in the country in 2006 was used in industry while 25% was used in the residential sector (IEA, 2013).

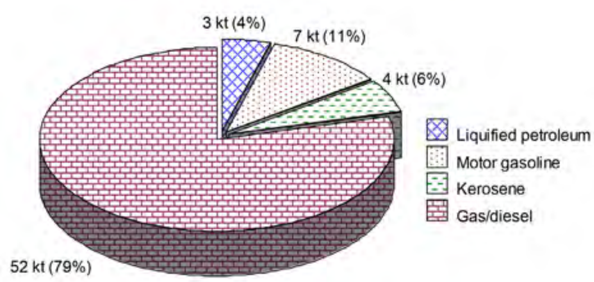

Fig 2.3 Liquid fuel usage by industry in 2006 (Source: IEA, 2013)

Transport

This sector contributed 1,303 GgCO_2eq in 2006 down from 1,950 GgCO_2eq in 2000 despite a 19% increase in vehicle population in 2006 (Figure 2.4). The decrease in emission could be attributed to fuel shortages experienced in 2006. Road transport contributed 97% of the CO_2 emissions, while rail contributed 3%. The transport sector was responsible for 90% and 60% of the national motor gasoline and diesel consumptions, respectively. Emissions are expected to continue to rise with the projected economic growth anticipated under ZimAsset.

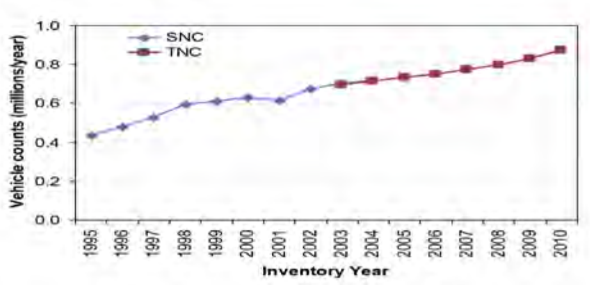

Fig 2.4 Vehicle population for the period 1995-2010 (Sources: MENRM (2012); ZimStat (2012)

Fugitive Emissions (1B)

A total of 201 Gg of carbon dioxide equivalent was emitted as fugitive gases in 2006, 90% of which was methane. The major sources of fugitive emissions in Zimbabwe are the coal mines. These emissions are a mixture of carbon dioxide and methane. Underground mining releases more fugitive gases than surface mining. The production report of one of the major coal miners indicate that coal from underground mining ranged from 6 to 14%. An average figure of 10% for underground mining contribution was used to estimate the fugitive emissions. This is an improvement on the method used in the SNC of assuming that 50% of the coal mined in 2000 was from underground and the other 50% from surface mining.

Time Series Analysis

Figure 2.5 below shows the trends of energy consumption obtained using the reference and sectoral approaches. Figure 2.7-6 shows the CO_2eq emissions.

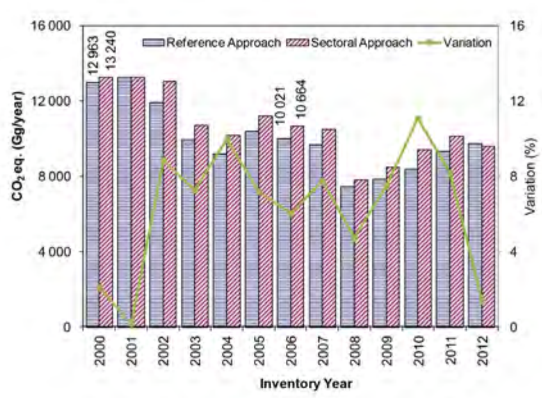

Fig 2.5 Energy trends for the period 2000-2012 for the reference and sectoral approaches

The GHG emissions for the INC and SNC were recalculated and results are shown in Figure 2.6. In the INC report the emissions were given as 18,469.9 Gg of CO_2, 58.59 Gg of CH_4, 0.74 Gg of N_2O, giving a carbon dioxide equivalent of 19,930 Gg. Recalculation gave 17,124 GgCO2eq (15,129 Gg for CO_2, 66.27 Gg for CH4 and 1.13 Gg for N_2O). In the SNC base year (2000) emissions from the energy sector were 23,832 Gg of CO_2, 47Gg of CH_4, 4 Gg of N_2O. Aggregating the emissions gives 26,199 Gg of CO_2eq. The recalculated emissions are 49% more than the 2000 emissions reported in this TNC report of 13,240 $GgCO_2$eq.

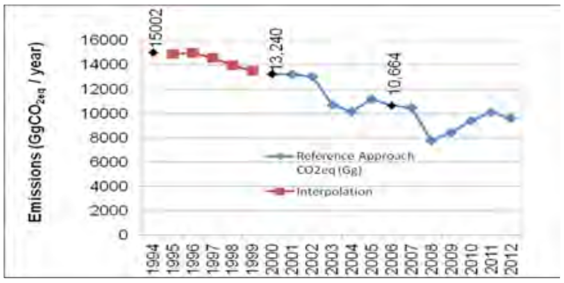

Fig 2.6 GHG emissions trends for the base year in INC, 15,002 $GgCO_2eq$ (recalculated), SNC, 13,240 $GgCO_2eq$ (recalculated) and the TNC, 10,664 GgCO2eq.

International Bunker Fuel

The emissions from international bunker fuels decreased sharply from over 350 $GgCO_2$eq in the year 2000 to an average of 24 $GgCO_2$eq from 2004 onwards (Figure 2.7). This was mainly caused by the significant decline in local flights during this period.

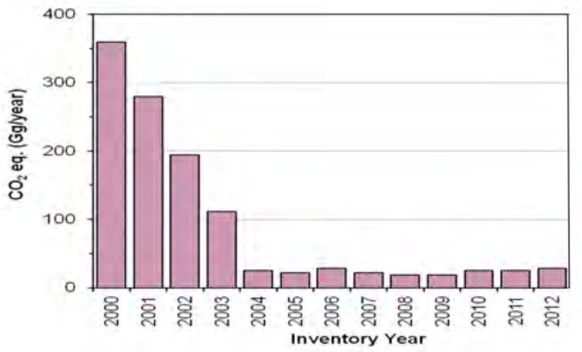

Fig 2.7 Trends of international bunker fuel usage

Uncertainties, QA/QC and Verification

Using 2000 as a base year the uncertainty in total inventory figures were as shown in Figure 2.8. The 2006 uncertainty for the GHG emissions was 3.0% while the range was 2.38 to 5.33% during the 2000-2012 period. The relatively wide range of the uncertainties indicates that there is room for improvement in the area of data quality.

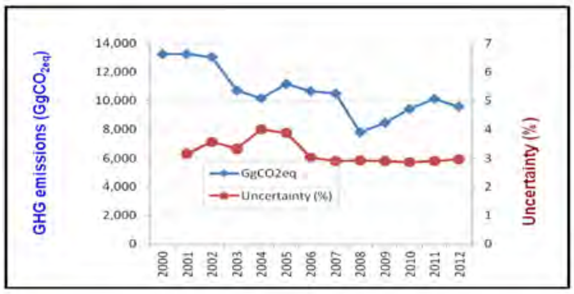

Fig 2.8 Trends on emissions and uncertainties

Electricity demand projections

Figure 2.9 shows the Demand Forecast up to the year 2030. The graph shows that about 12,000 GWh will be consumed in 2020 and 20,000 GWh will be required in 2030. The manufacturing and the domestic sectors will be the biggest consumers of electricity.

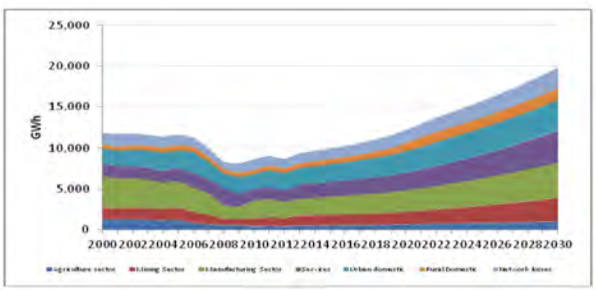

Fig 2.9 Electrical energy demand projections for Zimbabwe (Zimbabwe Load Forecast model of 2014)

Projections of GHG emissions up to 2020

In order to meet the energy needs of the various sectors, the country will be expected to build thermal and hydro power plants. Figure 2.10 shows that the small thermal plants which have been mothballed from 2006 to 2009 because of shortages of coal and spare parts were finally fired in 2010. There are plans to boost the output of these plants and that of Hwange Power Station which will add 370 MW to the national grid by 2018 (ZPC, 2015).

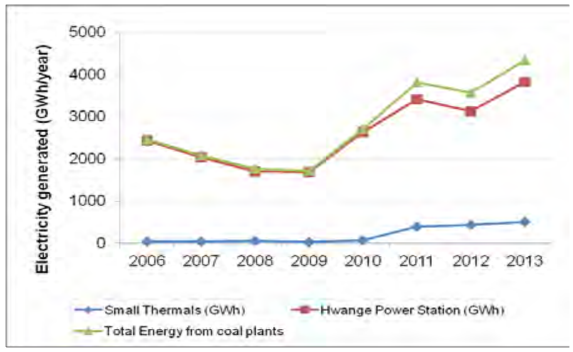

Fig 2.10 Electrical energy generated by coal-fired power plants (ZERA,2012)

The energy demand projections were used to construct the GHG trajectory in Figure 2.11. It is estimated that the emissions by the energy sector will be around 14,000 $GgCO_2eq$ by 2020.

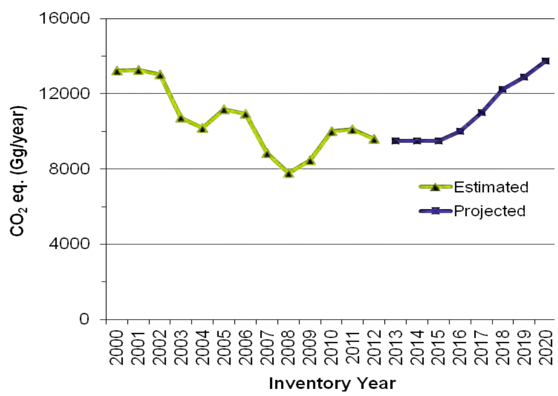

Fig 2.11 Projections of GHG emissions up to year 2020

2.5.3 Industrial Processes, Solvents and Other Product Use

2.5.3.1 Overview of the Sector

GHG emissions in the Industrial Processes and Product Use (IPPU) sector are produced as by-products from chemical reactions in various industrial activities and processes. The GHGs resulting from the chemical processes are CO_2, CH_4 and N_2O. Other important GHGs that are released from man-made fluorinated compounds are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Their continual usage as replacements for the Ozone Depleting Substances (ODSs) and subsequent accumulation in the atmosphere will have great impact on the long term effects on climate.

Cement plays a critical role in the construction industry in Zimbabwe hence the main drivers of its production are dependent on its market demand (availability of private and public funding) as well as overall prevailing economic conditions. In cement production, carbon dioxide is released during the production of clinker in Portland cement manufacture. During the production of clinker, limestone which is mainly calcium carbonate ($CaCO_3$) is heated or calcined to produce lime (CaO) and CO_2 as by products. There are no additional emissions associated with the production of Masonry cement.

Lime (CaO) is an important manufactured product mainly used in steel making, cement production, water purification and flue gas desulfurization systems at coal-fired electric power plants. Carbon dioxide is generated during the calcination stage, when limestone is roasted at high temperatures in a kiln to produce CaO and CO_2 emissions.

Zimbabwe imports soda ash. Soda ash is used primarily to manufacture many sodium-base inorganic chemicals, including sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates. Commercial soda ash is also used as a raw material in a variety of industrial processes and in some consumer products such as glass, soap and detergents, paper, textiles, and food.

Zimbabwe produces container glass. The major raw materials in glass production which emit CO_2 during the melting process are limestone ($CaCO_3$), dolomite $CaMg(CO_3)_2$ and soda ash (Na_2CO_3). Other raw materials in glass manufacturing that emit CO_2 are barium carbonate ($BaCO_3$), bone ash ($CaO_2P_2O_5$ and $CaCO_3$), potassium carbonate (K_2CO_3) and strontium carbonate ($SrCO_3$).

Ammonia gas is used as a fertiliser, in heat treating, paper pulping, nitric acid and nitrates manufacture, nitric acid ester and nitro compound manufacture, manufacture of explosives, and as a refrigerant. Amines, amides, and other miscellaneous organic compounds, such as urea, are made from ammonia (Austin, 1984).

Nitric acid (HNO_3) is an inorganic compound used primarily to make synthetic commercial fertilizers. It can also be used in the production of adipic acid and explosives (e.g., dynamite), for metal etching and in the processing of ferrous metals. During the production of nitric acid (HNO_3), nitrous oxide (N_2O) and nitrogen oxides (NOx) are generated and released as unintended by-products of the high temperature catalytic oxidation of ammonia (NH_3). The amount of N_2O and NOx formed depends on combustion conditions (pressure, temperature), catalyst composition and age, and burner design (EFMA, 2000).

Iron and steel production decreased from 152,000 metric tonnes in 2003 to 24,000 metric tonnes in 2006 indicating a 77.57% decline. The majority of CO_2 emissions from the iron and steel process come from the use of coke in the production of pig iron, with smaller amounts being emitted from the use of flux (limestone or dolomite) and from the removal of carbon from pig iron used to produce steel. The production of metallurgical coke from coking coal as well as the consumption of the metallurgical coke as a reducing agent in the blast furnace are considered in the inventory to be non-energy (industrial) processes, not energy (combustion) processes. The process for metallurgical coke production produces CO_2 emissions and fugitive CH_4 emissions.

Carbon dioxide and CH_4 are emitted from the production of several ferroalloys and in this Communication, emissions from the production of ferrochromium (both low carbon and high carbon) and ferrosilicon were calculated. For the current inventory, there were no ferroalloy production figures for the year 2000 from the industry trade association where the complete aggregated production data was collected. Some primary sources availed their data but others did not, thus most of the emissions were calculated using data provided by the Chamber of Mines of Zimbabwe.

Lead production in Zimbabwe is classified under secondary production primarily involving the recycling of lead. The recycled lead is used in lead acid batteries manufacture.

Motor and industrial oils, and greases used in industrial and transportation applications were the main sources of GHG emissions in this sector.

Emissions from Paraffin Wax Use came from production of candles, paper coating, wax polishes and surfactants.

Bread making and other food

Although there are seven categories in the food production sector, only the emissions from production of sugar were calculated because the data was available.

2.5.3.2 Methodology

The 2006 IPCC Guidelines for National GHG Inventories; Reference Manuals and the Good Practice Guidance (GPG) were used in estimating emissions. The IPCC derived default EFs from 2006 Guidelines and the Emission Factor Database (EFDB) of 2006 were used in all the calculations of emissions. For cement production, emissions were based on the clinker production estimates calculated from cement production data. The Tier 1 method was used in all the estimated emissions. To avoid double counting of emissions from lime, the lime produced in cement manufacturing and for agricultural purposes was not considered, as this was included elsewhere (IE) i.e. in cement production and agriculture sub-sectors.

The CO_2 emissions from pig iron production not processed into steel, sinter production, and the steel making process in the iron and steel production sub-category. Two types of furnaces were used in steel making namely the Basic Oxygen Furnace (BOF) and the Electric Arc Furnace (EAF). These emissions were summed up to get the CO_2 emissions for this source category.

Emissions of CO_2 from ferroalloy production were calculated using data from Chamber of Mines of Zimbabwe in three broad categories namely low-Carbon (low-C) and hi-Carbon (Hi-C) ferrochromium, and ferrosilicon. Additional data were also obtained from other primary ferroalloy producers.

Estimations of carbon dioxide emissions from lead production were based on national production statistics. A default emission factor of 0.52 tonnesCO_2/ tonne lead was chosen since national lead production data was obtained.

The Tier 2 approach was used to estimate CO_2 emissions from lubricant use. Data on quantities by type of lubricants and greases were obtained from ZimStat. Default Oxidised During Use (ODU) factors obtained from the 2006 IPCC Guidelines were used.

Estimates of CO_2 emissions from paraffin wax use were based on national activity data on paraffin waxes consumed and the default ODU factor of 20%.

Aggregated activity data for all wines was used and the EFs given in the EMEP/CORINAIR Guidebook (SNAP 40606-40608) were adopted since there was no country or regional specific EFs. Activity data which was used for the estimation of NMVOC was from wine and spirit production and excluded that of clear beer as this data was protected by the Census and Statistics Act [Chapter 10:29], 2007. Data on Opaque beer was also not available for the reporting period. Due to unavailability of data for other food categories only emissions from production of sugar were calculated.

2.5.3.3 Emissions by source categories

Cement Production (2A1)

Using the inventory base year of 2006 and factoring the exported and imported clinker, an estimated 53,9070.02 tonnes of clinker was produced resulting in 273.36 Gg of CO_2 (Gg 273.36 CO_2eq) emissions. The trend analysis showed that there was a general decrease in emissions between 2002 and 2010 (Figure 2.12).

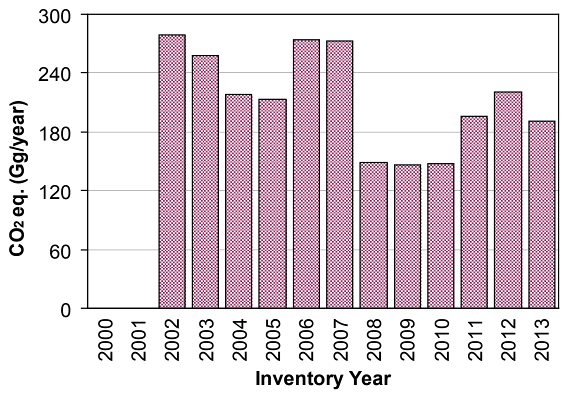

Fig 2.12 Emissions of CO_2 from clinker production during the period from 2002 to 2013

Lime Production (2A2)

In 2006 the production of lime resulted in the emission of 1.94 Gg CO_2. The CO_2 emissions followed a downward trend from about 20Gg CO2 in 2000 to 0.02Gg CO_2 in 2008 (Figure 2.13).

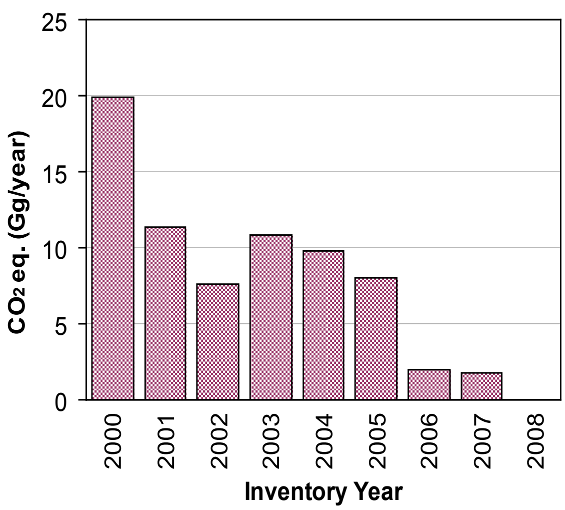

Fig 2.13 Emissions of CO_2 from lime production during the period from 2000 to 2008

Other Process Uses of Carbonates (2A3)

The limestone used in iron and steel, ferro-alloy production and cement manufacture was accounted for in the different subsectors. The other limestone used for fertilizer production was accounted for in the Agriculture Sector. However, limestone use data for glass manufacturing was not available hence the GHG emissions arising from its use could not be calculated.

Soda Ash Production and Use (2A4)

Using the inventory base year of 2006 soda ash use resulted in emissions of 3.43 Gg CO_2. Emissions from soda ash use followed an upward trend from 2000 to 2006. The emissions subsequently decreased from 2007 to 2013 (Figure 2.14).

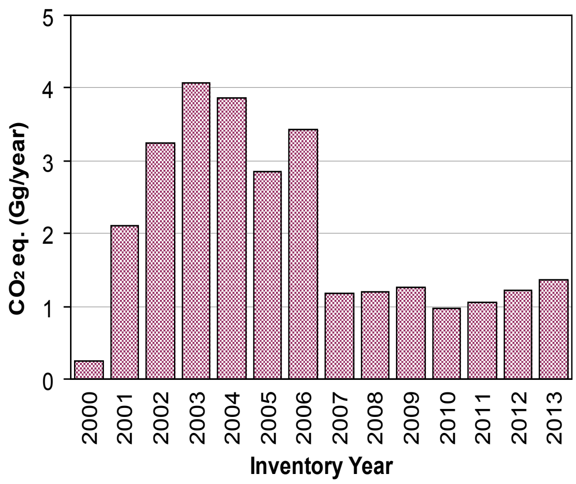

Fig 2.14 Emissions of CO_2 from soda ash use during the period from 2000 to 2013

Other: Glass Production (2A7)

The estimated CO_2 emissions for glass manufacturing in 2006 were 2.01Gg. The emissions increased by about 0.4 Gg CO_2 from about 1.6 Gg CO_2 in 2000 to about 2.0 Gg CO_2 in 2006. No definite trend was observed during the period from 2000 to 2013 (Figure 2.15). This could be attributed to fluctuations in the economic performance of the country. The rise in production of alternative packaging material namely polyethylene terephthalate (PET) based containers also contributed towards the reduced glass production.

Fig 2.15 Emissions of CO_2 from glass production during the period between 2000 and 2013.

Ammonia Production (2B1)

Ammonia production requires a source of nitrogen (N) and hydrogen (H). Nitrogen is obtained from air through liquid air distillation or an oxidative process where air is burnt and the residual nitrogen is recovered. Zimbabwe's sole producer of ammonia has a plant that uses hydrogen rather than natural gas to produce ammonia therefore does not release CO_2 from the synthesis process. Therefore GHG emissions from ammonia production were considered to be not occurring.

Nitric Acid Production (2B2)

In 2006, the production of nitric acid resulted in emission of 0.81Gg N_2O (249.98 Gg CO_2eq) and 1.08 Gg of NOx emissions (Figure 2.16). The trend on the time series graph showed nitric acid emission peaked in 2011 reaching 2.16 Gg N_2O emissions (642.51GgCO_2eq) and 2.87 Gg NOx emissions, a year when the economy recorded its highest average GDP growth of 11.9%. Emissions of N_2O and NOx decreased by 44% from the year 2000 to 2006. However, there was a general increase in emissions of both gases after 2009 with a peak in 2011. This suggests that nitric acid production was influenced by increasing demand in the agricultural sector.

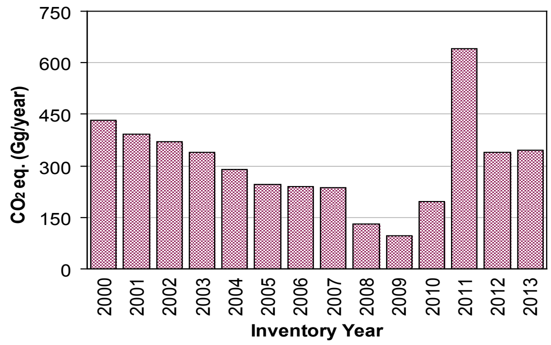

Fig 2.16 Emissions of N_2O (CO_2eq.) from nitric acid production during the period from 2000 to 2013.

The following activities were not occurring in Zimbabwe;

- 2B1: Ammonia production
- 2B3: Adipic Acid Production
- 2B4: Caprolactam, Glyoxal and Glyoxylic Acid Production
- 2B5: Carbide Production
- 2B6; Titanium Dioxide Production
- 2B7: Soda Ash Production
- 2B8: Petrochemical and Carbon Black Production
- 2B9: Fluorochemical Production

Iron and Steel Production (2C1)

Emissions of CO_2 from iron and steel production in 2006 were 114.42Gg and for methane 0.007Gg (0.17Gg CO_2eq.) The GHG emissions from iron and steel production decreased by 85% from the year 2000 to 2006. Production of iron and steel showed a steady decline from 2000 to 2008 as reflected by the GHG emissions arising from its manufacture. A significant decrease in GHG emissions (98%) was experienced between 2000 and 2008 (Figure 2.17). After the year 2008, one of the largest iron and steel producers closed down thus resulting in a significant decrease in iron and steel production. This resulted in a sharp decrease in GHG emissions. The remaining industries only focused on production of steel.

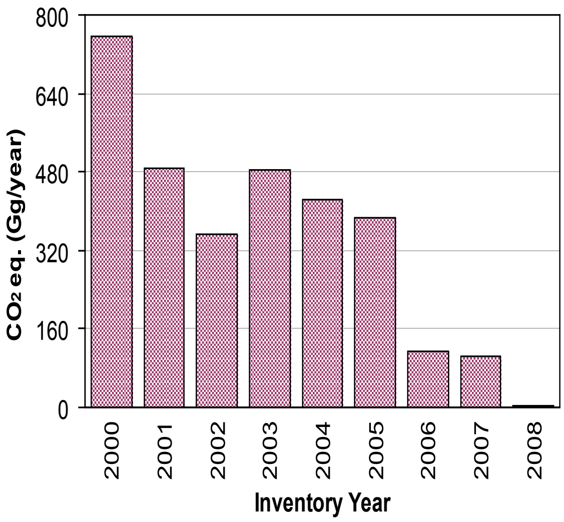

Fig 2.17 Emissions of CO_2 and CH_4 (CO_2eq.) from iron and steel production between 2000 and 2008

Ferroalloy Production

Emissions of CO_2 from ferroalloy production in the year 2006 were 263.43Gg CO_2eq, which was a ~21% decrease from the year 2000. This was due mostly to the decreased economic activity in the country during that period. Production of ferroalloys decreased from the year 2001 reaching its lowest production levels in 2009. Carbon dioxide emissions decreased by 74% in the same period from 366.91Gg in 2001 to 95.4Gg in 2009. The CO_2 emissions then increased between 2010 and 2011 due to increased production levels. The increase in production was a reflection of the high demand in ferrochrome during that period.

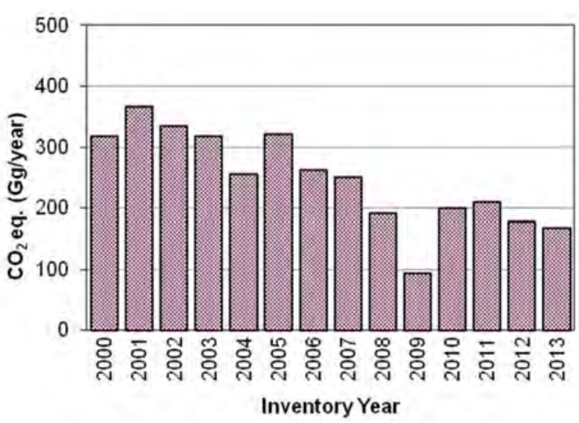

Fig 2.18 Emissions of CO2 from ferroalloy production during the period between 2000 and 2013

Aluminium Production

Zimbabwe does not have primary aluminium production. Thus there are no emissions for this sub-category.

Magnesium Production

The emissions from this sector were not estimated due to unavailability of data. Data from Small to Medium Enterprises (SMEs) in this sector was not available as many lack the capacity for record- keeping. In addition, some of the companies in this source category had closed down.

Zinc Production

Small to Medium Enterprises were the major players in this sector. However, emissions from this sector were not estimated due to unavailability of activity data arising from poor recording keeping systems.

Lead Production

In the reporting year of 2006, secondary lead production resulted in emissions of 0.93Gg CO_2. Lead production figures from the year 2000 to 2007 were based on estimates because the actual records were not available. There was no production activity from 2009 to 2010. The highest CO_2 emissions from lead production were in the year 2012 (Figure 2.19). Like in most of the source categories, emissions from lead production reached the lowest level in the year 2008.

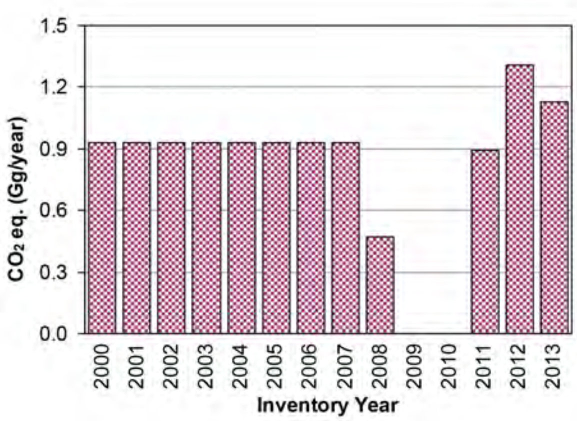

Fig 2.19 Emissions of CO_2 from secondary lead production during the period from 2000 to 2013

Lubricant Use

In 2006 emissions from lubricants use were 8.31Gg of CO_2. The fluctuations in the CO_2 emissions reflected the trends in the use of lubricants. The time series analysis showed that the highest CO_2 emissions were in the year 2003 and the lowest in 2005. From 2010 to 2013, the use of lubricants was almost consistent and resulted in CO_2 emissions which did not show a significant difference from one year to the next (Figure 2.20).

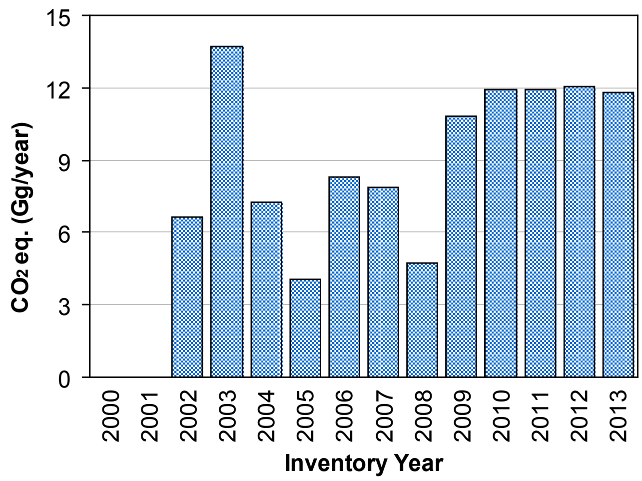

Fig 2.20 Emissions of CO_2 from lubricant use during the period from 2002 to 2013

Paraffin Wax Use

The use of paraffin waxes resulted in the release of 2.88Gg of CO_2 emissions in the reporting year of 2006. Although the CO_2 emissions fluctuated during the period 2000 to 2013, there was a general decreasing trend over the whole period (Table 2.4). The time series analysis showed that the highest CO_2 emissions were in the year 2000 and the lowest CO_2 emissions were recorded in 2008. Paraffin wax use decreased significantly during the years 2007 and 2008 due to the depressed economic environment.

Table 2.4 CO_2 emissions from paraffin wax use from 2000 to 2013

Parameter	Inventory Year													
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Emissions ($GgCO_2eq$)	3.90	3.70	3.35	3.50	1.63	1.54	2.88	0.79	0.39	1.44	2.15	2.47	2.28	1.64

Electronics Industry

Electronics manufacturing was not occurring in Zimbabwe.

Product Uses as Substitutes for Ozone Depleting Substances

Emissions from this source category were not estimated due to lack of annual leak rate and release profile although importation data of HFCs and PFCs gases was available. It is recommended to create a database in which all the relevant data will be captured and input into the IPCC workbook for estimation of the emissions arising from this source category.

Other Product Use

The estimation of emissions of SF_6 and PFCs from Other Product Use as well as N_2O emissions from Product Use was not done due to unavailability of adequate data for this process. In cases were data was available, it was not in the required format.

Pulp and Paper Industries (2H1)

GHG emissions from this category were not estimated. Production data for the reporting period was not available as most companies had stopped operations.

Alcohol, Food and Drink

There was an increase in NMVOC emissions from 2000 to 2004 mainly due to the increased production of both wines and spirits during this period (Table 2.5).

Table 2.5 NMVOC emissions from alcoholic beverages production from 2000 to 2011

Parameter	Inventory Year											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NMVOC (Gg)	0.29	0.55	0.78	0.83	0.83	0.82	0.68	0.75	0.78	0.79	0.41	0.55

A total of 5.51Gg of NMVOC emissions were emitted from the production of sugar in 2006 which was a 29% decrease from NMVOCs emissions in the year 2000 (Table 2.6). Sugar production fluctuated from 2000 to 2011 and this also resulted in similar fluctuations in NMVOC emissions.

Table 2.6 Emissions of NMVOC from Sugar Production between 2000 and 2011

Parameter	Inventory Year											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NMVOC (Gg)	7.71	7.25	8.02	6.86	5.38	5.74	5.51	4.54	3.73	3.05	3.86	4.27

A time series analysis of the emissions from the food and drink sector is shown in Figure 2.21. The decrease in emissions of NMVOC from 2000 is a reflection of the downward trend in economic activity.

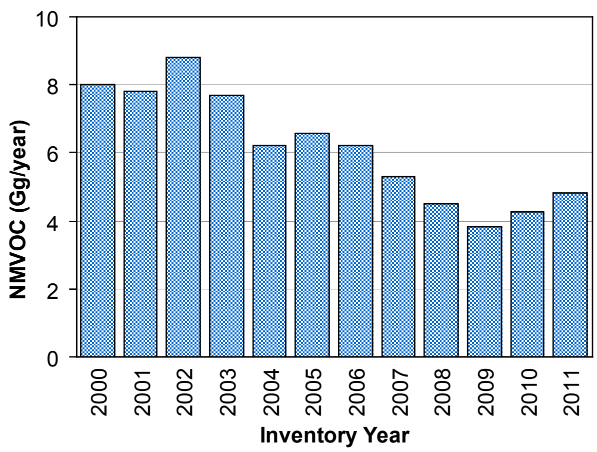

Fig 2.21 NMVOC Emissions from Food and Drink Production

2.5.4 Agriculture

2.5.4.1 Overview

The GHG inventories for the Agricultural Sector were compiled following the Revised 1996 IPCC Guidelines and using the 2006 IPCC Software for data processing. The activity data collected from multiple sources was used to calculate national average figures and their levels of uncertainties. Emission Factors (EFs) were obtained from the IPCC EFDB. The inventory methods were largely Tier 1 as no country-specific EFs have been established yet. The source categories covered by the inventory were: enteric fermentation (4A); manure management (4B); rice cultivation (4C); agricultural soil (4D); prescribed burning of Savannas (4E); and field burning of agricultural residues (4F).

The existing landholding system in Zimbabwe resulted from the Land Apportionment Act of 1930 and from the Land Reform Programme that started in 1980. Landholding classification after resettlement include A1: villagised communal resettlement model with on average 5 ha per household and communal grazing area ranging from 25-60 ha; A2: small-scale commercial farms ranging from 50 ha in Natural Region I and up to 300 ha in Natural Region V; and D: livestock development areas. The A1 and A2 started in 2000 and are variants of the old resettlement programmes, while the D model started in 1980 and has been based on willing-seller-willing-buyer concept.

The order of contribution to GHG emissions by different sub-categories in the agriculture sector for the base year 2006, in CO_2 equivalents, were: enteric fermentation (44.0%), agricultural soils (34.0%), prescribed burning of Savannas (19.2%), manure management (2.5%), field burning of agricultural residues (0.3%) and lastly rice cultivation (<0.1%). Enteric fermentation rated highest contributor of GHG emissions (CO_2eq) from the Agriculture sector in Zimbabwe. A similar trend was observed in the INC and the SNC. The trend generally reflected the relative proportions of the livestock and the effects of the drought years (1991/1992 and 2001/2002).

The INC and the SNC reported enteric fermentation as the highest contributor of GHG emissions (CO_2eq) from the Agriculture Sector in Zimbabwe. This category also received an overall third rank in the key source categories analysis, emitting 212.43 Gg of CH_4 for the base year 2000 (MENRM, 2012). There have been considerable changes in the livestock sector of Zimbabwe within the past two decades, which affected livestock population, ownership and consequently the dynamics of GHG emissions from enteric fermentation and manure management. Table 2.7 shows the livestock ownership changes between 1988 and 2006, with potential implications on livestock management, which affects the magnitudes of enteric fermentation and the ways in which livestock manure is managed.

Table 2.7 Proportion of the total livestock population owned by smallholder farmers (comprising of communal farmers and small-scale commercial farmers) in Zimbabwe

Inventory Year	Cattle	Sheep	Goat	Pig	Reference
1988	68	84	99	60	CR Zimbabwe, 2004
2000	72	94	94	48	FAO/WFP (2001)
2006	>90	81	99	35	FAO/WFP (2007)

Livestock management regimes vary widely from place to place and generalisations were made on manure management systems. The two Animal Waste Management Systems (AWMS) identified in the SNC were: solid storage and dry lot, and pastures/rangeland/paddock, considered when manure is deposited on land by livestock during grazing. Smallholder farmers are generally known to apply manure on croplands, while the second manure management system is common with the commercial livestock farmers. Thus, manure management is as dynamic as livestock ownership across production sectors.

Manure management made up less than 4% of all CH_4 emissions from livestock, and was reported to contribute less than 0.01% to overall GHG emissions from Zimbabwe in the previous inventories. Nitrous oxide (N_2O) from manure management was 0.22 Gg in the base year 2006. This was coming from emissions during storage of non-dairy cattle manure (3% of manure), pig manure in liquid systems (7%), and sheep manure (1%). Manure management contributed <2% of the total emissions (CO_2eq) from livestock.

Zimbabwe is generally not recognised as a significant rice producing country. However, over the past decade there has been an increase in national consumption of rice and the Government of Zimbabwe has been promoting rice production at a larger scale in order cut down on rice importation (Agronomy Research Institute, 2009). Government efforts towards self-reliance in rice production date back to the mid-1980s but the enthusiasm was not accompanied by a full complementary production technology (Mugabe and Mharapara, 1985). However, rice cultivation on wetlands and in irrigated systems may, in future, become a significant source of CH_4 emissions in Zimbabwe. Activity data on rice cultivation has not been capturing the amount of inputs used, variety of rice grown and the moisture regimes.

The direct N_2O emissions from agricultural soils in the base years for the SNC (2000) and current inventories (2006), respectively, and according to specific sources were:

Synthetic fertiliser application: 0.92 Gg (recalculated to 1.17 Gg N_2O or 349 Gg CO_2eq) and 0.80 Gg (238 Gg CO_2eq)

Animal waste use as manure: 1.24 Gg (recalculated to 0.17 Gg N_2O or 51 Gg CO_2eq) and 0.15 Gg (45 Gg CO_2eq)

Urine and dung input on grazed soil: 8.06 Gg (not reported in SNC) and 7.03 Gg (2,095 Gg CO2eq)

Cultivation of histosols: not occurring.

Indirect N_2O for the same reported periods were: 57.26 (recalculated to 1.22) Gg (SNC) and 1.21 Gg (2006) from N leaching; and 0.19 (recalculated to 0.97) Gg (SNC) and 0.82 Gg (2006) from volatilisation of NH3 and NOx from soil.

Emissions from Savanna burning have been increasing steadily between 2000 and 2010, while the emissions from the field burning of crop residues (cotton, sugarcane and tobacco) have been decreasing.

In Zimbabwe, the main sources emissions from Agricultural soils are synthetic fertiliser application, animal waste use as manure in soil and leaching of nitrogen and volatilisation of NH_3 and NOx from the soil.

Savannas are tropical and sub-tropical vegetation types with a predominant grass cover and interludes of trees and shrubs (IPCC, 1996) and cover most part of Zimbabwe. Early and late dry season fires are a common practice in most parts of Zimbabwe. This is the first time emissions from Savanna burning are being reported. Under the agriculture sector, prescribed burning of Savanna covers emissions from fires set as a management tool. Records of veldt fires in Zimbabwe do not separate between prescribed and illegal burning; hence all such burning is aggregated. No information is available on areas burnt under natural fires in Zimbabwe.

In Zimbabwe, the agricultural residues burned are mainly those of sugarcane, cotton and tobacco. On large scale commercial farms and other small-scale farms, sugarcane is burned prior to harvesting for easy handling and to kill venomous snakes commonly found in sugarcane plantations. The residues of cotton and tobacco are required by law (Plant Pests and Diseases (Amendment) Regulations of 1988) to be destroyed for pest control.

2.5.4.2 Methodology

Emissions from Enteric Fermentation and Manure Management were estimated based on livestock data obtained for seven livestock categories (dairy cattle, non-dairy cattle, sheep, goats, horses, mules and donkeys, and pig. The sources of activity data were: Department of Livestock Production and Development (LPD), Department of Veterinary Field Services (VFS), Department of Agricultural Technical and Extension Services (AGRITEX), ZimStat and Zimbabwe Poultry Association (ZPA). The two international organisations were: Food and Agriculture Organisation of the United Nations (FAO), and Southern African Development Community (SADC). Buffalos in Zimbabwe are not domesticated and therefore were not considered in the inventories. The activity data available on enteric fermentation was livestock population, which was in some cases categorised by provinces and/or by natural regions (NRs), but in most cases aggregated. Local information on the feeds and specific livestock characteristics was not available, and therefore only Tier 1 method was applicable. The IPCC Climate Zones and the maps of NRs and mean annual temperatures (MAT) were overlaid to come up with two generalised temperature climates which are cool (NR I with MAT <15 °C) and temperate (other NRs with MAT 15-25 °C). However, NR 1 had relatively insignificant proportions of the livestock and therefore only one temperature climate was considered for the total livestock populations.

The activity data is complete.

The land area under rice cultivation was obtained with several missing data. Missing data in between years was estimated by interpolation. The land area under rice cultivation was obtained from three major sources: (1) AGRITEX, (2) ZimStat and (3) FAO. Country specific information on EFs, water regimes, multiple rice cropping and soil amendments was not available, and therefore only Tier 1 method was applicable. Out of the total harvested area under rice cultivation in Zimbabwe, 25% was assumed to be under irrigation, and the remaining 75% was rain-fed upland based on the Revised 1996 IPCC Guidelines.

An overlay of the Harmonized World Soil Database v1.2 (Fischer et al., 2008); IPCC Climatic Zone layer (IPCC, 2006) ; and the Global Land Cover (GLC2000) was performed in a GIS to delineate soils according to the climate zones. The soils maps did not show any location of organic soils or Histosols.

The direct N_2O emissions from managed soils were estimated as the sum total of N_2O from synthetic fertiliser nitrogen, N_2O from manure nitrogen and N_2O from urine and dung deposited on pastures. The N_2O emissions from decomposing crop residues and from biological nitrogen fixation were not estimated due to limited data on such crops while N_2O from sewage sludge were considered under the waste sector. Indirect N_2O emissions were estimated as N_2O from leaching and N_2O from volatilisation of NH_3 and NOx from managed soils. The available data was mainly on the mass of synthetic fertiliser nitrogen, livestock population, and land area under cultivation delineated according to soil type and climate. The total amounts of synthetic fertiliser nitrogen, required for estimating direct N_2O emissions from soil and indirect N_2O from leaching, were obtained by averaging data from FAO and ZimStat. Information on nitrogen conversion factor of N fixing crops and other country specific EFs related to crops and livestock management was not available. Thus, only Tier 1 methods could be used.

The emissions of CH_4, N_2O, NOx and CO from Savanna burning were estimated using the Tier 1 method because there were no country specific EFs for this category in Zimbabwe. In this inventory, the FAOSTAT data generated using composite burned area values from monthly statistics of the Global Fire Emission Database v.4, based on MODIS remote-sensing data (GFED4; Giglio et al. 2013) was used to estimate burnt area. The default fuel mass burned per unit area and the combustion efficiency for the Africa region were obtained from the 2006 IPCC Guidelines.

The fuel mass burned per unit area was estimated from the Residue/Crop Product ratio of 0.4 for both cotton and tobacco. This value is applicable to potato but was adopted for cotton and tobacco because they have the closest morphology as noted in the 2006 IPCC Guidelines. The values of fuel mass burned were not adjusted for moisture content on the assumption that the moisture content was negligible since the yields of both crops are expressed on dry weight basis. An IPCC default value of 6.5 t/ha for sugarcane burned was used since the available production figures were not based on dry weights, and there are no country specific values for this parameter. As was the case with prescribed burning of Savanna the combustion efficiency values were also obtained from the 2006 IPCC Guidelines. The data on crop harvested area and production were sourced from ZimStat, FAOSTAT Database (FAO) and from the AGRITEX Crop Assessment Reports (MAID). For sugarcane the data was only for the Large Scale Commercial sector.

Emissions from Enteric Fermentation

Methane emissions in the years between 1990 and 2010 ranged from 156.01 to 208.09 Gg/year, with the lowest emissions occurring in 1993 while the highest emissions were in 2001 (Figure 2.22). The base year 2006 emissions were 170.29 Gg. The re-calculations on the previous base years 1994 (164.31 Gg) and 2000 (205.56 Gg) did not deviate considerably from the values reported in the INC and SNC. This was despite the use of the updated EFs factors for non-dairy cattle to cater for semi-arid and humid rangelands.

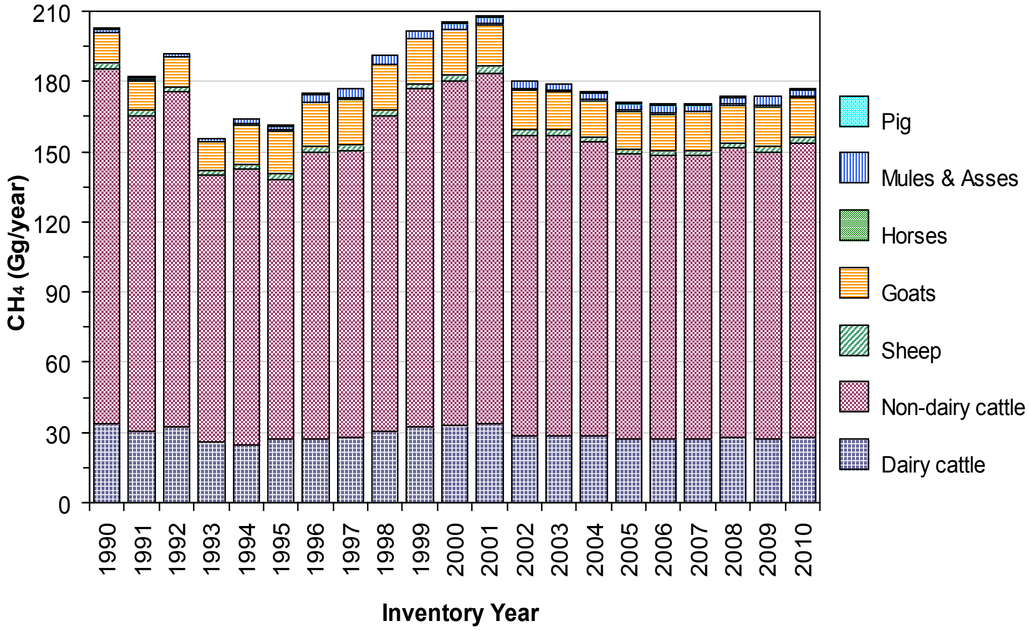

Fig 2.22 Methane emissions from enteric fermentation between 1990 and 2010

The incorporation of horses that were not included in previous inventories did not contribute significantly to the emission trends since their populations were very small. The trend generally reflected the relative proportions of the livestock and the effects of the drought years (1991/1992 and 2001/2002).

No significant changes in future emissions from enteric fermentation are expected in the 2020 forecast, in realisation of stability observed in the emissions between 2002 and 2010.

Emissions from manure management

Direct CH_4 emissions from decomposing manure during the years 1990 to 2010 (range: 5.85 - 8.05 Gg/year) followed similar trend as enteric fermentation, but there was a considerable contribution by poultry between 2000 and 2010 (Figure 2.23). The base year 2006 had 7.06 Gg CH4 from manure management. The re-calculations on the previous base years 1994 (5.97 Gg) and 2000 (7.84 Gg), however reflect the correction that was done on the mean annual temperature from >25 °C to the range 15-25 °C, which correspond to lower EFs. In the SNC the mules and donkeys were not included despite the nature of their excreta which contributes significantly to CH_4 emissions. These were however included in this Communication.

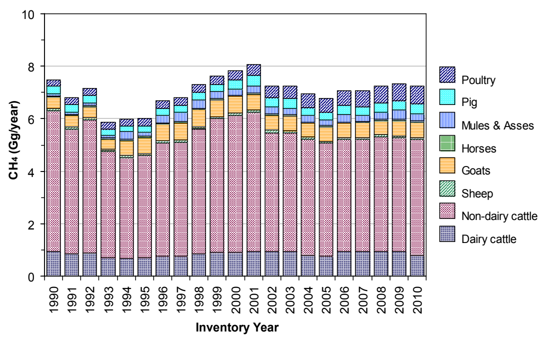

Fig 2.23 Methane emissions from manure management between 1990 and 2010

The direct emissions of N_2O during storage of non-dairy cattle manure, pig manure in liquid systems, and sheep manure are shown in Figure 2.23, while other manure-related N_2O emissions from soils are considered under Agricultural Soil. N_2O emissions from management of manure in other livestock categories were assumed not to occur before spreading according to the Revised 1996 IPCC Guidelines. The emissions ranged from 0.15 Gg in 1994 to more than 0.20 Gg in 2001.

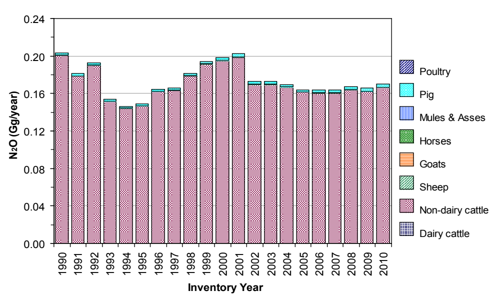

Fig 2.24 Nitrous oxide from manure management between 1990 and 2010

The indirect N_2O emissions from manure management ranged from 0.03 Gg in 1994 to 0.05 Gg in 2001 (Figure 2.24). The emissions in the base year 2006 were about 0.04 Gg N_2O. Indirect emissions result from volatile N losses in the forms of NH_3 and NOx after N is mineralised during manure collection and storage. The trends in indirect emissions from manure management followed similar trend to livestock population.

Fig 2.25 Indirect emissions of N_2O from manure management

Emissions from Rice Cultivation

Methane emissions from irrigated and wetland rice cultivation ranged from 0.01 Gg in 1992 to above 0.04 Gg in 2010 (Figure 2.26). Comparison of the 1990s' emissions with the 2000s' emissions showed that the emissions have doubled over the past one and half decades. Although the emissions are relatively low, the contribution from this category is increasing at a considerable rate. In the base year 2006, 0.040 Gg of Methane was emitted from rice cultivation.

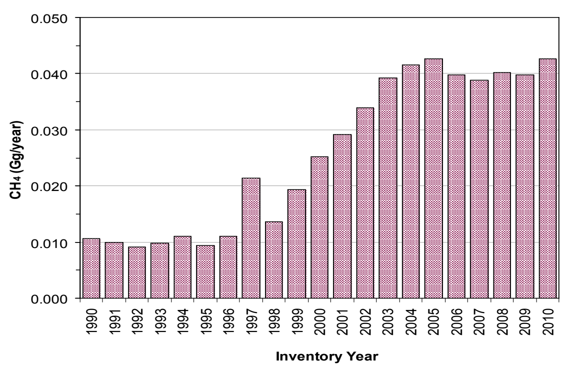

Fig 2.26 Methane emissions from rice cultivation between 1990 and 2010

There were high levels of uncertainty in the areas harvested for rice in Zimbabwe.

Direct N_2O emissions from managed soils

Direct emissions from managed soils, encompassing synthetic fertiliser nitrogen, manure nitrogen and nitrogen from urine and dung deposited on pastures, ranged from 7.20 Gg N_2O in 2008 to 10.45 Gg N_2O in 2001 (Figure 2.27). For the base year 2006 with 8.85 Gg N_2O, the greatest contribution was from nitrogen in urine and dung deposited on pastures (7.90 Gg) followed by nitrogen from synthetic fertilisers (0.80 Gg) and lastly the nitrogen in manure applied on soil (0.15 Gg). In contrast, the SNC reported 2.16 Gg as an aggregate from fertiliser nitrogen and animal waste manure, and 1.24 Gg from urine and dung.

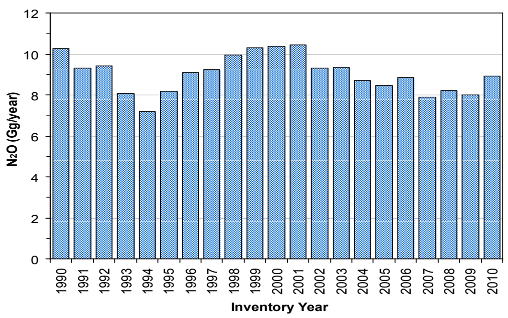

Fig 2.27 Direct emissions of N_2O from managed soil

Indirect N_2O emissions from managed soil

The indirect N_2O emissions ranged from 1.99 Gg N_2O in 2008 to 2.61 Gg in 2000, while the base year 2006 had 2.20 Gg, of which 1.21 Gg came from leached nitrogen (Figure 2.28). The leached nitrogen was assumed to be 30% of the total applied nitrogen, according to the 2006 IPCC Guidelines and the default EF of 0.0075 kg N_2O/kg N leached used.

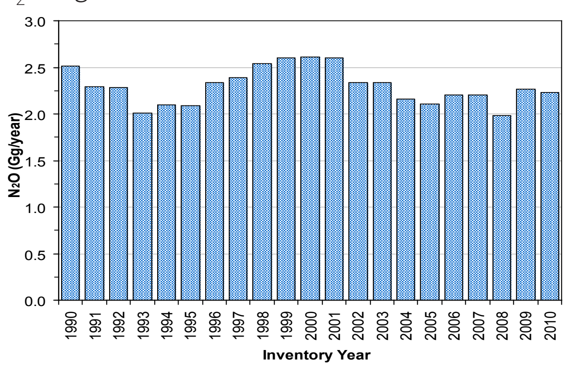

Fig 2.28 Indirect emissions of N_2O from managed soil

Agricultural soil emissions of GHG are predicted to increase steadily due to government efforts to revive the economy through the programmes such as Zim Asset. However, in 2020 the emissions are not likely to exceed those in the period between 1998 and 2000 due to expected limited land-use change in the future.

Prescribed Burning of Savannas

Savanna burning emitted between 24.9 Gg CH_4 (2003) and 54.3 Gg CH_4 (2009), while the base year 2006 emissions were estimated at 35.7 Gg CH_4 (Figure 2.29). The emissions decreased from the year 1998 to 2003, and started increasing from 2003 to 2010. The re-calculation of base year 2000 gave 29.1 Gg CH_4 relative to 49 Gg estimated for the same year in the SNC. The difference may be attributed to the use of the improved EFs, relative to the emission ratios from the Revised 1996 IPCC Guidelines.

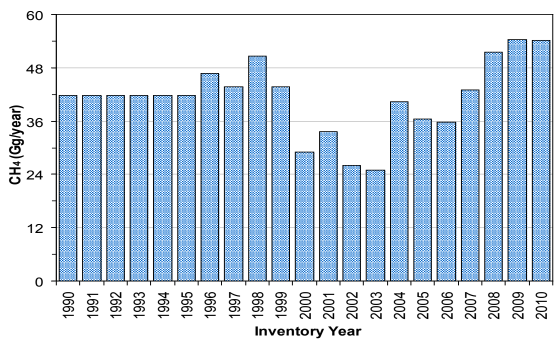

Fig 2.29 Methane emissions from Savanna burning between 1990 and 2010

The emissions of N_2O ranged from 2.27 Gg in 2003 to 4.96 Gg in 2009 (Figure 2.30), and followed the same trend as that of CH_4 emissions. The base year 2006 had 3.26 Gg N_2O. Emissions reported in the SNC base year 2000 (2.36 Gg N_2O) are close to the re-calculated emissions of 2.66 Gg for the same year.

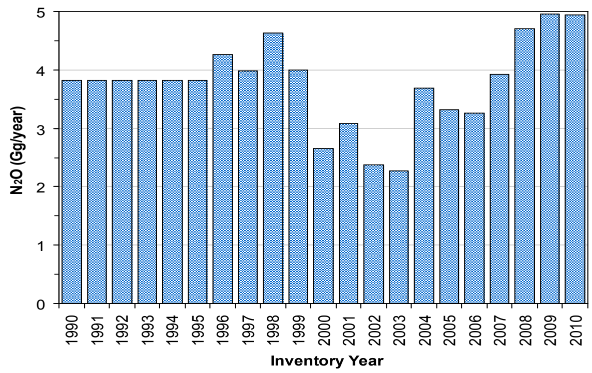

Fig 2.30 Nitrous oxide emissions from Savanna burning between 1990 and 2010

The oxides of nitrogen, which are GHG precursors, emitted from Savanna burning, ranged from 42.1 to 91.1 Gg and followed the same trend as that of CH_4 and N_2O. The recalculated base year 2000 emissions were estimated at 49.4 Gg NOx, and were slightly lower than the 58 Gg recorded in the SNC.

Savanna burning emitted between 703 Gg CO (2003) and 1,535 Gg CO (2009), and the base year 2006 emissions were estimated at 1,008 Gg CO. The re-calculation of base year 2000 gave 823 Gg CO relative to 1,363 Gg estimated for the same year in the SNC.

The emissions from Savanna burning are predicted to double by 2020 in view of the current trends and the current government policy on land. The data is complete.

Field Burning of Agricultural Residue

Emissions from field burning of agricultural residues

In the base year 2006, the burning of agricultural residues emitted 0.83 Gg CH_4. Time series of emissions from burning of agricultural residue were lowest in 1992 probably due to the 1991/1992 drought (Figure 2.31). A decrease in the emissions after the year 2001 could be attributed to the 2001/2002 drought and the farm ownership changes that took place during the land resettlement programme which started in 2000.

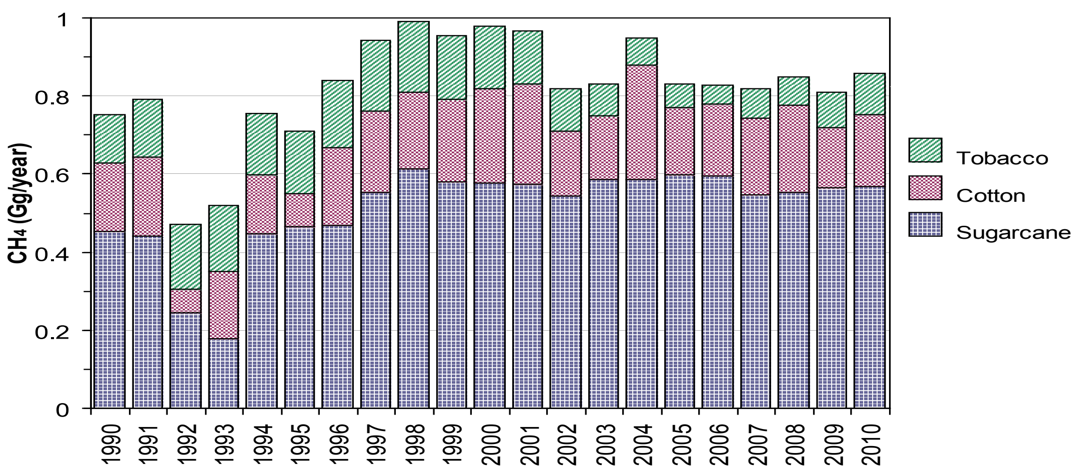

Fig 2.31 Methane emissions from field burning of agricultural residues, 1990 to 2010

Nitrous oxide, CO and NOx emissions from burning of agricultural residues for the same period showed similar trends. Sugarcane burning before harvesting contributed the highest emissions followed by cotton and lastly tobacco, particularly between 2000 and 2010. The sugarcane industry in Zimbabwe has been largely boosted by the government initiatives to increase biofuel production.

Emissions from field burning of agricultural residues is likely to remain unchanged up to 2020 in view of the fact that the emissions have been relatively stable between 2002 and 2010. It is highly unlikely that production of cotton will increase because of the unfavourable global price of cotton. Tobacco producing areas have generally been increasing in the late 2000s, but the yield per unit area have decreased with time there by compensating for the area expansion to the extent that the overall emissions from residue burning is unlikely to increase significantly. Moreover, global campaigns against tobacco smoking may contribute towards low production of the crop thus lowering related emissions.

2.5.5 Land Use, Land Use Change and Forestry (LULUCF)

2.5.5.1 Overview of Forestry sub-sector in Zimbabwe.

Zimbabwe's forestry resources cover approximately 46% of the total land area. Forests in Zimbabwe are varied, rich in biological diversity and genetic resources, and are renowned as unique natural ecosystems and habitats for wildlife. They provide most of Zimbabwe's biomass energy needs, timber and non-timber products. Other services offered by forests include watershed protection, carbon sequestration, microclimate stabilization, and the provision of windbreaks, shade and soil stability. Forests in Zimbabwe serve as levers for rural development and livelihood 'safety nets'.

Forestry sector in Zimbabwe is divided into two major sub-sectors - the indigenous and the commercial plantation forestry sectors. Zimbabwe's indigenous forests consist of natural forests, woodlands, bush lands and wooded grasslands that make up about 27 million hectares (Forestry Commission, 1992). Given the relatively extensive woodland cover across the country, Zimbabwe has the potential to increase its carbon sink status.

2.5.5.2 Indigenous Forestry Sector

The area of indigenous forests in Zimbabwe comprises of natural forests, mainly in the Eastern Highlands and the woodland ecosystem, covering most of the country. The woodland ecosystem is divided into the following types: dry Miombo; Teak, Mopane, Acacia and *Terminalia/Combretum.*

Natural forests

The forests belong to the Afromontane phytoregion, occurring in the Eastern Highlands of Zimbabwe. Four major zones are identified: Montane forest (1650 – 2100m a.s.l.), sub Montane forest (1350 – 1650m a.s.l.), Medium altitude forest (850 – 1350m a.s.l.) and lowland forest (350 – 850m a.s.l.) (Muller, 2006). The natural forests cover 0.8 million hectares (Forestry Commission, 2011).

Miombo Woodlands

These are the most extensive woodlands, bushlands and wooded grassland in southern Africa and Zimbabwe occurring in most parts of the central watershed of Zimbabwe. Miombo has diverse uses ranging from watershed protection, leaf litter, grazing and browsing, firewood, edible fruits, mushrooms and insects and timber. Furthermore, most of these forests have been converted into intensive agricultural areas. These cover about 17.7 million hectares (Forestry Commission, 2011).

Teak Woodlands

These are exclusive to the Kalahari sands and are predominantly found in the gazetted forests of western Zimbabwe and parts of Hwange National Park. Teak woodlands, bushlands have been managed for commercial timber exploitation, wildlife utilization, cattle grazing and water catchment protection. These cover 1.4 million hectares (Forestry Commission, 2011).

Mopane Woodlands

These are widespread in Zimbabwe and are often associated with low altitudes and hot areas with sodic or alluvial soils. The woodlands and bushlands can be divided into, the dry early deciduous (in the north & west of Zimbabwe), the dry deciduous shrubs (in Save valley and upper Limpopo) and the dry early deciduous shrubs (on basalt soils in Southern Zimbabwe). Mopane woodlands are an important source of browse for both wild and domestic animals, timber for craftwork, firewood, household items, fence posts, poles, mine props, railway sleepers and parquet flooring. Mopane woodlands and bushlands cover 12.3 million ha accounting (Forestry Commission, 2011).

Acacia Woodlands

These woodlands and bushlands occupy large tracts of land especially in drier areas. They are important in pastoral systems as the trees provide browse (leaves, flowers and pods). They also provide gum Arabic that is important in confectionary and manufacturing of paints. Acacia woodlands and bushlands cover a total of 1.6 million ha (Forestry Commission, 2011).

Terminalia/Combretum Woodlands

These woodlands and bushlands are found as tree-shrub combinations. They provide firewood, poles for construction and tool making. Combretum is an important component of this woodland type, but has been severely cut and most of the existing vegetation is secondary, and constitutes about 2.4 million ha of Zimbabwe (Forestry Commission).

It is important to note the area of indigenous woodlands in Zimbabwe has shown a continuous significant decline, estimated to be 330 000ha per year compared to 70 000, a few decades ago (Forestry Commission, 2010). This is driven by a number of factors including agriculture and settlement expansion, fuelwood consumption, fires and browsing by wildlife.

2.5.5.3 Commercial Plantations in Zimbabwe

Zimbabwe's plantation forest resource base covered 168,581ha in the year 2000 (TPF, 2000) with approximately 90% of the plantations being located in the eastern highlands. Major plantation forest species include *Pinus patula, P. elliottii, P. taeda, Eucalyptus grandis, E. camaldulensis and Acacia mearnsii*. Pines are used for structural timber, pulp and paper while eucalypts are used for poles, pulp and paper. Wattle is used for the production of tannin and high quality charcoal. There has been a steady decrease in areas planted with commercial forests between 2000 and 2012 due to resettlement losses, fire losses and tree felling. Area of commercial plantations by 31 December 2012 was 81 583 hectares, just 0.2% of the country's land area (TPF, 2012).

2.5.5.4 Methodology

The Revised 1996 IPCC Guidelines were used to estimate GHG removals in the LULUCF sector. Following the land use classification, decision trees were used for selecting the appropriate method for estimating GHG emissions by source and removals by sink.

LULUCF land categories and approaches.

Land use categories in Zimbabwe fall into the following IPCC categories: forestland, cropland, grassland, wetlands, settlements and other land. Generally three approaches can be used to represent land areas (IPCC GPG, 2003) i.e., Basic Land Use Data, Survey of Land Use and Land Use Change and Geographically Explicit Land Use Data. In this communication, approach one was used because of data constraints. Approach one identifies total area for each land use without detailing information on land use changes. Land distribution data came from sample surveys and maps obtained from the Forestry Commission. Generic climatic zones were sourced from global ecological zones, based on climate and vegetation patterns (FAO, 2001). Land area estimates and wood removals of commercial plantations in Zimbabwe were sourced from Timber Producers Federation in Manicaland. Zimbabwe is classified as TAWb, tropical dry forest.

GHG removal activity data suited Tier 1 level. Work sheets and reporting tables in Revised 1996 IPCC Guidelines assisted in manual calculations of the inventory. Time series analysis and emissions estimations from LULUCF could not be done due to non-availability of data, especially on indigenous forest production.

The inventory is organised into categories and sub-categories following Revised 1996 IPCC Guidelines into the following:

- Changes in forest and other woody biomass stocks.
- Forest and grassland conversion.
- Abandonment of croplands, pastures or other managed lands.
- CO_2 emissions and removals from soils.
- Other categories of reporting and specific cases.
- Changes in forest and other woody biomass stocks.

In the INC it was reported that wood biomass had sequestered 81,003 Gg CO_2 and biomass removals released 16,234 Gg CO_2. In the SNC it was reported that wood biomass had sequestered 88,035 Gg CO_2 in the base year, 2000. In 2006, biomass was estimated to have sequestered 83,000 Gg CO_2.

2.5.6 Waste

2.5.6.1 Overview of the Sector

Waste in Zimbabwe includes domestic, commercial, industrial material, whether in a liquid, solid, gaseous, or radioactive form, which is discharged, emitted or deposited into the environment in such volume, composition or manner as to cause pollution (Environmental Management Act Chapter 20:27). Waste handling and disposal practices fit into IPCC categories i.e:

- solid waste disposal,
- biological treatment of solid waste,
- incineration and open burning of waste, and
- wastewater treatment and discharge.

Treatment and disposal of municipal, industrial and other solid waste produces significant amounts of CH_4. In addition to CH_4, solid waste disposal sites (SWDS) also produce biogenic CO_2 and NMVOCs as well as smaller N_2O, NOx and CO (IPCC, 2006).The major GHG emissions from the waste sector are landfill CH_4 and, secondarily, wastewater CH_4 and N_2O. In addition, the incineration of fossil carbon results in minor emissions of CO_2 (Bogner et al., 2007). The CO_2 produced in the wastewater streams (WWS) is of both biogenic and fossil origin. Biogenic CO_2 is considered to be re-absorbed by vegetation for photosynthesis. Therefore in this inventory it was not accounted for. The N_2O emissions from SWDS, anaerobic digestion of organic matter, and mechanical–biological (MB) treatment are considered insignificant (IPCC, 2006).

2.5.6.2 Waste management practices

Municipal Solid Waste Management

In Zimbabwe, urban local authorities are responsible for urban solid waste management. The majority of these urban local authorities still use the traditional closed solid waste management system (2.5.6.2).

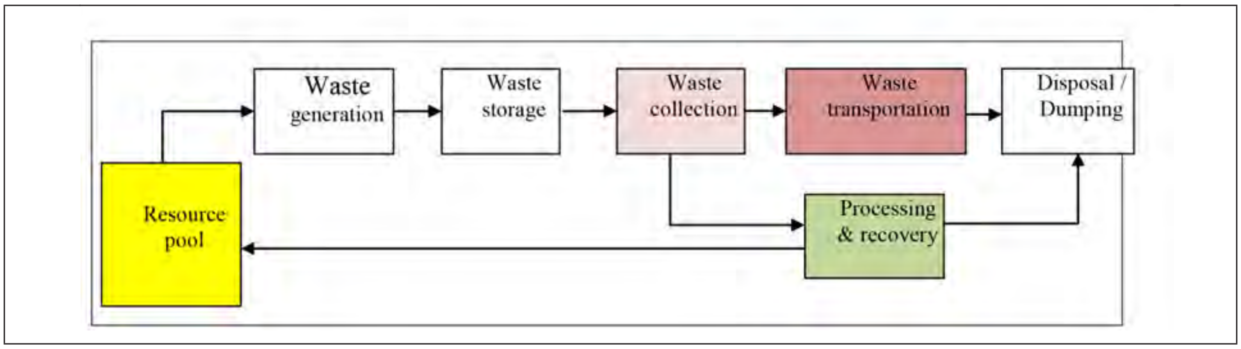

Fig 2.32 Traditional Waste Management System

In the year 2006, MSW collection by city authorities was very low due to economic downturn, for example, the City of Harare managed to collect about 15% of the generated waste (Harare City Council, 2014). The methane that was generated at all the SWDS in Zimbabwe was not measured, collected or flared. Managed solid waste disposal sites (MSWDS) are mainly found in urban centres while in growth points and other small settlements there are unmanaged SWDS, which are more similar to those in rural areas.

Sources of solid waste in Zimbabwe include refuse accumulated in households, offices, shops, markets, restaurants, public institutions, industrial installations, waterworks, sewage facilities, construction sites, demolition sites, and agricultural production farms. Solid waste is generally categorized into: (i) municipal solid waste (MSW), (ii) sludge, and (iii) industrial and other waste. Solid waste disposal in Zimbabwe is not separated into the different waste profiles at the disposal site. The treatment and disposal of municipal, industrial and other solid waste releases large amounts of methane (CH_4).

Biological treatment of solid waste

Biological treatment of organic matter (OM) is done in two ways: (i) anaerobic digestion, and (ii) composting. Anaerobic treatment is linked to methane recovery and combustion that is aimed at generating energy. The GHG emissions from this process, are therefore, reported under the Energy Sector. The mechanical-biological (MB) treatment of waste aims at reducing the volume of waste and gas emissions from disposal sites (IPCC, 1996). However MB treatment is not being practised in Zimbabwe. Composting on the other hand is done on a very small scale and emissions from composting were thus considered insignificant.

Incineration and open burning of waste

Incineration and open burning of waste are also important sources of GHG emissions. Incineration refers to the combustion of solid or liquid waste in controlled incineration facilities. Medical and hazardous waste are incinerated. There is insufficient activity data on incinerated medical waste to compute emissions. Moreover the waste is not characterised. Uncontrolled open burning of solid municipal waste occurs but no estimates of quantities of openly burnt waste are recorded. Hence, emissions from this source were not quantified.

Wastewater treatment and discharge

In Zimbabwe, wastewater consists of a mixture of industrial and domestic sewage that is usually conveyed into a combined wastewater treatment plant (Figure 2.32). All towns and cities have a sewerage system that is used for collecting and treating wastewater from formal settlements. Wastewater that is generated in areas without access to centralized sewer systems i.e., areas where sewage cannot be gravitated into the main municipal sewers, collects in septic tanks. For establishment of septic tanks, the landholding should cover at least 2,000 m^2 (UNEP/IETC, 2002).

Sewage from septic tank is eventually sent to sewage treatment works for processing.

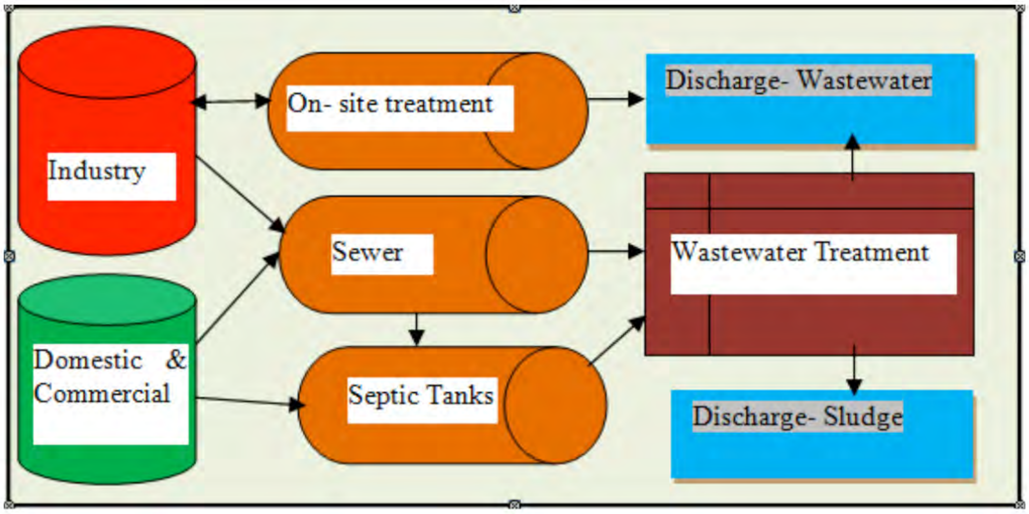

Fig 2.33 The general wastewater pathways in the urban areas of Zimbabwe.

Informal settlements are not served by the sewerage system (Makoni et al., 2004; Tsiko and Togarepi, 2012). In such areas pit latrines are widespread. On the other hand, the combined domestic and industrial wastewater is treated at various sewage work sites. Due to the inter-connectedness of sewer outfall drains, it is difficult to quantify domestic and industrial effluent separately (Thebe and Mangore, 2012). In this regard, wastewater reported in this report refers to a combination of municipal, industrial and domestic waste. The responsibility of wastewater treatment mainly lies with municipalities, although industry and institutions are required to treat their waste prior to discharging either into the municipal system or into the environment.

In Zimbabwe, information regarding the quantity of waste-water generated in rural areas is not available and scanty in urban areas (Sato et al., 2013). However, anecdotal data show that the amount of wastewater generated in Zimbabwe has been increasing over the years. This is due to the rapid urbanization, industrialization, especially of SMEs experienced in the country (Manhokwe et al., 2009). This has not been met with a corresponding increase in waste treatment plants (Feresu, 2010). For instance, the five major sewage treatment plants in Harare (Firle, Hatcliff, Crowborough, Marlborough and Donnybrook) were initially designed to handle approximately 18 Megalitres of sewage for 500,000 inhabitants in 1952 (Buka et al., 2014). Currently, sewage treatment plants in Harare are overloaded with total design capacity of 219, 500 m^3/day while current inflows average 287,000 m^3/day (Muserere et al. 2014). Other towns and cities of Zimbabwe are faced with similar challenge of overloading of wastewater treatment system (Thebe and Mangore, 2012). As a result these urban areas are facing difficulties in handling the ever increasing volumes of waste water. A number of planned sewage treatment plants have failed to take place due to prevailing harsh economic environment.

Figure 2.34 illustrates the variations in the amount of wastewater treated at two of Zimbabwe's largest treatment plants, Crowborough and Firle from the year 1995 to 2012.

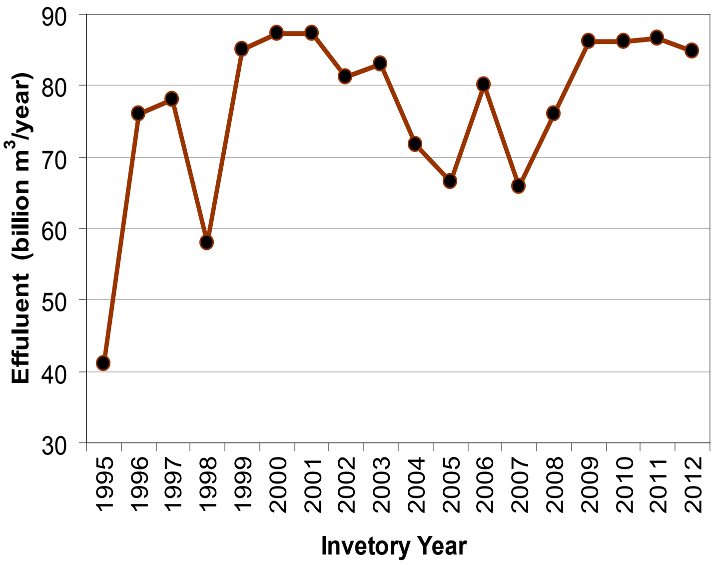

Fig 2.34 Volume of wastewater treated at the Firle and Crowborough Sewage Treatment Works in Harare (1995-2012). Source: Harare City Council.

Table 2.8 Estimates of generated and treated wastewater across major towns of Zimbabwe

City	Population in 2002	Estimated population 2012	Estimated water supply (m^3/day)	Estimated wastewater generated (m^3/day)	Estimated wastewater treated (m^3/day)	Dominant wastewater treatment type
Harare	1,850,000	2,257,000	600,000	390,000	190,000	Secondary - Modified activated sludge and trickling filter
Bulawayo	676,650	825,513	105,000	78,750	31,000	Secondary - trickling filter and Modified activated sludge
Mutare	170,106	207,529	55,000	33,000	30,000	Secondary-trickling filter
Gweru	141,260	172,337	50,000	30,000	10,500	Secondary - trickling filter
Total			810,000	531,750	261,500	

(Thebe and Mangore, 2012)

Overall, Zimbabwe has close to 49% of generated wastewater being treated, which leaves 51% of the wastewater untreated.

2.5.6.3 Wastewater Management

Whilst there are several wastewater treatment processes in Zimbabwe, in this inventory, only anaerobic wastewater treatment plants were considered as these are a source of methane. In these plants, modified activated sludge systems with biological nutrient removal and trickling filters are used. The other proportion is treated through waste stabilization ponds, aerated lagoons, and oxidation ponds.

Methodology

GHG Emissions from Solid Waste

The Revised 1996 IPCC methodology for estimating CH_4 emissions from SWDS based on the First Order Decay (FOD) Method (IPCC, 1997) was used. The method assumes that the degradable organic carbon (DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are emitted. Zimbabwe does not have a country specific methodology for estimating emissions from solid waste handling. Where local data were not available, default values were obtained from the Revised 1996 IPCC Guidelines.

In 2006 the total waste generated was estimated at 1437.05 Gg based on an urban population of 4,193,329 and waste generation rate of 342.7 kg per capita per year. This was obtained by surrogate and interpolation of surveyed quantities of 0.64 million tonnes for 2000 and 1.57 million tonnes for 2007. Urban population for the same years were also used. The amount of waste sent to SWDS was estimated at 215.2 Gg based on collection rate of 15% (Harare City) of the total generated waste. The mean waste composition aggregated from 11 cities and towns for the year 2007 is shown in Figure 2.35.

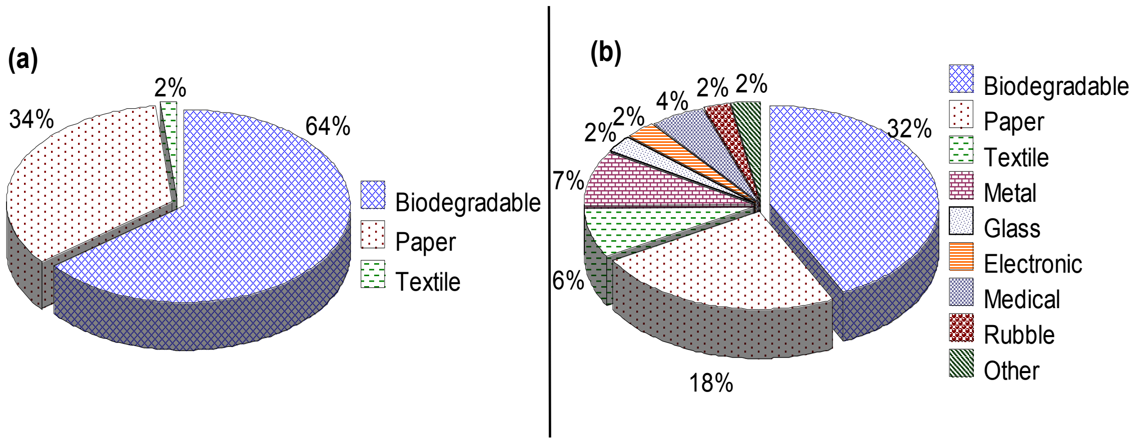

Fig 2.35 Estimated composition weight fractions of solid waste generated in 2007 in Zimbabwe (UNEP, 2008)

The 2011 baseline survey showed that the national mean collection of residential solid waste in 2011 was 52 %, while 28 % of the generated waste was being buried (EMA base survey report, 2013). The 52% collection rate is an improvement when compared with the previous decade where the collection rate was estimated to be averaging 30%.

GHG Emissions from Incineration and open burning of waste

The methane (CH_4), NOx, NMVOCs and CO emissions from incineration and open burning of waste were not calculated. There was insufficient activity data to compute the emissions from this source.

2.5.6.4 Estimation of Methane from Wastewater

In Zimbabwe, all streams of wastewater are fed into the centralised municipal treatment plants and thus it was difficult to quantify domestic and industrial effluent separately. The Biochemical Oxygen Demand (BOD_5) or Chemical Oxygen Demand (COD) determination was erratic for the years 2005-2008 and were thus not used in the estimation of methane. Methane generated from municipal wastewater was based on estimates from main wastewater treatments in Harare, whose bio-digesters were functional during the reporting period and constitutes more than 75% of the national wastewater. These estimates are based on direct measurements of methane generated on site as well as those based on IPCC methods. The calculations were based on the Revised 1996 IPCC guidelines and worksheets.

For the reporting period, wastewater treatment data through anaerobic means for Bulawayo and Harare's Crowborough and Firle treatment plants was used. Masvingo City's two digesters stopped functioning in 2005 and were refurbished in 2014, while City of Mutare's digesters were off from 2005 to 2008, hence from these cities, there was limited methane produced from anaerobic pockets as the whole process was deemed aerobic. The methane so produced was considered negligible. Bulawayo City handled 23,300.00 m^3/day of wastewater in 2006 and had 50% functional digesters. It was established that 50% of the digesters were operational; hence the methane generated was based on the assumptions that only 50% of the wastewater generated was treated. The total sludge was estimated based on the assumption that in Zimbabwe, sludge constitutes 1% of the total effluent.

The estimates of the quantities of wastewater treated at the sites were derived from measurements and estimates made at the treatment sites. The default methane conversion factor of 1 (IPCC, 1997) and the measured methane EF of 0.0240 m^3 methane/ m^3 sewage (MENRM, 2012) were used.

2.5.6.5 Emissions from Wastewater

The amount of methane generated from both industrial and domestic and commercial wastewater streams for the year 2006 was estimated at 2,022,506.87 m^3. The total methane emitted into the atmosphere for the year 2006 was estimated at 1,399,205.87 m^3, taking into consideration that some of the methane generated at Harare's treatment plants considered in this report is used as a source of heat to maintain digester temperature .The contributions from the cities are as shown in Table 2.9.

Table 2.9 Effluent treated and methane generated from city wastewater treatment plants in 2006

City	Treated sewage (m^3)	Total sludge (m^3)	Methane generated (m^3)	Methane emitted into atmosphere (m^3)	Data Source
Harare	80,018,828.00	800,188.28	1,920,452.87	1,297,152.87	City of Harare, 2006
Bulawayo	8,504,500.00	85,045.00	102,054.00 (50% digesters functional)	102,054.00	City of Bulawayo, 2006
Mutare	12,786,000.00	127,860	no functional digesters	-	City of Mutare, 2006
Masvingo	6,181,325.00	61,813.25	no functional digesters	-	City of Masvingo, 2006
Total	107,490,653.00	1,074,906.53	2,022,506.87	1,399,205.87	

Waste Sector Emissions

The waste sector emissions for 2006 are summarised in Table 2.10 with the sectoral report given in Table 2.7-31. Only methane emissions were estimated and these accounted for 772Gg CO_2eq from solid waste disposal and waste water treatment.

Table 2.10 Sectoral Report for Waste

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES						
Greenhouse Gas Source and Sink Categories	CO_2 (1) (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)
Total Waste	0	30.08	0	NE	NE	NE
A Solid Waste Disposal on Land (4)	0	25.45	0	NE (6)		NE (6)
1 Managed Waste Disposal on Land		25.45		NE		NE
2 Unmanaged Waste Disposal Sites		NE (3)		NE		NE
3 Other (please specify)		NE		NE		NE
B Wastewater Handling	0	4.63	0	NE	NO (7)	NE (8)
1 Industrial Wastewater		IE (2)	NE (5)	NE (5)	NO	NE
2 Domestic and Commercial Wastewater		4.63	NE (5)	NE (5)	NO	NE
3 Other (Sceptic)		IE (2)	NE (5)	NE (5)	NO	NE
C Waste Incineration					NE (4)	NE
D Other (please specify)		NE	NE	NE	NE	NE

Notes

(1) Note that CO_2 from waste disposal and incineration should only be included if it stems from non-biological or inorganic waste sources.

(2) Included in domestic and commercial since there in no separation of wastewater streams

(3) Decomposition considered mainly aerobic hence little to no methane generated

(4) No activity data is being recorded, moreover for hospital waste, apart from no recording of activity data, the incinerators themselves do not meet the standard specifications of incinerating equipments to use default data

(5) Not estimated due to no national figures for annual per capita protein generation

(6) Not estimated for solid waste due to very low emission of these gases from SWD and also that there is no most appropriate method to use

(7) There is no burning of sludge in Zimbabwe

(8) No applicable data and the incinerators themselves do not meet the standard specifications of incinerating equipment to use default data

Trends in Methane Emission from Solid Waste

For the waste deposited at MWDS in 2006, the resultant CH_4 emissions were estimated at 25.45 Gg. Figure 2.7-60 shows the generated waste as well as the trend in CH_4 emissions from MSW. There is clearly an increase in the amount of waste generated but this does not translate to an increase in CH_4 emission as the waste generated was not being collected to disposal sites due to the economic recession.

There was a huge increase in waste per capita per year between 2000 and 2007. In 2000 the generation rate was 0.174 tonnes (SNC) per capita per year and this compares with 0.371 tonnes per capita per year in 2007 (UNSD, UNEP 2008, cited in Feresu 2010). The increase was however marginal in 2011 (0.374 tonnes per capita per year) (Feresu 2013). The increase in waste generation and the inconsistencies in its collection to SWDS are shown in Figure 2.36. The low methane emissions from the MSW were due to the low rate of collection of the generated waste to the disposal sites

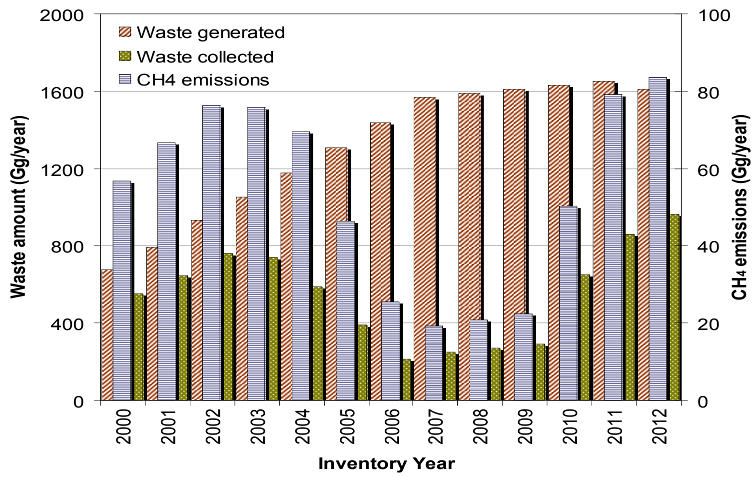

Fig 2.36 Generated and collected municipal solid waste, and CH_4 emissions for the period 2000 - 2012

The projected methane generation from MSW up to the year 2020 is shown in Table 2.11.

Table 2.11 Trends in Estimated Methane Emissions from MSW

Parameter	Inventory Year					
	1990 [2]	1994 [1]	2000 [2]	2006	2011	2020*
Urban Population (million)[3]	3.1	3.2	3.86	4.19	4.41	4.64
Waste Deposited (Gg)	521.00	720.00	553.05	215.2	857.8	1507.8
CH_4 Emissions (Gg)	131	24.31	56.8	25.45	79.26	139.39

Source: [1]Iniatial National Communication; [2]Second National Communication; [3]Zimstats

**projected emission based on population growth and waste per capita*

CHAPTER 3

3. VULNERABILITY TO CLIMATE CHANGE

Key Terms and Definitions

Climate change: A change in the state of climate that can be identified (e.g. by using statistical tests) or by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2007).

Vulnerability: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007).

Adaptation: Involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate change (Denton, 2010).

3.1 Background

Vulnerability assessments play a key role in understanding the vulnerability of communities to climate change and mitigation as it bridges the gap between hazards and the community resilience (Wilhite 2000b). In this report, the IPCC conceptual framework was adopted in which vulnerability is expressed as follows:

Vulnerability =ƒ (Exposure, Sensitivity)- Adaptive Capacity)

Where, exposure is defined as the nature and degree to which a system is exposed to significant climatic variations. In this case exposure was measured by frequency of hailstorms, drought and cyclones. Sensitivity is defined as the extent to which a system is affected, either adversely or beneficially, by climate-related stimuli. In this study, sensitivity was measured based on how the cropping and livestock systems responded to variability in climate based on historical data. Adaptive capacity on the other hand is the ability of a system (crop or livestock) to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences (Yusuf and Francisco, 2009).

The Sustainable Livelihood Framework (SLF) was used to assess the adaptive capacity of communities. The SLF considers natural, physical, human, social and financial capital as determinants of the ability of communities to cope with climatic shocks (Carney, 2002; Elasha et al., 2005). SLF identifies livelihoods as key determinants of vulnerability of communities to external shocks as they influence access to resources during periods of exposure to a shock. It is through the use of the different livelihood assets that communities are able to transform their vulnerability context. Thus, communities with several livelihood options are better able to cope with a shock than communities with limited livelihood options. The SLF approach was adopted in order to provide the context within which climate change impacts are occurring as well as provide the key livelihood options that are vulnerable to climate change with the ultimate aim of understanding coping strategies in the study region.

Future climate projections were based on Global Circulation Models. The CSIRO MK3 for the 2040s (http://www.ccafs-climate.org/), which is known to better represent southern African conditions, was adopted. The future climate projections were based on the IPCC Special Report on Emission Scenarios (IPCC_SRES_AR5). Two emission scenarios namely; the A1B and the A2 were selected. The A1B scenario paints a world which is characterized by a balance between fossil intensive and non-fuel energy sources and makes the assumption that similar improvement rates apply to all energy supply and end-use technologies. Herein referred to as the best case scenario (BCS). The A2 scenario family describes a very heterogeneous world with a continuously increasing population, regionally oriented growth and fragmented technological change (IPCC, 2007. Herein referred to as the worst case scenario (WCS).

The data were downloaded from http://www.ccafs-climate.org/. The rationale for adopting climate change scenarios for the 2040s is that they allow for medium term planning for adaptation. However, it has to be noted that over southern Africa, the IPCC models have more confidence in the projections of temperature than rainfall where the projected change in the latter was found to be uncertain (IPCC, AR5).

3.2 Trends in Zimbabwe Rainfall and Temperature Characteristics: 1960 To 2014

3.2.1 Introduction

In order to approximate the future impacts, the past changes of surface air temperature (SAT) and rainfall for Zimbabwe, including their consequential interactions, were analysed before zeroing in on the selected study area, Chiredzi. The IPCC AR5 has more confidence in the increasing SAT than on rainfall for southern Africa in the mid 21st century. This implies that the SAT will play a greater role that has to be recognised in regional climate change studies. Soil water losses due to increased evapotranspiration will also affect runoff, and the resultant deficits will affect river discharge and groundwater storage. In this regard, methods for monitoring the water balance at regional scale for the semi-arid regions such as Zimbabwe are required to preserve and manage water resources. This is particularly important in the light of increasing water demand, climate impacts and the consequent decreasing availability of usable water resources. Hence not only are the changes in the mean of SAT and rainfall but the alterations in their extreme events are more relevant and essential for impact assessment and adaptive strategies. During analysis, the rainfall season was divided into two parts vis October to December (OND) and the January to March (JFM). For the winter cropping season, only SAT during the May to July (MJJ) period was considered.

3.2.2 Surface Air Temperature (SAT) Changes

3.2.2.1 Spatial distribution of Surface Air temperature trends

The spatial distribution of the SATmean linear regression coefficients for the averaged MJJ, OND and JFM periods are shown in Figure 3.1. The figure show positive trends which are significant though with varying magnitudes across the country. The positive trends indicate general warming across the country. However, the distinctively different trend patterns, emphasises that the triggering mechanisms could be largely independent from one sub-season to the next. Trends were determined using regression coefficients.

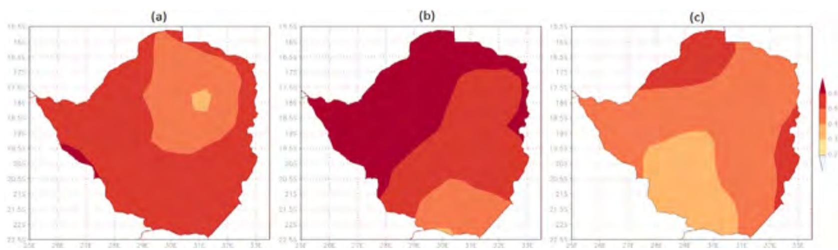

Fig 3.1 The spatial distribution of the SAT trends during (a) MJJ (b) OND and (c) JFM for the period 1960 to 2014.

3.2.2.2 Temporal distribution of SAT mean extremes

The winter (MJJ) extreme SAT mean temporal distribution that is sorted in descending order of their area averaged annual values is presented in Figure 3.2. The result show that the warmest extremes occurred after 1990 and the coldest winters occurred in the 1980s and earlier.

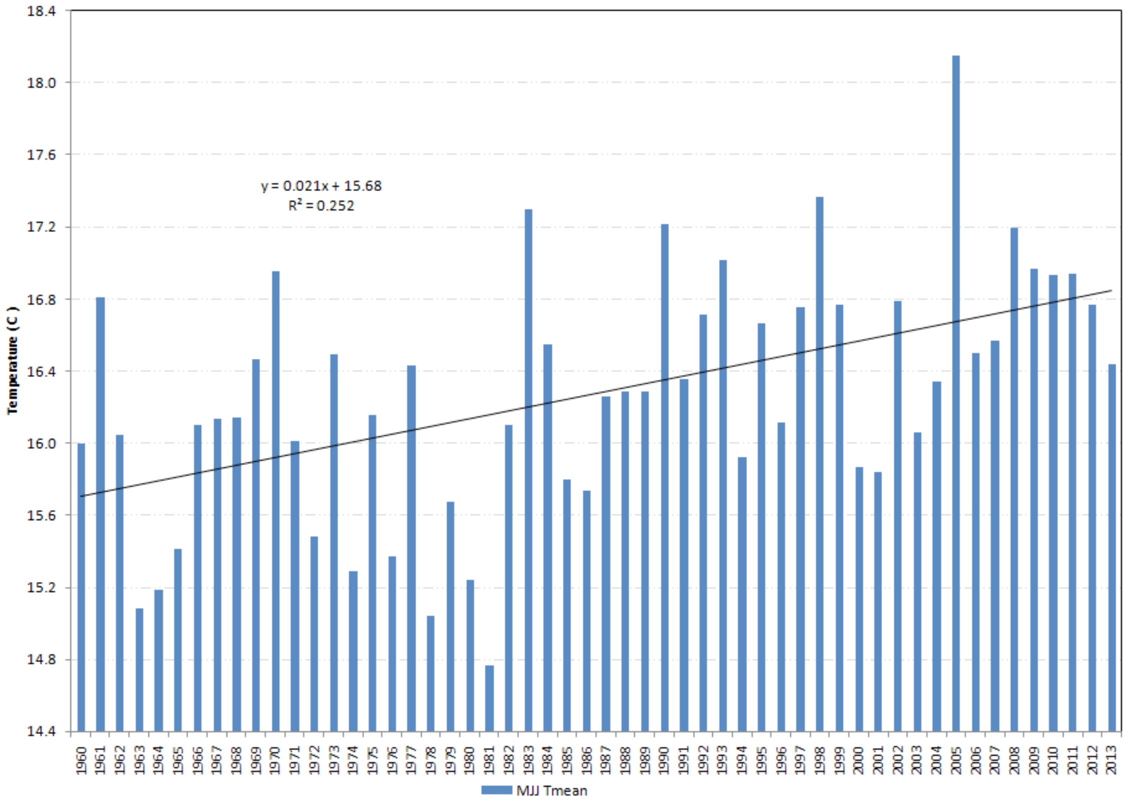

Fig 3.2 SAT mean values for the period MJJ from 1960 - 2013

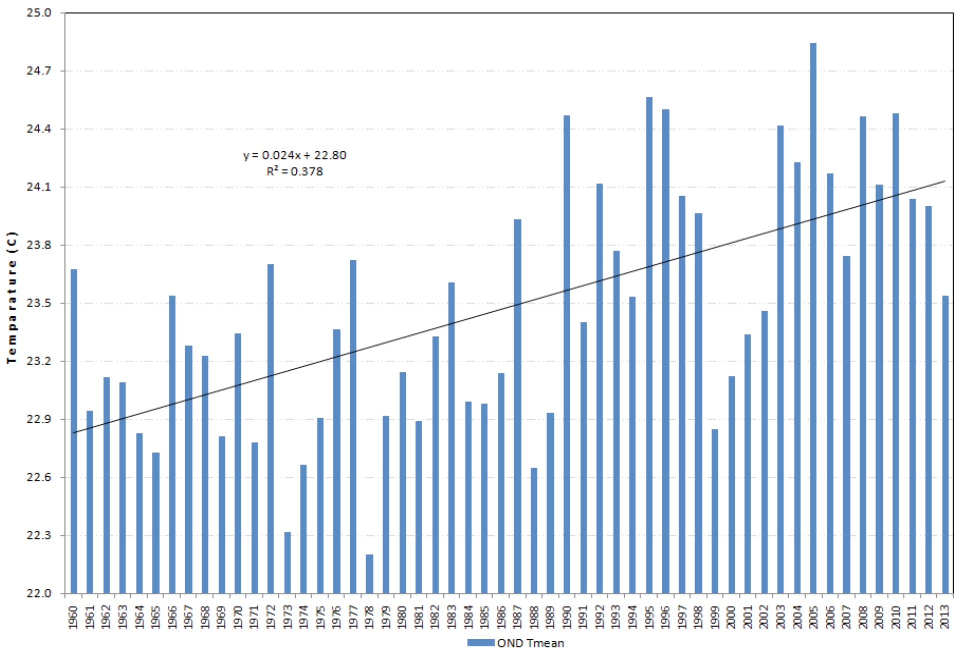

Fig 3.3 SAT mean values for the period OND from 1960-2013

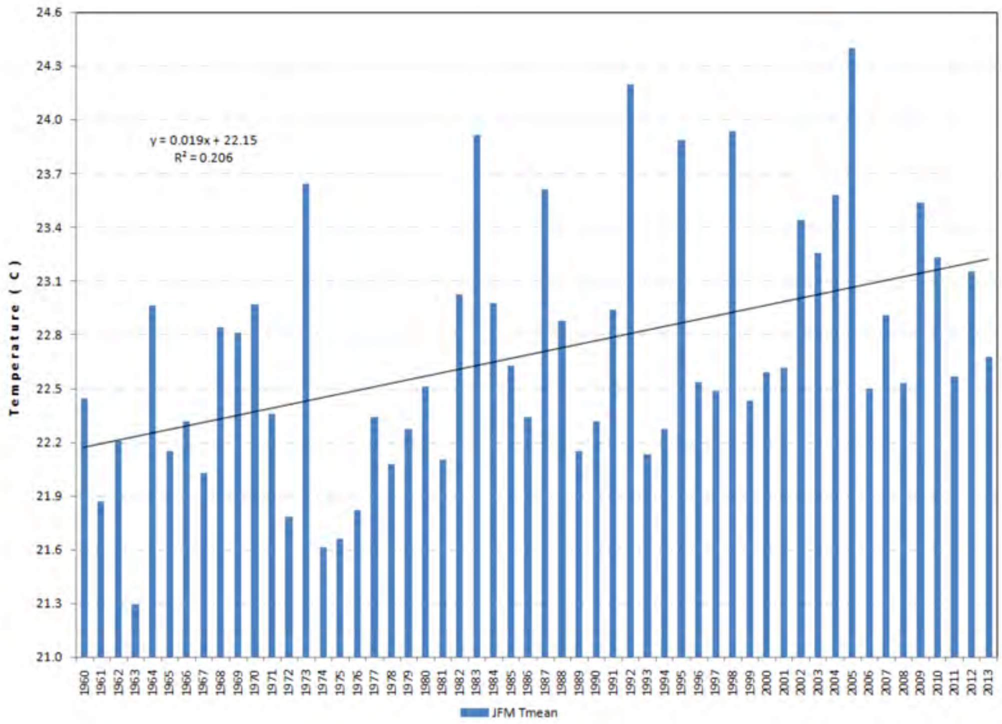

Fig 3.4 SAT mean values for the period JFM from 1960 to 2013

Eight out of the 10 hottest events occurred in the 1990s and later with the hottest year being 2005. On the other hand, 8 of the 10 coldest winters occurred in the 1970s and earlier, with 1981 being the coldest winter. For the OND SATmean, Figure 3.3 shows that all of the 10 warmest years occurred from the 1990 while 9 of the 10 coldest events occurred before the 1990s. 2005 and 1978 coincide with the warmest and coldest years respectively. A similar scenario is depicted in Figure 3.4 where 14 of the 15 warmest events occurred in the 1980s and later while the 9 of the 10 coldest occasions occurred before the 1980s. This suggests that the temperatures over the country have generally warmed over the past 5 decades. The figures for minimum and maximum SAT are not illustrated as they generally show similar patterns to the averaged conditions depicted in the SATmean figures.

3.2.2.3 Shifts in the Average Surface Air Temperature

Average SAT shifts were determined in relation to their monthly maximum and minimum records for both the winter and summer seasons. Figure 3.5 show that there is a significant rising trend when the period is considered in its entirety. The broken lines depict conspicuous turning points to persistent warming around 1981 on both figures. It is revealed that the created two epochs have jumped by an average of 0.7°C during the shifts in both occasions. This indicates that the winter temperatures may have shifted to a warmer phase.

(a) (b)

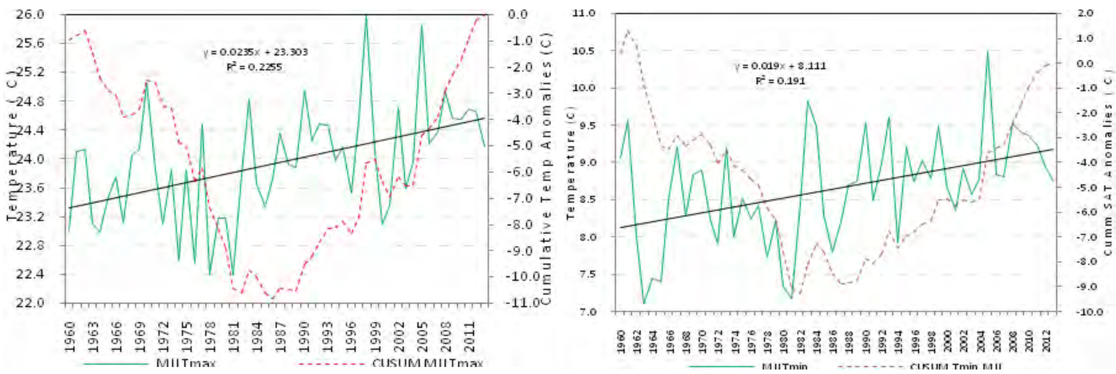

Fig 3.5 Temporal variability of winter maximum SAT for the period May to July. Superimposed, is the corresponding cumulative graph (broken line).

In the insert is the trend line and the related regression equations. (b) Same as in (a) but for minimum SAT.

Figure 3.6 and Figure 3.7 show the temporal SAT changes for the summer period. The first part of the rainfall season temperatures demonstrates a slightly different picture from the winter SAT. The general trends for both SAT minimum and maximum demonstrate a shift to warming which coincide around 1989. This suggests that the turning points to a warming phase for the summer season are located almost a decade later than in winter.

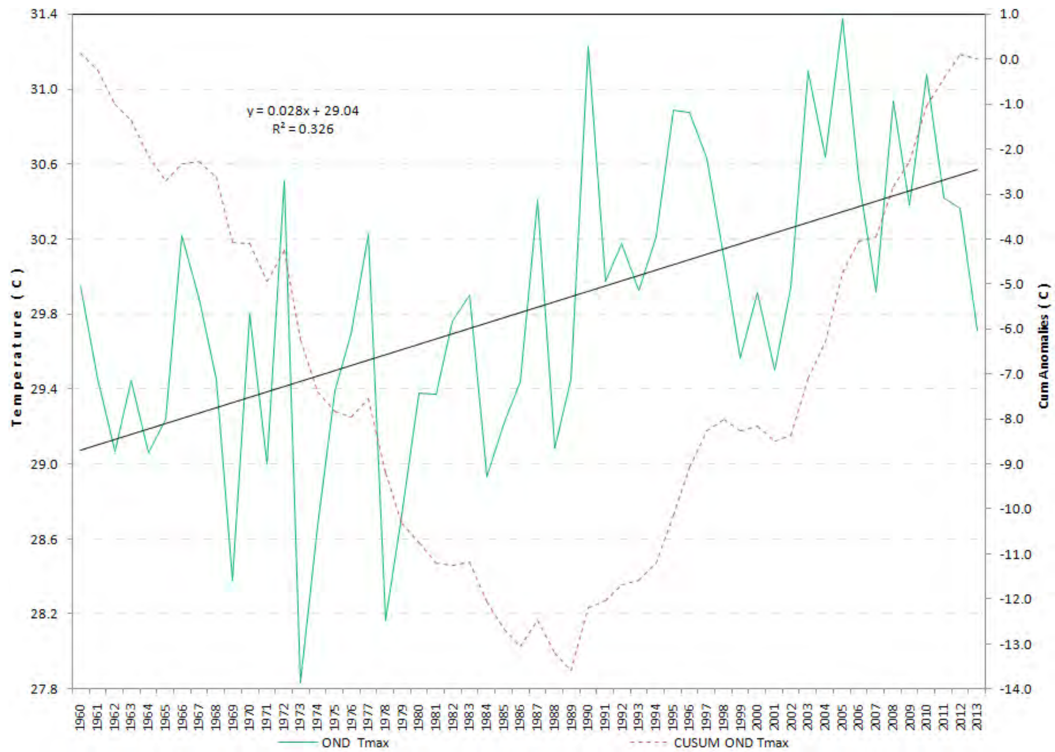

Fig 3.6 Summer SATmax temporal variability during the period October to December. Superimposed, is the corresponding cumulative graph calculated using the CUSUM method (broken line).

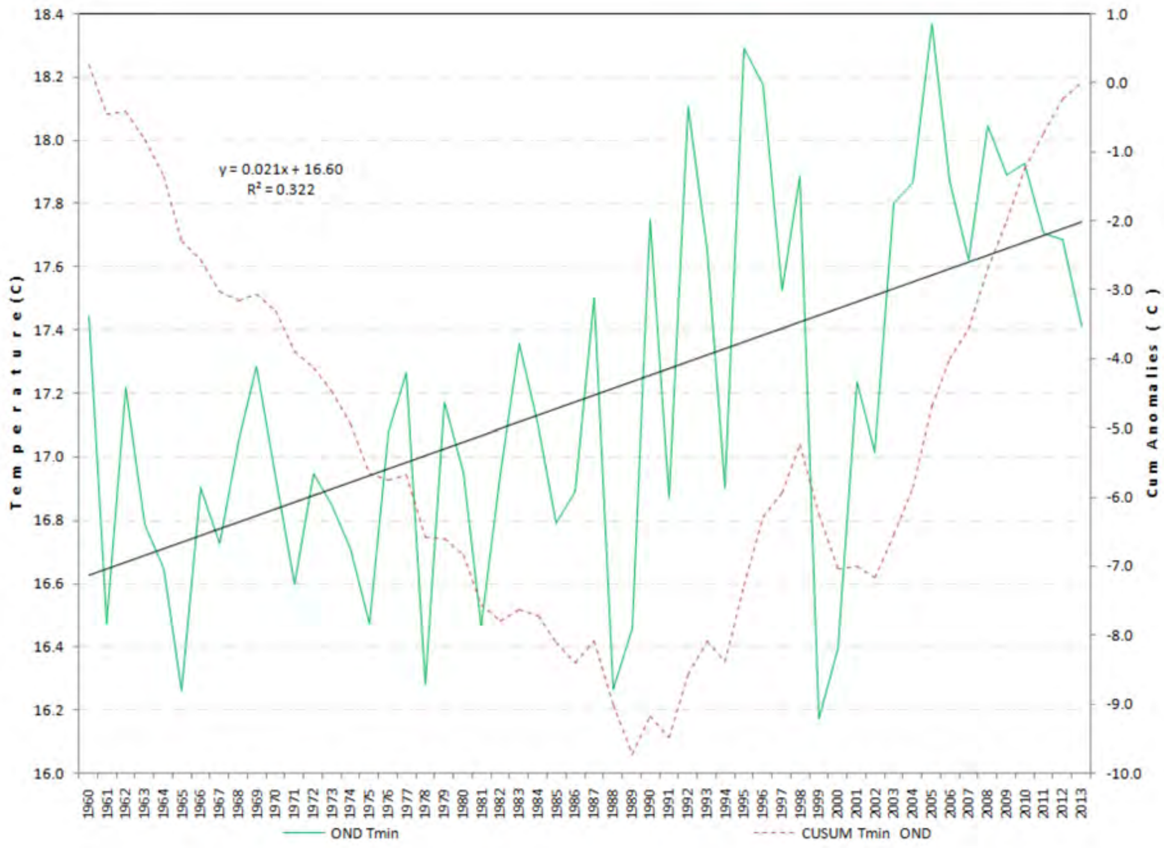

Fig 3.7 Summer SAT min temporal variability during the period October to December.Superimposed, is the corresponding cumulative graph calculated using the CUSUM method (broken line).

3.2.3 Changes in Extreme Rainfall events

In this section, the temporal distribution of the rainfall events for the OND and JFM periods is analysed using the average rainfall index for the country. The change in annual extreme rainfall events is more relevant and essential for impact assessment and adaptive strategies than the normally analysed mean rainfall change. Figure 3.8 shows that the temporal distribution of rainfall events according to their magnitude does not display a definite trend as that of temperature. Contributions from tropical cyclones which generally occur irrespective of the quality of the earlier part of the seasonfurther distorts the general picture in the rainfall total trends.

However results indicate the general shifts in the rainfall pattern in Figure 3.10 demonstrates prolonged periods of wet years alternating with periods of rainfall deficits. The regression line inserted on the OND season indicates no significant trend and hence implies that the annual average rainfall amount has remained almost stagnant during the 5 decades analysed. On the other hand, the JFM period indicates a general rising trend of the annual average rainfall amount, which could mean an increase in rainfall totals for the period under review.

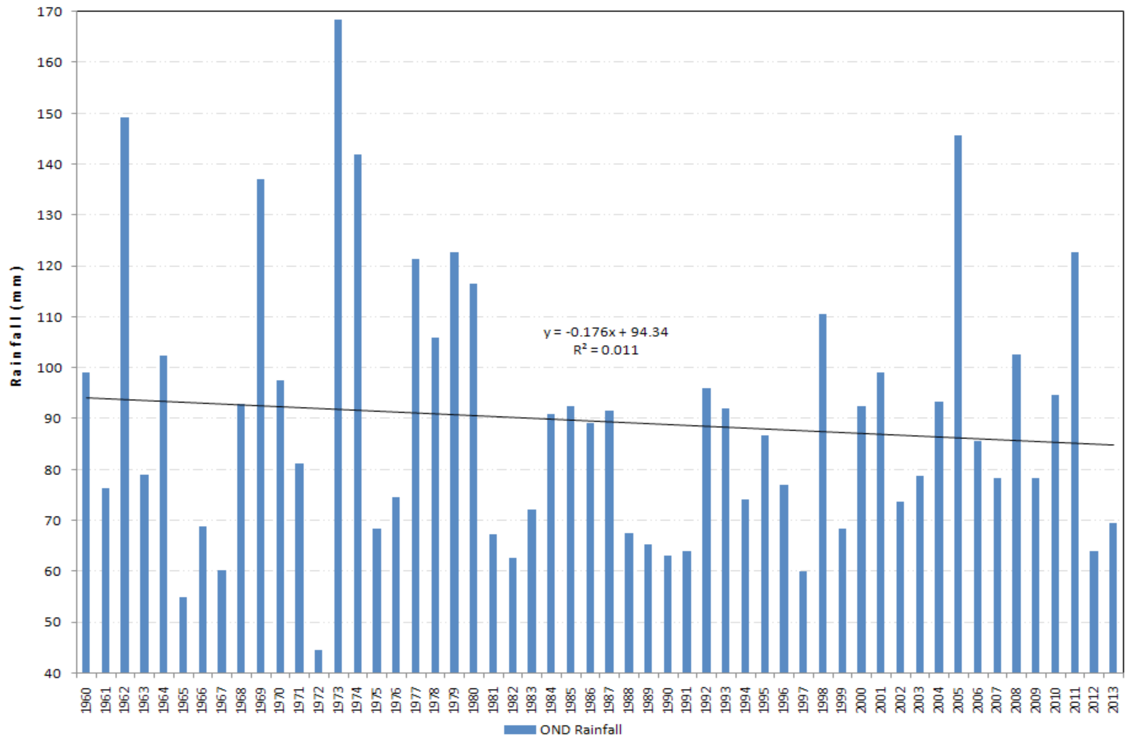

Fig 3.8 Annual rainfall total during OND from 1960 – 2013

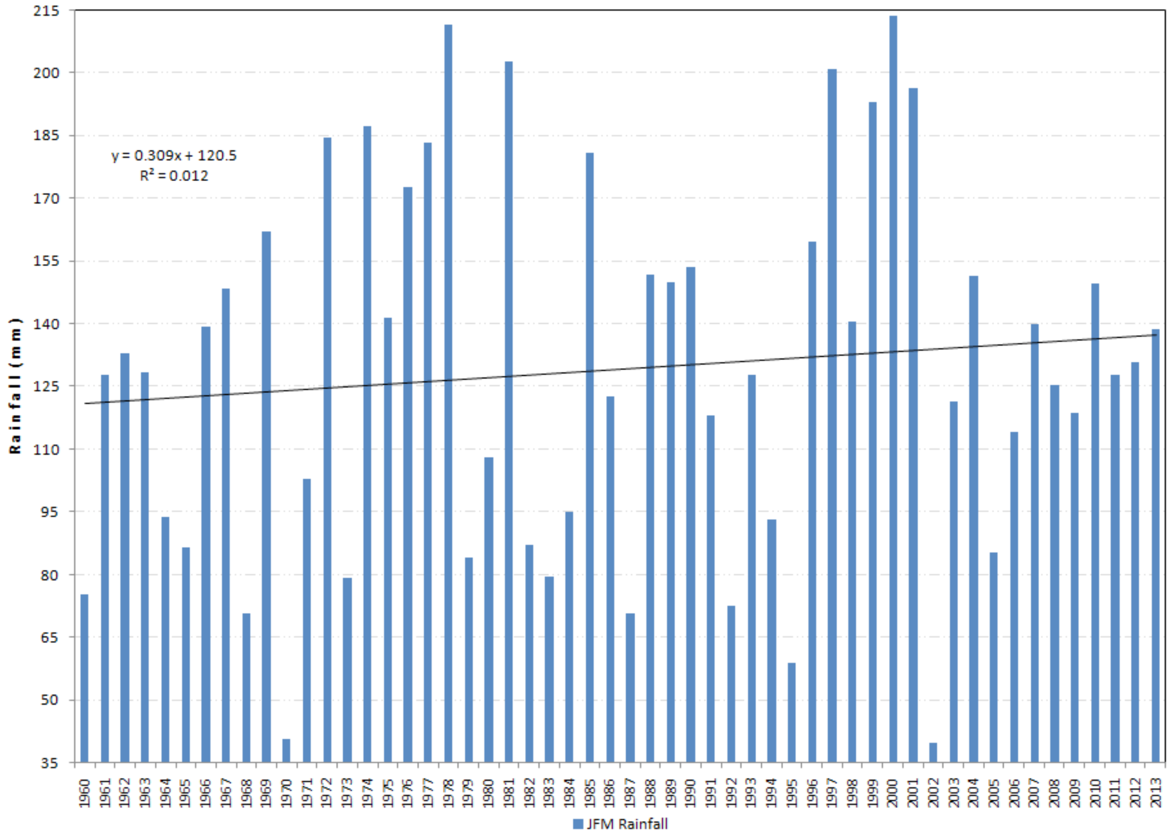

Fig 3.9 Annual rainfall total during JFM from 1960 – 2013

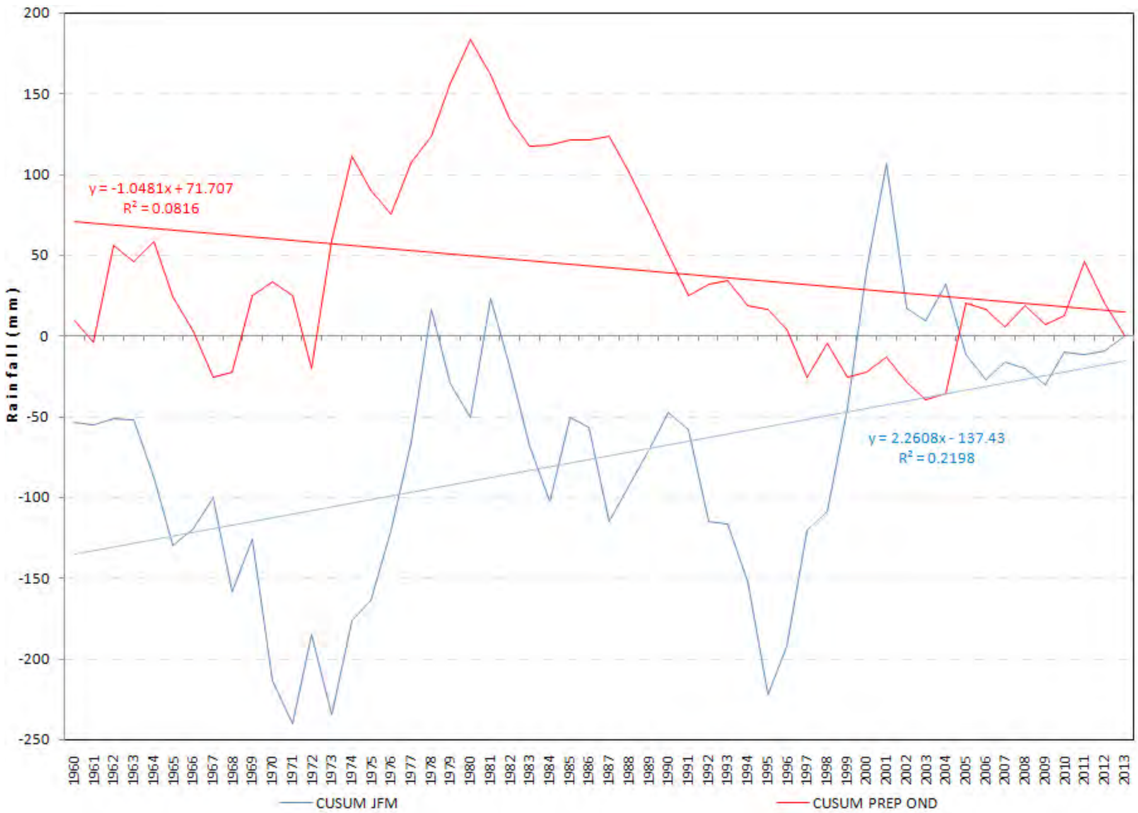

Fig 3.10 Cumulative rainfall anomalies for the OND period from 1960-2013 (red line) and JFM (blue line).

The anomalies are constructed with respect to 1960-2013 base period.

3.2.4 The impact of SAT warming shift in relation to usable water resources during the rainfall season

We have noted that the maximum and minimum surface air temperatures for Zimbabwe are characterised by a shift towards warming. These warming processes may aggravate drought impacts by depleting usable water resources as a consequence of water loss by evapotranspiration. The greater part of Zimbabwe is primarily semi-arid and moisture deficient, i.e. the difference between annual precipitation and potential evapotranspiration (PET) in most areas, is less than zero. It is therefore likely that the observed regional SAT warming tendencies could have contributed to increased drought conditions over the recent decades. As such a drought index based exclusively on precipitation data may not be sufficient to monitor the climate aspects related to summer regional droughts. In this regard an index incorporating the effect of temperature becomes a useful tool for the assessment of droughts not only during global warming but where temperature changes are significant as manifested in SAT.

The standardised precipitation index (SPI) is a multi-scalar index that is recommended by the World Metrological Organisation for characterising meteorological droughts. However, in the SPI construction, there are two important assumptions. The first one is that precipitation variability far outweighs that of other variables, such as evapotranspiration and the second assumption is based on the absence of temporal trends in these variables (i.e. they are stationary). It is important to note that these assumptions render the contribution of other variables in the calculation of the SPI negligible. In this regard, the index does not consider SAT which we noted to be playing a prominent role in defining the changing climate of the region. Simple calculations of rainfall minus evapotranspiration demonstrate that the efficiency of drying due to temperature anomalies could be as high as that due to rainfall shortage. An index called the standardised precipitation evapotranspiration index (SPEI) is calculated in a similar manner as SPI but incorporates estimates of moisture losses to the atmosphere due to temperature impact via evapotranspiration. It basically indicates the water balance between rainfall and evapotranspiration. The SPEI then becomes particularly suited to detecting, monitoring and exploring the consequences of the temperature shifts observed in recent decades over the country. By comparing the two indices, the SPI and SPEI the goal is to assess whether the observed temperature shifts to a warmer state, which drives higher PET rates, is having a marked influence on the characteristics of Zimbabwe droughts and hence the climate.

*3.2.5 Impact of warming shifts on droughts as determined by drought indice*s

To appreciate the assumed impact of temperature on the time evolution of the droughts, we present the CUSUM time series for the SPI and SPEI alongside that of the SAT mean for the OND period in Figure 3.11. The two time series showed a high degree of similarity. They both identified the main drought and wet episodes throughout the study period. In fact the difference between the two indices was low, and ANOVA indicated no statistically significant differences between the average droughts magnitudes determined from the SPI versus the SPEI amplitudes during the period. Therefore, under the current climate conditions for the OND period, the inclusion of the PET in the SPEI does not provide much additional information.

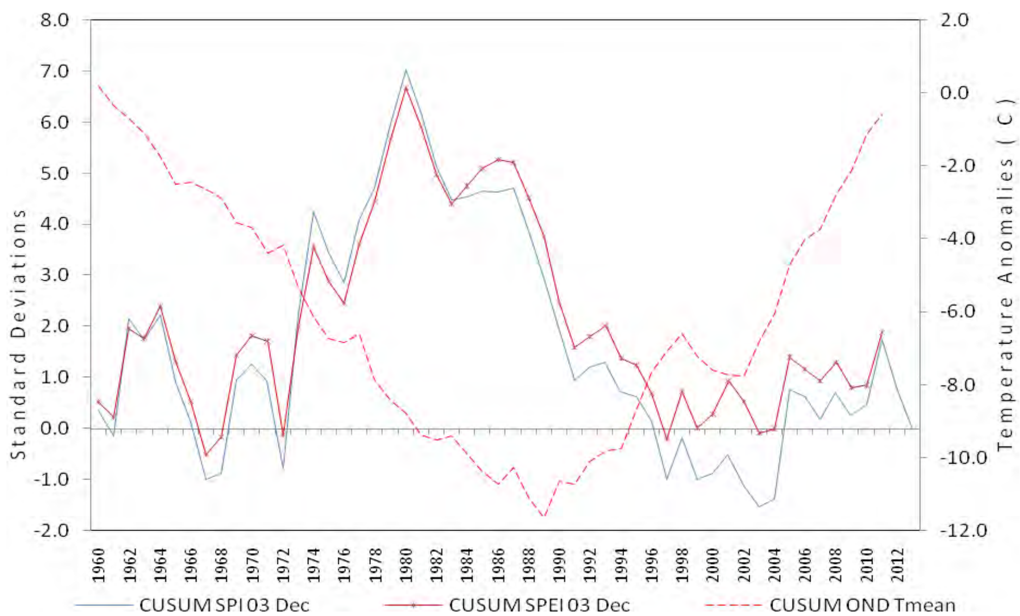

Fig 3.11 Temporal manifestation of the CUSUM, SPI (solid line) and SPEI (solid line with crosses) alongside that of Tmean (broken line) for the period 1960 to 2013 during the October to December period.

The situation is quite different for the JFM period which comparatively, has a higher rainfall and temperature variability. It is interesting to note that the SPI and SPEI were varying in a similar fashion during the cooling pre 1981 phase. This suggests that the effect of precipitation on drought conditions has been greater than that of PET. However, the calculation of the difference between the 2 indices used (SPEI–SPI) indicated a significant shift to greater negative values after the 1981 shift. The shift in the widening between the two indices is clearly visible in Figure 3.12. Given that this may be related to the intensification of the PET processes, this observation suggests that the shift to a warming epoch is influencing the evolution of drought in the region. As the calculation procedure was identical for both indices, this demonstrates that the observed trends in PET (which are related to warming processes) have contributed to the intensification of drought conditions in the recent decades. During the JFM sub season, it is likely that the significantly increasing trend in precipitation implied by the SPI was not enough in countering the influence of PET on the escalating drought severity after the temperature shift.

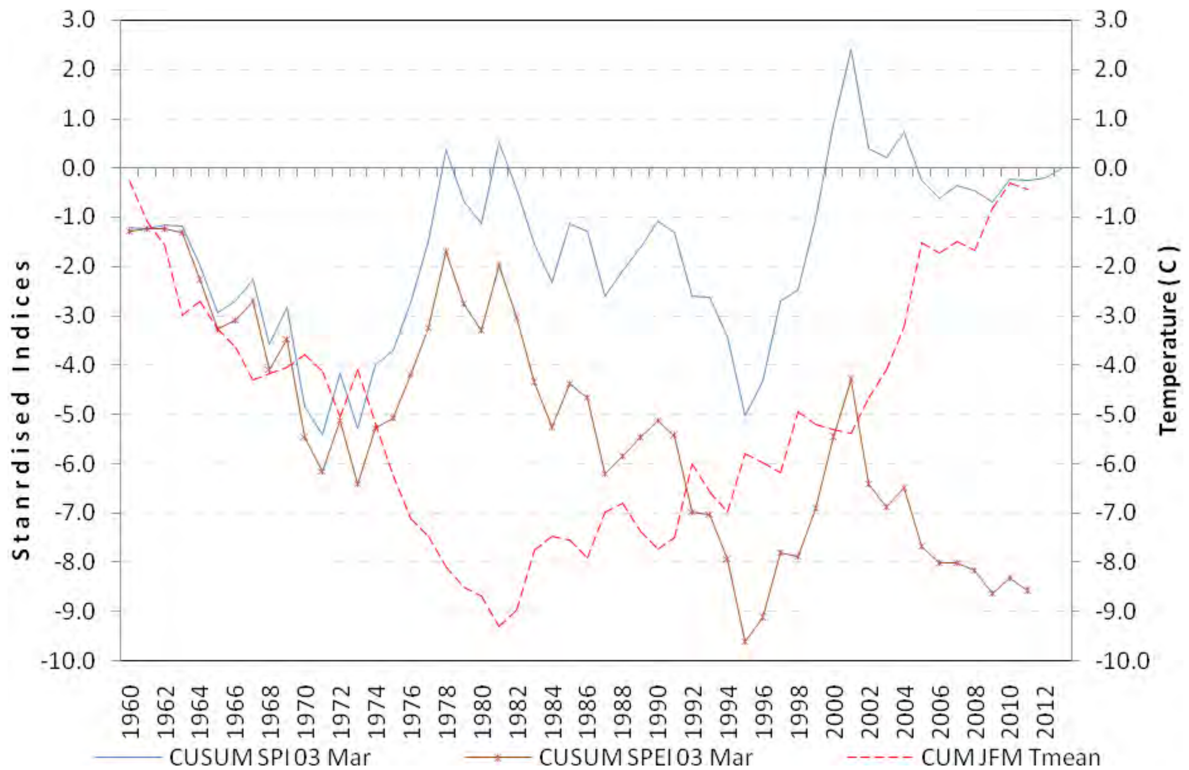

Fig 3.12 Temporal manifestation of the CUSUM, SPI (solid line) and SPEI (solid line with crosses) alongside that of Tmean (broken line) for the period 1960 to 2013 during the January to March period

3.2.6 Changing Summer Climate characteristics in Chiredzi

After having noted the changing climate characteristics at national level, the next focus is on Chiredzi, the district which was identified as the study area. Figure 3.13 demonstrates the temporal changes in the cumulative indices of the SPI and SPEI with that of SATmean superimposed. It can be noted that the SATmean shows shifts in 1981 and 2001 whereby there was cooling up to the first shift before levelling off to the second shift and a strong warming trend thereafter. However, these temperature shifts were not visible in the difference between the SPI and SPEI as the two time series were largely parallel throughout. Hence the impact of the warming shift did not really have a significant bearing on the difference between the SPI and SPEI temporal trends. This was the same scenario which was depicted by the OND period where the SPI and SPEI did not deviate significantly from one another.

Fig 3.13 Temporal manifestation of the CUSUM, SPI (solid line) and SPEI (solid line with crosses) alongside that of Tmean (broken line) for the period 1960 to 2013 during the January to March period for Chiredzi district.

3.2.7 Summary and Conclusions

Zimbabwe winter has exhibited a warming shift in both SATmin and SATmax during 1981. The summer period also demonstrated warming shifts in 1981 for the OND period but 1992 for the JFM period. The comparison of the SPI and the SPEI which are drought indices calculated using the same procedure but with the latter incorporating the effect of temperature was able to differentially identify the impacts of the warming shifts during the summer period. It was interesting to note that the control of the increased temperature on the intensification of the droughts was more prominent during the JFM period. The impact of the warming shift was not that obvious on drought intensity during the OND for the whole country and the entire rainfall period for Chiredzi district. These two scenarios were similar in that they both exhibited climatic conditions with low temporal variability in temperature, higher rainfall variability and relatively low rainfall total. Our results confirm that the increase in water demand due to PET in a global change context will affect the future occurrence, intensity and magnitude of droughts most probably during low rainfall and high temperature scenarios.

3.3 Detected shifts in the start of wet season in Zimbabwe's Agro-ecological regions

3.3.1 Introduction

The current agro-ecological zones of Zimbabwe were developed in the 1960s (Vincent and Thomas, 1961) (Figure 3.14). The Second National Communication (SNC) showed that climate change may result in spatial shifts in these agro-ecological zones of Zimbabwe and consequently crop suitability. Specifically, the SNC Report, projected suitability of typical crops grown in each of the five natural regions using the Ecological Crop Requirements Model (ECOCROP) under the best case and worst case scenarios. The model indicated that area suitable for tea production (Region I) will increase under the worst case and best case scenarios while area excellent for wheat production in Region II will significantly decrease under both scenarios. As for Region III, the results indicated a significant decline in area excellent for soya bean under the worst case scenario. The area suitable for millet production (Region IV) will slightly increase under the worst case scenario. Region V is typically reserved for livestock farming although farmers in the region are tempted to grow crops like maize since from their experiences over the years they tend to get good yields once in every five years.

During an inception workshop of the Third National Communication (TNC) held in Mashonaland West Province, stakeholders who participated indicated that they were experiencing high crop failure due to late onset and early season cessation of the rainy season leading to shortening of the growing season. Therefore in the TNC, the agro ecological zone vulnerability assessment will concentrate on determination of onset, cessation and length of growing season for stations in Zimbabwe. Such information if availed to farmers can be used to plant crops on optimum dates to take advantage of favourable climatic conditions for germination and other subsequent stages of crop development.

Fig 3.14 Agro-Ecological Regions of Zimbabwe

3.3.2 Changes in start of Growing Season (SoS)

The determination of start of season was done using the DEPTH method (Raeset al., 2004). According to this method, the start of season is defined as the first day of a 4-day period with cumulative rainfall of 36 mm while the end of season is the first dry day of a 14 day period with total rainfall less than 40mm in a 2 week period after mid-February. Daily rainfall data was obtained from MSD of Zimbabwe. Table 1 illustrates the start of season likelihoods or probabilities (%) as determined by Vincent and Thomas in 1962 compared with the start of season dates observed for 17 years between 1997 and 2014. In this case 20% is the lowest probability or likelihood while 80% is the most likely to happen. Recalling that the Zimbabwe Second National Communication to the UNFCCC indicated that climate change could result in spatial shifts in these agro-ecological zones of Zimbabwe and therefore crop suitability (GoZ, 2012) in this report, focus is primarily on determining whether there are observable shifts in seasonal onset dates based on five representative stations in each of the five agro-ecological zones of Zimbabwe. Such information if availed to farmers can be used for choice of crop varieties and optimum planting dates to take advantage of favourable climatic conditions for germination and other subsequent stages of crop development as the timing at planting determines conditions (Dapaah et al., 2000). In order to do this, the Vincent and Thomas SoS probability were used as the baseline and compared with the 1997 – 2014 SoS dates (Table 3.1).

Table 3.1 Start of Season (SoS) for representative stations in each agro-ecological zone by Vincent and Thomas together with the observed dates for current period

Zone	SoS probability (%) [Vincent and Thomas 1962]	SoS date (Vincent and Thomas 1962)	Observed median SoS (1997 – 2014)	SoS extremes and year observed (1997-2014)	Station used
V	20	31-Oct	21 November	6 January	Buffalo Range
	40	10-Nov		2005-2006	
	60	20-Nov			
	80	25-Nov			
IV	20	5-Nov	23 November	28 December	Plumtree
	40	20-Nov		2012-2013	
	60	25-Nov			
	80	5-Dec			
III	20	25-Oct	19 November	13 December	Gweru
	40	5-Nov		2012 – 2103	
	60	10-Nov			
	80	25-Nov			
II	20	25-Oct	22 November	19December 2003- 2004	Darwendale
	40	10-Nov			
	60	10-Nov			
	80	25-Nov			
I	20	25-Oct	22 November	30December 2006 – 2007	Chisengu
	40	05-Nov			
	60	15-Nov			
	80	25-Nov			

3.3.3 Observed shifts in Start of season (SoS) dates

A shift in the start of the wet or growing season (SoS) was observed for all the representative stations quantitatively compared to the baseline period used by Vincent and Thomas with the majority of the stations falling in the late SoS range (Table 3.2). In addition, Chiredzi is dominated by the drought hazard for the 3 month time step ending March (CwDCC, 2012) and therefore the predominance of late SoS for the 1997 – 2014 period suggests high frequency of crop failure of the late planted crop (Table 3.2). It should be noted that there was no baseline data to make comparisons with for cessation dates and length of season, these two aspects were left out in the analysis though it could have added value with regards to advice on cropping systems and choice of crop varieties.

Table 3.2 Characterisation of meteorological stations outside Start of growing Season (SoS) baseline range

Region	Meteorological Station	% Years outside baseline range	% Late SoS	% Early SoS
V	Buffalo Range	53	41	12
IV	Plumtree	53	53	0
III	Gweru	47	35	12
II	Darwendale	24	18	6
I	Chisengu	47	41	6

3.3.4 Conclusions

It can be concluded that the majority of the seasons which fell outside the range of the baseline SoS established for the agro-ecological framework of Zimbabwe by Vincent and Thomas (1962) indicate a shift towards late SoS for all agro-ecological regions. To this end practices such as conservation agriculture are critical as climate change adaptation and mitigatition strategies and in addressing land degradation. Therefore, the Ministry of Agriculture, Mechanization and Irrigation Development needs to do more in order to enhance adoption of conservation agriculture through addressing the common barriers to adoption of the technology. It is also critical for the Meteorological Services Department of Zimbabwe to ensure that there is timely dissemination of weather forecasts to farmers so that they are informed in order to make proper decisions on farm operations.

3.4 Vulnerability to Climate Change in Chiredzi district of Zimbabwe: A case study

3.4.1 Introduction

This section focuses on vulnerability in the agricultural and health sectors of Chiredzi district under baseline scenario. It then focuses on projected vulnerability of the agricultural sector in the 2040s under a changed climate. The agricultural and health sectors were selected because livelihoods in Chiredzi District are predominantly (97%) dependent on rain-fed agriculture and livestock while climate related diseases such as malaria, schistosomiasis and diarrhoea are predominant in the district.

3.4.2 Agricultural sector vulnerability in Chiredzi

Rain-fed agriculture and livestock production are the main sources of livelihood for more than 97% of households in the district. Of all the respondents 89% reported reliance on farming as a source of livelihood, 4% on formal employment and the rest on other sources, market gardening and small income generating activities including remittances from relatives in the urban areas and diaspora. This implies that the majority of the farmers are vulnerable to climatic extremes associated with climate change. This is confirmed by the observation that most of the farmers (80% of the respondents) experience food shortages during the period September – March when they will have exhausted the previous season's harvest, meaning that there is no food security in Chiredzi District.

Major food crops in Chiredzi are cereals (maize and sorghum), and major cash crops are cotton and horticultural produce (tomatoes and vegetables). Groundnuts, pearl millet, finger millet and groundnuts are also grown but on small land sizes. Farm sizes range between 1 – 2 hectares (ha). Both high (e.g. maize and groundnuts) and low (e.g. millets and sorghum) water demand crops are produced in Chiredzi district.

3.4.2.1 Crops

Figure 9 shows the average yields farmers in Chiredzi district attain, and the relationship between the area planted for each crop and the yields obtained. The yields of most crops grown in Chiredzi District are generally low. Farmers obtain the largest yield per acre for sorghum, followed by maize and cotton. The other crops do not give good yields in the district. Although much of the district is favoured by fertile soils, in terms of climate suitability classifications, most of the district has been deemed only suitable for drought resistant crops, such as sorghum, millet, cowpeas, sunflower and cotton. Figure 3.15 further illustrates that crop yields for both maize and small grains are sensitive to rainfall.

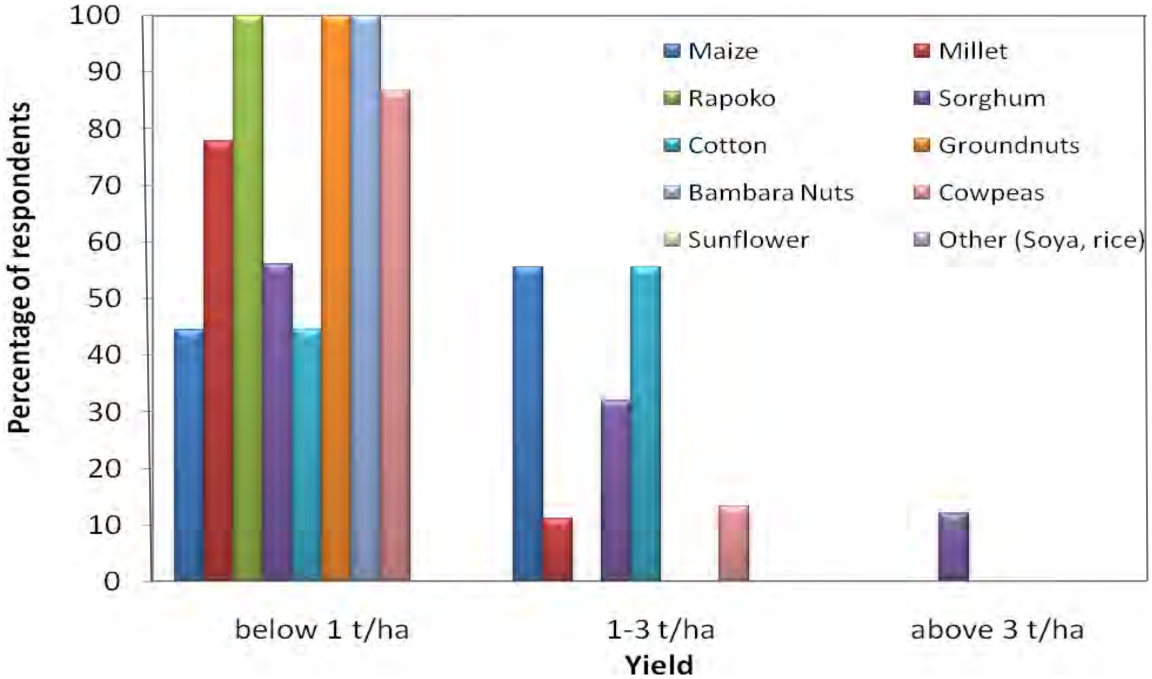

Fig 3.15 Yields for the important crops grown in Chiredzi District

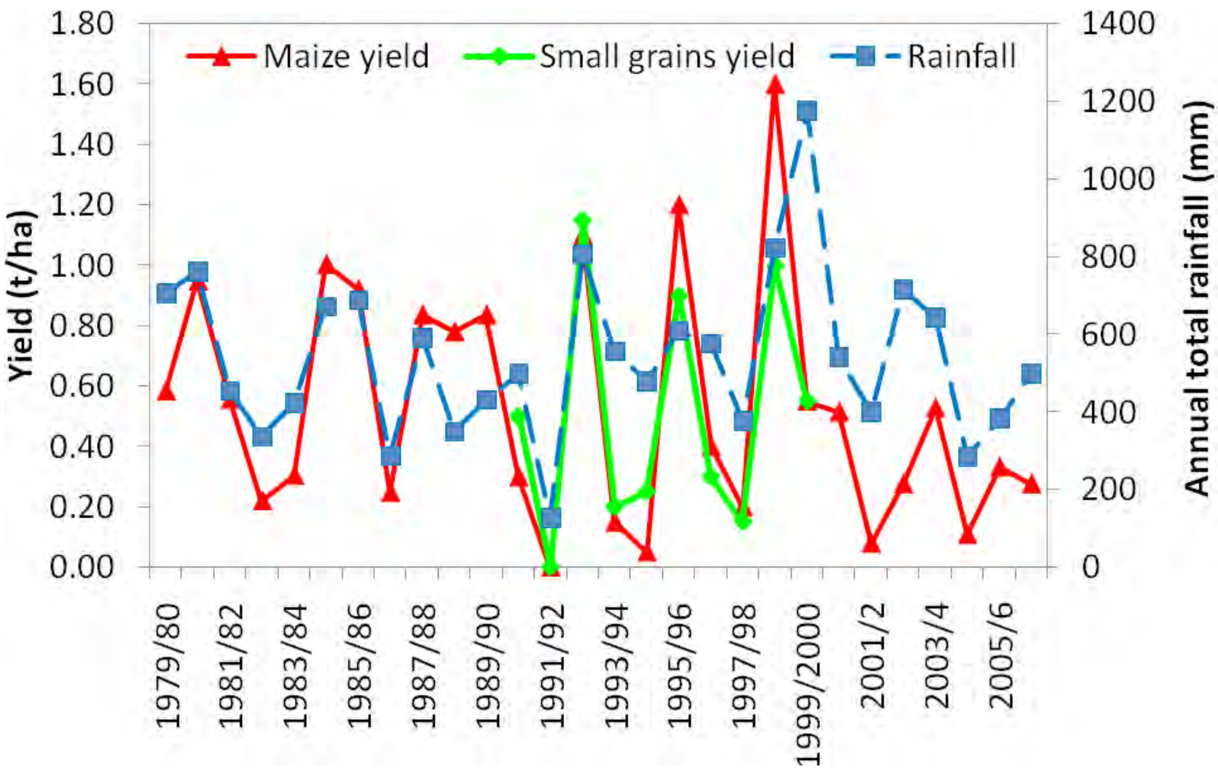

Fig 3.16 Crop yield and rainfall trends in Chiredzi district (1980 to 2007)

Figure 3.17 shows the time series of the anomalies for the annual rainfall and cereal yield, standardized using their respective standard deviations to obtain the corresponding indices.

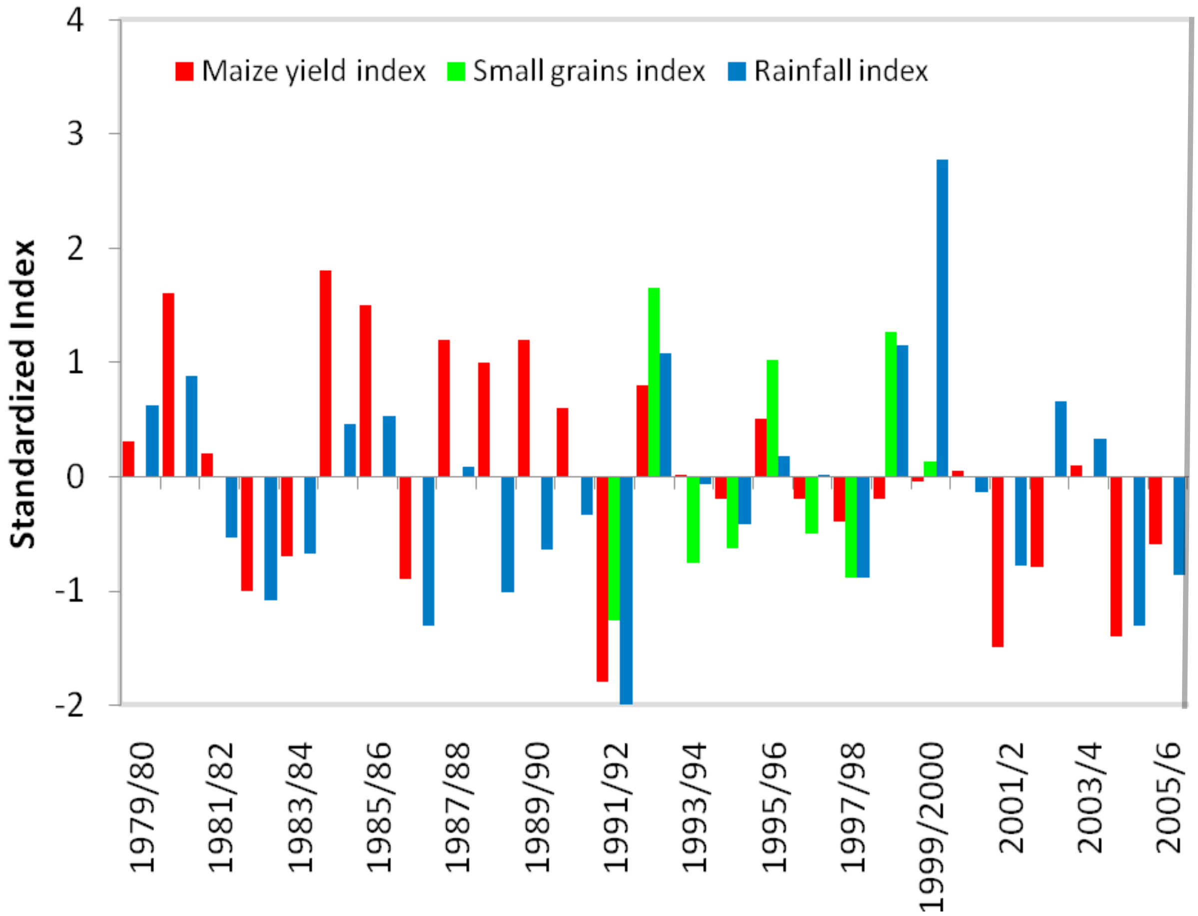

Fig 3.17 Comparisons of standardized indices of maize and sorghum yields and annual rainfall for Chiredzi district for the period1980–2007

The results show that in most years the yields of cereal crops are both low and erratic, with maize demonstrating a stronger sensitivity to rainfall variability than small grains (as typified by sorghum). During the 1991-92 cropping season the growing period was only 52 days. This period was too short to support any crop production in the district, and as a result most rain-fed crops were a complete failure. This was therefore a season in which the district experienced a severe agricultural drought. Farmers in the district therefore generally need to employ coping strategies to reduce adverse impacts of insufficient rainfall. However, what can also be seen is that there were some very good years in between these droughts. Consequently, rather than always adopting low yielding, early maturing varieties, farmers need to adjust their agricultural management decisions to take advantage of these favourable conditions in those years when the rainfall is abundant. However, what was also found was that in addition to low and erratic rainfall, yields are also constrained by lack of draught power to take advantage of early rains and lack of inputs (seed of appropriate crop varieties and fertilizer). The observation of poor maize yields in above normal rainfall years (such as the 1993/94, 1996/97 and 2002/03 seasons) could be a reflection of poor within season rainfall distribution. While there are other factors that farmers indicated as affecting their crop yields, 90% of them attributed the low yields to climate. Because agriculture in the district is rain fed, the erratic rainfall and droughts militate against crop production.

The previous section shows that the rainfall season in Chiredzi district on average starts about mid-November to early December and ends around mid to end of March, giving an average growing period of about 113 days. This has implications on the timing of land preparation in the district to ensure that planting dates generally coincide with the onset of the rainfall season, as every day after this leads to potential losses in yield, as shown in Figure 3.17. Based on Figure 3.17 the chances of a season being a drought year (characterized by poor yields) increases with the departure of the onset date from the normal onset date of 22 November.

Late onset of rains as well mid-season dry spells are common in Chiredzi due to the high rainfall variability. According to farmers' experience, maize and sorghum are affected by early drought or the false start of rains, with breaks at the beginning that cause poor crop establishment. Delayed onset of rains leads to late planting, resulting in a shortened growing period and consequently reduced yields (e.g. 1993/4, 1994/5 and 1997/8 seasons as shown in Figure 3.18). The crops are also constantly affected by mid-season and terminal drought. For example, due to the poor quality of the rains received in the 2014/15 rainfall season, the district only produced 2,941 metric tonnes of cereals (maize, sorghum, pearl millet and finger millet) against an annual requirement of 34,634 metric tonnes (a deficit of 31,693 metric tonnes). Adjusting the time of planting and staggered planting, based on climate forecast information, can reduce the impacts of drought. Alternative options would be to select drought-tolerant varieties. The adaptation options to climate change require appropriate use of climate information. Achieving potential crop yield requires increased resource management through appropriate use of climate information. It is essential to identify the key drought risks during the crop growth cycle and the management alternatives.

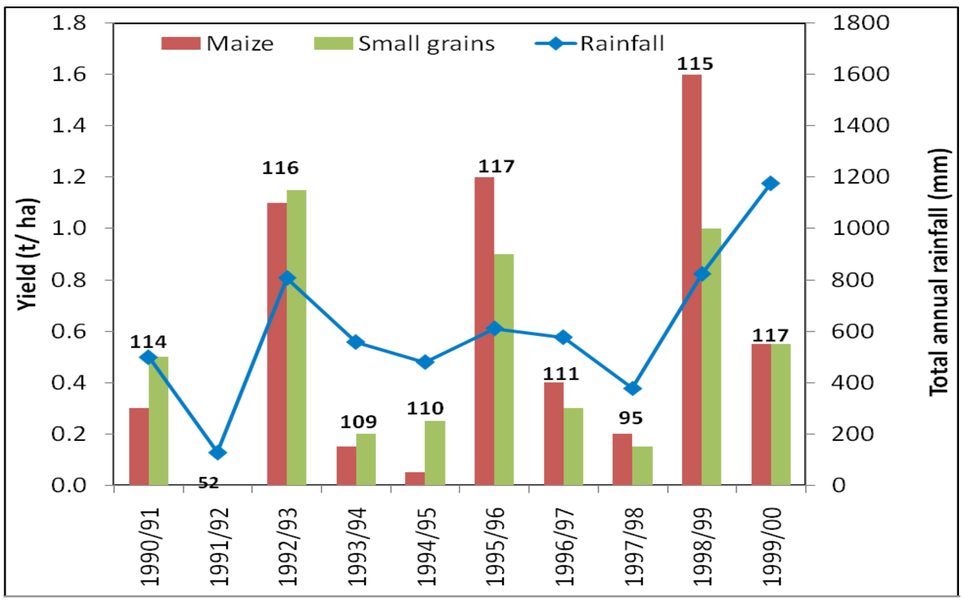

Fig 3.18 Sensitivity of the yields of maize and sorghum to rainfall amounts and LGP (the number above the bar graphs)

3.4.2.2 Livestock

The district is characterized by a north-south stratification of livelihood systems. In the extreme north, the communities practice rain fed crop production combined with livestock production, while those in the southern-most predominantly practice livestock production. Livestock rearing, which is composed mainly of cattle and goats, forms an important component of livelihoods in the district. However, the inconsistent rainfall patterns since the 1990s has caused intermittent droughts that have devastated the district food security status and are partly responsible for the diminishing livestock herd. Total cattle populations in the district were severely affected by the 1991/92 drought, with major mortalities and sales occurring across all wards. This was a period of extreme draught power shortage in the district, something which still persists for some households. However, according to the Department of Livestock and Veterinary Services of Zimbabwe(DLVSZ),through the rest of the 1990s, cattle populations gradually recovered through restocking and natural births, reaching 68,220 by 2000 (68% of the pre-drought numbers), and then dipping slightly again in the drought years of 2001-2. Trends in other livestock (goats, sheep and donkeys) have broadly mirrored these patterns seen for cattle, with all livestock categories suffering in the 1990s drought, although not as dramatically as cattle (Figure 3.19). By 2009 the district had about 153,250 cattle, 700,877 goats and 11,497 donkeys owned by about 14,505 households, according to the DLVSZ. However, in 2010 there was a 19% reduction in the district herd due to the 2011/12 drought as well as diseases, particularly foot and mouth disease (FMD), blackleg, babesiosis and lumpy skin disease (Gavera, 2013).

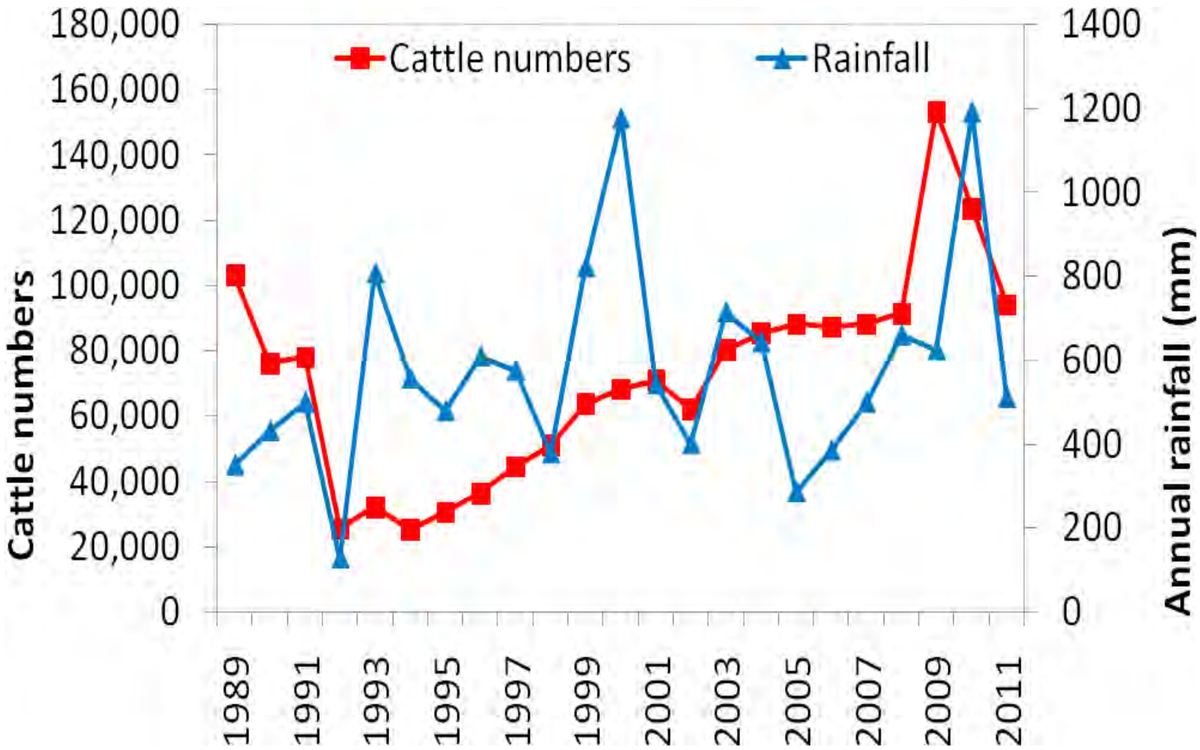

Fig 3.19 Cattle population trends in Chiredzi District (Source: DLVS)

3.4.3 Agricultural sector Adaptation strategies in Chiredzi

3.4.3.1 Adaptation options in the Cropping Sector

Adaptation strategies can be implemented at various scales and they range from planting, plot, household or the farm level and are meant to ensure that livelihoods are resilient to a wide range of constraints (Table 3.3).

Table 3.3 Adaptation practices that communities in Chiredzi adopt to cushion them against drought

Scale	*Before drought*	*During and after drought*
Planting	Optimise crop type selection Use drought tolerant crop varieties Early planting of groundnuts, sorghum and pearl millet (October/November) Staggered planting dates Reduce planting density (this is by far the most commonly practiced strategy among Chiredzi District farmers) Use climate information to optimise planting decisions	Replant with early maturing crop types or varieties
Plot	Use plots on soils with good water retention capacity Practice soil moisture conservation techniques, such as tied ridges, deep plough furrows and basins (the project successfully promoted soil moisture conservation)	Weed management Delay or avoid fertiliser use No use of inorganic fertilisers
Farm/ Household	Diversified cropping Land type diversification Keep cereal stocks to last two years or more if possible. Asset diversification Livelihood diversification Adopt conservation agriculture Reduce or increase land under crops Increase reliance on drought tolerant crops including sorghum, millet and cassava For livestock, encourage herd growth in good seasons (the assumption is that drought will provide a natural culling effect to avoid over population) Diversify livestock types by introducing goats, donkeys, etc which do not need as much grazing and water as cattle. -Keep indigenous livestock breeds	Reallocate resources in line with trends in the season Livestock or asset sales. Embark on casual labour Off farm employment Exploit ecosystem services such as wild fruits, game, etc. Use crop stover to supplement livestock grazing, Buy commercial stock feeds and feed drought survival rations to livestock. Graze animals early in the morning and for longer hours. It is believed that the palatability of pastures increases when soaked with early morning dew. Exploit social networks, safety nets and remittances

Source: Unganai 2012

3.4.3.2 Adaptation options in the Livestock Sector

Supplementary feeding is one of the adaptation strategies that communities indicated as being important for their livestock. Supplementary feeding from Hippo Valley Estates has helped communities when feed becomes scarce. Supplementary feeding from Hippo Valley is not always easy as in some cases this involves a lot of work to move the feed if the feed is to be in adequate quantities. The private sector has already started to engage farmers in supplementary and cattle fattening projects that are beginning to sustain farmers' income. In addition, new forms of supplementary feeding for livestock have emerged over time to complement the traditional supplementary feeding communities have relied on. In particular, use of drought tolerant grass, Neorautaneniabrachypus (Zhombwe) to feed cattle has really gone a long way to provide feed for livestock. In addition to the predictable strategy of seeking veterinary chemicals and dipping to lessen disease incidence, communities have also resorted to innovative ways of dealing with wounds such as use of washing powder (Surf) to treat wounds. Communities indicated that though there has not been any research done to verify these new responses, especially use of washing powder, these strategies have helped them in the absence and inaccessibility of veterinary chemicals that they considered to be very expensive given their little income.

3.4.4 Health sector vulnerability in Chiredzi

Malaria, schistosomiasis and diarrhoea were used as indicator diseases to assess the potential impact of climate change on the health sector as their distribution and seasonal transmission correlate significantly with temperature and rainfall. The data used for malaria was from 1990 to 2014 and the 2007 data shows a strong relationship between malaria distribution and rainfall ($R2=0.51$, $P<0.06$). For the other years however, there is no significant evidence to suggest that malaria incidences are a function of temperature and rainfall, (Hu et al. 2015). Several studies have linked malaria incidences to vector habitat suitability in Zimbabwe (Gwitira et al., 2015). The results of the study showed a positive ($P<0.05$) correlation between habitat suitability and recorded malaria incidences. Figure 3.20 shows that Chiredzi is a malaria hotspot.

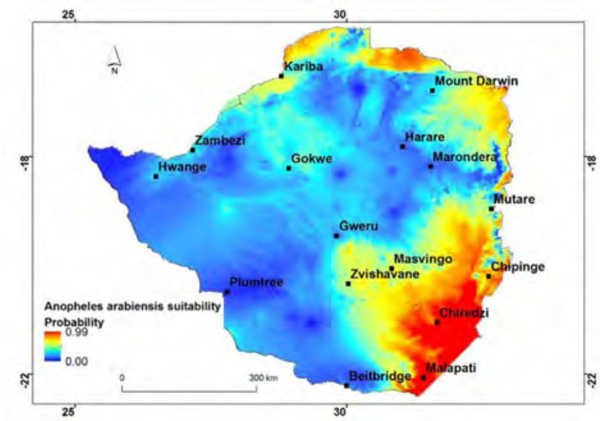

Fig 3.20 Suitability of malaria vector (Anopheles arabiensis) in Zimbabwe (Gwitira et al., 2014)

Although, no significant relationship between rainfall and schistosomiasis was found ($p<0.05$), there are schistosomiasis hotspots in Chiredzi district that could be as a result of nearby water surfaces or irrigation activities at Hippo valley estate (Figure 3.21). Other studies have found correlation between schistosomiasis and water sources related to irrigation (Bosompen et al. 2004).

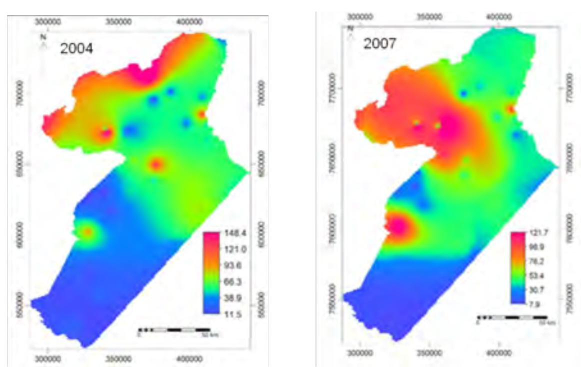

Fig 3.21 The distribution of Schistosomiasis in Chiredzi district

However there is insufficient evidence to suggest that rainfall directly affects the frequency of diarrhoea in Chiredzi given that 28% of variation in diarrhoea is due to random variability for rainfall. Other factors could be contributing to spread of diarrhoea. However, from Figure 3.22, we observe that the spatial distribution of diarrhoea could be a function of limited safe water which is a climate issue. Even though rainfall and temperature are inversely related to diarrheal diseases, erratic rainfall can compel people to make use of contaminated water.

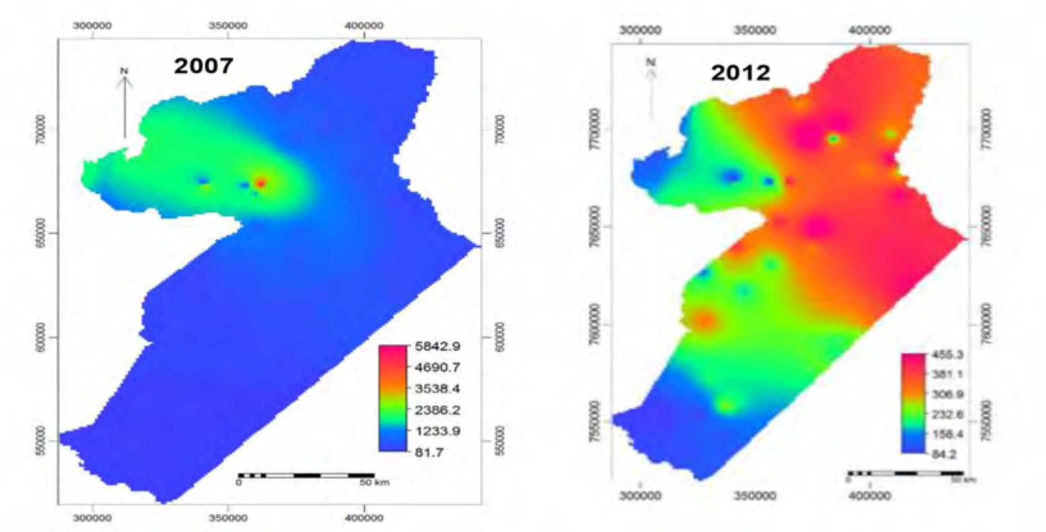

Fig 3.22 The distribution of Diarrhoea in Chiredzi district

3.4.4.1 Health sector Adaptation strategies in Chiredzi

There have not been many changes in terms of adaptation strategies for malaria under the National Malaria Control Programme which is under the Ministry of Health and Child Care in Zimbabwe. Measures in place to control malaria include selective vector control that include indoor residual spraying (IRS) programme and distribution of long-lasting insecticide treated mosquito nets, case management, disease surveillance and outbreak management, information, education and communication among others. The Roll Back Malaria Campaign, spearheaded by the World Health Organisation (WHO) continues to target interventions that are aimed at reducing deaths attributed to malaria by half in Zimbabwe. Under this programme, WHO provides technical and financial resources needed to combat malaria. In terms of case management, increasing access to health facilities and drugs will increase the country's adaptive capacity.

For schistosomiasis and diarrhoea, there is no strong evidence to show the relationship between climate and diarrhoea and schistosomiasis. It therefore suggests that the high prevalence and incidence rates for those diseases could be attributed to other factors such as underlying socio-demographic causes of high incidence areas and limited access to safe water and sanitation. Inter ventions to reduce these diseases should therefore target water and sanitation issues which will address other neglected tropical diseases. Schistosomiasis falls under the neglected tropical diseases that are a diverse group of diseases with distinct characteristics and thrive mainly among the poorest populations (WHO, 2015). Zimbabwe remains committed to reduce the incidence and prevalence of schistosomiasis through interventions such as advocating for safe water and sanitation, host snails control, mass drug administration and school based health education.

3.4.5 Future vulnerability in Chiredzi district under climate change

3.4.5.1 Possible Future Exposure of Cropping Systems to Climate Change

To assess future exposure of the crop system to changes in climate, suitability of sorghum (representative of the small grains recommended for the region) was modelled using the CSIRO MK3 under the BCS and WCS for the 2040s. An assessment of the changes in sorghum suitability under a changed climate in Chiredzi show that the area suitable for sorghum cultivation will significantly contract under the CSIRO MK3 scenario (Figure 3.23). Sorghum is a small grain and it is widely regarded as a suitable crop for Chiredzi, thus this finding calls for research into sorghum varieties that are tolerant to drier conditions.

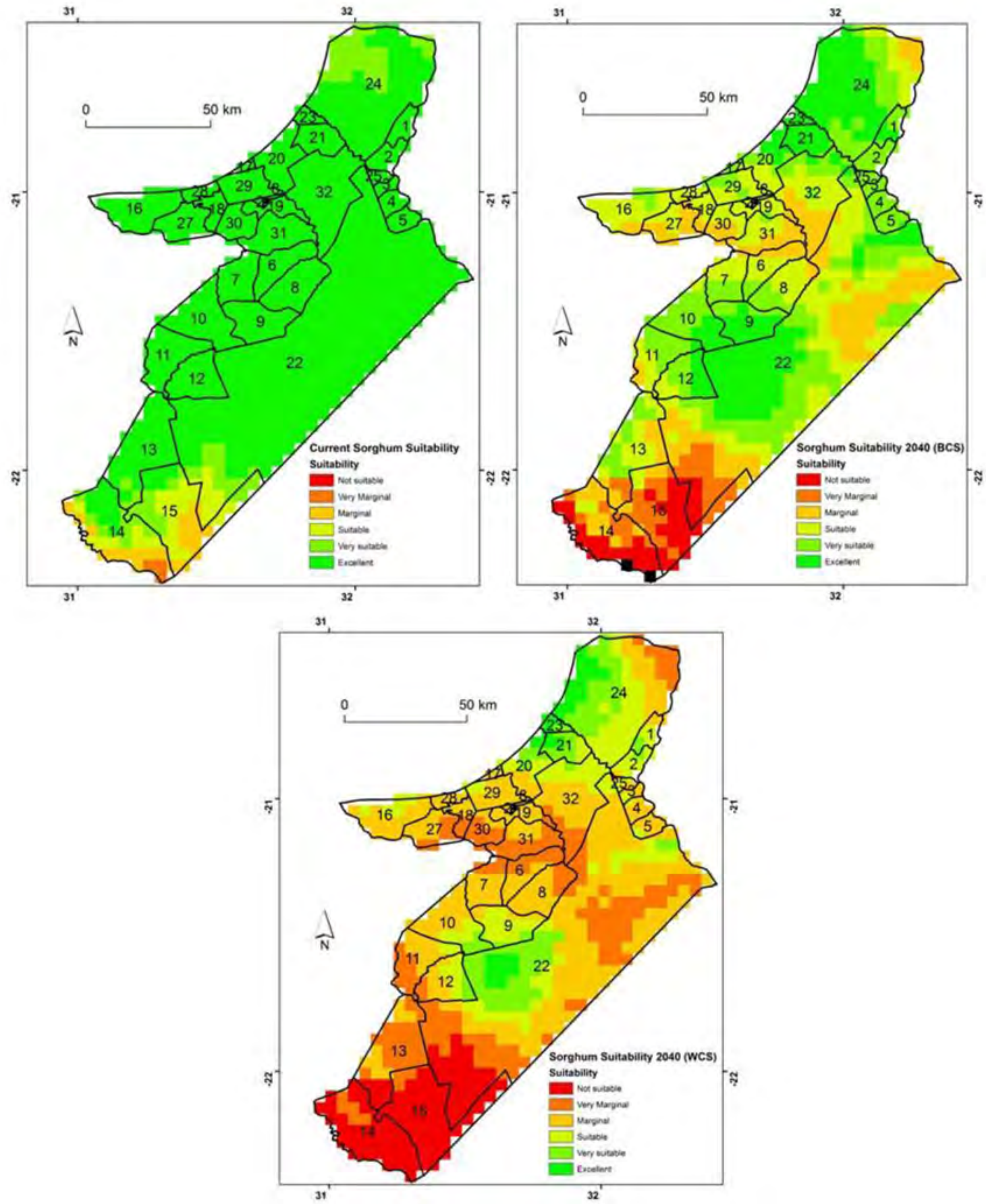

Fig 3.23 The current spatial variations in sorghum suitability (top left panel) and projected sorghum suitability under the CSIRO BCS (top right panel) and the CSIRO WCS (bottom panel)

3.4.5.2 Possible Future Exposure of livestock Systems to Climate Change

An assessment of the changes in net primary productivity (NPP) (an indicator of forage quantity and quality) as a function of climate change of the 2040s based on the CSIRO MK3, under BCS and WCS was performed to determine the possible impacts of climate change on the livestock sector. Figure 3.24 shows the current and projected geographical distribution of NPP in Chiredzi as predicted under CSIRO MK3, BCS and WCS respectively. Results indicate that all districts in the region are projected to experience a significant decrease in NPP albeit by varying magnitude.

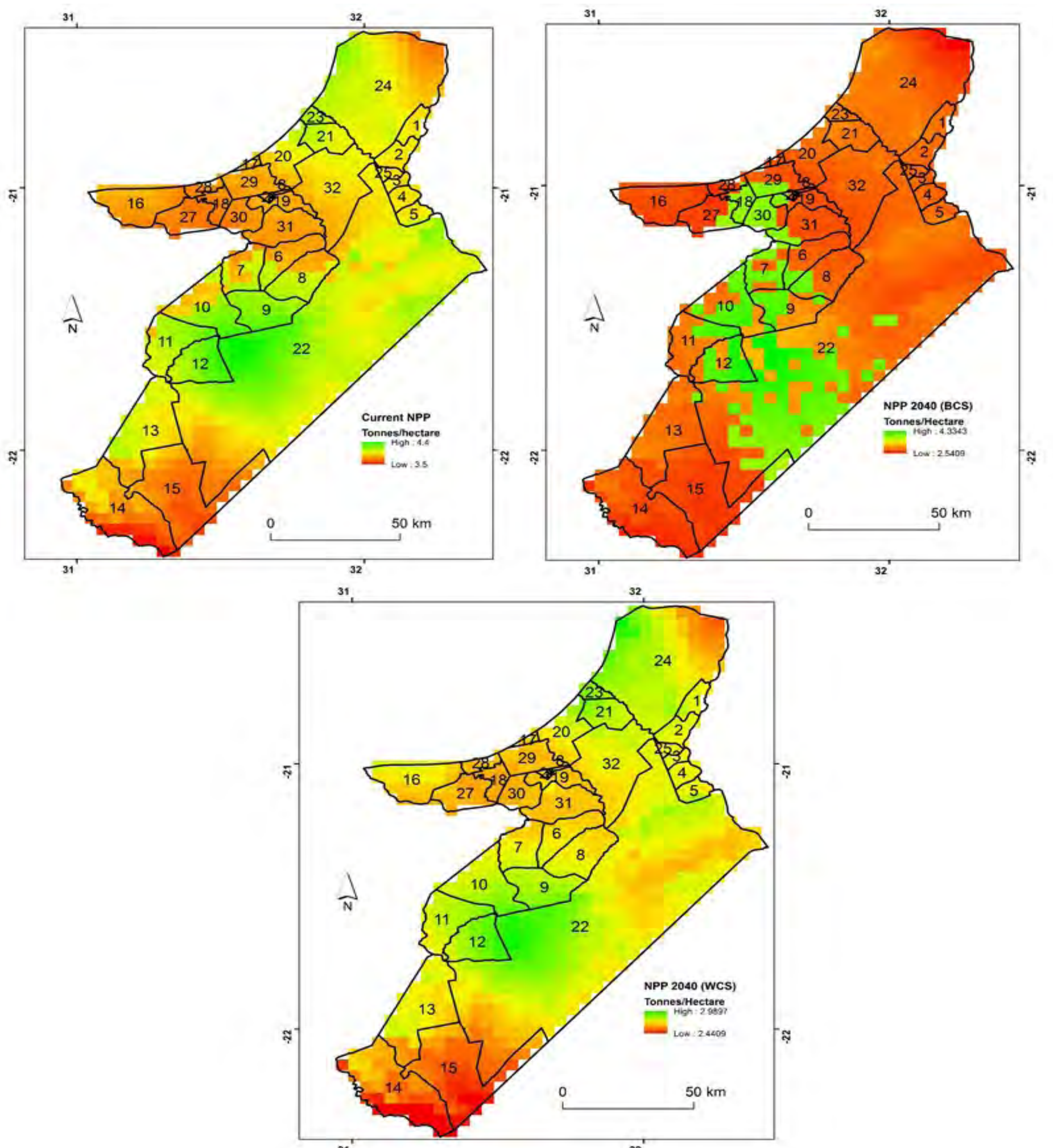

Fig 3.24 The current NPP (top left) and projected NPP under the CSIRO MK3 BCS (top right) and the WCS (below) for the 2040s.

The results of comparison of the current and projected NPP under a changed climate are presented in figures 3.24. We observe that although the models differ in the magnitude of decrease in NPP, there is a general consensus on the areas that are likely to experience major reductions in NPP. Generally the western, northern and eastern parts of Chiredzi are projected to experience a reduction in NPP (Figure 3.24).

CHAPTER 4

4. CLIMATE CHANGE MITIGATION

4.1 Overview of Climate Change Mitigation

4.1.1Energy Sector

Zimbabwe's energy industries are responsible for almost 50% of the energy-related emissions. Emissions from energy industries alone are projected to increase by 35% while that of the total energy sector emissions have a projected increase of 73%. The operational measures identified include improved maintenance of equipment and infrastructure while the capital investment measures involve technology change or fuel substitution. The thermal power plants have surpassed their useful lifespan and are now operating at very low efficiency. The proposed efficiency improvement of the thermal power plants and increase in the renewables would have economic, social and environmental benefits.

4.1.2 Industrial Processes, Solvent and Other Product Use

Greenhouse gas (GHG) emission sources from industrial processes in Zimbabwe for the year 2006 emanated from mineral production, chemical production, metal production and other production (food and beverages). The GHG emissions from this sector are projected to increase basing on the annual GDP growth rates projected under the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset). Although there are expected reductions in GHG emissions from implementing the proposed mitigation actions, the limiting factor remains funding. An estimated US$528 million is required.

4.1.3 Agriculture

Mitigation of GHG emissions from Zimbabwe's agriculture sector should be targeted at reducing CH_4 emissions in non-dairy cattle, N_2O emissions from agricultural soils and CO from the burning of Savannas. In future, the ability of pastures to compensate primary production of biomass in response to anthropogenic carbon losses will be compromised due to increased rainfall variability in Zimbabwe's savanna rangelands. An integrated, community based approach could be best in discouraging excessive burning of rangelands. Restoration of grazing infrastructure such as fencing of rangelands in resettlement areas of Zimbabwe presents an opportunity for controlling and optimising grazing and pasture quality. Awareness, training and extension support is required to promote buy-in of good management practices of grasslands including prescribed burning, and on-farm by-products.

4.1.4 Land use, Land use-Change and Forestry (LULUCF)

The LULUCF sector is the main sink for GHGs in Zimbabwe and responsible for the country's net sink status. National and international forest policies have the potential to redefine the opportunity costs of land-use in ways that either complement or counteract the attainment of climate change mitigation goals. Additionally, adequate policies are needed for orienting practices in agriculture and in forest conservation and management to cope with mitigation and adaptation. The policies to be considered here are those which will either be used to maintain carbon stocks and/or expand carbon sinks. Such policies include: the Forest Protection and Conservation Policies; policies on shared responsibility for managing existing protected areas between local communities and the central agencies; policies on aggressive afforestation and reforestation by both villagers and forest departments, and policies on incentives for private ownership of some forest resources.

4.1.5 Waste

The largest source of GHG emissions in the Waste Sector is landfill that emits methane followed by wastewater that emits CH_4 and N_2O. The key drivers for emissions from waste sector are population, urbanization, affluence and the extent of landfill gas capture. Emissions from waste are projected to increase in line with population growth. Zimbabwe as a developing country needs to pursue waste prevention, reduction or minimisation and re-use for solid waste. These processes have environmental social and economic benefits. End-pipe waste disposal methods such as waste to energy for both solid and liquid waste are relatively expensive and ideally should therefore be done after prevention, reduction and re-use. This can be achieved through regulatory instruments, green subsidies, voluntary and information based instruments.

Although Zimbabwe is currently assumed to be a net sink of GHGs, adaptation alone will not be sufficient to meet the challenge of global warming. Mitigation measures in the different sectors will present socio-economic benefits, in addition to environmental benefits. The country's various policies, programmes, and strategies that are in place should give some mileage when effectively implemented. International technical and financial support is essential.

4.2 Climate Change Mitigation in the Energy Sector

The commercial energy consumption for Zimbabwe decreased at an annual average rate of 2% during the period 2000-2012, from 152,000 TJ to 116,000 TJ. The per capita consumption dropped by 33% from around 12 GJ in 2000 to 8 GJ in 2012. Figure 4.1shows a five year electricity use and rationing trends. The decreasing capacity utilization in the manufacturing sector partly explains the decline in energy consumption.

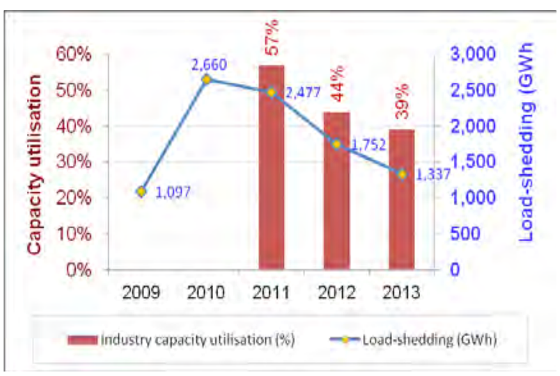

Fig 4.1 Load-shedding and industrial capacity utilization during the period 2009-2013. (Source: ZETDC, 2013)

In order to alleviate the power shortages the utility has been refurbishing the thermal power plants, as shown by the gradual increase of electricity generation in Figure 4.2. The Zimbabwe Power Company is planning to improve efficiencies of these power stations from around 20% to 27%, in order to boost power supply, reduce operational cost and reduce pollution.

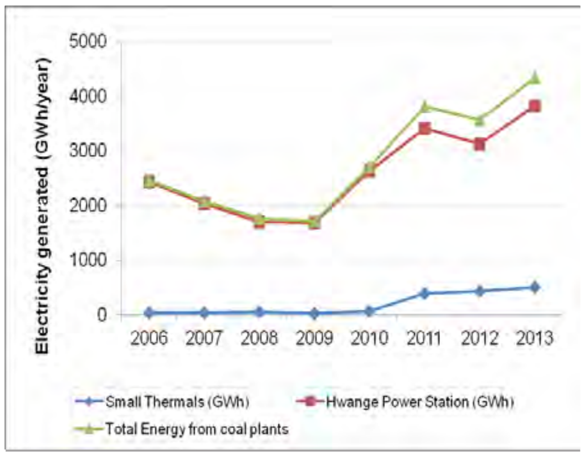

Fig 4.2 Electricity generation by the thermal power plants (Source: ZETDC, 2013)

Zimbabwe's energy emissions per capita fell from just above a tonne of CO_2eq in 2000 to around 700 kg in 2012, and is projected to rise to be around 3 tonnes by 2030 under the business as-usual scenario (Table 4.1).

Table 4.1 Zimbabwe's estimated and projected GHG emissions from energy use per capita under the business-as-usual scenario

Parameter	Inventory year					
	2000	2006	2012	2020	2025	2030
Emissions from energy use, Gg CO_2eq	13,240	10,664	9,591	29,185	47,858	47,858
National population, millions	12.5	12.7	13.1	14.1	14.9	15.6
Emissions per capita, Gg CO_2eq	1.1	0.8	0.7	2.1	3.2	3.1

Total fossil fuel consumption has increased steadily during the past three decades. Between 1970 and 2004, the share of fossil fuels dropped from 86% to 81%. As stated in the SNC, the energy sector uses considerable amounts of fossil fuels especially coal and diesel in the energy industries, transport sector and in other industry. Figure 4.3 shows the percentage changes in usage of fossil fuels such as coal, diesel and kerosene and electricity from the hydro power plant. The decrease in usage of the fossil fuels observed in the graph was mainly due to shortages. The output of the hydro power plant was increased from 666 MW to 750 MW during the period as a result of turbine upgrade. The energy industry sub-sector, which is responsible for almost 50% of the energy-related emissions, has a projected emission increase of 250% (from 5,000 Gg CO_2eq in 2000 to 18,000 Gg CO_2eq in 2030), while the total energy sector emissions have a projected increase of 260% (from 13,000 Gg CO_2eq to 48,000 Gg CO_2eq), as shown in Figure 1.3-2.

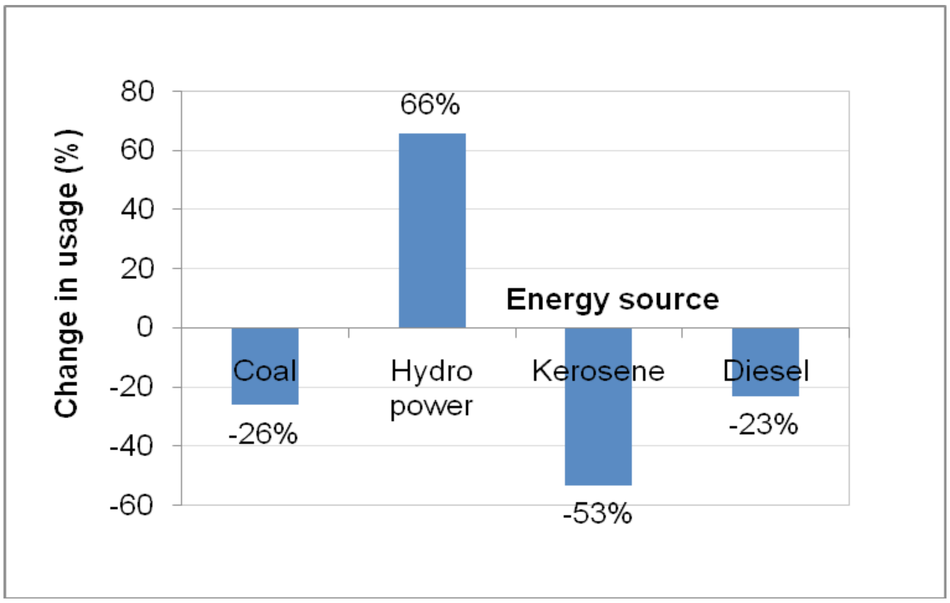

Fig 4.3 The changes in usage of coal, hydro-power, kerosene and diesel between 2000 and 2006

4.2.1 Mitigation options and potential

In 2014 Zimbabwe carried out a load forecast study, called the Zimbabwe Power Sector Analysis Project, to help in System Development Planning (SDP). Although the focus was on electricity the study was very relevant to the forecasting of energy consumption and GHG emissions up to 2030 (Figure 4.4 and Figure 4.5).

Some information and projects proposals on energy usage were provided by various ministries and institutions such as the Ministry of Energy and Power Development, the Zimbabwe Electricity Transmission and Distribution Company, the Zimbabwe Power Company, Rural Electrification Agency and the Zimbabwe Energy Regulating Authority.

In order to effectively reduce GHG emissions there must be a clear method of measuring and appraising performance of mitigation strategies. The mitigation performance indicators considered include:

- Total energy GHG signature
- Emission intensity of energy supply (CO_2eq / TPES)
- Per capita emissions, and
- Emissions per GDP

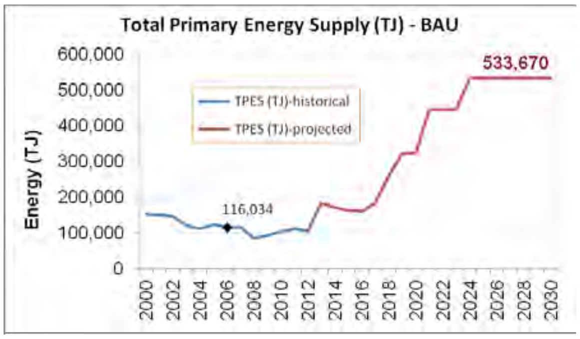

Fig 4.4 Historical and projected energy consumption/supply under business-as-usual, estimated from energy projects and development plans in various national documents.

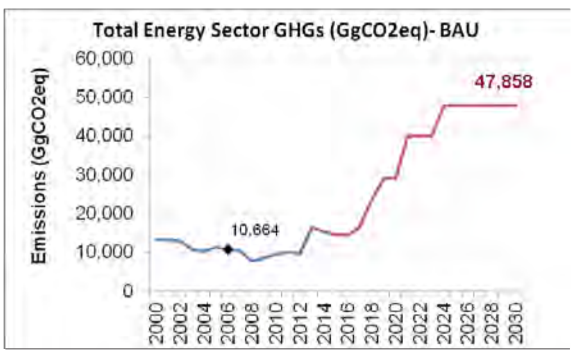

Fig 4.5 Projections of energy –related emissions under BAU, estimated from energy projects and development plans in various national documents

The amount of emitted GHG alone is not a good performance indicator for Zimbabwe. This is because the country still needs to develop (which means high energy consumption) and its economy is not stable. Thus, the emissions must be tracked together with other parameters. The emissions intensity of energy supply, measured in Gg CO_2eq / TJ, is given in Table 4.2. The BAU intensity is between 0.087 and 0.090 Gg CO_2eq / TJ. Mitigation measures will lower the intensity, by either reducing emissions or increasing non-fossil energy in the energy mix, or both. This performance indicator is recommended for measuring sectoral performance.

Table 4.2 Energy supply, emissions and emission intensity figures under BAU

Parameter	Inventory year					
	2000	2006	2012	2020	2025	2030
Emissions from energy use, Gg CO_2eq	13,240	10,664	9,591	29,185	47,858	47,858
Total Primary Energy Supply, TJ	152,395	116,034	106,948	325,442	533,670	533,670
Emission intensity, Gg CO_2eq / TJ	0.087	0.092	0.090	0.090	0.090	0.090

The per capita emissions and the emissions per GDP are also good mitigation performance indicators but the challenge is they require more accurate population and GDP estimates. GDP projections are generally made for 5-year periods.

4.2.2 Mitigation options for the energy industries

Coal burning is the major source of GHG emissions in the energy sector. It is estimated that about 50% of the coal mined is used to generate electricity at the four thermal power stations. The power needs of the nation are expected to come from: (1) repowering of the thermal plants which is expected to be done by 2018; (2) completion of the Kariba South expansion project, an energy efficiency and demand-side management; and (3) a new 300 MW Solar PV plant (Figure 4.6). By 2030 the electricity demand is projected to be 20,000 GWh (World Bank, 2014). However, there are quite a number of Independent Power Producers (IPPs) that have been licensed to generate power and feed it into the national grid. Some of the licensed projects use fossil fuels (coal and diesel), while others use hydro power, solar, and biomass.

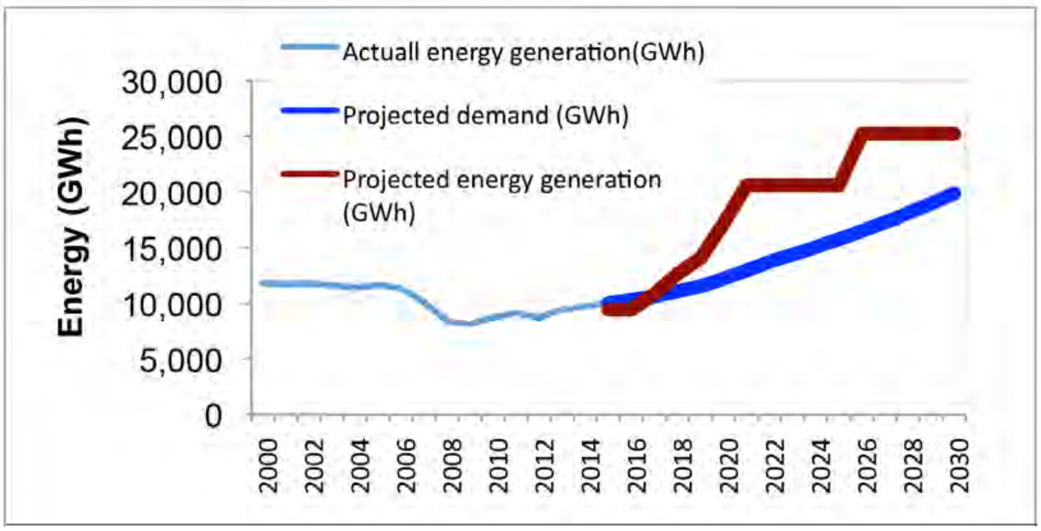

Fig 4.6 Historical and Projected electricity demand and generation (BAU)

The Ministry of Energy and Power Development (MoEPD) commissioned the work on the SDP in order to ensure that power projects are implemented in a way which does not compromise on access, affordability and reliability of power supply, and harm the environment. The BAU energy industries emissions and primary energy is shown in Figure 4.8. The new power plant included in the BAU scenario is the Coal-Bed-Methane (CBM) plant because of its economic and environmental advantages over coal and solar as well as other benefits it would give to industry such as by-products for use as inputs into other production processes.

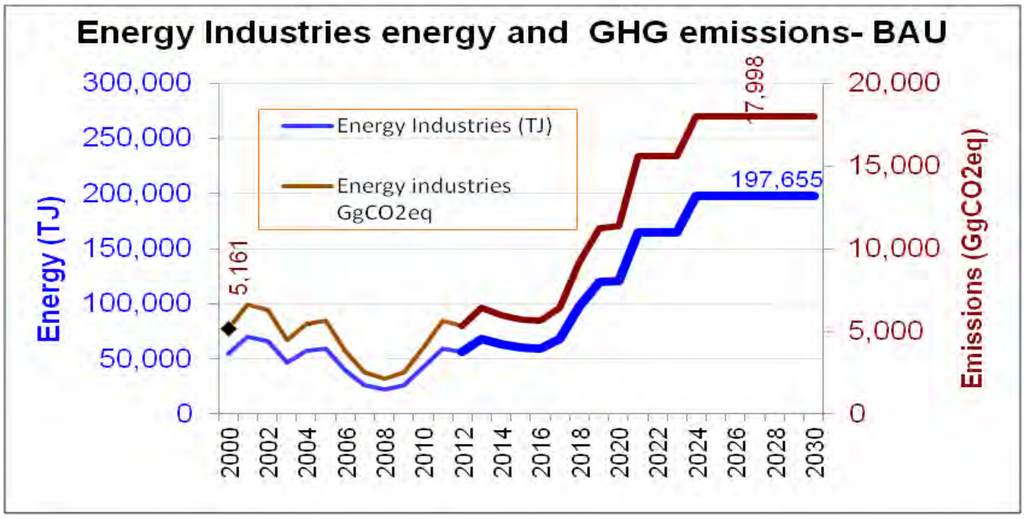

Fig 4.7 Historical and projected energy and emissions by the energy industries

There are various ways of reducing GHG emissions in the energy Industries sector. The low-cost measures include improved maintenance of equipment and infrastructure while the capital cost measures involves technology change or fuel substitution. The thermal power plants have passed their designed operational periods. They are also far away from the coal mines so much that transportation of coal consumes a lot of energy, in the process emitting a lot of GHGs from diesel combustion in engines. Replacing the three small thermal power plants with proposed hydro power plants (such as the Batoka-800MW) will have economic, social and environmental benefits (Figure 4.9).

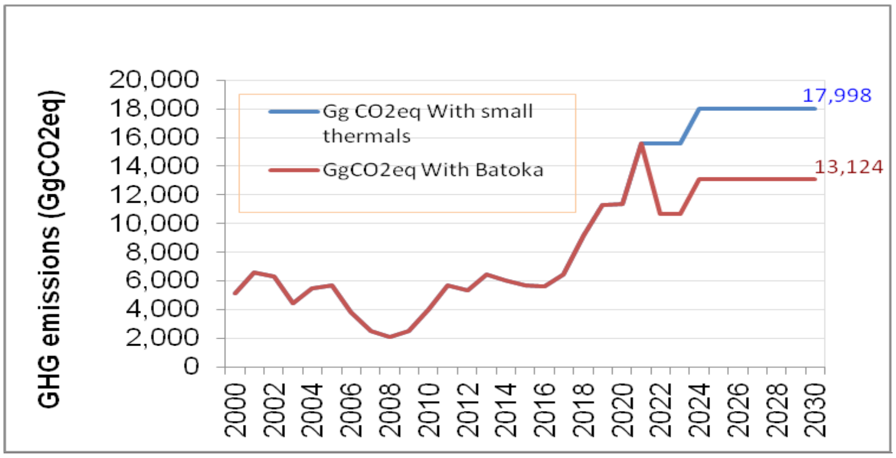

Fig 4.8 GHG emissions with and without mitigation (small thermal plants and Batoka plant)

Zimbabwe needs to adapt to the challenge of water shortages at Kariba dam by utilising, inland dams and the run-off rivers schemes to generate electricity. The proposed Batoka and Devil's Gorge (620MW) hydropower plants are viable alternatives for generating hydropower. These plants would complement the Kariba Power Station together with other existing mini-hydropower plants. However, all mini-hydro power plants are affected by seasonal variations in stream flow resulting in reduction of energy generated (Figure 4.9).

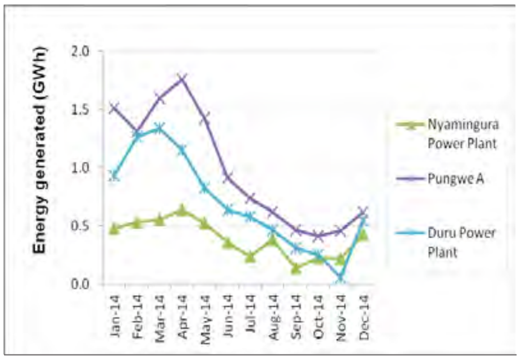

Fig 4.9 Graphs showing negative effects of water shortages on mini-hydro power plants

4.2.3 Other Mitigation Projects

4.2.3.1 Ethanol blending project

Estimates show that the consumption of ethanol blend (E10) is around 4% more than that of unblended petrol. The mandatory blending of gasoline with ethanol will reduce emission from fuel usage in the transport sector. The benefits also include reduced import bill and substitution of fossil fuel. The magnitude of the economic benefit to the consumer depends on the price of the blended fuel. Biodiesel will significantly reduce vehicular emissions. The Biofuels, Renewable, Transport and Climate policies which are being crafted are expected to address several barriers encountered in the area of biofuels.

4.2.3.2 Energy efficiency project

Energy efficiency and demand management are the easiest, quickest and cheapest way of boosting supply. The National Energy Efficiency Audit was concluded in 2015. The Audit estimated a potential saving of 2130 GWh from all sectors of the economy.

4.3.3.3 Rail electrification project

Road transport (diesel and petrol) is responsible for most of the transport sector GHG emissions. The use of road trucks to move heavy goods results in high GHG emissions, high product costs, high road maintenance costs, traffic congestion and increased rates of accidents. The use of electrified trains will help alleviate the above-mentioned challenges. In estimating the GHG emissions reduction the following two issues were considered:

The replacement of the small thermal plants with a hydro power plant will reduce the amount of related GHG emissions. An estimated 75% of the diesel will be saved.

Refurbishment of rail infrastructure and electrification will then save part of the remaining 25% of the diesel.

4.3.3.4 Installation of solar water heaters project

Water heating is responsible for about 30 to 40% of the electricity consumption in the domestic sector. Replacing part or all of the electricity that is used by electric geysers will result in reduced load-shedding and disruption of production, reduced power imports, reduced bills and GHG emissions. However, there are challenges that need to be addressed. These include:

- Unreliable water supply tends to make the solar geyser unusable. Intermittent water supplies cause corrosion of pipes and fittings.
- Use of conventional electricity meters, which is however, being phased out.
- Limited financing mechanism such as rebates for the project.
- Low awareness on the benefits of renewable energy technologies including solar water heaters.

In summary, with four mitigation measures (Batoka, National Energy Efficiency, Petrol blending with ethanol, and rail electrification) the emission intensity in 2030 is 5% below base-year intensity and 7% below BAU intensity. The larger the potential of mitigation options the larger the decrease of emissions and emissions intensity (Figure 4.10 and Figure 4.11). The amount of emissions ranged from 0.087 to 0.092 Gg per TJ of energy during the period 2000-2012 and 0.090 $GgCO_2eq$ / TJ is a baseline intensity which can be used to measure mitigation performance for the period 2013-2030. This baseline was calculated using the emissions shown in Figure 4.11and the anticipated energy mix for the same period. Some of the mitigation measures are ethanol blending, installation of solar water heaters (SWHs) and energy efficiency (EE) improvement.

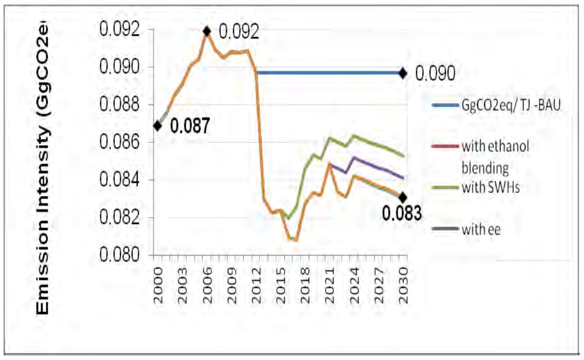

Fig 4.10 Mitigation measures and emissions intensity

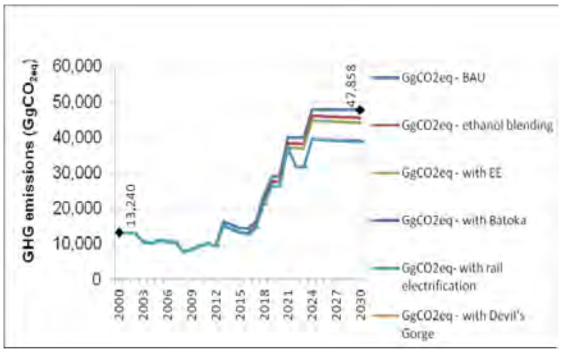

Fig 4.11 Mitigation measures and potential emissions reductions

4.2.4 Monitoring

Accurate data must be collected timeously, processed and analysed for a monitoring system to work. The major sources of data are the national statistics office (ZimStat), ZETDC, ZPC, REA, Ministry of Mines and Mining Development, Ministry of Environment, Water and Climate and the Ministry of Energy and Power Development. Therefore, there is need for strengthening the Energy Information System and the capacity of ZimStat.

4.2.5 Barriers to Mitigation

Several barriers to the proposed mitigation measures were identified and these include:

- Obsolete and inefficient equipment
- Lack of skilled maintenance personnel
- Lack of technical expertise on certain technologies such as harmonics, power factor correction, demand management, steam generation and distribution, compressed air systems, landfill gas capture
- Lack of appropriate measuring/ data capturing equipment
- Lack of willingness to share information especially by the private sector
- Some organisations do not record energy or climate-related data.
- Limited financial resources to buy climate –related equipment
- Inefficient public transport system
- Heavy reliance on imported technologies
- Importation of second-hand equipment including vehicles
- High propensity for bigger things, especially vehicles

4.2.6 Conclusion

Climate change adaptation alone will not be enough for Zimbabwe. There is need to integrate resource efficiency in both the industrial and domestic sectors. The country can exploit the high potential for hydro-power which currently exists. However, a number of challenges need to be addressed for the country to reach its full mitigation potential.

4.3 Industrial Processes, Solvents and Other Product Use

4.3.1 Mitigation Assessments, Programs and Measures

Mitigation measures in the IPPU sector focused on the following subsectors; mineral production (cement, lime, glass and other uses of soda ash); chemical production (nitric acid manufacture); metal production (iron and steel, ferroalloy and lead) and other production (food and beverages). A summary of the GHG emissions from the initial communication, recalculated figures for the second national communication and the current one is shown in Table 4.3.

Table 4.3 GHG sources and emission levels in Zimbabwe

Source category	Inventory Year		
	1994	2000	2006
Industrial processes	------------- Gg CO_2eq -------------		
Mineral production,	472.35	1369.20	280.74
Chemical manufacture	1923.35	117.00	240.19
Metal production	1859.74	487.50	378.96
Others			
Food and beverages	*NE	6.23	6.20
Solvents and Other Product Use			
Lubricant and paraffin wax use	NE	NE	11.18

*NE = not estimated

Projections of GHG emissions under the baseline 'business-as-usual' case were made up to 2020 and similar projections were done to assess the total effect of policies and measures to mitigate climate change for the same period as the baseline scenario. There was no coverage of mitigation actions implemented for these sectors in the previous national communications.

4.3.2 Policies, programs and measures to mitigate climate change

Zimbabwe has developed and implemented a number of environmental and other policies to support mitigation efforts that guard against environmental degradation. Most of the policies are broad and are not specifically focused on addressing climate change mitigation. However, the recently published National Climate Change Response Strategy (NCCRS) (GoZ, 2015) has a number of specific mitigation options for different sectors. The NCCRS has some specific mitigation strategies for industry which include:

- Creation of a policy and regulatory framework that promotes resource use efficiency and cleaner production (RECP) in industry and commerce.
- Developing an enabling policy and legal framework that encourages the setting up and operation of climate resilient industries.
- Developing regulatory frameworks to encourage emission reduction and investment in resource efficient technologies.
- Enforcement and monitoring the implementation of mandatory and voluntary environmental management systems.
- Supporting research and development of technologies to mitigate climate change.

The strategies are expected to be implemented over a period of 10 years with a review of progress after every 5 years. Financial resources to implement the strategies are expected from Government treasury; the private sector, Green Climate Fund; bilateral donor and international agencies support; mitigation financing including Clean Development Mechanism (CDM); international, regional and local banks.

The country is finalizing its National Climate Policy in which policy statements regarding mitigation and low carbon development pathways for industry are highlighted. This is envisaged to help Zimbabwe to develop in an environmentally sustainable way.

The National Environmental Policy and Strategies was developed to promote the adoption of low carbon development pathways, greening industry regulations, voluntary greening initiatives, and environmentally sustainable lifestyles among other considerations (GoZ, 2009).

The main regulation on environmental issues is the Environmental Management Act [Chapter 20:27] of 2002. The Act is supported by the following regulations:

- Environmental Management (Atmospheric Pollution Control) Regulations, 2009 (Statutory Instrument (SI) 72 of 2009)
- Environmental Management (Environmental Impact Assessment and Ecosystems Protection) Regulations, 2007 (SI 7 of 2007).
- Environmental Management (Effluent and Solid Waste Disposal) Regulations, 2007 (SI 6 of 2007).

These regulations ensure that economic activities do not cause harm to the environment by releasing GHG and other gases beyond the prescribed limits. Thus, there is a need to come up with regulations that address emissions arising from industrial processes, solvents and other product use.

Other policies and strategies that are relevant to national climate change mitigation response efforts include: Industrial Development Policy (2012-2016); Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset) (2013 – 2018);

The Industrial Development Policy's 2012-2016 aims to transform Zimbabwe's industry from a producer of primary goods into a producer of processed value-added goods. Some of the objectives include re-tooling and replacement of obsolete machinery and adoption of new technologies.

Other programs that the Government of Zimbabwe implemented but were not reported in the previous communications include the establishment of the Zimbabwe National Cleaner Production Centre (ZNCPC) which is housed under the Scientific and Industrial Research and Development Centre (SIRDC). The mandate of the ZNCPC is to assist industry implement Resource Efficient and Cleaner Production (RECP).

In 2013, Zimbabwe launched the Zimbabwe Green Industry Initiative (GII) which focused on the two components of the green industry, that is, greening of existing industries and establishment of new green industries or technologies. The GII is a Public-Private Partnership between the Business Council for Sustainable Development Zimbabwe (BCSDZ) and Government of Zimbabwe with technical support from the United Nations Industrial Development Organisation (UNIDO). The programme aims at greening of existing industries through resource efficiency; pollution prevention and safe chemicals management through adoption of competitive technologies and production systems.

4.3.2.1 Projections of the total effect of policies and measures to mitigate climate change

The baseline scenario for industrial processes, solvents and other product use

GHG emission projections scenarios are expected to increase under Industrial Processes, Solvents and Other Product Use (IPPU) in the baseline 'without measures' (Figure 2.4-1). The Long-Range Energy Alternative Planning (LEAP) software was used to project future GHG emissions. The projections were based on annual GDP growth rate projected under Zim Asset of 1.5% (2013), 3.2% (2014), 6.5% (2015), 7.5% (2016), 8.4% (2017) and 9.5% (2018) and the figure for industrial growth rate for 2018 was maintained for the years 2019 and 2020. Under the baseline scenario (business as usual), GHG emissions are expected to increase as the country embarks on revamping its industry and opening up of new industries in line with Zim Asset (2013-2018) and the Industrial Development Policy (2012-2016). Increased construction programs will result in a corresponding increase in the manufacture of cement, glass and solvents e.g. paints which will also cause an increase in CO_2 emissions. Expected growth in crop production will result in more chemical (nitric acid) production for the manufacture of fertiliser hence a rise in nitrous oxide emissions. In the baseline scenario, the mitigation measures that have already started being implemented and are on-going are RECP in cement production e.g. clinker substitution.

The mitigation ('with measures' and with additional measures') scenario

A summary of the mitigation options to reduce GHG emissions from Industrial Processes, Solvents and Other Product Use are highlighted in Table 4.4.

Table 4.4 Mitigation actions for industrial processes, solvents and other product use

Sub sector	Potential Mitigation Action	Concept	Status of Implementation
Chemical (Nitric acid)	N_2O emission reduction (Installation of catalyst to decompose nitrous oxide)	CDM project (RECP/GI (Pollution prevention & waste reduction)	Approved
Mineral production (Cement)	CO_2 emission reduction (change in clinker content)	RECP (Raw material substitution)	Implemented & on-going
	CO_2 emission reduction (Process improvement through use of blast furnace slag & fly ash as mixed additives)	RECP (Process improvement)	Implemented & on-going
Metal	CO_2 emission reduction (Process improvement, replacement of obsolete equipment	RECP/ LM/ GI	Proposal
Food & Beverages	NMVOC emission reduction (Process improvement – industrial efficiency)	RECP/ LM/ GI	Proposal
Solvents & Other Product Use	CO_2 emission reduction (Industrial efficiency)	RECP/ LM/ GI	Proposal

The reduction potentials offered by the mitigation options in comparison to the baseline scenario for the mineral, chemical, metal, food and beverages, solvents and other product use sub sectors is shown in Figure 4.12 and Figure 4.16.

A reduction in CO_2 emissions of around 428 Gg CO_2eq is projected in 2020 with continued substitution of clinker with other materials (Figure 4.12).

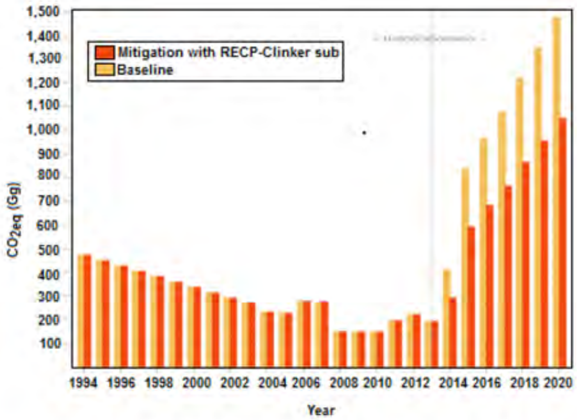

Fig 4 .12 Comparison of the baseline with the mitigation scenario for clinker substitution in cement manufacture

Installation of a catalyst to decompose N_2O will result in a decrease in nitrous oxide emissions of 160Gg CO_2eq annually from 2016 to 2020 as shown in Figure 4.13.

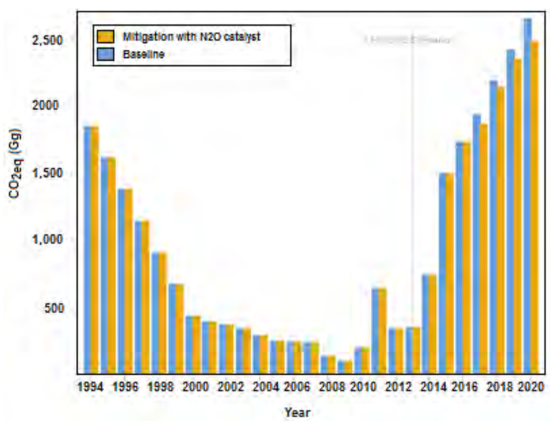

Fig 4.13 Comparison of the baseline with the mitigation scenario for N_2O decomposition in nitric acid manufacture

About 381Gg CO_2eq of carbon dioxide emissions will be reduced from metal production (especially iron and steel production) by implementing lean manufacturing, green industry or RECP (Figure 4.14).

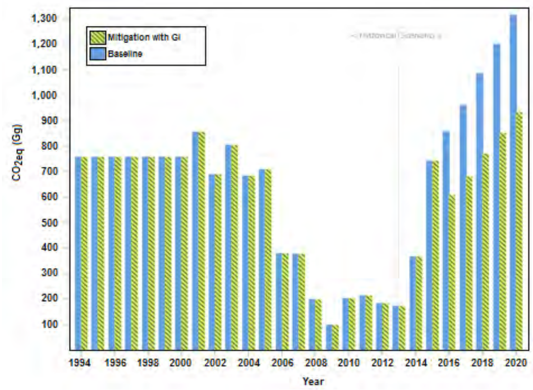

Fig 4.14 Comparison of the baseline GHG emissions with the mitigation scenario of either GI or LM in metal production

Carbon dioxide emissions from solvents and other product use are projected to decrease by about 30Gg CO_2eq in 2020 if either the lean manufacturing, RECP or green industry is implemented as early as 2016 (Figure 4.15).

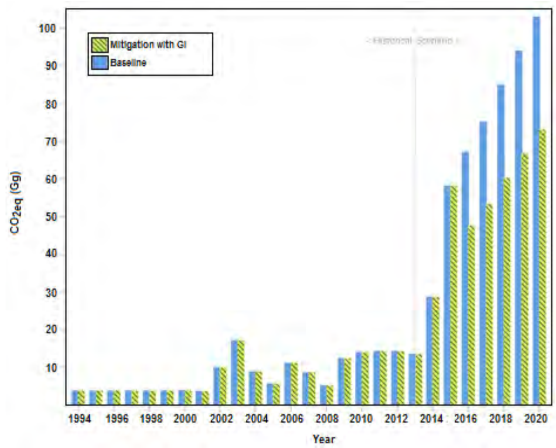

Fig 4.15 Comparison of the baseline with the mitigation scenario of either GI or LM in solvent and other product use

A reduction potential in NMVOC emissions of about 11Gg is projected if lean manufacturing, RECP or green industry is implemented in the food and beverages sub sector as shown in Figure 4.16.

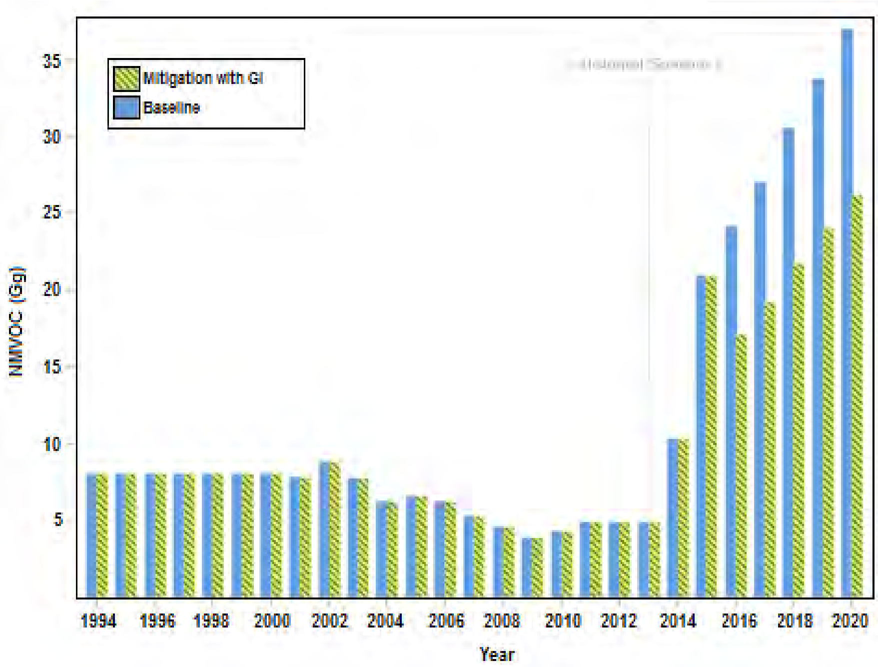

Fig 4.16 Comparison of the baseline GHG emissions with the mitigation scenario of either GI or LM in food and beverages manufacture

Although there are expected reductions in GHG emissions from implementing the proposed mitigation actions, the major limiting factor remains funding. In order to implement mitigation options for climate change in industry and commerce an estimated $528 million is required (GoZ, 2015).

4.3.3 Conclusion

Despite the economic challenges that Zimbabwe as a developing country faces, efforts are continuously being made to ensure GHG emissions from industrial processes are reduced. With the prioritization of such technologies as lean manufacturing, green industry, resource efficiency and cleaner production across many industrial sectors, it is expected that the GHG emissions arising from industrial processes will be reduced significantly as was highlighted in this section. However, the process will be long for Zimbabwe industries to reach their full mitigation potential due to financial constraints involved in the implementation of the mitigation actions and the continued use of old machinery and equipment.

4.4 Agriculture

4.4.1 Introduction

In Zimbabwe, agriculture occupies a central role and contributes between 10 and 15% of GDP, over 40% of national exports, 60% of raw materials to agro-industries, and provides livelihood to over 70% of the population as well as employment for about one-third in the formal labour force. Table 4.5provides a summary of GHG emissions from these categories giving a total of 9,686.38 Gg CO_2eq from the sector. Methane is the major gas emitted from all the sources considered in this study followed by nitrous oxide.

Table 4.5 Summary of GHG Emissions for Zimbabwe/2006 (Gg)

GHG SOURCE AND SINK CATEGORIES	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)
4. Agriculture	213.90	14.56	1,036.50	61.27
A. Enteric fermentation	170.29			
B. Manure management	7.06	0.22		
C. Rice cultivation	0.04			
D. Agricultural soils	NE	11.06		
E. Prescribed burning of savannahs	35.68	3.26	1,008.3	60.50
F. Field burning of agricultural residues	0.83	0.02	28.2	0.77

Mitigation of GHGs in the agriculture sector was based on the current and previous GHG inventories carried out for the following sub-sectors: enteric fermentation, prescribed burning, manure management, rice cultivation and burning of crop residues.

A comparison of the baseline inventory and previous inventories show that in 1993 the total methane emissions were 166.066 Gg while in 2000 they increased to 216.961 Gg. The figure then decreased to 213.90Gg in 2006. For Nitrogen Oxide, in 1993 the total emissions were 16.137Gg while in 2000 they decreased to 13.308Gg before increasing to 14.56Gg in the base year of 2006 (Table 4.6).

Table 4.6 GHG emissions in 1993, 2000 and 2006

Source category	Inventory Year					
	1993		2000		2006	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Enteric fermentation, Gg	155.68	0.153	205.44	0.045	170.29	NE
Manure management, Gg	NE	5.846	7.834	0.198	7.06	0.22
Rice cultivation, Gg	0.009	NE	0.025	NE	0.04	NE
Agricultural soils, Gg	NE	10.125	NE	13.04	NE	11.06
Prescribed burning of savannahs, Gg	3.858	NE	2.683	NE	35.68	3.26
Field burning of agricultural residues, Gg	0.519	0.013	0.979	0.025	0.83	0.02
Total, Gg	160.066	16.137	216.961	13.308	213.90	14.56
Total as CO_2e					9,686.38	

In this mitigation report, activities that can be undertaken to mitigate GHG emission in the agricultural sector per sub category are given.

Figure 4.17 shows the trends in methane emission from both enteric fermentation (right panel) and manure management (left panel). The projections for methane emission from enteric fermentation for 2013 based on the base year of 2006 shows that there will be marginal increase in methane emission by 2013 under the business as usual scenario. The increase will not be significant based on the stability in emissions between 2002 and 2010 resulting from the changes in the livestock sector.

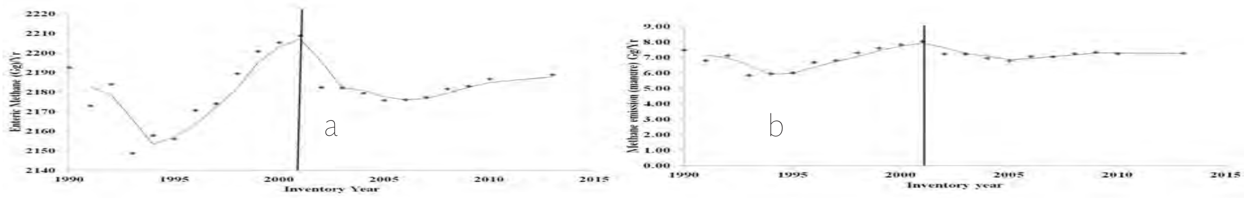

Fig 4.17 Methane Emission from Manure Management (a) and from Enteric fermentation (b)

Emissions from manure management are also projected to remain stable up to 2013 based on the changes in livestock production that occurred from 2000. In this regard the figures are not likely to be different from the ones recorded between 2002 and 2010.

The emissions from Savanna burning are predicted to double by 2020 due to changes in land tenure (Figure 4.18).

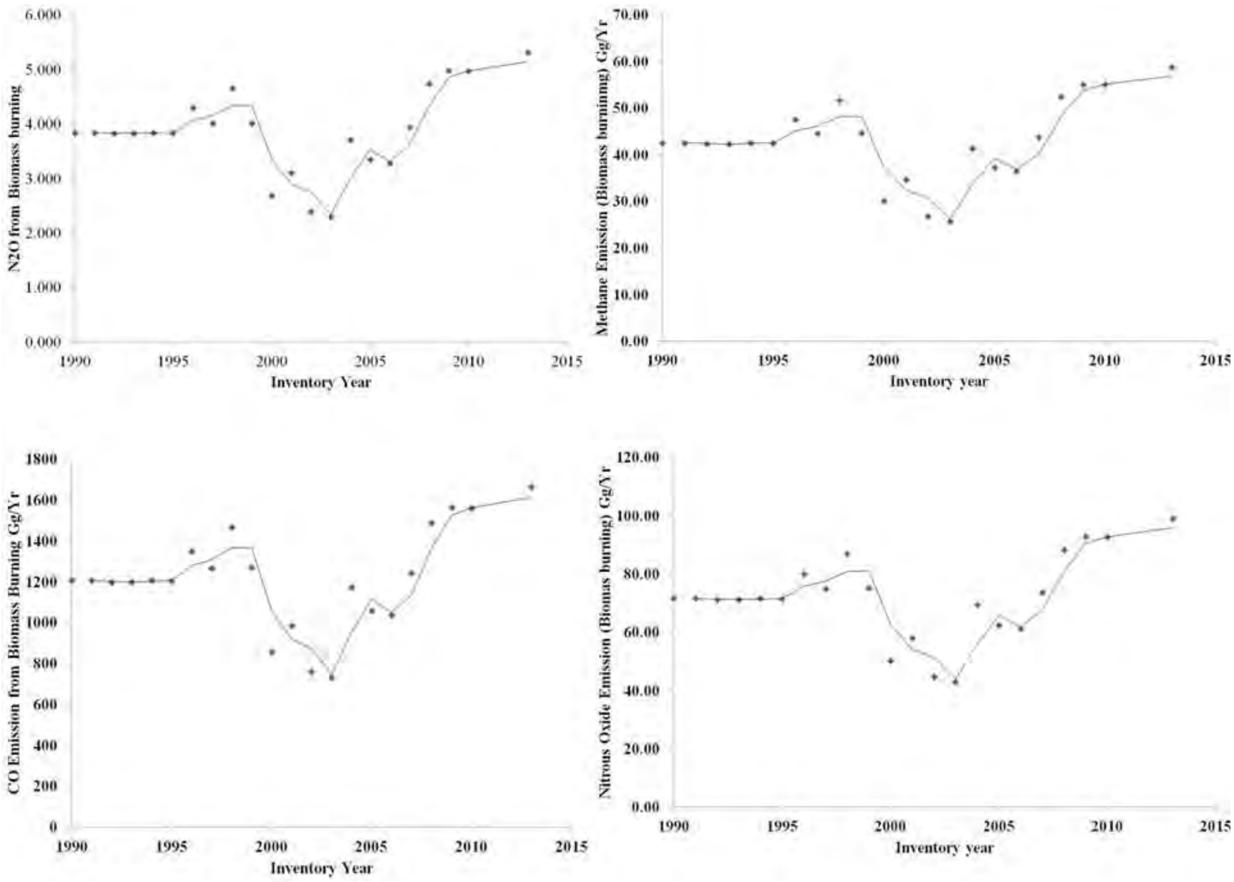

Fig 4.18 Emissions from Prescribed Biomass burning in the Savanna

Figure 4.19 shows the trends in emission from agricultural soils. The agricultural soil emissions of GHGs are predicted to steadily increase under BAU scenario. However, in 2020 the emissions are not likely to exceed those in the period between 1998 and 2000.

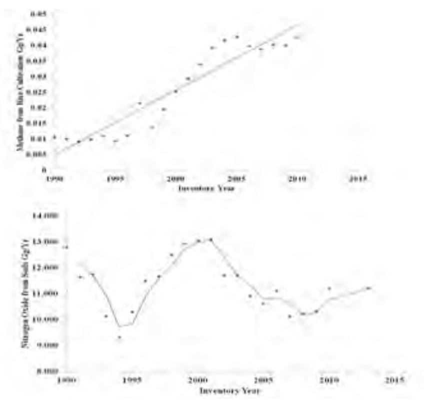

Fig 4.19 Emission from Agricultural Soils

Opportunities for mitigating GHGs in agriculture fall into three broad categories based on the underlying mechanism that is, reducing emissions, enhancing removals and avoiding emissions.

4.4.2 Reducing emissions

CH_4 and N_2O emissions from agriculture can be significantly reduced by more efficiently managing the flows of carbon and nitrogen in agricultural ecosystems e.g., practices that deliver added N more efficiently to crops often suppress the emission of N_2O (GIZ, 2014).

Enhancing removals

Agricultural ecosystems hold large reserves of carbon (IPCC 2001), mostly in soil organic matter. GHGs can be removed from the atmosphere by practices that increase the photosynthetic input of carbon or slows the return of stored carbon by sequestering carbon or building carbon sinks (Smith et al. 2008, GIZ 2014).

Avoiding (or displacing) emissions

Crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to fuels such as ethanol or diesel. Emissions of GHGs, notably CO_2, can also be avoided by agricultural management practices that forestall the cultivation of new lands now under forest, grassland or other non-agricultural vegetation.

4.4.3 GHG Mitigation per category source and sink

4.4.3.1 Enteric Fermentation

Proposed measures for reducing CH_4 emissions from enteric fermentation include improved feeding practices and management changes and animal breeding. Methane emissions can be reduced by using more concentrates feed, and replacing forages. Other practices include improving pasture quality which in turn improves animal productivity and reduces CH_4 emissions. Increasing productivity through breeding and better management practices spreads the energy cost of maintenance across a greater feed intake, often reducing methane output per kilogram of animal product. With improved efficiency, meat-producing animals reach slaughter weight at a younger age, with reduced lifetime emissions. Another option is the adoption of agroforestry. Agroforestry is the production of livestock or food crops on land that also grows trees, either for timber, firewood or other tree products.

4.4.3.2 Emissions from manure management

To mitigate the emission of methane from manure management, the manure can be digested anaerobically to maximize retrieval of CH_4 as an energy source. The country is promoting the use of biogas as a renewable energy option that will suppress CH_4 emissions, although it may increase N_2O formation.

4.4.3.3 Rice Cultivation

The mitigation options in this category include using cultivars with low methane exudation rates, adjusting timing of residue incorporation and/or composting prior to incorporation and producing biochar from rice straw and husk to avoid GHG during decomposition.

4.4.3.4 Agricultural Soils

To reduce GHGs from agricultural soils, conservation agriculture is being promoted to maximize labour and fuel/energy use and conserve moisture. The adoption of Conservation Agriculture (CA) is part of Climate Smart Agriculture strategies of reducing GHG emissions. Conservation agriculture reduces the use of compound fertilizers in favour of organic farm-made manure. The effectiveness of CA to mitigate GHGs emissions can be enhanced through the provision of targeted extension capacity development to support CA as identified in the SNC. This can be done through formalising AGRITEX /NGO partnerships at district level to support scaling up of CA and consolidate the mainstreaming of CA in policies and programmes of government, donors and NGO's to realize the long term benefits of CA. Plans are underway to mechanize the CA.

4.4.3.5 Prescribed Burning of Savannas

Zimbabwe relies on law enforcement and suppression as well as holistic community-based approach to fire management. The Environmental Management Agency is mandated under the Environmental Management Act Chapter 20:27 to monitor the occurrence of fire in the country and to carry out community education programmes aimed at reducing the frequency of fire. The emission of gases from burning can also be kept at a minimum through reducing the fuel load by vegetation management; and burning at a time of the year when less CH_4 and N_2O are emitted.

4.4.3.6 Field Burning of Agricultural Residue

One viable option is the conversion of the crop residues into bioenergy.

Policy Dimensions of Mitigation in the Agricultural Sector

In Zimbabwe, national development strategies include the Zimbabwe Comprehensive Agriculture Policy (2012-2032); Food and Nutrition Security Policy (2012), the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (2013 - 2018) and Zimbabwe's National Climate Change Response Strategy. Some of the Zim Asset specific areas of intervention for agriculture identified in Zimbabwe Agricultural Investment Plan (2013) include:

- Targeted mitigation interventions on specific products such as cereals, tobacco, cotton, horticulture and livestock;
- Targeted mitigation interventions in irrigation, mechanisation, research, extension, education and training, financing, inputs supply management, as well as marketing and trade.
- Implementation of national programmes and projects namely Completion and Rationalisation of the Land Reform Programme, Irrigation Rehabilitation, Expansion and Development Programme as well as Strengthening National Agricultural Research, Extension and Training Systems.

In addition to Zim Asset, there are several programmes, projects and investments that have both adaptation and mitigation components. These initiatives include;

- FAO, Agritex and Famine Early Warning Systems Network (FEWSNET) programme on Agricultural and Food Security Monitoring Systems (AFSMS)- crop harvest forecasts;
- Food Assistance Working Group (FAWG) initiatives;
- Livestock Working Group (LWG) initiatives;
- Market Linkage Working Group (MLWG);
- Africa Union-NEPAD Agriculture-Climate Change Adaptation-Mitigation Framework;
- Practical Action Project on mainstreaming Climate Change Adaptation in Zimbabwe's Agricultural Extension System;
- Oxfam climate change project; and
- FAO climate smart agriculture projects e.g., conservation agriculture; UNDP coping with drought project

4.4.4 Barriers to GHG Mitigation in the Agriculture Sector

Key considerations in agriculture mitigation should include addressing farmer's priority concerns, equity considerations and addressing the diversity among farmers as these are important barriers to mitigation. Under addressing farmer's concerns, for most farmers in Zimbabwe, mitigation of GHG and its contribution to climate change is not their primary concern. Most farmers are concerned with food security, income or profitability. There is therefore need to ensure that mitigation of

GHG have synergies with these objectives. Those agricultural mitigation plans that directly help farmers to address their primary concerns have a higher chance of success than those which are independent of the farmer's concerns. In this regard, there is need to involve farmers and farmer organizations in the planning process to help align mitigation planning with farmers' priority concerns.

In addition, there is also need to take equity considerations into account. In Zimbabwe, just like in most developing countries, there is growing concern about promoting agricultural modernization. This often includes the commercialization of agriculture as a means of increasing the sector's contribution to economic growth, rural employment and income generation. In such situations, the adoption of mitigation practices is more feasible for large-scale, commercial operations. This raises concerns about the distributional impacts of schemes to provide subsidies and incentives to support GHG mitigation.

Lastly there is need to address the diversity of interests among farmers. The interests of most farmers in particular practices and their potential to adopt them may depend on their existing endowments of resources and other attributes which vary greatly among farmers. The mitigation policies and measures should aim to target specific characteristics of individual farmers (e.g. wealth levels, gender, ethnicity, age) which may limit their ability to adopt and benefit from the promoted practices. If mitigation plans are poorly designed or implemented they may even increase inequality of opportunity and outcomes among farmers.

One of the key challenges in mitigation in the agriculture sector is the rapid changes in management practices in the sector, unlike some other economic sectors. These changes are influenced by many factors other than policies and investments. There is need to understand barriers to adoption of mitigation practices by farmers, and designing policies and measures to effectively address these barriers are critical elements in the design of feasible and effective mitigation actions in the agriculture sector. The agricultural practices that can mitigate GHG emissions in the agriculture sector in most countries including Zimbabwe are widely known. Yet there are several reasons why farmers have not adopted these practices. The policies and measures to promote mitigation practices should address the specific barriers to adoption faced by farmers in the targeted subsector. This would allow for a more realistic assessment of the costs of mitigation programmes, potential adoption rates and their GHG mitigation potential. Most barriers to adoption of mitigation practices are not specific to GHG mitigation, but are also present when the practices are promoted for other agricultural development objectives. On the one hand, the presence of these barriers is indicative of the potential challenges to achieving GHG mitigation in the agriculture sector; on the other hand, they may serve to justify leveraging climate finance as a means to overcome them.

There are several strategies that can be adopted to overcome barriers to mitigation. In general, technical measures to mitigate GHG emissions are selected from the list of options drawn by experts and suggested by stakeholders in consultation processes. In most mitigation planning processes, the options are screened according to various agreed criteria, including: feasibility, consistency with national or sectoral development plans; mitigation potential; cost-effectiveness; feasibility of GHG measurement; and synergies with adaptation to climate change. To date, most agricultural mitigation plans have focused on identifying technical measures for support. The effectiveness of alternative policies and measures to support their adoption has received less attention, but can be expected to become the focus of subsequent planning phases. Zimbabwe should aim to develop NAMAs specifically for the country. NAMAs, focus on strengthening policies and institutions (e.g., extension agencies) as a pre-condition for effective support to adoption of specific agronomic measures by farmers.

The analysis of the relationship between the specific financing needs in the agriculture sector and suitable forms of financial or policy support is another aspect of identifying mitigation policies and measures that have been outlined during planning. For example, on the basis of cost-benefit analysis, agricultural options identified in Ethiopia's Green Economy Strategy were categorized into three types: options with a positive net present value (NPV) in the first five years that require short-term financing; options with a positive NPV over 20 years, but not in the first 5 years that require long-term financings; and options with a negative NPV over 20 years that require grant financing or performance-based payments based on GHG mitigation to increase the option's financial attractiveness. All options in the livestock sector were identified as requiring grant financing or performance-based payments. Around 40% of cropland management options were estimated to have positive returns within five years. An analysis of financial payback periods may indicate the need for long-term financing mechanisms.

4.4.5 Conclusion

Mitigation of GHG emissions from Zimbabwe's agriculture sector should be targeted at reducing CH_4 production in non-dairy cattle, N_2O emission in agricultural soils Prescribed burning of Savanna rangelands reduce their capacity to regrow (carbon assimilation) to compensate carbon losses in grazed and burned biomass. In future, the ability of pasture to compensate primary production of biomass in response to anthropogenic carbon losses will be compromised due to increased rainfall variability in Zimbabwean savanna rangelands.

Since more than 90 % of non-dairy cattle (beef and dual purpose cattle) in Zimbabwe are under small scale farmers, good management practices aimed at reducing CH_4 and CO emissions from non-dairy cattle and prescribed burning of savannas, respectively need to be holistic since cattle rely on rangelands throughout the year. Good grazing management practices and feeding practices e.g., optimized grazing and supplementation of cattle on low quality diets improves utilisation of feed nutrients, thus reducing enteric CH_4 emissions. Improved grazing management and pasture quality increases production and leads to an increase of soil carbon stocks. In addition, implementation of mitigation actions for carbon sequestration often lead to increased production and greater economic returns by reducing feed costs. Restoration of grazing infrastructure such as fencing of rangelands in resettlement areas of Zimbabwe presents an opportunity for controlling and optimising grazing and pasture quality. Awareness, training and extension support is required to promote buy-in of good management practices of grasslands including prescribed burning, and on-farm by-products.

4.5 Land Use Land Use-Change and Forestry

4.5.1 Introduction

Articles 4.1 and 12.1 of the Convention commits Parties to develop national, and where appropriate, regional programmes and measures that will result in the reduction of human-induced greenhouse gas emissions. Such measures can either reduce the increase in greenhouse emissions (abatements) or increase terrestrial storage of carbon (sequestration). Zimbabwe's greatest potential lies in the latter. In this sector, the discussion shall focus on the country's forest cover and modelling projections shall define the different options that face the country in terms of mitigation in the forestry sector. In the Second National Communication little mention was made of the mitigation potential in LULUCF.

4.5.2 Baseline forest cover and GHG emissions projections

Forest cover is expected to decrease from 17.54 million hectares to 6.18million hectares by 2030 based on an average deforestation rate of 312,900 hectares per annum representing 35.3% reduction over a period of 25 years. The Comprehensive Mitigation Assessment Process (COMAP) was used to estimate the product and supply demand during the target period as shown in Table 4.7.

Table 4.7 Historic and Projected Product supply and demand of forest resources ('000' tonnes).

	2005	2025	2045
Supply	19,042	19,752	16,095
Demand	6,285	11,873	13,329

In view of Zimbabwe's abundant forest cover, current demand is still within supply levels although this supply cannot be infinite. Given on Table 4.1-2 are land use change and forestry (LULUCF) emissions projections.

4.5.3 Methodology

The COMAP approach was used to find the least expensive way of providing forest products and services while reducing the most amount of carbon emitted from the land use sector. The approach consists of the following key steps:

- Identification and categorization of the mitigation options appropriate for carbon sequestration.
- Assessment of the current and future land area available for these mitigation options
- Assessment of the current and future wood-product demand.
- Determination of the land area and wood production scenarios by mitigation option
- Estimation of the carbon sequestration per unit area for major available land classes, by mitigation option.
- Estimation of the unit costs and benefits.valuation of cost-effectiveness indicators
- Development of future carbon sequestration and cost scenarios.
- Exploration of the policies, institutional arrangements and incentives necessary for the implementation of options.

Alternative combinations of future land use and wood product demand patterns lead to different scenarios of the future. The baseline scenario was based on forestry data obtained from FAO and Timber Producers Federation (TPF). The mitigation options were then matched with the types of future wood-products that will be demanded and with the type of land that will be available. Based on this information, the potential for carbon sequestration and the costs and benefits per hectare of each mitigation option were determined. The carbon and, cost and benefit information was used to establish the cost-effectiveness of each option, which yields its ranking among other options. In addition, the information, in combination with land use scenarios, was used to estimate the total and average cost of carbon sequestration or emission reduction.

4.5.4 Main Types of Mitigation Options in Forestry

Mitigation options may be classified into three basic types. One option is to expand vegetation stocks and the pool of carbon in wood products. Expansion of stocks will capture carbon from the atmosphere and maintain it on land over decades. The second option is to maintain the existing stands of trees and the proportion of forest products currently in use. Maintenance of existing stands, whether achieved through reduced deforestation, forest protection, prolonged useful lifetime of products or through improved cook stoves, lengthens the duration the carbon stays trapped in terrestrial ecosystems and provides immediate carbon benefit. A third avenue to reduce carbon emissions is to substitute wood derived from renewable sources, e.g., plantations, for more GHG intensive products, particularly fossil fuels. Fossil fuel substitution with biomass derived from sustainably managed renewable sources delays the release of carbon from substituted fossil fuel indefinitely and may increase the standing stock of carbon on land if the biomass is from newly afforested/reforested areas.

4.5.5 Land Use and Wood-Product Demand

The technical availability of land for the implementation of response options does not appear to be an important constraint to carbon sequestration. Whether technically available lands are ever used for biomass growth depends on economic, political, demographic, social, cultural, and other factors. Based on interviews with experts, they reported that it was socio-economically feasible to utilize about 69% of the technically available land.

4.5.5.1 Scenarios

The scenarios of land use and wood products demand depict the amount of wood that would be demanded as well as the land area that could be consequently sequestering carbon over time. The amount of sequestered carbon that can be potentially stored and the associated cost varies with the types of options that are included in the scenarios.

In order to specify a baseline scenario extrapolation of current trends of land use, tree planting and forest protection as well as consumption of forest products and services was used. A recommended method in this approach was to use end-use scenarios, which are mainly driven by the projections of the demand for wood products and for land in the country. End-use scenarios have the advantage that they take into consideration an end-user's needs for forest products and land. Thus, forestry mitigation options that provide multiple and adequate benefits, including carbon storage, to a diverse set of beneficiaries are more likely to be implemented and managed sustainably. This approach aligns it-self with the nation's ZimAsset program which seeks to improve livelihoods through multiple benefits in a sustainable manner.

4.5.5.2 Mitigation analysis

Biomass Demand and Supply (BIOMASS Module)

One of the main roles of the forestry sector is to meet the current and projected biomass demands (fuel wood, industrial wood, sawn wood, etc.). These demands can be supplemented by imports when necessary. Such demand on biomass should not exceed the rate of growth; neither should there be a decline in the size of the forest estate (deforestation) or degradation of the biomass density which becomes evident. In most cases some of the mitigation options cannot be implemented, without arrangements for meeting biomass demands, including imports to cover biomass deficits.

Given the population increase and declining land productivity as a result of climate change impacts, more and more forest land is being converted to agricultural land for food production and other farm output. Furthermore, forestland is also converted to infrastructure and human settlements. Thus it is necessary to analyze the current and projected changes in land use patterns and the resulting changes in biomass supply. This has to be followed by assessing the impact of the proposed mitigation option on biomass supply, with a goal to match it with the demand on biomass. BIOMASS module in COMAP was used to track the dynamics of land use patterns over time, including changes in biomass pools, product supply and demand.

Forest Protection as a mitigation option

By using the model Forest Protection (FORPROT) in COMAP carbon abatement potential of forest protection and conservation options and assessed cost effectiveness of the options was estimated. FORPROT provided estimates of the associated annual and cumulative changes in carbon stocks; and the cost effectiveness indicators for the mitigation policy. This was done for baseline and mitigation scenarios to obtain net reduction in carbon emissions.

Forest Protection

In year 2000 the area under forest protection was 120 182 ha and by 2010 it had been reduced to 86 940 ha through conversion to agriculture and fire. At this rate, the baseline scenario assumes that all the forest will have been converted to agricultural land by the year 2030. The proposed mitigation option involves protecting the forest through measures such as setting a new policy for the area, boundary demarcation, surveillance, enforcement, and provision of equivalent or better alternatives for the people who were converting the forest area to farm land.

To evaluate this mitigation option, estimates of carbon densities under baseline and mitigation scenarios were generated. Under baseline scenario, the vegetation carbon per unit area is expected to decline to about 166.04tC/ha by 2030 (Table 4.8), though the soil carbon is conservatively projected to remain unchanged. If the area is protected, both the vegetation and soil carbon are projected to increase significantly. The incremental carbon gain is projected to reach 647.02 tC/ ha (Table 4.8) by the end of the program.

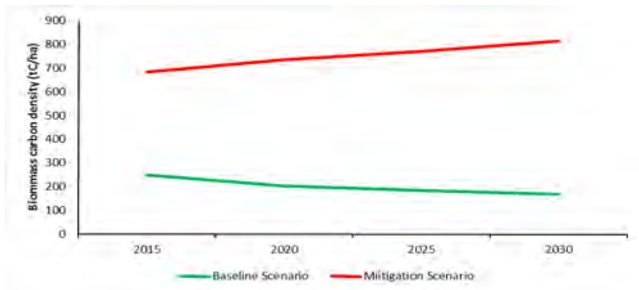

Fig 4.20 Biomass Carbon Density projections (tC/ ha).

Table 4.8 Biomass Carbon Density projections (tC/ ha).

	1996	2010	2020	2025	2030
Baseline Scenario	330	248.70	203.2075	183.68	166.04
Mitigation Scenario	330	435.43	530.78	586.03	647.02

The cost of protection is minimal ($1.61/ha/year) under baseline scenario, mostly for reducing the acceleration of the process by influx of more farmers, and boundary fire protection to avoid burning of the remaining forest or its spread to other forested areas. However, the benefits accruing from the agricultural production are estimated at $84.38/ha/yr, which will be considered as an opportunity cost of protecting the area under the cost of the program. Furthermore, the annualized value of direct cost of protection under mitigation rises to $ 9.43/ha/yr.

Using the stream of monetary costs and benefits from the program, and dividing this by the carbon benefits which will accrue, the cost effectiveness indicators reveal that it will cost $0.15/tC or a total of $278/ha of protected forest. The value of the BRAC indicator implies that in US dollars, it will cost 1 cent per ton of carbon withdrawn from the atmosphere per year, if the damage rate would rise at the same rate as the social rate of discount. The initial cost of protecting the forest is about 1 cent per ton of carbon or $ 10/ha, and it would require an endowment of $343/ha in the base year to ensure the protection of the forest, or 18cents per ton of carbon.

These estimates are consistent with expectations since there are no products with monetary value that are obtained from the area under the mitigation scenario. However, as mentioned earlier, the cost per ton of carbon is still quite low compared to other mitigation options, especially in the fossil fuel sector.

Estimated Carbon Pool and Sequestration

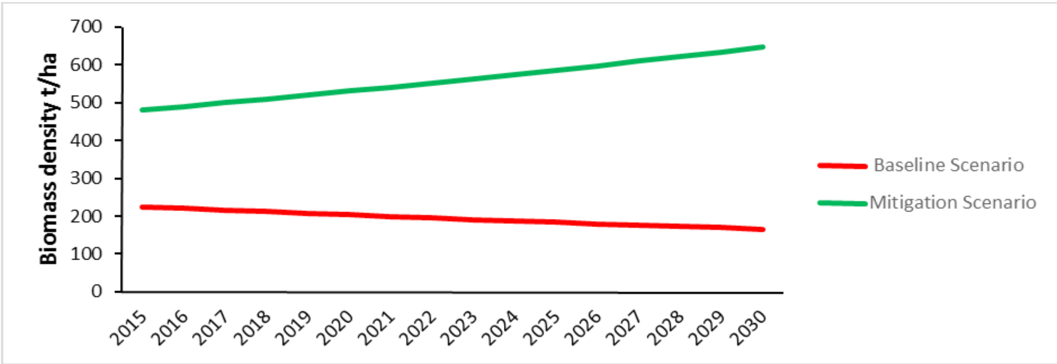

Fig 4.21 Carbon Pool and Sequestration

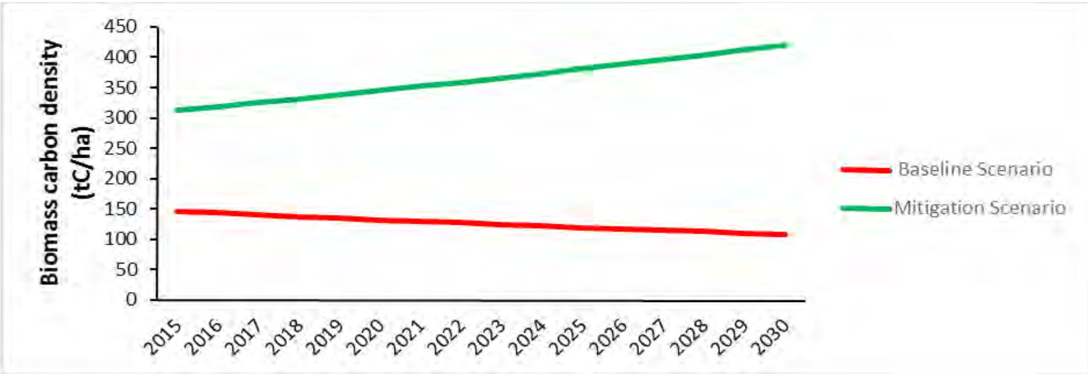

Fig 4.22 Estimated Biomass Carbon density

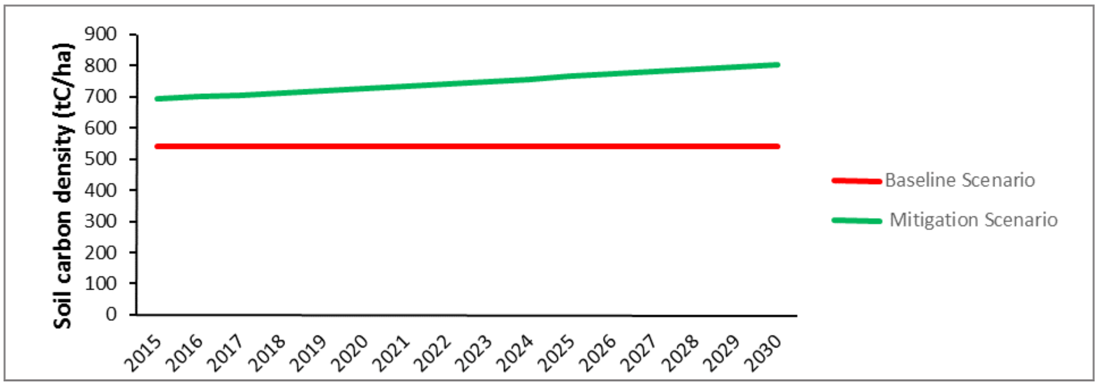

Fig 4.23 Estimated soil carbon density

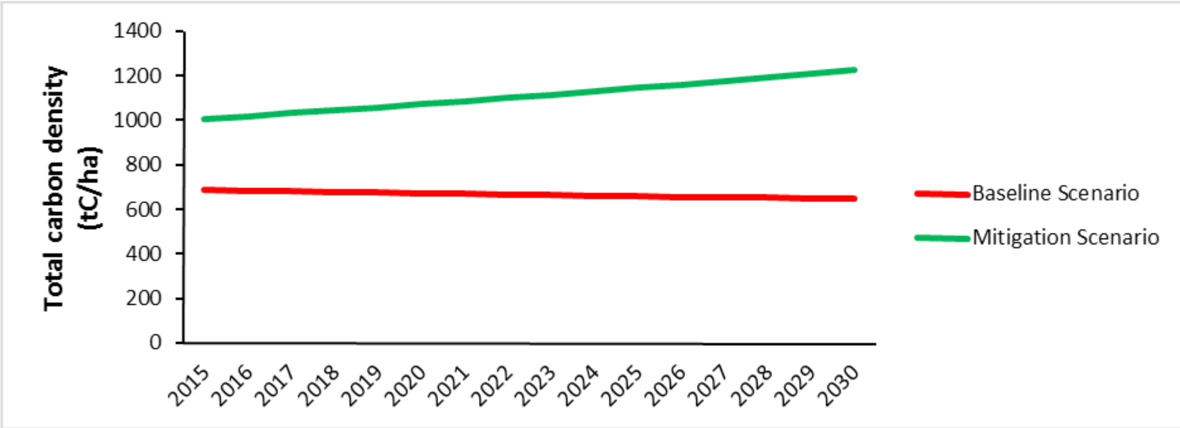

Fig 4.24 Estimated Total Carbon density

Reforestation

Output on potential mitigation options andnet financial benefits were generated using the REFOREST model. The cost-effectiveness indicators generated were:

- Endowment cost ($/tC and $/ha)
- Net Present Value (NPV) ($/tC and $/ha)
- Benefit of Reducing Atmospheric Carbon (BRAC) ($/tC-yr)

The mitigation option chosen is to reforest a degraded land at a rate of 1108 hectares per year over a 30 year period. In the baseline scenario, this area would have remained as a degraded land with low vegetation biomass density (10 tB/ha), and a stable soil carbon density estimated at 35 tC/ha. Under the mitigation scenario, the degraded land will be reforested by fast growing species whose rotation age is 15 years, and will be managed in perpetual rotations. The sequestered carbon will be stored in four pools, i.e.; (i) growing vegetation, (ii) decomposing biomass, (iii) soils and (iv) harvested wood products. In this scenario, it is assumed that soil carbon will accumulate at a rate of 2tC/ha through the first rotation, and remain constant after that. The difference between the carbon stock under the mitigation and baseline scenarios, provide an estimate of incremental carbon pool arising from the reforestation project (Table 4.9)

Table 4.9 Variance in carbon stock under different scenarios.

	1996	2010	2020	2025	2030
Baseline Scenario	754.50	701.66	672.08	659.39	647.92
Mitigation Scenario	787.72	941.93	1072.84	1145.88	1224.55

The costs per hectare under baseline scenario are minimal ($3.30/ha/yr), mainly from management such as fire protection. In the mitigation scenario, a large initial cost is incurred in the first three years for ground preparation, planting, weeding and blanking. For the remainder of the rotation, there is a small but increasing maintenance and monitoring cost ($10 – $20/ha/yr) for activities such as pruning, thinning and protection.

The value of products obtained from the reforested lands such as firewood and non-timber forest products is estimated at $20/ha/yr. Under mitigation these would increase to $75/ha/yr, but the largest benefit comes from the timber products which are valued at $1000/ha at harvest. At 10% discount rate, the reforestation program yields benefits whose present value is estimated at $ 4125/

ha, or an annualized value of $423/ha/yr. The net present value is estimated at $2209/ha for the mitigation project.

The present value of initial cost is estimated at $1.80/tC or $227/ha, an amount which is critical for policy purposes, since the availability of such funds is necessary to initiate the project. The net cost of removing a ton of carbon from the atmosphere for a year (BRAC) was estimated at 2.3 cents (negative cost), assuming that the damage caused by its atmospheric residence increases at a rate equal to the societal rate of discount. In this scenario, we actually gain 2.3 cents per ton of carbon withdrawn from the atmosphere by the reforestation project.

Table 4.10 Summary of cost effectiveness indicators for reforestation.

	$/tC	$/ha
Endowment cost	38.70	4761
NPV	30.41	3741
BRAC – per year	-0.023	-

The large NPV (Table 4.10) can be attributed to the substantial stream of timber benefits from the project.

Reforestation and bio-electricity

Table 4.11 Mitigation scenario - Reforestation.

>> Wood replacing fossil-fuel (avoided tC/ha/yr)	0.9
>> Wood product available for combustion (tonne of wood/ha/yr)	3.6
>> Carbon emissions avoided (tC/MWh)	0.31
>> Fossil power plant efficiency	0.3
>> Carbon content of displaced fuel (kgC/GJ)	25.8
>> Electricity efficiency of wood power plant (MWh/tonne of wood)	0.83
>> Wood power plant efficiency	0.2
>> Heat value of wood (GJ/tonne)	15

Table 4.12 Stream of costs ($) of bioelectricity generation for a One MW gasifier.

>> Initial Cost of Power Plant ($/MW)	100000000
> Present Value of Capacity Cost ($/MW)	514947
> Cost of Electricity Generation ($/MWh)	16
> Annual Electricity Generation (MWh/yr)	5256
> Capacity factor	60%
>Gasifier Lifetime (Yrs)	10
>> Price of fossil-fueled electricity ($/MWh)	90

Table 4.13 Benefits

>> Baseline Scenario (Wastelands) ($/ha/yr)	20
>> Mitigation Scenario (Bioelectricity) ($/ha/yr)	372

Cost-effectiveness indicators for the 30 year program - bioelectricity.

Table 4.14 Summary of cost effectiveness indicators for bioelectricity generation.

	$/tC	$/ha
NPV of benefits	15.38	1163
BRAC – per year	0.01	-
Initial cost	3.6	276
Endowment (present value costs)	8.11	613

Summary - Land use, land use change and forestry

Mitigation options to reduce greenhouse gas emissions and sequester carbon in land use sectors have been described in this section. The analysis highlights those options in the forestry sector, which are relevant to Zimbabwe's situation. Cost-effectiveness indicators for ranking mitigation options were proposed, including those, which account for non-carbon monetary benefits such as those derived from forest products, as well as opportunity cost of pursuing specific mitigation options. A final analysis on the likely policies, barriers and incentives to implement such mitigation options is given.

Emission Reduction Options

Forest Protection and Conservation - strengthen wildlife area protection, soil conservation, water catchment preservation, and recreational reserves, which will also reduce eminent carbon emissions and sequester carbon if the biomass density increases.

Efficiency Improvements - Installing capacities for residue utilization for bio-fuels and tertiary products also maximize useful biomass utilization and reduces emissions.

Bio-energy Initiatives - The mitigation options in the bio-energy field will mainly reduce the use of biomass and thus maintain stocks of carbon, while refraining emission of trace GHGs. Use of sustainably-grown biomass (sugar-cane, saw dust and timber waste) for fossil fuel substitution is a viable option, given the option of ethanol blending.

Reducing emissions from land-use changes - Permanent intensive agriculture/ pasture is a good long-term mitigation option to reduce emissions from land use changes. Supplementary economic activities for rural farmers may boost their earnings and as such reduce their demand on forest land for subsistence.

Wild-fire management - Since large areas of Zimbabwe's woodlands and grasslands are torched every year, management of these fires is an attractive option for reducing carbon and trace gas emissions.

Wildlife and range management - Mitigation options to reduce emissions from rangelands with wildlife involve improved range management, wildfire prevention and control, including sustaining numbers which are within the carrying capacity of the range. Elephant populations pose a threat to rangelands through their destruction of trees, and controlling their numbers is vital to reduce emissions.

4.5.5.3 Options to Sequester Carbon

- Afforestation - Planting forests in bare land
- Reforestation - Replanting and/or natural regeneration of deforested or degraded lands

- Agroforestry - The most commonly practiced forms are include inter-cropping for the purpose of producing both agricultural and forest products
- Urban and Community Forestry - the additional biomass in non-contiguous tree cover such as residential shade trees, road side and demarcation trees in the rural areas
- Range and grasslands - options to sequester carbon in rangelands involve improved range management

4.5.6 Current programmes and Planned Activities

This analysis presented an assessment of the implications of current and future forest conservation and regeneration policies and programmes for forest carbon sink in Zimbabwe. It also estimates the carbon stocks under current trend scenario for the existing forests as well as new area brought under afforestation and reforestation for the period 2006–30. The Comprehensive Mitigation Analysis Process (COMAP) model for projecting carbon stock estimates is used. During 1980–2005, forest area in Zimbabwe not only remained stable but marginally increased. This is due to favourable policies and initiatives pursued by the government through Forestry Commission. We expect that Zimbabwe will not only keep pursuing aggressive policies of afforestation and forest conservation, but also go a step forward. A case in point is the President's recent encouragement of the 'National Tree Planting Day' programme. If the assumptions of continuation of current rates of afforestation, forest conservation policies and no significant degradation of forest carbon stocks are changed, the future carbon stocks projected will also change.

The first rural afforestation programme (RAP 1) which ran from 1983-1989 was based on a perceived fuel wood crisis in the communal areas. RAP 1 was targeted at afforesting these areas using fast growing exotic trees in order to relieve pressure on indigenous woodlands. The second phase of the rural afforestation programme (RAP II) ran from 1990-1998. This phase broadened its content from eucalyptus woodlots alone to include agroforestry and indigenous woodland management with emphasis on poverty alleviation and food security. Since 1999, the rural afforestation programme is being implemented within the context of the Agricultural Services Support Programme (ASSP). The ASSP recognises the link between agriculture and forestry in communal area land use systems and within the livelihood of rural people (Shumba 2001).

Zimbabwe is a signatory to several important international and national policy frameworks for sustainable natural resource use. These include the Convention on Biodiversity, the Convention to Combat Desertification, the Montreal Protocol and the Convention on International Trade in Endangered Species of wild fauna and flora (CITES). Regarding the implementation of the country's obligations to some of these conventions, the following has been done:

- A National Biodiversity Strategy and Action Plan document has been produced in line with the requirements of the Convention on Biological Diversity.
- A National Action Plan on the Desertification Convention is now in place.

Zimbabwe joined the UN-REDD programme in 2013. In 2015, Zimbabwe conducted a REDD+ Country Needs Assessment in preparation for full participation in the UN-REDD programme. Through the REDD+ programme, the country intends to improve sustainability of its forests. Currently Zimbabwe has 2 pilot projects namely, The Kariba REDD+ project and South East Lowveld project.

Table 4.15 Current and Planned programmes

Current programmes	Planned activities to 2030
Tobacco wood energy program – woodlots	Addressing carbon markets initiatives.
National Forest Programme – targeting to increase forest cover	Other REDD+ projects in the contiguous REDD+ zone (14.3 million ha of forest).
National tree planting day practiced every year since 1980	The Parks and Wildlife Management has some 5 million ha (approx. 1.3% of Zimbabwe landmass): can also be leveraged for mitigation activities
Enforcement of SI 116 Of 2012 – Control of Firewood, Timber and Forest Produce	Degraded hotspots (16,361,020 ha) identified by the Forestry Commission.
Agroforestry practices and agriculture intensification: e.g., conservation agriculture	Combined, this is 35 million ha which represents 9.11% of Zimbabwe landmass.
Promotion of alternative (greener) energy sources: solar, biogas, LPG	Increase sequestration potential of Zimbabwe's forests.

Afforestation and reforestation programmes

Zimbabwe has been implementing an aggressive afforestation programme. The country initiated large-scale afforestation under the social forestry programme starting in the late 1980s. This includes community woodlots, farm forestry, urban forestry and agro-forestry. Afforestation and reforestation in Zimbabwe are being carried out under various programmes, namely social forestry initiated in the late 1980s, Joint Forest Management Programme initiated in 1990, afforestation under National Tree Planting Day (NTPD) programmes since 1980, and private farmer (e.g. tobacco farmers) and industry initiated plantation forestry.

Factors contributing to stabilization of carbon stocks in Zimbabwean forests

Zimbabwe is one of the few countries where deforestation is a challenge. However, the projections of carbon stocks for the period 2006–30 showed that the carbon stock will increase. Thus, it is important to understand the likely factors contributing to the observed and projected stabilization of forest cover as well as forest carbon stocks in Zimbabwe. The factors include legislations, forest conservation and afforestation programmes, and community awareness and participation.

The passing into law of promulgated regulations such as the Tobacco Wood Energy Regulations, Plantation Timber Industry Regulations and Firewood Trading and Movement of Timber Regulations will assist in reducing rates of de-forestation in the country.

The Forest Act

This Act is one of the most effective legislations contributing to reduction in deforestation. This was enacted to reduce indiscriminate diversion of forest land for non-forestry purposes, and to help regulate and control the recorded forest land-use changes. The Forest Act provides for the establishment of demarcated forest areas. In line with the provisions of the Forest Act, government gazetted 800,000 ha of indigenous forests in the fragile Kalahari sands of western Zimbabwe.

Compensatory afforestation

According to Environmental Management Act, 2002, when after careful consideration forest land is released for any infrastructure projects, it is mandatory for compensatory plantations to be raised on an equivalent non-forested land or equal to double the area on degraded forestland.

***Wildlife Parks and Protected Are*a**

Currently the Parks and Wildlife Estate constitutes 13% of the total land mass of the country, where all human intervention or extraction is banned. The purposes of these parks include the preservation and protection of the natural landscape, scenery of wildlife and plants and the natural ecological stability of wildlife and plant communities found therein. Appropriate authority status for wildlife in communal areas is granted to Rural District Councils (RDCs) to exploit wild animals and plants on behalf of the communities they serve. This saw the inception of the Communal Area Management Programme for Indigenous Resources (CAMPFIRE) programme and 33 of the country's 55 RDCs are participating in this programme.

Afforestation

Zimbabwe has been implementing large-scale afforestation/reforestation since 1980 under social forestry, Joint Forest Management, farm forestry and agro-forestry programmes, covering over 30 mha. This may have reduced pressure on the forests.

National Forest Policy

The National Forest Policy to be finalized in 2017 envisages people's participation in the development and protection of forests. The basic objective of this policy is to maintain conservation stability through protection of forests as a natural heritage.

With approximately 40 % of Zimbabwe's total land area occupied by forests, the country has potential to develop and implement beneficial strategies under the REDD+ umbrella. Nearly 21 million hectares of the forests land are indigenous trees and 156 000 hectares under plantations (Shumba 2001)..

4.5.7 Mitigation Policies, Barriers and Incentives

The policies to be considered here are those which will either be used to maintain carbon stocks and/or expand carbon sinks. Such policies may include:

(i) Forest protection and conservation policies. For example, local or national laws prohibiting conversion of gazetting vulnerable ecosystems into nature reserves.

(ii) Policies on shared responsibility for managing existing protected areas between local communities and the central agencies, which also include the sharing of benefits from the protected area, tend to reduce "encroachment" by the surrounding population. An example is the shared forest and wildlife management in through CAMPFIRE and REDD+.

(iii) Aggressive afforestation and reforestation policies both by villagers and forest departments will help expand the carbon sinks in the country, including incentives for private ownership of some forest resources.

Production-side mitigation options have been described according to IPCCC guidelines. Per-area mitigation potentials for forestry mitigation options are given. All measures are summarised in Table .12-1.

4.5.8 Mitigation technology options and practices, and behavioural aspects

***4.5.8.1 Production-side mitigation measure*s**

Production-side mitigation options have been described according to IPCCC guidelines. Per-area mitigation potentials for forestry mitigation options are given. All measures are summarised in Table 4.16.

Table 4.16 Summary of production-side mitigation options in the LULUCF sector

Option	Description	Project name
Reducing Emissions from deforestation and forest degradation (REDD+)	REDD+ (Existing forest areas with demonstrable risk of land-use change or reduced carbon storage are conserved, resulting in the avoidance of a business-as-usual scenario that would have produced higher emissions; emissions reductions occur primarily through avoided emissions.)	Kariba REDD+, Binga District, Chiredzi District.
Afforestation / Reforestation	Afforestation: Establishment of forest plantations on land that, until then, was not classified as forest. Implies a transformation from non-forest to forest. Reforestation: Establishment of forest plantations on temporarily unstocked lands that are considered as forest. Emission reductions occur primarily through additional sequestration.	National Tree Planting Day- target of 1 million trees a year.
Improved Forest Management	Existing forest areas are managed to increase carbon storage and/or to reduce carbon losses from harvesting or other silvicultural treatments; emissions reductions may occur through additional sequestration and/or avoided emissions and manipulating rotation length.	Silviculture/ Tree-Breeding Programme - Forestry Research Centre.
Forest management in plantations	Planted forest are managed to improve productivity for wood fuel, timber, fruits including cocoa, coffee, wild fruits and NTFP such as gum, resins, rubber etc.	Strategic Directions of the Forestry Commission (2015 – 2017)
Sustainable management in native forest	This includes traditional conservation techniques through protected forest and community forests. Conservation is the major strategy for this activity	Strategic Directions of the Forestry Commission (2015 – 2017)

4.5.8.2 Demand-side options for reducing GHG emissions from LULUCF

Table 4.17 Summary of consumption-side mitigation options in the LULUCF sector

Change Consumption of Wood Products	By changing habits to conserve wood and using to substitute for wood in various products, wood consumption could be reduced and then conserving existing carbon pools in the forest.
Substitution of wood for carbon intensive products	By using forest products as substitutes for fossil fuels or non-renewable materials, emissions from fossil C sources can be displaced. The efficiency of emissions displacement depends on the product, its lifecycle and the fossil-fuel based reference system that is substituted.
Increased C stocks in Wood Products	Sequestration in products and uses can be increased by altered processing methods, shifts in products used, end-use durability, and landfill management.

Table 4.18 Issues related to LULUCF mitigation options and sustainable development

Dimensions	Issues
Social and human framework	Population growth and migration, human capacity, existence and forms of social organization, indigenous knowledge and cultural background, equity and food security
Natural assets	Availability of natural resources (land, forest, water, agricultural land, minerals, fauna, etc.), GHG balance, ecosystem integrity, biodiversity conservation, ecosystem services, ecosystem productive capacity, climate change resilience and vulnerability
State of infrastructure and technology	Availability of infrastructure and technology, technology development, appropriateness, acceptance
Economic factors	Credit capacity, employment creation, income, wealth distribution/distribution mechanisms, carbon finance
Institutional arrangements	Land tenure and land use rights, participation and decision making mechanisms, sectoral and cross-sectoral policies

The development context defines the enabling conditions and thus determines the feasibility of the LULUCF mitigation options. For example the existence of local capacities is highly relevant for implementing and monitoring the reduction of deforestation. On the other hand, planning and implementing LULUCF mitigation options have an impact on the development context; for example promoting agroforestry plantations can have an impact on improving food security besides the carbon sequestration effect. In Zimbabwe, this dual relation between LULUCF mitigation options can be considered when proposing measures aimed at achieving long term development goals.

Table 4.19 Summarizes the findings on potential impacts of LULUCF mitigation options and the corresponding development context.

	Forestry	Bioenergy	Cropland management
Social and human framework	Recognition of the relevance of indigenous knowledge in managing natural forest. Protection of cultural habitat, especially in natural forests Promote or prevent from migration and displacement of activities.	Potential competition with food production/food security. Promote an improvement on local skills through capacity building.	use of traditional knowledge and improvements in food security
Natural assets	Increase resilience of communities to climate change events. Negative impacts on biodiversity conservation and other ecosystem services, including impacts on soil properties, water availability. displacement of people or activities	Large scale monocultures have impacts on biodiversity and soil quality as well as on environmental services. Biofuels/bioenergy plantations can displace natural ecosystems, including forests, causing leakages and other environmental damages.	Have positive impacts on soil fertility and other environmental services. Impact on ecosystem services including conserving biodiversity or soil quality.

State of infrastructure and technology	Production and availability of vegetal material that is adequate under long term climate consideration is key for any forest mitigation option. New forestry systems need to be checked in terms of acceptability by local stakeholders before being promoted as mitigation options	Availability of infrastructure in the same area where biofuels crops are produced can increase the development benefits. Lack of (access to) infrastructure can increase social misbalance.	Availability of infrastructure and technology for food processing can increase the development impact.
Economic factors	Some activities are Creation of additional income through non-timber forest products (NTFP). Employment creation (when less intense land use is replaced)	Provides new economic opportunities for farmers and local economies. Contribute to the increase of the price of feedstock used for food and feed. Promote concentration of income and increase poverty.	Impacts on economic factors are highly related to changes in productivity and to extend of cultivated area. Certification processes can increase competitiveness of sustainable cropland management.
Institutional agreements	Clarification of land tenure and use rights is key in all LULUCF mitigation options, impacts can be positive or negative for local stakeholders. Harmonization/Conflict with customary rights. Increase/decrease in participation of local stakeholders in planning, implementing and monitoring forest mitigation options Cross-sectoral coordination at the level of policies and land use planning is key, including forestry, agriculture, and energy and mining. Mechanisms for sharing benefits and liabilities need to be clarified with all relevant stakeholders at various levels (including local, provincial/departmental and national). Governance issues in rural areas are highly relevant for realizing the mitigation potential in the LULUCF sector.		

4.5.9 Gaps in knowledge and data

Data and knowledge gaps include:

- A national data base of the area of land use change and further fate of affected ecosystems.
- A national, high resolution data base of typical land management practices.
- A better characterization of national grazing areas, in terms of their quality, the intensity of use, management, including the GHG effects of changes in management.
- Better data on agricultural management practices employed globally including crop rotations, variety selection, fertilization practices (amount, type and timing) and tillage practices.
- More accurate data on C stocks in biomass for grasslands, croplands and wetlands, and C stocks in pools of dead organic matter and soils for different types of ecosystems around the country, including forests.

- A national data base of fires, including forest fires (in particular large-scale and open forest fires), fires on the grasslands and croplands with data on the amount of biomass burned.
- Better data on forest degradation, in particular selective logging, collection of fuel wood and non-timber forest products, grazing, and sub-canopy fires.
- A better understanding of effects of different mitigation options on social and economic conditions of poor people, in particular on those living largely in subsistence conditions

4.5.10 Sectoral policies

National and international forest climate policies have the potential to redefine the opportunity costs of land-use in ways that either complement or counteract the attainment of climate change mitigation goals. Additionally, adequate policies are needed for orienting practices in agriculture and in forest conservation and management to cope with mitigation and adaptation.

Table 4.20 Barriers and opportunities arising from mitigation actions in the LULUCF sector

	Barriers	Opportunities
Socio-economic	Economic/financial: Land competition, technology vs. effective mitigation; integrity vs. measurement, reduced access to markets (especially for the poor).	Clear land tenure and use rights systems/ well enforced legislation.
	Policy, institutional, legal: Contradictory policies, sectoral conflicts, lack of enforcement.	Coordinated cross-sectoral policies.
		Existence of participatory mechanisms that ensure stakeholders active participation.
Technological	Technological: State of R&D, availability/ acceptability of technologies.	
Public perception	Acceptability, sense of no-urgency, individual priorities vs. global priorities, individual preferences, lack of knowledge.	Increasing desertification, Clarification of land tenure and uses rights.
		Recognition of customary rights.
	People's perceptions of (new) rights and regulations, perception of (social) justice in legislations and mechanisms for LULUCF.	

4.6 Waste Sector

4.6.1 Background

GHG emissions in the waste sector are mainly from the key source categories of solid waste and wastewater streams; thus mitigation measures will focus on these two source categories. In 2006 the total waste generated was estimated at 1437.05 Gg based on an urban population of 4.19 million and waste generation rate of 342.7 kg per capita per year. The waste deposited at disposal sites was 215.6 Gg generating 25.45Gg of methane. Wastewater streams in 2006 accounted for 9.09 Gg of methane.

The waste GHG emissions were projected up to the year 2020 based on the LEAP software (version 2014.2). The urban population growth rate of 1.1% per annum and a waste collection rate of 82% achieved by Harare in 2000 were used. The waste collection rate in 2011 was 52%. The projections were done from year 2011 in order to avoid underestimation of emissions from solid waste category by making projections from period of economic depression (2006). The content of the biodegradable matter was assumed to be 40%. Under the business as usual scenario, generated waste is projected to increase to 1.84 million tonnes, emitting 3100.2 Gg of CO_2eq in 2020.

A number of initiatives are being promoted by various stakeholders including Community Based Organisations (CBOs) with support from local authorities and non-governmental organizations. These include waste composting at household level. The Environmental Management Agency (EMA) has set standards for waste composting, segregation at source and recycling. The National Waste Management Plan (NWMP) has been developed by EMA. Enforcement of SI 6 of 2007 and other related instruments such as SI 10 and 12 of 2007 and SI 98 of 2010 will go a long way in enhancing waste emission reduction. SI 6 of 2007 Part IV deals with waste management and targets while Part V addresses waste collection and targets. The National Climate Change Response Strategy details waste management plans and strategies towards development and implementation of an Integrated Waste Management System (IWMS).

4.6.2 Mitigation Options

The over-arching mitigation option has been implementation of the Zimbabwe Integrated Waste Management Plan (IWMP) which entails prevention and minimization of waste; reuse; feed and compost; recycle and dispose with the order of preference starting with prevention and ending with disposal. The specific mitigation measures under the IWMP are;

- reduction of waste at point of generation;
- composting of biodegradable waste;
- use of activated sludge and trickling filter water treatment systems and anaerobic digestion of sewage and subsequent methane gas capture;
- Engineered landfills for MSW disposal with or without methane gas capture (Waste to Energy (WtE) technology);

These mitigation options are achievable through education and awareness campaigns. End-pipe waste disposal and treatment methods require human expertise and capital investment.

4.6.3 Mitigation Potential

The biodegradable waste sent to SWDS can be reduced by 25% through livestock feed, anaerobic digestion and composting household waste. This translates to a 21.5% reduction in emissions from solid waste disposal. The national institutional biogas programme by Rural Electrification Agency (REA) is promoting reduction of biodegradable matter being sent to SWDS. Capturing methane from sludge digestion at wastewater treatment plants will reduce emissions from this sub sector by a further 10.5%. This gives an overall emission reduction of 745.2Gg of CO_2 equivalent in 2020.

There is an anticipated overall decrease of 24% in emissions below BAU by 2020 through implementation of the IWMP (Figure 4.25).

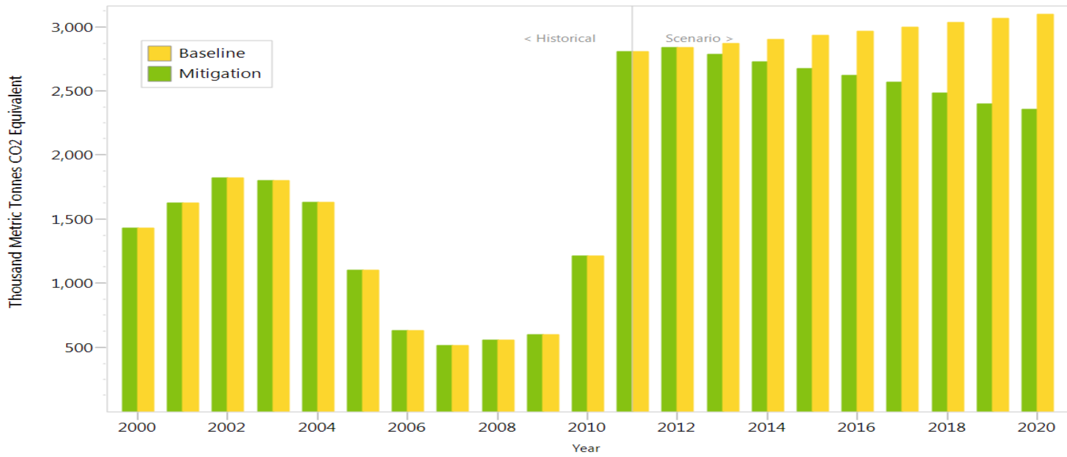

Fig 4.25 Emission projections for the Waste Sector (up to 2020)

4.6.4 Barriers to Mitigation

The most significant barriers to mitigating emissions from the waste sector are;

- Limited awareness;
- Lack of infrastructure and equipment
- Financial/economic constraints
- Limited skills capacity
- Weak Institutional arrangements
- Strategies to overcome barriers

Addressing these barriers will further unlock more methane abatement in the waste sector. The barriers can be overcome through;

- Awareness, training and campaigns on behaviour change towards waste reduction and separation at source;
- Capacitating local authorities in integrated waste management practices; and
- Promoting investment into WtE through Public-Private Partnership (PPP).
- Cost of mitigation measures

The cost of implementing IWMP and refurbishment of existing infrastructure will require about US$231 million. Table 4.21 summarizes the cost of implementing the mitigation options suitable for Zimbabwe.

Table 4.21 Summary of costs of mitigation options

Mitigation Measure	Strategy	Estimated Implementation Cost (million US$)
Prevention, reduction segregation and re-use	Awareness and training, Education and behaviour change Capacity building for local authorities Promotion of ordinary and vermi composting Promotion of recycling	10.5
Anaerobic digestion of biodegradable solid waste,	Capacity building for local authorities in anaerobic digestion of solid biodegradable waste with energy generation - reduce open burning of waste	34.0
Landfill gas capture	Capacity building for engineered landfill construction with gas capture and energy generation Technology transfer	100.5
Wastewater treatment methane abatement	Capture methane for energy generation Capacity building for local authorities Technology transfer	65.0
Policy framework	Strengthen enforcement of legal instruments, -Develop an enabling framework that promotes Public-Private Partnerships (PPP) in Waste to Energy projects - Promote research, development and deployment of technologies in waste to energy	21.0
Estimated Total Cost		231.0

4.6.5 Monitoring and Verification

The following are suggested indicators for measurement, and monitoring the potential emissions reductions in the sector:

- % Degradable Organic Content (DOC) in waste disposed to MSWDS
- Fraction of collected waste deposited at MSWDS
- Annual methane gas production from digesters
- Annual organic fertilizer output

4.6.6 Conclusion

Zimbabwe, as a developing country, needs to pursue waste prevention, reduction or minimisation and re-use for solid waste. Waste re-use is accompanied by source segregation either for composting, anaerobic digestion or recycling. These processes have apart from environmental benefits, social and economic benefits as well. End-pipe waste disposal methods such as waste to energy for both solid and liquid waste are expensive but complimentary after prevention, reduction and re-use.

CHAPTER 5

5. RESEARCH, SYSTEMATIC OBSERVATION AND TECHNOLOGY TRANSFER

5.1 Research and Systematic Observation

5.1.1 Background

In the UNFCCC Articles 4.1(g) and (h), 5 and 12.1b, of the Convention on Research and Systematic Observations, each member state is expected to provide information on the country's participation in the Global Climate Observing System (GCOS) activities. Systematic observations provide tangible information on a continual regular basis about past and present climate patterns and trends. Such data is the basis for research which provides tangible evidence on current impacts of climate change and variability. Such data is also invaluable in modelling future scenarios of climate impacts. Countries are able to develop response options for both mitigation and adaptation strategies using results of such research.

Zimbabwe has institutions involved in systematic observation of its climate at local and national level, among which are the Meteorological Services Department, Zimbabwe National Water Authority (ZINWA), Forestry Commission, Ministry of Agriculture, Mechanization and Irrigation Development (MoAMID), Ministry of Energy and Power Development(MoPED) and Ministry of Health and Child Care (MHCC).

5.1.2 Status of national observation programs

5.1.2.1 Meteorology

Zimbabwe is a member of the World Meteorological Organisation. The Meteorological Services Department (MSD), a government entity within the Ministry of Environment, Water and Climate, has the mandate to provide all meteorological services in the country. The MSD is ISO 9001 certified. Its tasks are:

- Monitoring the state and evolution of meteorological conditions for the purpose of providing short, medium and long term public forecasts.
- Monitoring and disseminating warnings and advisories of impending meteorological hazards for the purpose of disaster risk reduction.
- Developing meteorological, aviation and agro-meteorological forecasts.
- Participate in the international data exchange within Global Climate Observing Systems (GCOS) plan.

The MSD operates a network of 64 synoptic stations shown in Figure 5.1, some of which have data dating as far back as 1901. At least 60% of the stations are concentrated over the central watershed, supporting commercial agriculture. There is sparse coverage in the drier areas where livestock and small grains production are the major livelihood activities. These stations form the global station network (GSN) and global upper air network (GUAN) as required under Global Climate Observing System (GCOS). Only 47 stations which are part of the GSN are fully functional while 1 station out of 14 stations under GUAN is fully operational.

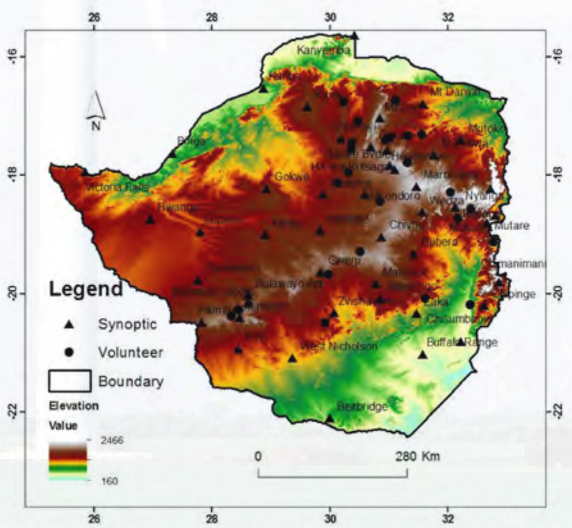

Fig 5.1 The spatial distribution of the synoptic stations that form part of the GSN and GUAN for Zimbabwe. Included are some of the volunteer stations measuring rainfall only which are concentrated mostly over the central parts of the country.

Within the sub-tropics rainfall is the most variable meteorological element in space and time. The MSD has a rainfall station network of ~300. Some of the stations are manned by volunteer observers such as from Agricultural Research stations and they provide 24 hour total rainfall measurements. There is an additional 15 automatic weather stations (AWS) that provide data on weather parameters such as temperature, wind speed and direction and 5 Automatic Weather Observing Systems (AWOS) installed at airports. These provide important aviation data on clouds (cloud base, amount and genre), meteorological optical range and meteorological luminance.

Research institutions also take part in atmospheric systematic observations, for example, the University of Zimbabwe (UZ) has AWS installed in research sites. The data from the AWS is utilised mostly by the host institutions. The data has been used mostly to improve the spatial coverage of existing synoptic stations hosted by MSD. Smallholder farmers have embraced the idea of making their own rainfall measurements. This has helped them understand morethe temporal distribution of rainfall at a local level; rainfall onset, end of season, dry spells and the resultant impact on crop production.

The MSD hosts a dedicated database management system (CLIMSOFT v3) for all its atmospheric observations. The climate database derived from the meteorological observations include parameters such as minimum and maximum temperature, ground minimum temperature, wind speed and direction, pressure, evaporation, radiation, precipitation, and cloud data (cloud base, amount and genre). The data is uploaded on the database after a rigorous quality control process. Locally the data is used to generate meteorological, aviation and agrometeorological forecasts. The MSD is operating on a 'cost-recovery' basis and hence agrometeorological and rainfall bulletins are developed and disseminated to subscribers only. The data is also shared regionally and internationally through the Global Telecommunication System (GTS). The structure allows for real-time data to be exchanged rapidly for forecasting and warning of meteorological hazards.

The MSD's operations are hampered by financial resource constraints leading to non-calibration of instruments and this coupled with lack of back-up support for the old equipment. Consequently this affects data availability and accuracy. Needless to say the major impediment to expansion of the observation network is also limited funding for acquisition of up-market observation equipment.

5.1.2.2 Hydrology

The major player in water resources assessment and management is the Zimbabwe National Water Authority (ZINWA), a parastatal in the Ministry of Environment, Water and Climate. The Authority has the mandate to plan, develop and manage water resources for the State and to ensure sustainable development and equitable distribution of the country's water resources to all Zimbabweans at an affordable price. Apart from maintenance of dams and water supply infrastructure, ZINWA contributes towards minimising the impacts of droughts and floods on communities through monitoring programs.

Data collection and monitoring is done for surface and ground water resources. Surface water monitoring focuses on runoff, dam levels, sediment levels and water usage. Ground water resource monitoring focuses on ground water levels, ground water quality and ground water recharge.Runoff data is collected from 342 stations which are fully functional. River level data is collected through automatic recorders. Sediment data is monitored from 50 points across the country.Monitoring of ground water levels is done monthly in the country's major aquifers namely Nyamandhlovu Sandstone Aquifer with 94 boreholes, Lomagundi Dolomite Aquifer with 198 boreholes and the Save Alluvial Deposits with 168 boreholes. Groundwater Database Management is done using the HydroGeoAnalyst (HGA) software. Routine monitoring exercise is often not possible due to limited financial resources.

As a member of the Southern Africa Development Community (SADC), Zimbabwe benefitted from the SADC HYCOS project.

Under this project 9 stations were installed. However, the real time network still remains sparse to meet national requirements. Through its parent ministry ZINWA drafted a Statutory Instrument (SI206/2001), on Groundwater Development and Management which regulates the registration of all boreholes and wells in the country as further supported by the Water Act (CAP 20:24).

ZINWA participates in data sharing programs locally, regionally and internationally. Runoff data from the SADC region is also shared through the SADC HYCOS website in line with the SADC Protocol on Shared Water Courses (2003). However, ground water data is currently not being shared owing to data paucity and lack of web-based sharing platform.Surface water data is shared through the Zambezi River Basin Water Resources Managers and Dam Operators (ZAMDO) agreement for hydrometeorological data sharing between dam operators andwater resources managers in middle and lower Zambezi for Mozambique, Zambia and Zimbabwe) through the Zambezi Watercourse Commission (ZAMCOM) platform. The Zambezi Water Resources Information System (ZAMWIS) developed to cater for the medium and long term water resources information needs of the Zambezi river basin is being further enhanced.

5.1.2. 3 Agriculture

The Departments of Research and Specialist Services (DR&SS) and Agricultural, Technical and Extension Services (AGRITEX) within the MoAMID in collaboration with MSD carry out agrometeorological monitoring. The focus is on agricultural production in relation to the temporal and spatial variability of rainfall. AGRITEX operates 32 agrometeorological stations where apart from the parameters measured by MSD there is additional monitoring of planting dates, soil moisture, evaporative loses, and crop condition. The data from the 32 stations is hosted by MSD and archived in the CLIMSOFT database. Every fortnight a bulletin is produced for all districts describing the amount of rainfall received, a medium range forecast and advisories related to the forecast period. To augment this work, weekly reports are produced on crop condition, stage of growth and vigour. Validation of crop condition is done through 3 crop assessments that take place usually in November after planting, February when crops are expected to be mostly at the reproductive stage and in April before harvesting. Using Water Requirement Satisfaction Index (WRSI) and the water balance method, an estimate of cereal production for the season is produced.

5.1.2.4 Health

The Disease control and Surveillance section within the Ministry of Health and Child Care (MoHCC) is mandated with monitoring diseases and epidemics in the country. Surveillance is done on a daily basis at every health facility in the country. The data is stored in a Rapid Weekly Notification System that passes on data to the next administrative level using the Frontline SMS system, a cell-phone based system designed to transmit data on epidemiological diseases, related deaths and public health events. The Ministry also uses the DHIS2 System, an active computer based system that uses internet for compiling and transmitting weekly and monthly reports from district through to national level. Data is shared regularly with locals, authorised organizations and interested partners. The reports can also be accessed on the Ministry's website (www.mohcc.gov.zw).

5.1.2.5 Forestry

The Forestry Commission (FC) monitors, regulates and manages forest resources. In agro-forestry, agricultural and forestry technologies have been combined to create more diverse, productive, profitable, healthy, and sustainable land-use systems. Forest resource measurement and monitoring is done every 10 years using Vegetation Resources Monitoring System (VegRIS). The FC has its own database for archiving forestry data which is also readily available for climate research upon request.

5.1.3 Participation in international activities

At regional level, Zimbabwe participates in MESA activities. Capacity building done for active participation and adoption of MESA has resulted in an increase in the uptake and use of earth observation data. Remote sensing is being used for fire monitoring, flood assessment and monitoring, food security and climate change research. Continentally, Zimbabwe participates in the Africa Group of Negotiators (AGN), where several members have been trained in the process of negotiation, negotiation skills and conduct in international meetings. Also, the country actively participates in the AMCEN activities such as development of the regional report on Africa's environment. Internationally, a number of Zimbabwean scientists contribute to the Intergovernmental Panel on Climate Change (IPCC) as lead authors and/or contributors of sections or regional reports and as experts in task forces such as the IPCC Expert Meeting on National Forest GHG Inventories. Participation in UNFCCC processes and activities is quite active with Zimbabwe serving as the chair of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA), a subsidiary body of the convention. Several scientists participate in Conference of Parties (COP) negotiation meetings.

5.1.4 Research programs on adaptation and mitigation

Zimbabwe continues to carry out climate change related research in many areas in order to formulate mitigation and adaptation strategies. Climate change related research has focused mainly on current and future climate change conditions and the impact on crop and livestock production, water resources and energy production among others. The following sections highlight some of the research completed and on-going which are meant to improve community resilience towards increased vulnerability due to climate change.

5.1.4.1 Research programs in Meteorology

The MSD hosts atmospheric data, and currently is running a Local Area Prediction System (LAPS) supported by a high performance computer (HPC) housed at the University of Zimbabwe. Capacity building is required in order to fully utilise the existing technologies and respond to the needs of the sector.

Projects that have been done by MSD and its partnerships include:

- Strengthening weather and climate information dissemination. This was possible through support given by Oxfam. Areas covered included Masvingo and Matebeleland provinces
- Weather Insurance Index: The project was supported by Econet Wireless in which AWS were installed in Mashonaland East.
- Using weather information in Agriculture: This was a CIMMYT project in which they monitored crop response to weather changes where the MSD provided forecasts and atmospheric observation in the area where research was carried out.

Indigenous Knowledge Systems vs. Conventional Forecasting project

The project is run by the University of Zimbabwe (Department of Physics) working with communities to document indigenous knowledge systems (IKS) for short and long range weather forecasting. Similar studies have been done by Great Zimbabwe University in Masvingo and in Manicaland provinces. Further research will focus on a countrywide documentation of IKS, some of which can be eventually used to improve the spatial resolution of science based forecasts.

5.1.4.2 Research programmes in hydrology

A World Bank funded study published in August 2014 highlights the need for strengthening, monitoring and interpretations systems for reliable information as one of the major adaptation actions for climate change when considering water resources planning and development in Zimbabwe (Davis and Hirji, 2014). The need was also included in the Climate Change Response Strategy under the Water Chapter.

5.1.4.3 Research programmes in agriculture

Several players from government and NGOs, together with research institutions have taken initiatives to develop community based adaptation strategies starting with an understanding of the vulnerability of agriculture systems to climate change and variability. UZ, Midlands State University, Chinhoyi University of Technology, have actively participated in research focusing on understanding trends in start of season, end of season, extreme events, multidimensional structure of drought, climate change signatures and climate change scenarios and opportunities among others. The focus is to move away from blanket solutions to specific local solutions using local data. Examples include:

- The Community Technology Development Organisation (CTDO) in collaboration with UZ and farming communities are conducting comparative experiments to identify suitable cultivars between hybrids and indigenous varieties.
- CIMMYT has done research under "Maize for Africa" to improve resilience of hybrid *Zea-may* to climate extremes.
- Matopos Research Station is researching on the performance of new sorghum varieties. 12 new varieties are currently being tested for productivity and heat tolerance in UzumbaMarambaPfungwe (UMP) district.
- Seed Co has developed a short season variety of maize, hare/*tsuro* (SC301) which matures in slightly less than 3 months. Current research is also focusing on the development of an even shorter variety called 'rat/*gonzo*) with maturity period less than two and half months.

Seed Co is also focusing on improving the soil pH through the use of vermiculite. So far the results show that a pH of 5.3 compared to 4.5 results in the following soil moisture retention characteristics,

- improved soil aeration, improved soil structure
- reduces leaching of nutrients and minerals
- reduces the risk of water logging
- enhances germination
- improved vigour.

The whole thrust of research by Seed Co is to adapt seed varieties to current climatic patterns while improving on heat tolerance, drought resistance and productivity.

Zimbabwe Farmer's Union (ZFU) with support from Sustainable Agriculture Technology (SAT) has partnered with farmers in Mashonaland East and Manicaland (3 districts per province) to uphold Conservation Agriculture (CA), having minimal soil disturbance while reducing greenhouse gas emission. In addition they are encouraging use of mulch and crop rotation methods to improve productivity.

ICRISAT is doing some work in agricultural economic projections for rural households under a changed climate in Matabeleland (Agricultural Model Inter-comparison Project Phase 2)

5.1.4.4 Research programmes in health

Research within the MoHCC has also focused on climate related diseases. Results have indicated that climate change works with or sometimes against efforts to bring malaria under control. Future projections of geographic distributions of malaria using 16 projections suggest that changes in temperature and precipitation could alter the geographic distribution of malaria in Zimbabwe, with previously unsuitable areas of high density of human population becoming suitable for transmission.

Research results also suggest an increase in diarrheal diseases and deaths during periods of extreme weather events such as floods. Salmonella food poisoning increased due to increases in temperature. Intensified flooding increased incidences of water borne diseases such as cholera, typhoid and bilharzia and warmer temperatures enhanced the spread of meningitis.

Schistosomiasis has become a re-emerging disease and evidence based research is required.

There is need to strengthen surveillance programs, establish Early Warning Systems (EWS) on climate related diseases and strengthen risk-management approaches. Research should focus on a methodical way for a year to year predictability of malaria and other climate sensitive diseases.

5.1.4.5 Research and development programmes in energy

Feasibility studies in the energy sector have revealed the following:

- Some locations in the Eastern Highlands and Bulawayo experience wind speeds in excess of 4ms-[1] which are good for localised wind power generation (Chikoto et al., 2014). In 2015 IRENA did a feasibility study for zoning renewable energy and produced an interactive map as shown in Figure 5.2 for wind power generation
- Two sugarcane crushing mill companies in Chiredzi use more than 1.3m tonnes of bagasse to generate electricity used by the sugar factories. In recent years the combined heat and power plants have been improved to produce ethanol for fuel blending
- SIRDC, a research institution with 12 institutes is focusing on development low carbon emission technologies .
  - › GeoRemote Sensing Institute focuses on GIS resource mapping and solar PVs
  - › Environmental Technology Institute (ETI) focuses on renewable energy and energy efficiency.
  - › The Environmental Science Institute (ESI) focuses on cleaner production in industries.
- The National Biogas pilot program on large scale biogas digesters for institutions such as schools and industry was launched.

Geothermal energy remains untapped in Zimbabwe. Research should focus on how to harness geothermal energy considering the flow rate and temperature of water and the costs involved.

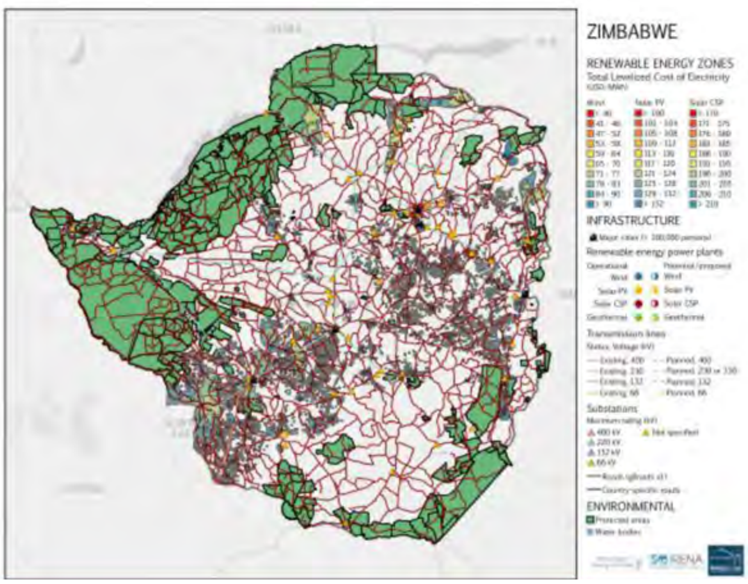

Fig 5.2 Renewable energy zoning interactive pdf map.Source IRENA, 2015

5.1.4.6 Research activities in Forestry

Forestry Research Division has embarked on studies on domestication of regionally important indigenous trees with multipurpose use in an effort to mitigate climate change. The aim is to introduce tree species suitable for pasture and food crop systems with emphasis on nitrogen fixing species for soil protection and improvement. Research into forestry species for the dry zones is ongoing focusing on fuel wood and establishing tree plantations in the semi-arid regions of the country.

5.1.5 Constraints gaps and needs in the Research and Systematic Observations

Institutions taking part in systematic observations face multiple constraints. Some of the primary constraints are as follows;

- lack of financial resources to acquire and maintain equipment.
- brain drain of expertise in areas of observation and equipment maintenance.
- obsolete equipment and unavailability of spare parts for aged equipment.
- lack of support for local innovations.
- incompatibility in old and new data formats making it difficult to migrate data into new databases.
- absence of a database management system
- incompatibility of data formats for use in database management system.
- absence of a web based platform for sharing data and research, among institutions.
- lack of a data sharing policy among institutions.

5.1.6 Conclusion

Government entities, research institutions, public sector and some NGOs are actively involved in data collection, archival and analysis with the aim of developing evidence based research which should influence development of adaptation and mitigation strategies. There is need for data homogeneity that can be achieved through standardization of the data. This will allow more players in systematic observations, therefore closing data gaps both spatially and temporally. Capacity building in numerical weather prediction and climate sciences is required in order for the country to fully understand and disaggregate local climate stressors.

5.2 Technology Transfer for Climate Change Adaptation and Mitigation in Zimbabwe

5.2.1 Background

The Second National Communication suggested technologies for adoption in agriculture, meteorology, hydrology, energy and industry. Technologies suggested for agriculture included gene technology, water harvesting, conservation of soils and efficient irrigation technologies. In meteorology the need for radars to monitor extreme events, automatic weather stations and instruments for soil moisture and temperature measurements were highlighted. In the energy sector technology for reducing domestic and industrial energy usage as well as for increasing generation in climate friendly ways were discussed. This communication captures technology transfer developments since the previous communication and identifies needs that still exist in key economic sectors in Zimbabwe. A number of sector specific technology transfer projects, needs and limitations are discussed. Estimated costs of some of the technology transfer requirements have also been included.

5.2.2 Technology transfer in the agriculture sector

Agriculture remains a key economic activity in Zimbabwe and is heavily affected by increasing evapotranspiration due to rising temperatures as well as by dry spells and recurrent droughts. The solution to water demands in agriculture lies with effectiveness of water management strategies including water supply technologies as well as the ability of crop varieties to survive under water stress.

Improved irrigation techniques such as drip irrigation are useful in conserving water. However, most communal farmers cannot afford the equipment required to operate drip irrigation systems thus limiting its widespread use in the country. There is an opportunity for the local farmers to improvise and use local materials such as drums, clay pipes, bamboos and polyvinyl chloride (PVC) pipes. Other affordable irrigation technologies such as use of trenches to channel water towards agricultural fields can be promoted.

Development of short season drought tolerant crop varieties that can withstand the prolonged dry spells and droughts imposed by climate change is essential. This is envisaged to improve the nation's adaptive capacity to climate change. Local and international research and development organizations are active in the development of such seed varieties.

Inadequate funding for public technology transfer means that the smallholder farmer will not be able to keep up. Government in partnership with development partners, Civil Society Organizations (CSOs), research and academia are facilitating the dissemination, testing and adoption of conservation agriculture among smallholder farmers in Zimbabwe. One such example is the Protracted Relief and Recovery Program (PRP) funded by DFID. Sustainable technology transfer involves long-term commitment to work with farmers and communities to test and adapt technology options while most NGO projects have a limited lifespan and scale. It is therefore imperative for the Government to collaborate with all partners to scale up initiatives and enhance sustainability.

The MoAMID has indicated technology transfer activities that include the development of irrigation in the small scale farming sector, increased rain water harvesting, breeding for new drought tolerant varieties, training of farmers on sound agronomic practices, training of extension officers and improved early warning system. Some of the equipment required to effectively carry these activities are rain gauges and automatic weather stations for access and promotion of utilization weather and climate information among farmers, AGRITEX and MoAMID would help farmers benefit by introducing such equipment for testing soil acidity,, improving harvesting techniques, promoting moisture conservation techniques and research that targets the breeding of drought tolerant crop varieties.

Other technologies that have been identified as options for climate change adaptation and mitigation in agriculture include;

- Fodder cutting which helps increase the availability of quality food resources for livestock during the dry season
- Contour stone bunds which can be used to reduce soil erosion and enhance water infiltration, thus reducing crop water stress during drought periods.
- The permeable rock dams for rehabilitation of gullies and improve water infiltration and groundwater recharge.
- Grass strips on the contour for promoting water infiltration, minimising soil erosion, and increase fodder and domestic straw availability.
- Mulching (or organic soil cover)to shield the soil surface from direct insulation thereby minimising evaporation.
- Improved fallow for improved soil fertility
- Compost application for increased water retention capacity and soil fertility.
- Intercropping and crop diversification for reducing the risk of crop failure Agroforestry – it reduces demand for fuel wood from indigenous tree species
- Fireguards – reduces emissions from unprescribed burning

5.2.2.1 Challenges for technology transfer in agriculture

Technologies that do not present immediate economic benefits to the farmers would not be prioritized by the farmer. Lack of adequate resources, primarily capital have inhibited most farmers to invest in projects such as irrigation. Last, but not least, the majority of farmers have not been able to access some of the above mentioned technologies available in the country due to limited extension services. There is thus need for financial resources for awareness activities to promote technologies particularly those that are locally available.

5.2.3 Technology Transfer in Hydrology

Hydrological monitoring is critical for climate change vulnerability assessment and adaptation of communities in Zimbabwe. Technology transfer in the hydrology sector is required in the area of monitoring, data collection and interpretation, as well as reporting.

There is need for training of personnel, procurement of laboratory equipment, vehicles and consumables in order to monitor the quality of groundwater. In hydrological stations where there are no Global System for Mobile (GSM) communication networks it is necessary for the network to be expanded so as to receive flood information from remote areas. Other equipment required include, data loggers, barometric pressure measuring instruments and telemetry system which can allow data to be measured continuously. Migrating from Water Resource System (WRS) to HYDSTRA for run-off monitoring has remained a challenge due to data format incompatibility. Flood modelling in Zimbabwe is currently done at seasonal time scale using forecasts issued by the Meteorological Services Department. There are no model outputs issued with shorter lead time as there are few real time observation sites. In order to complete installation of real time stations, Zimbabwe National Water Authority (ZINWA) requires financial support.

ZINWA requires equipment that is scalable, expandable and sustainable in order to fully respond to climate change demands. Efficient pumping equipment would allow right amount of water abstraction while reducing on the energy requirements. Scheduled irrigation promotes correct response to plant water requirements thus reducing abnormal water use.

5.2.4 The Manufacturing and Mining sectors

There is need to continually improve processes by adopting appropriate technologies that increase energy use efficiency which leads to reduction in emission of greenhouse gases in industry.

5.2.4.1 Adaptation Technologies in Manufacturing/Mining

Technologies for improving water-use efficiency and wastewater recycling are essential for climate change adaptation in the manufacturing and mining sectors. There is also need for promoting climate resilient infrastructure.

5.2.4.2 Mitigation Technologies in Industrial Processes sector

Mitigation options in the industrial or mining sector include the following:

- Material substitution for example use of blast furnace slag in cement production.
- Water conservation
- Upscaling of Biological Nutrient Removal (BNR) systems in municipal wastewater treatment plants
- Methane recovery and use as energy source at sewage works
- Resuscitation of material recycling for example hardboard and newsprint
- Optimising blast furnace charge to reduce excess coke combustion
- More efficient use of energy, and promotion of renewable energy
- Use of wood waste as an alternative to fossil fuels.
- Control of non – carbon dioxide gas emissions and a wide array of process – specific technologies, for instance, Carbon Capture (Utilisation) and Storage (CCUS) for cement, ammonia and iron manufacturing; inert electrodes for aluminium manufacturing; and technologies for catalytic decomposition of N2O in fertilizer manufacture.

Provision of benchmark information, performance standards, subsidies, tax credits, trade permits and voluntary agreements may stimulate technology uptake.

5.2.5 Technologies for sustainable transportation

The following technologies and practices are recommended in the transport sector:

- Non-motorized transport (walking and biking)

- Transport mode shifts and optimum land use planning
- Reducing travel demand through ICT use, e.g. telecommunications
- Less carbon-intensive fuels and technologies
- Improved efficiency of transport systems.

5.2.6 Adaptation and mitigation technologies for Energy sector

The following technologies and practices are recommended in the energy sector:

- Adoption of solar energy for domestic and industrial uses; Some entities have begun to roll out solar energy for staff residential homes.
- Improved cook stoves – stove efficiency is at 30-50%
- Electrifying cities towards reduced emissions – solar street lighting, solar water heating, telecommunications, biogas technologies.
- Energy efficiency in buildings –including the use of natural lighting in building, bio-mimic among others.
- Low carbon electrification of remote areas - Zimbabwe Rural Electrification Agency is promoting solar technologies.
- Scaling up renewables in the energy sector – The Ministry of Energy is accelerating universal access to renewable and affordable energy by 2030. The techniques for energy acceleration include the installation and use of solar energy technology, small hydropower (SHP), bio-fuels and wind technology. Mandatory blending of mineral gasoline with ethanol has been introduced in Zimbabwe.

5.2.6.1 Technologies for power generation

Renewable energy technologies in Zimbabwe that can be up-scaled include:

- Mini hydropower
- Biomass based power generation
- Solar-thermal/PV power
- Waste to Energy technologies

5.2.7 Conclusion

Scalable and sustainable technologies are available for adoption in Zimbabwe. The last technology needs assessment was done more than 10 years back. A new technology needs assessment should be done in order to understand the current needs of different climate sensitive sectors. This would allow for adoption of sound technologies that promote low carbon emissions yet with high efficiency. It is recommended to start with low cost technologies that are locally available.

CHAPTER 6

6. CLIMATE CHANGE EDUCATION, TRAINING AND AWARENESS

6.1 Introduction

This chapter examines major issues about Climate Change Education, Public Awareness and Training (CCEAT) in Zimbabwe. It focuses on developments that have taken place since the Second National Communication (SNC) Report of 2012. The chapter is divided into three major sections, namely:

- Climate change (CC) related curriculum developments (from pre-school to tertiary levels) within the educational system including out of school (informal) education
- Public participation in knowledge exchange and awareness raising activities on climate change
- Developments in training of trainers and sector-specific in-service training on climate change

These key approaches originated from an inception meetingand the ensuing series of consultative workshops. Countrywide workshops were held to collect primary data at the local, provincial, national and regional levels. Outside the primary sector of education, the stakeholders included, inter alia, environmental management officersdrawn from sector-specific areas such as water, environment, agriculture, forestry and wildlife.

The environment sector-specific stakeholders were drawn from the Zimbabwe National Water Authority (ZINWA); the Environment Management Agency (EMA); the Department of Agricultural Technical and Extension Services (AGRITEX); the Forestry Commission (FC); and the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) and stakeholders from Education. Parliamentarians, media (both print and electronic); poets, performing artists, and families were important audiences for climate change awareness rising. Faith-based organisations, industrialists, mining, and commerce were also targeted. Vulnerability and adaptation assessments on education, public awareness and training were carried out by the review team. Local communities, local authorities and traditional leaders participated.

Public participation and awareness was observed to be higher than it was during the SNC. This was discerned by the good and high turn out by various stakeholders at the major climate change workshops and fun days held in a number of provinces in Zimbabwe. These high levels should be sustained through continued awareness raising activities.

The chief strategies for raising public awareness are:

a) harnessing the media as a vital Climate Change dissemination tool

b) empowering officers in various sectors with awareness materials

c) developing awareness materials such as t/shirts, songs, posters, pamphlets, videos, compact discs (CDs) in both English and vernacular languages

d) mounting drama, poetry and essay writing competitions

e) using media such as newspapers, radio, and television and

f) utilization of Junior Parliamentarians.

The strategies for public awareness and behavioral change required an effective Climate Change Communication Strategy entailing the following:

g) use of the media

h) participatory approach

i) production and dissemination of educational information

j) school debates

k) use of social gatherings

l) use of the Catch Them Young concept

m) commemorations focusing on specific climate change themes (See Section 8.2.4).

In addition, training of local natural resource officers in the communities, local non-governmental organizations (NGO) officers working with the communities, local community leaders (chiefs, headmen, councillors and village heads) and community popular opinion leaders and in-service training of teachers in primary and secondary schools, was done.

It was observed that climate change language should be simple enough for all stakeholders to understand. The chapter concludes with proposed strategies and action plans in the three sectors of education, public awareness and training.

6.2 Climate change related curriculum developments

The Ministry of Primary and Secondary Education has responded to both national and international initiatives to integrate climate change into the school curriculum. This is also in line with the *Presidential Commission of Inquiry into Education and Training* (Nziramasanga, 1999). The commission recommended that Environmental Education (EE) should be integrated into the school curriculum. This is now supported by Zimbabwe's sustainable development national goals which state that in order to achieve climate education it should be imperative to make sustainable development a national priority. Specifically, SDG's 2, 7 and 13 about ending hunger, achieving food security and improving nutrition as well as promoting sustainable agriculture and ensuring access to affordable, reliable and modern energy for all will assist in combating climate change.

In pursuit of these goals, the Curriculum Development Unit (CDU) in the Ministry of Primary and Secondary Education has developed materials on climate change which are being incorporated into the school curriculum as cross cutting innovations in all subjects. The new curriculum incorporated climate change topics and themes in all areas of learning for Early Childhood Development (ECD). At primary school (from grades 3-7), aspects of climate change are mainly covered in Agriculture, Science and Geography lessons and are furtherincorporated into the teaching of languages. For forms 1-4, climate change matters are covered in general in the lessons on Agriculture, Engineering, Crop Science, Animal Science and Horticulture. At forms 5 and 6, there are proposals to offer a more detailed coverage of climate change education. The information provided on the national curriculum in the subsequent sections of this chapter was obtained from the CDU.

6.2.1 Pre-school level

Currently the CDU has introduced subjects that have a direct bearing on climate change at the pre-school or ECD level. The creation of the Ministry of State for Liaising on Psychomotor Activities in Education and Vocational Training will assist in targeting the young individuals to grow up with the right attitude, behaviour and practice towards climate change. Continued consultation with the relevant stakeholders is recommended.

6.2.2 Education and awareness at formal educational levels

The Zimbabwean school curriculum provides knowledge from three sources in which climate change has been mainstreamed:

- The formal curriculum that is planned by the school and approved by the Ministry of Primary and Secondary Education
- The co-curricular activities such as sports, clubs, games, cultural activities and educational tours; and
- The hidden curriculum which can be defined as lessons that are taught informally and usually unintentionally in a school system. These include behaviours, perspectives and attitudes that students pick up while they are at school.

Pursuant to the recommendations in the Second National Communication, the development of an integrated climate change curriculum which prioritizes a needs assessment still needs to be addressed. However, there are proposals to establish a centre of excellence on climate change at the University of Zimbabwe or any other university chosen by the State.

6.2.3 Out of school youths

There is a proposal to conduct a situational analysis of the status of out-of-school youths in terms of their awareness of climate change and its impacts. These youths constitute a major proportion in the country (See 2012 Zimbabwe National Census Report) and paying attention to their awareness of climate change is a priority of Government and all relevant stakeholders.

6.3 Awareness raising activities on climate change

6.3.1 Production of Information, Education and Communication (IEC) materials

This activity involved the production of climate change related IEC materials. These included pamphlets explaining what climate change is all about (causes, consequences, adaptation and mitigation). These were produced in English and will have to be translated into the vernacular for both schools and the general public. Bags, rulers, t-shirts, pens and pencils bearing climate change messages were also produced.

6.3.2 Primary and secondary school levels competitions

These are on-going activities and entail poetry, drama, debates, painting and essay writing. EMA is running such competitions with schools in Masvingo and Midlands provinces. These are done during commemorations such as World Wetlands Day, Fire Week, and National Tree Planting Day. These activities are included in the EMA calendar issued every year and available to the public for a small fee. Artistswork with schools to produce poetry, paintings, documentaries and songs related to CC and its impacts. The plan is for the CCEAT team to participate in school competitions in future.

6.3.3 Sector-specific awareness raising workshops and in-service training

Sector-specific awareness raising workshops involving various stakeholders were carried out in Harare, Bulawayo, Manicaland, Mashonaland West, Mashonaland East and Masvingo provinces. The workshops were aimed at reaching out to identified stakeholders. The workshops had the following structure:

- An official opening event in which the purpose and objectives of the workshop were outlined. The opening is conducted by a high ranking government official (at least of director rank).
- Article 6 of the United Nations Framework Convention on Climate Change (UNFCCC) was presented to improve participants' understanding of the mandate for the education, awareness and training activities.
- CCEAT activities, as covered in the SNC were presented and copies of the same, together with IEC materials were distributed for use in provinces, districts and local areas. Officials from EMA, ZINWA, AGRITEX, FC, Parks and Wildlife, local authority representatives or traditional leaders gave sector specific presentations on CC status in areas workshops had earlier been held.

Group work using the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was undertaken based on the sector presentations and Chapter 6 of the SNC. After this a plenary session was held. This resulted in recommendations which fed into the Third National Communication (TNC). These recommendations formed the basis of future action plans.

The group work wasused as a training tool for analysing climate change processes using the SWOT approach. Many participants have benefitted from this exercise. The following major themes were the driving force behind the national Climate Change Education, Public Awareness and Training (CCEAT) activities from 2012 and were also used for the TNC workshops:

- Climate Change Is Real: Act Now
- Ignore Climate Change At Your Own Peril
- Climate Change: - Everyone's Concern
- Climate Change Can Be Managed
- Climate Change Awareness - Today Or Never
- Climate Change: What's Your Role?

6.3.4 Radio/TV talk shows

Zimbabwe-TV (ZTV) has a programme called 'Green Studio' whose main motto is 'a better life for you, a better life for me'. It is aimed at the youth and discusses climate change issues and emphasizes behaviour change as a means of combating climate change. The programme facilitates meetings and discussions with the youthful public to get their views and responses on climate change. It is recommended that more such shows be done to cover a wider public.

Radio stations, both public and privately owned, have been active in airing topics on climate change. They have invited several university lecturers and climate change practitioners or resources persons to discuss the subject to increase awareness. Some programmes enable listeners to phone in and ask questions, comment and contribute to what the climate change resources persons would have presented. The programmes are quite lively because of the interchange between the experts and the public.

6.4 Training on climate change

The training of climate change trainers was conducted at various fora throughout Zimbabwe. The Department of Climate Change Management (DCCM) in the Ministry of Environment, Water and Climate (MEWC) has held several climate change workshops since the Second National Communication was concluded in 2012. These workshops were designed to exchange information and raise public awareness about climate change, among other things. The results of these workshops show that awareness of climate change and the risks it poses has increased since 2012. One of the major challenges remains that of equipping communities with coping skills that lead to sustained behaviour change.

6.4.1 Training of trainers

Workshops provided a means to train the trainers on climate change, basing on Article 6 of the Convention as well as Chapter 6 of the SNC. The understanding of these documents was vital in order for the trainees to effectively communicate the climate change messages to their respective communities. The use of the SWOT analysis was designed to provide participants with a tool for use in their day-to-day analysis of problems and solutions related to climate change.

6.5 Proposed sector-specific climate change communication strategies

The Zimbabwe National Climate Change Response Strategy (GoZ, 2015) recognises the need to have sector specific climate change response strategies. To this end, the document gives objectives for each sector, the goals and the pillars for that sector, action plans and proposed budget. Thus for education and public awareness the strategic objectives were to:

- Develop an effective climate change communication information management and communication system that facilitates access by all stakeholder groups
- Strengthen and mainstream climate change in all education curricula

These strategic objectives were then supported by seven pillars. The one relevant to the fulfilment of our strategic objectives was capacity building to carry out:

- Climate change communication and
- Education and awareness raising.

These pillars then cascaded into guiding principles as outlined in the NCCRS document. The NCCRS further identifies sector-specific strategies to be implemented. For the formal education sector it identifies two strategies. For public awareness raising it identifies four strategies. These strategies are matched to action plans found in the NCCRS document for each sector and estimated costs are provided. net financial benefits.

6.6 Gaps, constraints and related needs

This section focuses on gaps, constraints and related needs in relation to education, awareness, public participation and communication.

6.6.1 Education Gaps

6.6.1.1 Primary and Secondary

The establishment of climate change parameters in Zimbabwe in relation to the education system:

- Conducting curriculum audits in terms of the content and process of climate change.
- Convening of national workshops to fully integrate climate change into the school curriculum.
- Conducting in-service training workshops for educators on the integrated climate change curriculum.
- Monitoring and evaluation of the teaching and learning of climate change.

6.6.1.2 Tertiary level

The tertiary institutions are divided into two groups namely technical colleges and universities. Under technical colleges the following needs have been identified.

Conducting a needs assessment:

- Preparation of draft IEC and improved curriculum materials based on the findings of the needs assessment
- Reviewing the content of the draft materials for quality and consistency especially in the definition of terms and the understanding of concepts related to climate change
- Pre-testing the materials for suitability in terms of use for training and teaching on climate change
- Editing the draft manuals after a thorough evaluation of the content by educational and climate change curriculum development experts has been done
- Printing and distributing these materials to the teacher and agricultural training colleges for use by new graduates for their certificate programmes
- Production of a teacher's guide to these materials for use in the classroom.

6.6.1.3 Universities

There is lack of a coherent or integrated curriculum on climate change in all the universities andthus the following gaps need to be addressed:

- Conducting a situational analysis of the courses offered on climate change by all universities in the country
- Standardizing the teaching of courses throughout the country's universities much in the same way as suggested under the section on teacher and agricultural training colleges.

6.6.2 Constraints

- Lack of enough qualified personnel in teachers', technical and agricultural colleges
- Inadequate and outdated teaching equipment in colleges
- Non-availability of financial resources to carry out the necessary training of trainers

6.7 Related Needs: Financial, Technical and Capacity

Identified related needs in terms of the education sector are:

- Designing of appropriate curricula, adequately covering climate change issues at all levels
- In-service training for teachers and climate change practitioners
- Provision of adequate and sustainable funding
- Provision of sustainable infrastructure, teaching materials, other resources and the requisite funding.

6.8 Awareness, public participation and Communication

6.8.1 Gaps

- Lack of appropriate expertise on climate change awareness training
- Lack of evidence-based research for message formulation targeting behaviour change
- Lack of sustained coordination and communication among relevant

stakeholders

- Low participation of traditional leaders and local authorities on climate change governance
- Lack of documented indigenous knowledge systems on climate change adaptation and mitigation.

6.8.2 Constraints

- Limited resources to engage in innovative and more effective means of engaging the public in climate change awareness raising
- Inadequate climate change awareness materials
- Inadequate media coverage (electronic and print resources)
- Lack of trained media personnel to report on climate change.

6.8.3 Related Needs: Financial, Technical and Capacity

- Funding needed to train people in media houses on climate change to report competently
- Curricula needed to adequately train climate change personnel
- To secure funding to upgrade and upscale equipment and human resources to modern standards.

6.9 Training

6.9.1 Gaps

- There is a limited number of competent personnel to train trainers
- Limited financial resources to carry out training of trainers
- Lack of training programmes and materials on climate change
- Lack of trained leaders at various community levels that include:

› Training of local natural resource officers in the communities

› Training of Local NGO officers working with the communities

› Training of Local community leaders (chiefs, headmen, councillors and village heads)

› Training of Community popular opinion leaders

› Training of Leaders of faith-based organizations.

6.9.2 Constraints

- Limited monetary resources, materials and human capital resources
- Non-availability of infrastructure specifically designed for climate change training.

6.9.3 Related Needs: Financial, Technical and Capacity

Financial, technical and human capital needs to be boosted and there is also a need for resources for other capacity building requirements as revealed by the needs assessment exercise.

6.10 Conclusions and recommendations

6.10.1 Conclusions

Qualitative data obtained from several consultative workshops and stakeholder in-depth interviews in addition to desk top research led to the development of the Zimbabwe Climate Change Education, Awareness, Training and Communication Chapter of the TNC. The qualitative data gathering process targeted teachers, heads of schools (both primary and secondary), education officers (both primary and secondary), curriculum development unit officials, Zimbabwe Examination Council officials and principals of teachers' training colleges as well as traditional and local authorities.

Among areas covered was the exploration of courses within the educational system which cover climate change concerns. It was established that climate change was taught at primary, secondary and tertiary education levels but not as a stand-alone subject. Carrier subjects such as Geography, Science and Social Studies were used to teach climate change but the curriculum lacked depth. At the same time, there is an urgent need to develop relevant climate change teaching materials for distribution to schools and tertiary colleges.

Awareness of climate change by the public and policy makers was found to be generally high, but not directly translating into the intended behaviour change. There is therefore a need for evidence-based research to design behaviour change messages targeting specific stakeholders' attitudes and behaviours. The suggested awareness strategies to be used include, but are not limited to both electronic and print media as well as school competitions, commemorations and workshops at grassroots levels as well as social media.

The strategy should aim at the establishment of multi-stakeholder fora at ward, district, provincial and national levels. Regional and international organizations should continue to be engaged in the discourse on climate change for intensified education, public awareness, and training (CCEAT) in line with the UNFCCC Article 6. One of the main tools for broad engagement is the proposed newsletter to be entitled: Climate Change Communicator. This will report on the various efforts being made at national level towards achieving high levels of climate change adaptation and mitigation. It is also proposed that a climate change ambassador be appointed to further promote awareness on climate change.

6.10.2 Recommendations

For effective awareness, education and training on climate changethe following recommendations are made:

- Develop an integrated curriculum on climate change for tertiary level institutions
- Carry out a national situational analysis of levels of awareness on climate change among out-of-school youths
- Carry out evidence based research to guide designing of climate change messages targeting specific attitudes and behaviours
- Produce electronic communication material including CDs, DVDs and documentaries on climate change
- Assess the training needs of environmental stakeholders in sector-specific areas such as education, water, forestry, mining and environment
- Increase involvement of the private sector and civic organizations in climate change education, awareness and training programmes
- There is need for translation of all climate change IEC materials which are currently in English into vernacular languages
- Establish programmes for promoting climate change awareness through song and drama, debates at tertiary level, including school competitions
- Engage faith based organizations, media, captains of industry, mining and commerce in the climate discourse
- Hold regional workshops and exchange programmes on climate change
- Establish a climate change commemoration day at national level
- Use social media for communicating and disseminating climate change information and good practices
- Organize and hold national concerts on climate change
- Appoint a climate change ambassador and champion.

CHAPTER 7

7. CONSTRAINTS, GAPS AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

7.1 Policy Review in Zimbabwe

7.1.1 Introduction

Zimbabwe is a signatory to the UNFCCC, Kyoto Protocol and its Doha Amendment, and is in the process of ratifying the Paris Agreement. The country is also Party to the Convention on the Conservation of Biological Diversity (UNCBD) and United Nations Convention to Combat Desertification (UNCCD). At continental level, it is also Party to the Water, Climate and Development Programme (WACDEP). The WACDEP is an initiative of the African Ministers Council on Water (AMCOW) which seeks to support the development of climate change policies, strategies and national adaptation and mitigation plans.

At the regional level, Zimbabwe was part of the development of the SADC Climate Change Adaptation Strategy for the Water Sector. An addendum to the SADC Protocol on Gender and Development is being negotiated to take into consideration climate change and its impacts on gender. The regional instruments provide guidance for national laws and policies.

7.1.2 Country Updates

The country is currently in the process of realigning its acts and sector policies with the Constitution of Zimbabwe enacted in 2013. In the climate sector the major highlight has been the development of a NCCRS (GoZ, 2015). The strategy which was launched in November 2015 also identified the need to have a National Climate Policy as one of the key enablers of integrating adaptation and mitigation measures of Climate Change in Zimbabwe. The NCCRS has action plans and strategies which will also require close to US10 billion to be implemented over a period of 5years, with 50% of the budget going towards the implementation of water and agriculture related strategies. This is also in line with the priorities of the national blue print, the Zim Asset. Development of the National Climate Policy is expected to be complete in 2016.

7.1.3 Institutional, Legal and Governance Framework

Climate change has created urgency in the promotion of good governance at national level especially in the context of adaptation and development (GoZ, 2015). The MEWC is responsible for the development, coordination and implementation of policies relating to the environment, water and climate. The Ministry is also mandated to create and maintain a safe, clean, and healthy environment as well as ensuring management, conservation and the sustainable use of natural resources. It is the first time that the issue of coordinating climate, water and the environment are now being done under one ministry. This has resulted in better coordination and management of climate related issues. Furthermore, the Office of President and Cabinet (OPC) has taken responsibility for overall guidance on implementation of the Paris Agreement, with particular reference to Nationally Determined Contributions. The CCMD was established in 2013 and is responsible for the coordination of climate change issues.

7.1.4 Analysis of Climate Change Related Policies

This section gives an analysis of climate change related policies, programmes and measures. In addition to the policies stated in the SNC the current climate change related policies with various sectors that indirectly address and guide climate change decisions include:Agricultural policies including Irrigation Development Policy; Horticultural Development Policy; Subsidies Policy; Livestock Production and Development Policy; Research and Extension Policy; Agriculture Trade Policy; Renewable Energy Policy; Bio Fuels Policy and Disaster Management Policy.

The Government of Zimbabwe through MEWC is in the process of finalising a National Climate Policy that will guide the country to implement a more strategic, coordinated and unified response to climate issues. The National Climate Policy will also guide mainstreaming of climate change into sectoral policies and development plans. This is meant to improve planning, policy and institutional frameworks and development of appropriate infrastructure to cope with potential impacts of climate change.

The water sector is mainly guided by the National Water Policy of 2013. The strategic issues identified in the policy such as the establishment of Water and Wastewater Services Regulatory Unit, synchronization of the Acts and the development of the national plan and implementation strategy have not yet been implemented due to lack of funding.

7.1.4.1 Agriculture and Food Security

At its peak, agriculture was by far the largest single water user in Zimbabwe utilising more than 81% of the available country's water resources. Most of the inland dams were constructed for irrigation purposes to ensure food security. Agriculture is currently contributing a mere 5% to GDP and is expected to increase to 12.5% by 2018 after the implementation of a cocktail of measures which include development of irrigation infrastructure, increased livestock and crop production and, crafting of enabling policies (Zim Asset, 2013). Any reduction in the available water due to climate change will have a huge impact on the country's economy which has already witnessed cropping patterns being negatively affected by climatic variability while irrigated land has also been reduced.

The rain-fed agricultural system in small scale and communal farms where they do not have irrigation systems is already suffering from climate variability resulting in crop failure and loss of livestock on an annual basis. The sector is currently crafting an irrigation policy to ensure increased food production. The sector has already started importing irrigation equipment from countries such as Brazil, China and Belarus which have highly mechanised irrigation systems. This is also in line with the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) which has been inviting its member states to elaborate national policies for agriculture to boost agricultural productivity, hence, contribute towards the attainment of food security and poverty reduction. However an increase in agricultural production under business as usual may also increase GHGs as agricultural activities are known to release significant amounts of CO_2, CH_4 and N_2O.

7.1.4.2 Disaster Management

In the National Climate Change Response Strategy (2015) it was noted that the country is already experiencing increased frequency of droughts, floods and heavy storms. Climate change is predicted to further increase and intensify these extreme events. The Department of Civil Protection (DCP) has a Disaster Management policy and bill currently tabled in parliament to repeal the Civil Protection Act of 1989. The current legislation has a bias towards recovery whereas the new law will encompass all aspects of Disaster Risk Reduction i.e. preparation, response and recovery. Measures to finalise a framework for disasters are also underway.

7.1.4.3 Education and Capacity Building

The education sector is undergoing policy changes to address some education gaps e.g. the education curriculum is currently being revised witha deliberate bias towards Science, Technology, Engineering and Mathematics subjects (STEM). This curriculum shift towards STEM through science subjects will bring out aspects of environment and climate change at early childhood development stages. The new curriculum for primary and secondary education incorporating STEM is expected to commence in 2017.

The Water, Climate and Developments Programme (WACDEP) being spearheaded by AMCOW and Global Water Partnership Southern Africa in Africa has a capacity building component for policy makers to enable them to be part of the global climate debate.

7.1.4.4 Gender

The Gender Policy (2013) incorporates climate change issues. The policy noted that women who form the bulk of the population living in rural and farming communities in Zimbabwe are highly vulnerable to climate change. Most of them depend on rain fed agriculture whose yields have been affected by the rainfall variability and weather extremes such as drought and floods. They will need to be capacitated with resources such as potable water supplies close to their homes and sustainable clean energy.

7.1.4.5 Energy Sector

The National Policy is focused ondeveloping the use of other renewable sources of energy to complement conventional sources of energy and create and promote a conducive environment for the energy sector players to be able to identify and develop approaches for energy supply that promote sustainable development. Some of the renewable energy sub-sector objectives include: increasing usage of and investment in renewable energy; promoting renewable energy as an environmentally friendly form of energy. Strategies include developing and adopting Renewable Energy Feed-In-Tariff, incentives and strengthening institutional frameworks.

SADC has advocated a shift from rate of return determination model to cost plus pricing model in 2016. This shift unfortunately is expected to increase tariffs for consumers in Zimbabwe. However this may result in an increase in the number of players in the electricity generation field, opening up new projects such as the coal bed methane project and new coal power fired plants which have been on the cards for a while. There is still a huge potential to exploit clean energy from sources such as solar, hydro and biogas which have lower carbon footprints.

Below is the summary of climate related policies and legislation in Zimbabwe (Table 7.1)

Table 7.1 Climate related Policies and Legislation in Zimbabwe

Sector		Responsible Authorities	Act	Climate Change Related Policy	Policy Status/ Comment
1	National	Government of Zimbabwe	Constitution of Zimbabwe	Zim Asset (2013)	Sets the tone for the development and realignment of all country policies, strategies and plans from 2013-2018
2	Climate Change	Climate Change Management Department, Meteorological Services Department, MEWC	Meteorological Services Act [13:21]	Climate Policy (not finalised)	NCCRS complete Climate policy still under development
3	Water	ZINWA, MEWC	Water Act [20:24] of 1998 (Amended in 2005)	National Water Policy (2013)	Policy highlights the need d to include impact of climate change in all water related planning e.g. river system outline plans. Current talks of having a separate climate change water policy were never envisaged in the early stages.
4	Environment	EMA, MEWC	Environmental Management Act [20:27] of 2003	National Environmental Policy (2009)	May need revision to concentrate on environmental issues alone
5	Energy	ZERC, Ministry of Energy and Power Development	Energy Regulatory Authority Act [13:23] of 2011, Electricity Act [13:19] of 1985 (amended in 2002), Petroleum Act [13:22] of 2006	National Energy Policy (2012)	Focus on increased use of underutilised renewable energy and energy efficiency. Enactment of Energy management act to support policies
				Renewable Energy	Under development. A policy shift as it was never anticipated or mentioned in the Energy Policy
				Bio fuels Policy	Under development. A policy shift as it was never anticipated or mentioned in the Energy Policy

Sector		Responsible Authorities	Act	Climate Change Related Policy	Policy Status/ Comment
6	Forestry	Forestry Commission, MEWC	Forest Act [19:05] of 1999, Communal Lands Forest Produce Act [20] of 1987	Forestry Based Land Reform Policy	Under development
7	Disaster Management	Ministry of Local Government, Public Works and Urban Development	Civil Protection Act of 1989	Disaster Management Policy	Under development together with a new act both with emphasis on disaster management (preparation, response and recovery) as opposed to civil protection which is only reactive
8	Agriculture and Food Security	ARDA, Ministry of Agriculture, Mechanisation and Irrigation Development, (MAMID), Food and Nutrition Council, Office of the President and Cabinet	Food and Food Standard (15:03) 0f 1971 amended 2001, Public Health (15:09) of 1924 revised 1978	Comprehensive Agriculture Policy	Under development since 2012
				Livestock Policy	Under development since 2014
				Mechanisation & Irrigation Policy	Under development since 2015
				Food and Nutrition Security policy (2013)	Considers risk reduction from climate change impacts. Now supported by the National Nutrition Strategy (2015)
9	Education & Aware-ness	Ministry of primary and Secondary Education, Ministry of Higher and Tertiary education Ministry of Psychomotor Activities	Zimbabwe Education Act Chapter [25:04] (1989) Zimbabwe Council For Higher Education Act [Chapter 25:08] (2006)		No definite policy. Skills development and capacity building covered in Science and technology but only focussed on scientific subjects
10	Gender	Ministry of Women Affairs, Gender and Community Development	Referred to in the Constitution	The National Gender Policy (2013)	Advocating for a framework to comprehensively address gender inequalities in environment conservation and climate change adaptation and mitigation.

Sector		Responsible Authorities	Act	Climate Change Related Policy	Policy Status/ Comment
11	Industry and technology Transfer	Ministry of Industry, Ministry of Science and Technology		Industrial Development Policy (2012)	Concerned with sustenance without mention of energy efficient and reduction of GHGs emissions
				Science, technology and Innovation Policy (2012)	Focus on capacity and skills development. Aims to implement research to find scientific solutions to climate change impacts
				Trade Policy (2012)	Geared towards at increasing exports and international competitiveness. No mention of climate change although targeted markets such as COMESA and SADC have climate change initiatives

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

7.2.1 Background

Zimbabwe produced its INC in 1998, and following that a number of local climate change studies and pilot projects have been done. These studies include the Technology Transfer Needs Assessment (TTNA) (MET, 2004) and the National Capacity Self-Assessment (NCSA) for climate change, biodiversity and land degradation (MET, 2006). The SNC was produced in 2012 building on the findings and improving on the gaps identified in the INC.

In 2012 the MEPIP produced a Baseline Report on Climate Change and Development, and this was followed by a Climate Change Situational Analysis done by the MENRM in 2013. These studies identified constraints, information gaps, and related financial, technical and capacity needs. Progress has been made in addressing some of the identified gaps and constraints. The country has since developed a National Climate Change Response Strategy (GoZ, 2015) as part of the strategy of addressing policy gaps which existed. Other significant developments since the last communication include:

- Institutional arrangements enhanced e.g. establishment of a fully-fledged department in the Ministry of Environment, Water and Climate to manage climate change affairs in Zimbabwe
- Zimbabwe Energy Regulatory Authority
- Clean energy and efficiency import incentives, and mandatory blending of petrol
- Awareness on climate change adaptation and mitigation options
- Energy information system developed
- Development of relevant policies have been initiated e.g. Climate policy, Biofuels policy, Forestry policy, Renewable energy policy)

In this chapter, climate change related constraints, gaps and proposed solutions are presented.

7.2.2 Scope of work and methodology

The information contained in this report was gathered through literature review and stakeholder consultations in the context of national development priorities for Zimbabwe. National documents reviewed include;

- Initial National Communication to the UNFCCC (MMET, 1998)
- Second National Communications to the UNFCCC (MENRM, 2012)
- Technology Transfer Needs Assessment (MET, 2004)
- National Capacity Self-Assessment (MET, 2006)
- Climate Change Situational Analysis (MENRM, 2013)
- National Climate Change Response Strategy (MEWC, 2015)
- Zim Asset (the economic blue print to provide for the development context 2013-2018) (GoZ, 2013)
- Intended Nationally Determined Contributions (INDCs) (GoZ, 2015)

Stakeholder consultations targeted climate change consultants involved in the TNC, related fields practitioners, researchers and policy makers. Implementing organisations such as the development agencies, civil societies and relevant government ministries and institutions were also consulted.

7.2.3 Gaps and constraints

7.2.3.1 Data, Information and knowledge gaps

The following data, information and knowledge gaps were identified:

- Data on GHG inventories; there are activity data gaps across all sectors. Specific examples include data on: generator use, fuel combustion in vehicles, and production data from informal sector.
- Country-specific emission factors; there are no country-specific emission factors for most of the sectors.
- There is lack of disaggregated activity data.
- Lack of consolidated information on national or sector specific socio-economic impacts of climate change.
- Insufficient coverage of hydro-

meteorological observation network.

- Lack of adequate climate knowledge within the country's education sector.

Some of the interventions to address the gaps in data and information are:

- Development of relevant capacity and systems.
- Development of a Sustainable National GHG Inventory Management System.
- Establishment of data contact points within specific sector or line ministries to facilitate flow of data or information.
- Training on specific methodologies and tools on GHG inventories.
- Establishment of a Climate Change Information and Knowledge Management System.
- Establishment of a national network for direct measurements of GHG emissions.

7.2.3.2 Awareness and behavioral change

Generally people are informed about climate change through various awareness campaigns but there has been limited progress in behavioral change.

Some of the interventions for behavioral change are:

- Promoting the understanding of climate change at very early stages of academic development.
- curriculum that mainstreams climate change.
- Design appropriate behavioral change information material suitable for various levels of the society and use various and appropriate communication channels to deliver them.

7.2.3.3 Financial constraints

Financial resources are required for conducting relevant research, capacity building and awareness and to implement adaptation and mitigation options. Zimbabwe has limited financial resources to carry out climate change related activities.

Some of the interventions to address financial challenges are:

- The country should source funds from available international funding windows such as the Green Climate Fund, GEF and World Bank.
- Strengthen capacity in developing bankable projects on climate change adaptation and mitigation.
- Establish a National Climate Change Fund.
- Promotion of Public-Private-Partnerships.
- Financial incentives to promote mitigation and adaptation technology transfer.

7.2.3.4 Technological constraints

The identified technological gaps were on systematic observation, climate change mitigation and adaptation and technology transfer.

The following interventions are proposed in the technological sector:

- Investment in and procurement of modern and advanced systematic observation systems and equipment, such as automated weather stations (AWS).
- Promotion of research on appropriate adaptation and mitigation technologies including indigenous knowledge systems.
- Establishment and monitoring of technology import standards and screening mechanisms so as to safeguard against importation of inappropriate technologies.

7.2.4 Reporting and negotiations

Climate change convention negotiations and decisions follow a long and protracted process that normally culminate in an annual climate conference, the COP. Zimbabwe has limited capacity in climate change negotiations due to limited funding to support negotiating teams.

The following interventions are proposed in the reporting and negotiations:

- Establishment of a framework and funding for preparatory meetings.
- Engage in inclusive national, regional and continental dialogues.

BIBLIOGRAPHY

1. AMCOW (2012), Water Security and Climate Resilient Development
2. Atakan, V., S. Sahu and N. DeCristofaro. 2015. Low clinker Cements - Sustainable alternatives. International Cement Review. Tradeship Publications Ltd, USA
3. Bandura, A. (1986). Social Foundations of Thought and Action: A Social Cognitive Theory. Englehood Cliffs, Prentice-Hall.
4. Central Statistical Office, (CSO) Zimbabwe, 2000, Quarterly Statistics
5. Central Statistical Office, (CSO) Zimbabwe, 2006, Quarterly Statistics
6. Chapin F.S, Zavatela E.S, Eviner V.T, Naylor R.L, Vitousek, P.M, Reynolds H.L, Hooper D.U., Lavorel S, Sala O.E, Hobbie S.E, Mack M.C and Diaz S. 2000. Consequences of changing biodiversity. Nature 405:234-242
7. Chenje, M., Sola, L. &Palency, D. (eds.) (1998). The State of Zimbabwe's Environment. Ministry of Mines, Environment and Tourism, Government of the Republic of Zimbabwe, Harare
8. Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995.
9. Default Emission Factor Handbook (CORINAIR, 1994)
10. Denmark's Third National Communication on Climate Change; Under the United Nations Framework Convention on Climate Change.
11. Energy Resource Assessment Study, Government of Zimbabwe Ministry of Energy and Power Development.
12. Environmental Management Agency, 2009: Fire Assessment Report for 2009.
13. FAO FRA, (2005). Global Forest Resources Assessment 2005.
14. FAO FRA, (2010). Global Forest Resources Assessment 2010. Guidelines for Country Reporting for FRA 2010.Fourth National Communication Under the United Nations Framework Convention on Climate Change; Republic of Poland
15. Fishbein, M. &Ajzen, I. (2010). Predicting and Changing Behaviour. Psychology Press, Taylor and Francis Group, New York.
16. Fishbein,M. &Ajzen, I. (1975). Belief, Attitude and Behaviour: An Introduction to Theory and Research. Reading, MA: Addison-Wesley.
17. Government of Zimbabwe (2009), Zimbabwe National Environmental Policy and Strategies. Government of the Republic of Zimbabwe, Ministry of Environment and Natural Resources Management, Harare.
18. Government of Zimbabwe (2012), Industrial Development Policy, Ministry of Industry and Commerce, Harare
19. Government of Zimbabwe (2012), Science, Technology and Innovation Policy, Ministry of Science and Technology Development, Harare
20. Government of Zimbabwe (2013), Food and Nutrition Security Policy,
21. Government of Zimbabwe (2013), National Energy Policy, Ministry of Energy and Power Development, Harare
22. Government of Zimbabwe (2013), National Water Policy, Ministry Of Water Resources Development And Management, Harare
23. Government of Zimbabwe (2013), The National Gender Policy, Ministry of Women Affairs, Gender and Community Development, Harare.
24. Government of Zimbabwe (2015), Zimbabwe's National Climate Change Response Strategy, Government of the Republic of Zimbabwe, Ministry of Environment, Water and Climate, Harare.

25. Government of Zimbabwe (GoZ) (2009). Zimbabwe National Environmental Policy and Strategies. Government of the Republic of Zimbabwe, Ministry of Environment and Natural Resources Management, Harare.
26. GoZ (2015) Zimbabwe's Intended Nationally Determined Contribution (INDC) Submitted to the United Nations Framework Convention on Climate Change (UNFCCC) http://www4.unfccc.int/submissions/INDC/Published%20Documents/Zimbabwe/1/Zimbabwe%20Intended%20Nationally%20Determined%20Contribution%202015.pdf
27. GoZ, 2013. Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset). Government of Zimbabwe (GoZ), Harare. http://www.zimtreasury.gov.zw/zim-asset
28. GWP (2015), National Consultations on Water, Food Security and Nutrition, Zimbabwe, Global Water Partnership, http://www.gwp.org/en/gwp-in-action/News-and-Activities/Securing-Water-Food-Energy-Ecosystems-GWP-Africa-Responds-to-the-Global-Agenda
29. Hijmans, R.J,Guarino, L,Bussink, C,Marthur,P,Cruz, M,Barrantes, I and Rojas,E.2004 DIVA-GIS, version 4. A geographic information system for the analysis of biodiversity data. Manual.
30. International Cement Review, 2004, Circle shut down for upgrade: International Cement Review, Building Bulletin, issue 72, April, p. 4
31. IPCC (1996) Revised IPCC Guidelines for National Greenhouse Gas Inventories, 1996.
32. Ito A (2004) Global mapping of terrestrial primary productivity and light-use efficiency with a process-based model. In: Proceedings of the global mapping workshop, TERRAPUB, Tokyo,pp 343–358.
33. Karspryzk, D. & Montano, D. Application of an Integrated Behavioural Model to Understanding HIV Prevention Behaviour of High-risk men in Rural Zimbabwe. In I. Ajzen, R. Hornick, & D. Albarracin (Eds.) Prediction and Change of Behaviour: Applying the Reasoned Action Approach (pp. 149-172). Mahwah, NJ:Lawrence Erlbaum.
34. Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Ramesteiner, E., chlamadinger, B., Wunder, S. and Beach, R. 2008 Global cost estimates of reducing carbon emissions through avoided deforestation. Proceedings of the National Academy of Sciences 105 (30): 10302–10307.
35. Kunjeku, E., Frost, P.G.H, Nabane, N., Murwira, H.K., Mushove, P., Chidziya, E., Gambiza, J., Mkwanda, R., Semwayo, D.T., and Bond, I (1998)."Research , Inventory and Monitoring" In: M. Chenje, L. Sola and D. Paleczny (eds). The State of Zimbabwe's environment. Government of the Republic of Zimbabwe, Ministry of Mines, Environment and Tourism, Harare, Zimbabwe.
36. Kwesha D.and Dreiser, C. (1998) Vegetation Mapping in Zimbabwe Using Satellite Remote Sensing and Geographic Information System. ForMat Volume 10 No.1 March, 1998.
37. Mabugu R and Chitiga M, 2002. Accounting for forest resources in Zimbabwe CEEPA Discussion Paper No 7, CEEPA. University of Pretoria, Pretoria, South Africa.
38. Mapaure, A and Timberlake J.R, A checklist of Zimbabwean Plant Red Data List (Sabonet Report No. 14 2002).
39. Matarira C.H. 1990. Drought over Zimbabwe in a regional and global context. International Journal of Climatology 10: 609–625.
40. MENRM, 2012. Zimbabwe Second National Communication to the UNFCCC. Ministry of Environment and Natural Resources Management (MENRM). Harare.
41. MENRM, 2013. Climate Change Situational Analysis for Zimbabwe. Ministry of Environment and Natural Resources Management (MENRM). Harare.
42. MEPIP, 2012. Baseline Report on Economic Development and Climate Change. Ministry of Economic Planning and Investment Promotion, Harare. http://cdkn.org/wp-content/uploads/2011/08/Zimbabwe-baseline-report-FINAL.pdf
43. MET, 2004. Technology Transfer Needs Assessment in Zimbabwe. Ministry of Environment and

Tourism (MET), Harare. http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNR_CRE/e9067c6e3b97459989b2196f12155ad5/58eec8175271459a93e40a38fac3e75a.pdf

44. MET, 2006. National Capacity Self Assessment. Ministry of Environment and Tourism (MET), Harare. http://www.unep.org/dgef/Portals/43/publications/ZimbabweNCSA.pdf
45. MEWC 2015. Mitigation and Low Carbon Pathways Stakeholders' Consultative Meeting and National Communication Mitigation Inception Report. Montclair, Nyanga (Zimbabwe)
46. MEWC, 2015. Intended Nationally Determined Contributions Presentation of the INDCs policy component. Harare
47. MEWC, 2015. Zimbabwe's National Climate Change Response Strategy. Ministry of Environment, Water and Climate (MEWC). Harare
48. Michie, W. D. and E. S Nhandara (1999), Geography Today
49. Ministry of Economic Planning and Investment Promotion (2011), Zimbabwe Mid Term Plan, Printflow, Harare
50. Ministry of Mines, Environment and Tourism. (1998). 'Zimbabwe's Initial National Communication on Climate Change.' Government of Zimbabwe, Ministry of Mines, Environment and Tourism, Harare, Zimbabwe.
51. Mobbs P.M., 2004, The Mineral Industry of Zimbabwe, US Geological Survey Minerals Yearbook.
52. MOEPD, 2012. National Energy Policy, Ministry of Energy and Power Development. Harare.
53. Mukandi, W.R.L (1998): Mitigation Options in Forestry, Land-Use Change and Biomass Burning in Africa. Environmental Energy Technologies Division, May 1998
54. NEPAD (2003). Action Plan for the Environment Initiative. New Partnership for Africa's Development,Midrand. http://nepad.org/2005/files/reports/action_plan/action_plan_english2.pdf
55. Nziramasanga. N, Maya.R.S and Fenhann Jorgen; UNEP Greenhouse Gas Abatement Costing Studies, Zimbabwe Country Study Phase Three, November 1994.
56. Rafemoyo, B (2012) investment opportunities in the Zimbabwean power sector. ZESA Holdings P/L. http://www.esi-africa.com/wp-content/uploads/B_Rafemoyo.pdf (accessed 03 December 2015)
57. Renewable Energy Opportunities for Zimbabwe, Government of Zimbabwe Ministry of Energy and Power Development
58. Running S., Nemani., R.R.,Heinsch.,F.A, Zhao, M, Reeves, M & Hashimoto H 2004 Bioscience 54 (6): 547-560.
59. Sadalmelik. 2007. Topographic map of Zimbabwe.https://commons.wikimedia.org/wiki/File:Zimbabwe_Topography.png (accessed 03 December 2015)
60. Sankaran M, Ratnam J, Hanan NP. 2004. Tree-grass coexistence in savannas revisited-insights from an examination of assumptions and mechanisms invoked in existing models. Ecol. Lett. 7:480–90.
61. Sankaran M, Ratnam J, Hanan NP. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. Global Ecology and Biogeography, 17, 236–245.
62. Svotwa E, F. Ndangana, O. I Manyanhaire and Mushava 2002: In Veld Fire Risk Assessment and Community Based Control Strategy in Norton Farming Area of Zimbabwe.
63. Timber Producers Federation (1995). Zimbabwe Timber Industry Statistics for the year ended 31 March, 1995.
64. Timber Producers Federation, (1996). Zimbabwe Timber Industry Statistics for the year ended 31 March, 1996.
65. Timber Producers Federation, (1997). Zimbabwe Timber Industry Statistics for the year ended

31 March, 1997.

66. Timber Producers Federation, (1998). Zimbabwe Timber Industry Statistics for the year ended 31 March, 1998.
67. Timber Producers Federation, (1999). Zimbabwe Timber Industry Statistics for the year ended 31 March, 1999.
68. Timber Producers Federation, (2000). Zimbabwe Timber Industry Statistics for the year ended 31 March, 2000.
69. Timber Producers Federation, (2001). Zimbabwe Timber Industry Statistics for the year ended 31 March, 2001.
70. UN.2004. General maps: Zimbabwe. United Nations Geospatial Information Section. http://www.un.org/Depts/Cartographic/map/profile/zimbabwe.pdf (accessed 03 December 2015)
71. Waste Sector Greenhouse Gas Emissions Projections for Australia for 2007, http://www.climatechange.gov.au/projections
72. Zimbabwe Country Study: Implementation of RET Opportunities and Barrier Removal, Southern Centre for Energy and Environment, UNEP.
73. Zimbabwe Meteorological Services Department. 1981. Climate Handbook of Zimbabwe.
74. Zimbabwe National Energy Policy, Government of Zimbabwe Ministry of Energy and Power Development.
75. Zimbabwe's Initial National Communication on Climate Change, 1994
76. FAO (Food and Agriculture Organization of the United Nations) Fishery Country Profile, The Republic of Zimbabwe. 2007. ftp://ftp.fao.org/FI/DOCUMENT/fcp/en/FI_CP_ZW.pdf. (accessed on 27 December 2015)
77. ZIMSTAT (2012), National Profile 2012 Population Census
78. ZIMSTAT (2013), National Accounts Statistics
79. Zimstat (2013), Statement of External Trade
80. ZimStats (2012), Zimbabwe Population Census 2012, www.zimstat.co.zw
81. ZINWA. 2014. http://www.zinwa.co.zw/catchments/location (accessed 03 December 2015)

INTERNET SOURCES

- http://cdm.unfccc.int/EB/021/eb21repan15.pdf
- http://extension.missouri.edu/publications/displaypub.aspx?p=g6957
- http://practicalaction.org/docs/technical_information_service/recycling_organic_waste.pdf
- http://www.benefits-of-recycling.com/compostingequipment.html
- http://www.cleanairgardening.com/accessories.html
- http://www.dmoz.org/Business/Environment/Waste_Management/Composting/
- http://www.epa.gov/epawaste/conserve/rrr/composting/index.htm
- http://www.epa.gov/osw/conserve/rrr/composting/basic.htm
- http://www.rethinkrecycling.com/residents/throw-buy/materials-name/food-waste.pdf ecenter.colorado.edu/.../77342c92dbad96e181e5ea3805db9a1dbf39441d.pdf
- http://www.epa.gov/osw/conserve/rrr/composting/science.htm
- http://www.urbangardencenter.com/drum-composting.aspx
- http://www.cool2012.com/tools/technologies/Composting methods & technologies
- Ashburner R., Zimbabwe Sugar Association, The Sunday Mail, 06/18/2006
- http://www.zimbabweherald.com/index.php?id=38100&pubdate=2004-11-24. Kadzere, M, 2004 (November 24), Ziscosteel needs proper turnaround, says industry captains, The Herald, accessed July 25, 2005

Appendix 1: List of Chemical Symbols, Units and Currency

CHEMICAL SYMBOLS

CO_2	Carbon Dioxide
CH_4	Methane
NOx	Nitrogen Oxides
CO	Carbon Monoxide
H_2O	Water Vapour
N_2O	Nitrous Oxide
O_3	Ozone
NMVOCs	Non-methane Volatile Organic Compounds
CFCs	Chlorofluorocarbons

UNITS

kg	Kilogrammes
km	Kilometres
mm	millimetre
ha	Hectares
t	Tonnes
dm	Dry matter
KW	Kilowatts
MW	Megawatts
m^3	Cubic metres
Gg	Gigagrams
PJ	PetaJoule

CURRENCY Z$ **Zimbabwe Dollar**

Appendix 2: Forestry Baseline Summary Sheet

BIOMASS BASELINE SUMMARY							
2000 DEMAND	Ag. Waste '000t	Fuel Wood '000t	Ind. Wood '000t	Agric. '000t	Livestock '000s	Elec-tric. GWh	Total
TOTAL SUPPLY OF PRODUCTS	1,595	4,518	120	12,450	315	45	**19,042**
TOTAL DEMAND FOR PRODUCTS	1,515	70	1,100	3,240	315	45	**6,285**
Average intensity of product extraction							
2010 DEMAND							
TOTAL SUPPLY OF PRODUCTS	2,708	8,118	1,100	7,211	516	99	**19,752**
TOTAL DEMAND FOR PRODUCTS	2,761	128	1,100	7,211	574	100	**11,873**
2030 DEMAND							
TOTAL SUPPLY OF PRODUCTS	3,940	2,294	1,100	7,969	693	99	**16,095**
TOTAL DEMAND FOR PRODUCTS	3,372	156	1,100	7,969	628	104	**13,329**

Appendix 3: Forest Protection

FOREST PROTECTION		
OUTPUT		
>>> FROM STEPS 2 AND 3: LAND AREA		**Hectares**
>> Baseline Scenario		50,000
> Land Converted from Forest		25,000
>> Mitigation Scenario		50,000
>>>> STEP 4: ESTIMATING CARBON POOL AND SEQUESTRATION		
>>> STEP 4.1: BIOMASS DENSITY		**t/ha**
>> Baseline Scenario		320
>> Mitigation Scenario (t/ha)		320
>>> STEP 4.2: BIOMASS CARBON DENSITY	**C (%)**	**tC/ha**
>> Baseline Scenario	0.65	208
>> Mitigation Scenario	0.65	208
>>> STEP 4.3: SOIL CARBON DENSITY		**tC/ha**
>> Baseline Scenario		540
>> Mitigation Scenario		540
>>> STEP 4.4: TOTAL CARBON DENSITY		**tC/ha**
>> Baseline Scenario		748
>> Mitigation Scenario		748
>>>> STEP 5: ESTIMATING COSTS AND BENEFITS		
>>> STEP 5.1: COST OF FOREST PROTECTION		**$/ha/yr**
>> Baseline Scenario		3.30
>> Mitigation Scenario		19.00
>>> STEP 5.1.1: STREAM OF COSTS AND PRESENT VALUE		**$/ha**

FOREST PROTECTION		
>> Initial Costs		
>> Recurrent (Maintenance etc.) Costs		
>> Monitoring Costs		
>> Total Costs		
>> Present Value of Costs		19.00
>>> STEP 5.2: BENEFIT FROM LAND CONVERSION		**$/ha/yr**
>> Baseline Scenario		75.00
>> Mitigation Scenario		
>>> STEP 5.4: BENEFIT FROM FOREST PROTECTION		**$/ha/yr**
>> Baseline Scenario		5.00
>> Mitigation Scenario		30.00
>>> STEP 6.1: TOTAL CARBON POOL		**tC**
>> Annual Incremental C Protected		
>> Baseline Scenario C Pool		37,400,000
>> Mitigation Scenario C Pool		37,400,000
>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF CSEQ		**$**
>> Incremental Net Cost		-13,901,618
>> Baseline Scenario Benefit		-1,228,443
> Cost		2,767,276
> Benefit from Land Conversion (Opportunity Cost)		-2,431,851
> Benefit from Forest		3,970,684
>> Mitigation Scenario Benefit		12,673,175
> Cost		17,157,074
>Alternative Supply of Imported Products		-2,553,443
> Benefit		27,276,806
>>> STEP 7: COST-EFFECTIVENESS INDICATORS		**$/tC**
>> Net Present Value of Benefits		
>		0.15

FOREST PROTECTION		
> $/ha.		278.00
>> Benefit of Reducing Atmospheric Carbon		
> $/tC-yr.		0.01
>> Initial Cost of Forest Protection		
> $/tC		0.01
> $/ha.		10.00
>> Endowment (Net Present Value of Costs)		
> $/tC		0.18
> $/ha.		343.00

Appendix 4: Reforestation

OUTPUT	Ha
>> Baseline Scenario	
>Degraded land	33,342.00
>> Mitigation Scenario	
>Degraded land	32,134.00
> Reforested Land	1,108.00
> Dry Weight (t/ha)	
> Carbon density (%)	
>>> Carbon Pool (tC/ha)	39.00
>> 1. Vegetation Carbon Pool	45.00
> Rotation Period (Years)	15.00
> Mean Annual Increment (tB/year/ha)	12.00
> Carbon density (%)	0.50
>> 2. Soil Carbon Pool	30.00
> Accumulation Period (Years)	15.00
> Amount of carbon stored in soil (tC/ha/yr)	2.00
>> 3. Decomposing Matter Carbon Pool	22.00
> Decomposition Period (Years)	6.00
> Amount of decomposing carbon (tC/ha/harvest)	5.00
>> 4. Product Carbon Pool	30.00
> Average Age (Years)	30.00
> Amount of carbon stored in product (tC/ha/harvest)	30.00
>>> Carbon Pool Created by Mitigation Option (tC/ha)	127.50
>>> Carbon Pool Including Baseline Soil Carbon (tC/ha)	162.50
>>> STEP 4.3: TOTAL CARBON DENSITY (tC/ha)	
>> Baseline Scenario	
>Degraded land	39.50
>> Mitigation Scenario	
>Degraded land	39.50
> Reforested Land	162.50
>>>> STEP 5: ESTIMATING COSTS AND BENEFITS	

OUTPUT	Ha
>>> STEP 5.1: COSTS ($/ha/yr)	
>> Baseline Scenario (Degraded lands)	3.30
>> Mitigation Scenario (Reforestation) **($/ha/yr)**	1,922.00
>>> STEP 5.1.1: STREAM OF COSTS ($/ha) OF REFORESTATION	
>> Initial Costs ($/ha/yr)	500.00
>> Recurrent (Maintenance etc.) Costs ($/ha/yr)	20.00
>> Monitoring Costs ($/ha/yr)	10.00
>> Establishment Costs ($/ha/yr)	
>> Total Costs ($/ha/yr)	530.00
>> Present Value of Costs ($/ha)	
>> Annualized Value of Costs ($/ha/yr)	
>> Present Value of Initial Cost	
>>> STEP 5.2: BENEFITS ($/ha/yr)	
>> Baseline Scenario (Degraded lands)	20.00
>> Mitigation Scenario (Reforestation)	423.00
>>> STEP 5.2.1: STREAM OF BENEFITS OF REFORESTATION PROGRAM	
>> Timber Product ($/ha/yr)	0.00
>> Non-timber benefits (fuel wood) ($/ha/yr)	10.00
>> Non-timber benefits (resin/honey/fruits) ($/ha/yr)	5.00
>> Other benefits ($/ha/yr)	
>> Total Benefits ($/ha/yr)	15.00
>> Present Value of Benefits ($/ha)	
>> Annualized Value of Benefits ($/ha/yr)	
>>> NET PRESENT VALUE OF BENEFITS ($/ha)	
>>> STEP 6.1: TOTAL CARBON POOL (tC)	
>> Annually Created Incremental C Pool	136,284.00
>> Baseline Scenario	
>Degraded land	1,313,059.00

OUTPUT	Ha
>>> STEP 5.1: COSTS ($/ha/yr)	
>> Baseline Scenario (Degraded lands)	3.30
>> Mitigation Scenario (Reforestation) **($/ha/yr)**	1,922.00
>>> STEP 5.1.1: STREAM OF COSTS ($/ha) OF REFORESTATION	
>> Initial Costs ($/ha/yr)	500.00
>> Recurrent (Maintenance etc.) Costs ($/ha/yr)	20.00
>> Monitoring Costs ($/ha/yr)	10.00
>> Establishment Costs ($/ha/yr)	
>> Total Costs ($/ha/yr)	530.00
>> Present Value of Costs ($/ha)	
>> Annualized Value of Costs ($/ha/yr)	
>> Present Value of Initial Cost	
>>> STEP 5.2: BENEFITS ($/ha/yr)	
>> Baseline Scenario (Degraded lands)	20.00
>> Mitigation Scenario (Reforestation)	423.00
>>> STEP 5.2.1: STREAM OF BENEFITS OF REFORESTATION PROGRAM	
>> Timber Product ($/ha/yr)	0.00
>> Non-timber benefits (fuel wood) ($/ha/yr)	10.00
>> Non-timber benefits (resin/honey/fruits) ($/ha/yr)	5.00
>> Other benefits ($/ha/yr)	
>> Total Benefits ($/ha/yr)	15.00
>> Present Value of Benefits ($/ha)	
>> Annualized Value of Benefits ($/ha/yr)	
>>> NET PRESENT VALUE OF BENEFITS ($/ha)	
>>> STEP 6.1: TOTAL CARBON POOL (tC)	
>> Annually Created Incremental C Pool	136,284.00
>> Baseline Scenario	
>Degraded land	1,313,059.00

OUTPUT	Ha
>> Mitigation Scenario	1,449,343.00
>Degraded land	1,269,293.00
> Reforested Land	180,050.00
>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF FORESTATION PROGRAM ($/yr)	
>> Incremental Net Benefit	-1,679,134.00
>> Baseline Scenario Net Benefit	555,141.40
> Cost	109,698.60
> Benefit	664,840.00
>> Mitigation Scenario Net Benefit	-1,123,992.00
> Annual Cost of Degraded land	106,042.00
> Annualized Cost of Converted Land	2,129,821.00
> Annual Benefit from Degraded land	642,680.00
> Annualized Benefit from Converted Land	469,191.00
> Present Value of Initial Costs ($/ha)	1,028,084.00
>>> STEP 7: COST-EFFECTIVENESS INDICATORS FOR THE 40 YEAR PROGRAM	
>> Net Present Value of Benefits	
> $/tC	-30.41
> $/ha.	-3,741.00
>> Benefit of Reducing Atmospheric Carbon (BRAC)	
> $/tC-yr.	-0.23
>> Initial Cost	
> $/tC	1.80
> $/ha.	227.00
>> Endowment (Present Value of Costs)	
> $/tC	38.70
> $/ha.	4,761.00

Appendix 5: Bio-energy

>>> STEP 5.1.2: STREAM OF COSTS ($) OF BIOELECTRICITY GENERATION FOR A ONE MW GASIFIER	
>> Initial Cost of Power Plant ($/MW)	1,000,000.00
>> Recurrent (Maintenance etc.) Costs ($/yr)	90,000.00
>> Total Costs	
>> Present Value of Capacity Cost ($/MW)	514,947.00
>> Cost of Electricity Generation ($/MWh)	16.00
> Annual Electricity Generation (MWh/yr)	5,256.00
> Capacity factor	0.60
>Gasifier Lifetime (Yrs)	10.00
>> Price of fossil-fuelled electricity ($/MWh)	90.00
>>> STEP 5.2: BENEFITS	
>> Baseline Scenario (Degraded lands) ($/ha/yr)	20.00
>> Mitigation Scenario (Bioelectricity) ($/ha/yr)	372.00
>>> STEP 5.2.1: STREAM OF BENEFITS OF REFORESTATION PROGRAM	
>> Timber Product ($/ha/yr)	
>> Non-timber benefits ($/ha/yr)	
>> Other benefits ($/ha/yr)	
>> Total Benefits ($/ha/yr)	
>> Present Value of Benefits ($/ha)	3,634.00
>> Annualized Value of Benefits ($/ha/yr)	372.00
>>> NET PRESENT VALUE OF BENEFITS ($/ha)	1,726.00
>>> STEP 6.2: TOTAL COSTS AND BENEFITS OF BIOELECTRICITY PROGRAM ($)	
>> Annualized Incremental Net Benefit ($/yr)	
>> Baseline Scenario Net Benefit ($/yr)	
> Annual Cost	
> Annual Benefit	
>> Mitigation Scenario Net Benefit ($/yr)	
>>> STEP 7: COST-EFFECTIVENESS INDICATORS FOR THE 40 YEAR PROGRAM	
>> Net Present Value of Benefits	
> $/tC	
> $/ha.	

	15.38
>> Benefit of Reducing Atmospheric Carbon (BRAC)	1,163.00
> $/tC-yr.	
>> Initial Cost	0.12
> $/tC	
> $/ha.	
>> Endowment (Present Value of Costs)	
> $/tC	3.60
> $/ha.	276.00





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