THE GOVERNMENT OF LESOTHO

UNEP/GEF CLIMATE CHANGE

STUDY IN LESOTHO

PROJECT NUMBER GF/2200-96-16

GREEN HOUSE GAS EMISSIONS INVENTORY REPORT

FOR THE BASE YEAR 1994

LESOTHO
METEOROLOGICAL
SERVICES

UNEP
UNITED NATIONS
ENVIRONMENT
PROGRAMME

NATIONAL
ENVIRONMENT
SECRETARIAT

ACKNOWLEDGEMENTS

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Special thanks are due to all local institutions and individuals who took part in this exercise especially by providing the necessary data and invaluable comments without which this report would not have been completed.

Lastly but by no means least, the team would like to thank Dr Pak Sum Low and Dr Ravi Sharma, both from UNEP in Nairobi, for their respective pivotal roles they played from the inception to the implementation of this project.

FOREWORD

The subject of climate change is of special interest to the Government and people of Lesotho. Our national greeting "***Khotso, Pula, Nala***" which literally translates into " ***Peace, Rain, Prosperity***" is testimony of the importance of climate, indicated by rainfall in the day to day life of way of every Mosotho. Lesotho possesses a fragile mountainous ecosystem and as a result is vulnerable to drought, desertification and large-scale land degradation. By appending its signature to the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 in Rio de Janeiro and its subsequent ratification in March 1995, Lesotho was not only unequivocal in its appreciation of the threat posed by human induced climate change to the well being of the present and future generations but also expressing its full commitment to the terms of the Convention.

This report of the inventory of emissions and sinks of greenhouse gases is an initiative towards meeting Lesotho's obligation under article 4 of the Convention, which commits all Parties:-

·To develop, periodically update, publish and make available to the Conference of the Parties (COP), national inventories of anthropogenic emissions by sources and removal by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the conference of the Parties.

The preparation of this report involved local and international experts of various backgrounds. It represents the first activity ever implemented on the subject of Climate Change in the country. It therefore cannot claim to be free of problems. However, it is a source of pleasure to me that it has been completed. It provides an important base for further activities and ultimately the National Action Plan on Climate Change. The Government of Lesotho identifies and sanctions this report on the Inventory of the Greenhouse Gases over the territory of Lesotho.

I thank both the Global Environment Fund (GEF) of the World Bank for providing funds to undertake this study and the United Nations Environment Programme (UNEP) for preparing the project document and overseeing its implementation.

I acknowledge, the role played by members of the National Study Team, in particular, the implementing group led by Project Supervisor Mr. B.T. Sekoli, Project Coordinator Mr. S.P. Raboqha, the Energy Sector Coordinator, Mr. T. Phuroe, Land-use change and Forestry Sector Coordinator Mrs. M. Mphale, the Agriculture Sector Coordinator Dr. M.V. Marake and the Project Assistant Coordinators Mr. L.E. Bulane, Mrs. F.M. Mahahabisa and Miss. J.R. Mphethi. I also recognize the role played by the National Environment Secretariat (NES) under the leadership of Mr. B.M. Motsamai as the overall coordinator of the project. Finally I offer my sincere thanks to all those who have participated in the activities of the project and I look forward to future cooperation.

Monyane Moleleki

October 1998

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
BOS	Bureau of Statistics
CO_2	Carbon Dioxide
CO	Carbon Monoxide
COP	Conference of the Parties
m^3	Cubic metre
m^3/day	Cubic metre per day
m^3/ha/year	Cubic metre per hectare per year
DOC	Degradable Organic Compound
dm	dry matter
Gg	Gigagrams
Gg C	Gigagrams of Carbon
Gg dm	Gigagrams of dry matter
GEF	Global Environment Facility
GWh	Gigawatt hour
GWP	Global Warming Potential
GOL	Government of Lesotho
GHG	Green House Gas
GDP	Gross Domestic Product
ha	Hectare
IPCC	InterGovernmental Panel on Climate Change
Kg	Kilogram
Kha	Kilohectare
Kha/year	Kilo hector/per year (hectare)
Kt	Kilotonnes
KtC	Kilo tonnes of Carbon
KtN	Kilo tonne of Nitrogen
LPG	Liquified Petroleum Gas

Mg	Megagrams
MJ	Mega Joule
MJ/m^2	Mega Joule per Square Metre
MW	Megawatt
CH_4	Methane
m	metre
Mha	Million hactare
MSW	Municipal Solid Waste
NES	National Environment Secretariat
N_2O	Nitrous Oxide
NO_x	Oxides of Nitrogen
NMVOC	Non-Methane Volatile Organic Compounds
OECD	Organisation of Economic Cooperation and Development
m^2	Square metre
TJ	Tera Joule
TJ/m^3	Tera Joules per cubic metre
TJ/kt	Tera Joules per kilo tonnes
t	tonnes
tC	tonnes of Carbon
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WASA	Water and Sewerage Authority
Yr	Year

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EXECUTIVE SUMMARY

Climate is a fundamental resource that has an enormous influence on a wide range of human activities. A stable climate is therefore a basic prerequisite for development planning of a country. Increasing concentration of anthropogenic greenhouse gases in the atmosphere which results in global climate change has become an issue of major concern worldwide in recent years because it impacts negatively on each country.

At the Earth Summit in June 1992 in Rio de Janeiro, Brazil, the United Nations Framework Convention on Climate Change (UNFCCC) was signed by 155 countries including Lesotho. The Convention came into force on 21st March 1994. The objective of the Convention is to achieve "stabilization of greenhouse gas concentration in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystem to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner".

Lesotho ratified the UNFCCC in March 1995. As a first step towards meeting her obligations under the Convention, and also laying groundwork for preparation and subsequent implementation of the National Programme on Climate Change, the project entitled **Lesotho: Enabling Activities for the Implementation of UNFCCC** was initiated. The project has the following main activities: public awareness campaigns, inventory of greenhouse gas emissions, assessment of vulnerability to climate change, mitigation and adaptation options, development of the national action plan on climate change and preparation of Lesotho's first national communication to the Conference of the Parties (COP) of UNFCCC on the country's adherence to the UNFCCC.

This is a report of activity 2 of the project, on greenhouse gas (GHG) emissions in the country. Various sectors are examined in terms of GHG emissions. The objective of this activity is to assess Lesotho's share of the global GHG emissions. The GHG's considered are: Carbon Dioxide (CO_2), Carbon Monoxide (CO), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxide (NO_x) and Non-Methane Volatile Organic Compounds (NMVOC), under Energy, Agriculture, Land Use Change and Forestry and Waste Sectors. The sectors Industrial Processes and Solvents are not taken into account since there is very little industrial activity in Lesotho and therefore emissions are considered negligible.

The Energy Sector

The energy sector of Lesotho is characterised by lack of a proven resource base of fossil fuels. Consequently, the needs for these energy sources are met through imports from the Republic of South Africa (RSA). Electricity and even tradable fuelwood are also imported. Renewable sources of energy in the country include hydropower, solar energy, wind energy and biomass. However, the potential of these energy carriers has been confirmed for hydropower and solar energy. Hydropower and solar energy require substantial exploitation. Efforts to harness hydropower have already been initiated. It is planned that a 72MW hydropower plant will be commissioned before the end of 1998.

Biofuels (fuelwood, agricultural residues and animal dung) are the major source of energy in the country. They are expected to continue to be the major source of energy unless there is a substantial improvement in the economic situation country wide. These free, in monetary terms, energy carriers are virtually all

consumed in rural areas, where more than 80 percent of the total population reside, to meet the basic needs of cooking and space heating.

The Energy sector emits 803.29 Gigagrams (Gg) of GHG's of which 79%(635.99Gg) is carbon dioxide. Carbon dioxide is mainly emitted from the combustion of fossil fuels in the residential sector and transport. In the residential sector carbon dioxide is emitted from burning of coal, Liquid Petroleum Gas (LPG) and paraffin. Whereas in transport carbon dioxide is emitted from combustion of Diesel and Gasoline. The residential sector also emits significant amounts of methane (CH_4) and carbon monoxide (CO), as well as NMVOC due to the burning of biofuels. Emissions of CO_2 from biofuels are not considered since the IPCC guidelines have assigned an emission factor of zero for these fuels.

Table 1 Sectoral report for energy

(Sheet 1 of 2)

Sectoral Report For National Greenhouse Gas Inventories

(Gg)

Greenhouse Gas Source And Sink Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2 (1)
Total Energy	635.99	7.63	0.10	4.92	137.08	17.57	0.00
A Fuel Combustion Activities	**635.99**	**7.63**	**0.10**	**4.92**	**137.08**	**17.57**	**0.00**
(Sectoral Approach)							
1 Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
a Public Electricity and Heat Production							
b Petroleum Refining							
c Manufacture of Solid Fuels							
and Other Energy Industries							
2 Manufacturing Industries and Construction	27.87	0.00	0.00	0.09	0.03	0.00	0.00
a Iron and Steel							
b Non-Ferrous Metals							
c Chemicals							
d Pulp, Paper and Print							
e Food Processing, Beverages and Tobacco							
f Other (please specify)							

Table 1. Sectoral Report For Energy

(Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

(Gg)

Greenhouse Gas Source And Sink Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
3 Transport	**220.69**	**0.05**	**0.00**	**2.10**	**17.70**	**3.33**	**0.00**
a Civil Aviation	0.25	0.00	0.00	0.00	0.00	0.00	
b Road Transportation	220.44	0.05	0.00	2.10	17.70	3.33	
c Railways	0.00	0.00	0.00	0.00	0.00	0.00	
d Navigation	0.00	0.00	0.00	0.00	0.00	0.00	
4 Other Sectors	**382.55**	**7.58**	**0.10**	**2.73**	**119.25**	**14.22**	**0.00**
a Commercial/Institutional	2.15	0.00	0.00	0.00	0.05	0.00	
b Residential	357.42	7.58	0.10	2.72	119.20	14.22	
c Agriculture/Forestry/Fishing	22.99	0.00	0.00	0.01	0.00	0.00	
5 Other (please specify)	**4.87**	**0.00**	**0.00**	**0.00**	**0.10**	**0.01**	
B Fugitive Emissions from Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Solid Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Coal Mining	0.00						
b Solid Fuel Transformation							
c Other (please specify)							
2 Oil and Natural Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Oil		0.00		0.00	0.00	0.00	0.00
b Natural Gas		0.00					

The Agriculture Sector

Agriculture, in terms of its size and as a means of subsistence, is the most important economic sector in Lesotho. It continues to dominate the domestic economy, with the highest percentage (55%) of the population engaged in this sector.

Livestock production and acquisition is an important component of the domestic economy. Sheep and goats have an additional value as producers of wool and mohair.

Emissions from this sector amount to 39.25Gg of which 81% (31.95Gg) is derived from methane. The methane is primarily from enteric fermentation from animal manure and manure management. Non-CO_2 emissions are from indiscriminate burning of rangelands and a much more rare burning of agricultural wastes.

Table 4 Sectoral Report For Agriculture

(Sheet 1 of 2)

Sectoral Report For National Greenhouse Gas Inventories

(Gg)

Greenhouse Gas Source And Sink Categories	CH_4	N_2O	NO_x	CO	NMVOC
Total Agriculture	31.95	0.44	0.13	6.73	0.00
A Enteric Fermentation	30.29				
1 Cattle	19.12				
2 Buffalo	0.00				
3 Sheep	5.55				
4 Goats	3.82				
5 Camels and Llamas	0.00				
6 Horses	1.74				
7 Mules and Asses	0.00				
8 Swine	0.06				
9 Poultry	0.00				
10 Other (please specify)					
B Manure Management	1.47	0.01			
1 Cattle	0.60				
2 Buffalo	0.00				
3 Sheep	0.18				
4 Goats	0.13				
5 Camels and Llamas	0.00				
6 Horses	0.16				
7 Mules and Asses	0.00				
8 Swine	0.38				
9 Poultry	0.04				

Table 4 Sectoral Report For Agriculture

(Sheet 2 of 2)

Sectoral Report For National Greenhouse Gas Inventories

(Gg)

Greenhouse Gas Source And Sink Categories	CH_4	N_2O	NO_x	CO	NMVOC
B Manure Management (cont...)					
10 Anaerobic		0.00			
11 Liquid Systems		0.00			
12 Solid Storage and Dry Lot		0.01			
13 Other (please specify)		0.00			
C Rice Cultivation	0.00				
1 Irrigated	0.00				
2 Rainfed	0.00				
3 Deep Water	0.00				
4 Other (please specify)					
D Agricultural Soils		0.43			
E Prescribed Burning of Savannas	0.19	0.00	0.13	6.73	
F Field Burning of Agricultural Residues [1]	0.00	0.00	0.00	0.00	
1 Cereals					
2 Pulse					
3 Tuber and Root					
4 Sugar Cane					
5 Other (please specify)					
G Other (please specify)					

The Land Use Change and Forestry Sector

The natural vegetation of Lesotho is dominated by grassland, and by indigenous shrubs in some mountain areas. Although the present vegetation is regarded as a sub climax resulting from human interference and modification, it is highly unlikely that large areas of Lesotho were ever covered by forests or woodland. However, patches of bush and small evergreen trees that occur on rocky slopes of sheltered valleys suggest that forest cover was previously more extensive than at present. The wholesale clearance of all types of habitat for settlements as well as burning and indiscriminate gathering of fuelwood have destroyed most of Lesotho's biological diversity. A little of what remains is under threat and is likely to escalate the emissions of greenhouse gases.

This sector has net emissions of 1260.57Gg of carbon dioxide, which is the only GHG gas. The main sources of emissions are agriculturally impacted soils and to a lesser extent from forest and grassland conversion. On the other side, sinks are largely due to abandonment of managed lands followed by changes in forest and other woody biomass stocks.

The land use change and forestry sector has total carbon dioxide emissions of 4299.77Gg. On the other hand it is the only sector that provides sinks for carbon dioxide. Sinks amounting to 3039.20Gg emanate mainly from abandonment of managed lands and changes in forests and other woody biomass stocks

Table 5 Sectoral Report For Land-Use Change And Forestry

(Sheet 1 of 1)

Sectoral Report For National Greenhouse Gas Inventories

(Gg)

Greenhouse Gas Source And Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO
Total Land-Use Change and Forestry	**1,260.57**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
A Changes in Forest and Other Woody Biomass Stocks		**0.00**		**-289.20**		
1 Tropical Forests						
2 Temperate Forests						
3 Boreal Forests						
4 Grasslands/Tundra						
5 Other (please specify)						
B Forest and Grassland Conversion	**1,630.20**		**0.00**	**0.00**	**0.00**	**0.00**
1 Tropical Forests	0.00					
2 Temperate Forests	0.00					
3 Boreal Forests	0.00					
4 Grasslands/Tundra	1,630.20					
5 Other (please specify)	0.00					
C Abandonment of Managed Lands		-2,750.00				
1 Tropical Forests		0.00				
2 Temperate Forests		-896.50				
3 Boreal Forests		0.00				
4 Grasslands/Tundra		-1,853.50				
5 Other (please specify)		0.00				
D CO2 Emissions and Removals from Soil	**2,669.57**	**0.00**				
E Other (please specify)						

Please note that the signs for removals are always (-) and for emissions (+).

THE WASTE MANAGEMENT SECTOR

In general, waste management has not received sufficient attention in the country. As a result there has been no coherent and integrated policy on waste management. The growing global attention of environmental issues is expected to stimulate the process of improving waste management in the country.

Emissions have been assessed from solid waste, domestic, commercial and industrial wastewater.

In this sector 1.97Gg of GHG emissions are only methane and nitrous oxide. Methane emissions are mostly from solid waste in landfills and industrial wastewater and sludge. Nitrous oxide emissions are from human sewage.

Table 6 Sectoral Report For Waste

(Sheet 1 of 1)

Sectoral Report For National Greenhouse Gas Inventories

(Gg)

Greenhouse Gas Source And Sink Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Total Waste	0.00	1.88	0.09			
A Solid Waste Disposal on Land	0.00	1.88	0.00			
1 Managed Waste Disposal on Land						
2 Unmanaged Waste Disposal Sites						
3 Other (please specify)						
B Wastewater Handling	0.00	0.00	0.09			
1 Industrial Wastewater		0.00				
2 Domestic and Commercial Wastewater		0.00	0.09			
3 Other (please specify)						
C Waste Incineration						
D Other (please specify)						

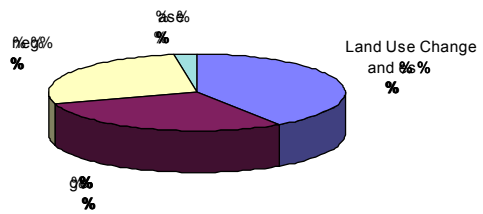
CONCLUSION/RESULTS

In 1994 greenhouse gases emissions from all the sectors amounted to 6154.25Gg in the units of CO_2 Equivalent. The sinks amounted to 3039.20Gg. This shows a net emission of 3115.06Gg. Thus Lesotho is a net emitter of greenhouse gases.

Table 7C Sectoral Global Warming Potential for Different Gases

(Gg)					CO_2	CH_4	N_2O	Total	Net GHG Emissions	
			1,896.56	41.47	0.63		Global Warming Potential(GWP) 100 years			
		1	24.5	320			Integration			
1000T CO_2 Equivalent						1896.56	1015.95	202.55	3115.06	
Percentage						60.88	32.61	6.50	100.00	
					Total	CO_2 Sinks	Total Net Emissions			
					Emissions					
Greenhouse Gas(Gg)(TCE)										
	A	B	C	D	E	F	G	H		%of Total
Sector			=24.5*B		=320*D	=A+C+E		=F - G		
	CO_2	CH_4	CH_4	N_2O	N_2O					
Energy 635.99	7.63	187.00	0.10	31.48	854.47		854.47		27.43	
Agriculture		31.95	782.89	0.44	142.03	924.92		924.92		29.69
Land Use Change and	4299.77		0.00		0.00	4299.77	3039.20	1,260.57		40.47
Forestry										
Waste		1.88	46.05	0.09	29.04	75.09		75.09		2.41
Total Net Emissions	1,896.56	41.47	1,015.95	0.63	202.55	6154.25	3039.20	3,115.06		100.00

Fig.6.2: GHG Emissions (1000TCE) by Sector in Lesotho (1994)



Land Use Change and Forestry have the largest contribution (40.47% of net emissions) of all the sectors, followed by Agriculture with 29.69% and Energy 27.43% and waste 2.41%. Carbon dioxide has the highest contribution 94.38% of all the gases, followed by Carbon Monoxide with 3.83%. Although energy contributes only 27.43% of the total sectoral CO_2 emissions, considering CO_2 alone, it is the second largest emitter after Land Use Change and Forestry at about 34% while 66% is due to the latter sector. Energy is ranked in this manner since biomass fuels which are the major source of energy are assigned carbon emission factor of zero. With respect to environmental degradation in general, especially land degradation the use of biomass for energy purposes requires special attention due to inadequate land vegetation cover in the country.

1.0 INTRODUCTION

1.1 Country Overview

Lesotho is situated between latitudes 28 degrees and 31 degrees South, and longitudes 27 degrees and 30 degrees East, on the Southern African subregion. It is totally surrounded by the Republic of South Africa and has a land area of 30,355 square kilometres. Lesotho's altitude varies from 1388 to 3482metres and it is inhabited up to 3200 metres above sea level.

The orography of the country is characterised by two mountain ranges; the major range is the Drakensberg on the eastern side of the country spanning the whole length of the eastern border. The Maluti mountain ranges are naturally divided between the lowlands region on the western side and the mountainous (the highlands) region. There are two other ecological zones, the foothills and Senqu Valley regions.

The climate of Lesotho is continental and temperate with some alpine characteristics. It is highly variable on all time scales. Temperature varies from the lowest value of -21°C to a maximum of 39.5°C. Rainfall in Maseru, the Capital, can vary from 419 millimetres in one year to 1119 millimetres in another year. Rainfall can also be of very high intensity.

In 1994 Lesotho had an estimated population of 2 million growing at a rate of 2.6% per annum. Life expectancy at birth is 56.9 and 55.2 years for females and males respectively. For the same year literacy rate was about 70% with females and males school enrolment ratio of 57.5:42.5.

The country has a very poor natural resource base. Only alluvial diamonds have been mined in the past. Sale of water to the Republic of South Africa through the Lesotho Highlands Water Project will provide much needed revenue to the Government. The real Gross Domestic Product (GDP) in 1994 was 540.8 million Maloti showing an increase of 11.9% from the previous year. The share of various sectors to the GDP is as follows:

Gross domestic product by kind of activity (1980 = 100) (As a share of GDP at factor cost in per cent)	
	1994
Primary Sector:	**13.7**
1.1.2 Agriculture	13.1
Mining & Quarrying	0.6
Secondary Sector:	**39.9**
1.1.3 Manufacturing	13.6
Electricity & Water	1.2
Building & Construction	15.1
Tertiary Sector:	**46.4**
1.1.4 Wholesale & Retail Trade	8.6
Government	22.2
Other Services	15.6
GDP at Factor Cost	**100.0**

Source: Central Bank of Lesotho, 1995

Soil erosion is the single major environmental problem experienced in Lesotho. It is due to orographic characteristics of the country, high intensity rainfall and poor land management practices.

1.2 The Project Background

Human activities, primarily the emissions of industrial gases into the atmosphere and changes in land use and land cover, are increasing the atmospheric concentrations of greenhouse gases resulting in global climate change. Climate change is not conducive to sustainable economic development, thus worldwide efforts to combat climate change were initiated. The governments established the United Nations Framework Convention on Climate Change (UNFCCC) to consider international action to address the issue. To illustrate their commitment, 155 countries signed the UNFCCC document in June 1992 at the Earth Summit in Rio de Janeiro, Brazil. Over 189 countries, states and regions have now ratified the convention.

Parties to the convention commit themselves to its ultimate objective to "stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

Lesotho ratified the UNFCCC in March 1995. As a first step towards meeting her obligations under the Convention, and also laying groundwork for preparation and subsequent implementation of the National Programme on Climate Change, the project entitled **Lesotho: Enabling Activities for Implementation of UNFCCC** was initiated.

The project has the following main phases: public awareness campaigns and capacity building, inventory of greenhouse gas emissions, assessment of vulnerability to the climate change, mitigation and adaptation options, development of the national action plan on climate change and preparation of Lesotho's first

national communication to the Conference of the Parties (COP) of UNFCCC on the country's adherence to the UNFCCC.

Public awareness campaigns were the first activities to be initiated. These were followed by greenhouse gas inventories, the subject of this report. Results of the Inventory of sources and sinks of greenhouse gases activity are also presented.

1.3 Organisation of the Project

The project, Lesotho: Enabling Activities For the Implementation of the UNFCCC, is implemented by the Lesotho Meteorological Services (LMS), under the auspices of the National Environment Secretariat (NES). The LMS installed the National Study Team under its direction.

At the international level, the project is being executed by the United Nations Environment Programme, who monitors the progress as reported by LMS.

1.4 Organisation of the Inventory Report

The Inventory study was conducted using comparative 1996 standard methodologies developed by IPCC/OECD, as per decision of the COP. The GHG emissions were evaluated for 1994 as the base year.

The IPCC methodologies divided the Inventory into six categories namely: Energy, Agriculture, Industrial processes, Solvent and other product use, Land Use Change and Forestry and Waste. This report is organised into four main chapters as shown below.

Chapter 2 Energy

Chapter 3 Agriculture

Chapter 4 Land Use Change and Forestry

Chapter 5 Waste

Chapter 1 is this Introduction and Chapter 6 is the Conclusion and Recommendations.

There is little industrial activity in the country on Industrial processes and Solvent and other product use, therefore the emissions due to these sectors are considered negligible. Hence these sectors have not been considered in the report. Emissions of GHG from the Energy Sector were estimated from combustion of fossil fuels and biofuels.

In the Agriculture Sector GHG emissions were estimated from enteric fermentation and manure management, Savanna burning and Agricultural soils.

In the Land Use Change and Forestry, CO_2 emissions and sinks were estimated from changes in Forestry and other woody biomass (including fuelwood), Forest and grassland conversion, abandonment of managed lands and agriculturally impacted soils. Emissions of other GHG gases from on-site burning of grasslands were also calculated.

Emissions of Methane in the Waste Sector were estimated from Solid waste, Domestic and Commercial wastewater and sludge. Nitrous oxide emissions from human sewage were also included.

1.5 References

Central Bank of Lesotho:

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2.0 ENERGY

2.1 Overview of the Energy Sector

The energy sector of Lesotho is characterised by lack of a proven resource base for fossil fuel energy carriers. Consequently, the needs for these energy sources are met through imports, from the Republic of South Africa (RSA). Electricity and even tradable fuelwood and charcoal are also imported. Renewable sources of energy in the country include hydropower, solar energy, wind energy and biomass. However, the potential for this energy carriers has been confirmed for hydropower and solar energy. Hydropower and solar energy require substantial exploitation.

2.1.1 Renewable Sources of Energy

Hydropower

The national potential for hydropower has been estimated as 1400 GWh per year [IPC]. However, only 513 GWh is expected to be exploited annually beginning 1998, when Muela hydropower project, part of the Lesotho Highlands Water Project (LHWP) starts operation and produces 500 GWh [GTZ,1991]. The remaining 13 GWh is from four minihydro plants already operational [GTZ,1991]. This annual electrical energy generation (513 GWh) is about 53 percent more than the electric energy sales of 243 GWh of Lesotho Electricity Corporation (LEC) in 1993/94 [SwedPower,1996]. The forecast shows that even in 1998, the annual electric sales will be 255 GWh and the peak maximum demand will be 78 MW [DANCED,1997]. The problem will be with the peak demand since Muela and the four minihydro plants have an installed capacity of 75 MW [GTZ,1991]. The commissioning of the Muela hydropower plant will have positive environmental impacts in the subregion. This plant will substitute the electricity from South Africa, which is generated via coal fired plants. Electricity contributed 2 percent [GTZ,1991] of the national energy consumption in 1990.

Solar Energy

The annual total solar radiation over the country is between 5700MJ/m^2 and 7700MJ/m^2 [Gopinathan,1989]. There are prospects for solar energy utilisation to meet some of the energy demand. The exploitation of solar energy can possibly substitute 50 percent of the total energy use for water in the residential sector[GTZ, Vol. 1, part 1, 1988]. About 22 percent of energy demand for space heating could be met via solar energy [GTZ, Vol. 1, part 1, 1988].

Biofuels

Biomass fuels, especially fuelwood, have limited and unsustainable reserves. There is an enormous pressure on vegetation cover (indigenous trees shrubs) which has contributed to land degradation. Despite this limitation biofuels (fuelwood, agricultural residues and animal dung) play a significant role in the national energy balance. This situation is expected to continue in this direction unless there is a substantial improvement in the economy and/or technical substitution options. In 1984 about 80 percent of the national energy consumption (26000 TJ) was derived from biofuels [GTZ, 1991]. These energy sources are virtually all consumed in rural areas, where more than 80 percent of the total population reside, to meet the basic needs of cooking and space heating. Technical potential for reducing the energy consumption in rural areas exists. The adaption of improved stoves could save about 60 percent of the energy consumption

for cooking [GTZ, Vol. 1 part II, 1988] in the rural areas. However, promotional activities and dissemination strategies have to be extensively pursued to achieve this goal. Alternatively, substitution for biomass fuels can be achieved by focusing on development programmes with income generating activities in the rural areas.

The consumption of charcoal is not popular. It is used by a very small percentage of the population for roasting meat and in informal sector for also roasting meat and maize. It is thus not surprising that charcoal does not appear explicitly as one of the energy sources in the 1994/95 Household Budget Survey published by the Bureau of Statistics.

2.1.2 Fossil Fuels

Petroleum fuels

Petroleum products are imported as refined products. In 1984 these energy carriers contributed about 16 percent of the total energy consumption and met 90 percent of the secondary energy demand [GTZ, 1991]. Secondary energy includes petroleum fuels and electricity. The petroleum fuels are consumed mainly in the transport sector.

Coal

Virtually all coal combusted is of bituminous type. Anthracite is used to a lesser extent. In this report coal will mean bituminous type. Coal is consumed mainly in the residential sector. In 1984, the total consumption of coal was 2344 TJ [GTZ, 1991], 89.3 percent of these was used in the residential sector. The remaining was used in the Industry and public sector.

Others

Since September, 1995 a brick factory, Loti Brick has been using waxy oil from South Africa. This has not been dealt with here since only 1994 GHG inventories are reported. It will be included in the next cycle of inventories. Biomass fuels considered include fuelwood, agricultural residues and animal dung.

As outlined in the IPCC guidelines, GHG emissions are due to fugitive and combustion processes. Fugitive processes are not applicable in Lesotho, since there are no coal mining, flaring and venting of Natural gas activities. Therefore GHG emissions have only been considered with respect to combustion of fossil fuels and biofuels. The gases reported include carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), non-methane volatile organic compounds (NMVOC) and oxides of nitrogen (NO_x). Fossil fuels which have been discussed include gasoline, diesel, Liquid Petroleum Gas (LPG), paraffin, jet fuel and coal.

In general literature survey has been relied on as a source of information. It was not possible to improve this information by field surveys because GHG inventories are prepared in 1996/97 for 1994. The IPCC reference approach procedure has been employed to estimate the GHG emissions.

2.2 Inventory of Greenhouse gas Emissions from Energy Use

2.2.1 Data collection and Analysis

The survey for energy consumption was last made in 1984 and this led to the preparation of the Lesotho Energy Masterplan (LEMP). For the years, after 1984, the Department of Energy (DOE) produces annual

energy balances that are only projections. The annual energy balance for 1994 has been used to get consumption data for fuels which are not regulated. These include coal and biofuels. These figures should be handled with caution since they are only projections based on the survey from 1984. Regarding petroleum fuels namely gasoline, diesel,paraffin (other kerosen), aviation fuel and liquid petroleum gas (LPG), the oil industry supplies DOE with a consumption data on a regular basis. This has been useful since the information for 1994 could be used for these fuels. In the analysis the limitation of this data is that only total petroleum consumption is given without sectoral distribution. Consequently, sectoral energy consumption data has been estimated in table 2.3 using tables 2.1 and 2.2. The percentages of fuel consumption by sector for the years 1984,1985 and 1986 were calculated from LEMP for each fuel. It was found out that for the three years each fuel has the same percentage of sectoral consumption. The percentage sectoral consumption of each fuel in the three years was assumed for 1994 and this led to the completion of table 2.3. The reader is invited to note that consumption in original units from the different data sources has been transformed to common units of terajoules for comparison of individual fuels to the total consumption. Table 2.1 shows energy consumption by fuel in 1994.

FUEL	CONSUMPTION	CONSUMPTION	% OF TOTAL
	(original units)	(TJ)	
Gasoline (m^3)	63809	2080.17	6.68
Paraffin (m^3)	54332	1901.62	6.11
Diesel (m^3)	40928	1514.34	4.86
LPG (m^3)	3125	140.63	0.45
Jet fuel (m^3)	101	3.54	0.01
Coal (t)	87943	2576.73	8.28
Biomass Fuels (kt)	1478.14	22911.17	73.60
Total		**31128.20**	**100.00**

Table 2.1: Energy consumption by Fuel in 1994

Sources for consumption in original units:

- For solid fuels, Annual Energy Balance (1994)
- For liquid fuels, DOE unpublished data.

The total consumption of biofuels 1478.14Kt constitutes fuelwood (479.51Kt), shrubs (481.08Kt), crop residues (92,22Kt) and cow dung (425.33Kt).The average moisture content for these is 12.3%,10.5%,8.7% and 9.4% respectively [DOE unpublished data].

Sector	Consumption (%)						
	Gasoline	Diesel	Jetfuel	Coal	Paraffin	LPG	Biofuel
Construction		6.00		0.30			
Commercec& Services							
1.20							
0.90							
Manufacturing		1.80		7.70			
Government		0.30		1.90			
Agriculture		20.70					
Transport	100.00	70.00	100.00				
Residential							
Urban				66.90	15.00	100.00	
Rural				22.40	85.00		100.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 2.2: Percentage Fuel Consumption by sector in 1994

Sector	Consumption (TJ)							
	Gasoline	Diesel	Jetfuel	Coal	Paraffin	LPG	Biofuel	Total
Construction		92.2		7.72				99.92
Commerce and		18.2		23.17				41.37
Services								
Manufacturing		27.3		198.21				225.5
Government		4.5		48.91				53.41
Agriculture		313.5		313.5				
Transport	2080.17	1060	3.54					3143.71
Residential:								0
Urban				1722.11	285.24	140.63		2147.88
Rural				576.61	1616.38		22911.14	25104.10
Total	2080.17	1515.7	3.54	2576.73	1901.62	140.63	22911.14	31129.39

Table 2.3: Fuel Consumption by Sector in 1994

The consumption figures in table 2.3 were entered in worksheets 1-1 and 1-2.

Calorific values were from the Southern African Development Coordination Conference (SADCC) energy statistics (1991).

According to the Department of Transport and Traffic the total vehicle population in the country in 1994 was 27173. This figure has the following breakdown:

Type of Vehicle	Number
Cars	6484
Vans	13077
Combis(Mini buses)	2547
Buses	670
Trucks	2605
Others[1]	1990

Table 2.4: Vehicle Population by type in 1994

Source: Department of Transport and Traffic

These figures may be overestimated since according to the Department of Transport and Traffic, estimates on the vehicle population not operational in 1994 were not made.

2.3 Greenhouse Gas Emissions from Traditional Bio-fuels

Emissions of methane, carbon monoxide, NMVOC and nitrous oxides (N_2O, NO_x) from the combustion of biofuels are estimated. Biofuels considered are fuelwood, shrubs, which included both tradable and traditional firewood, agricultural residues and animal dung.

2.3.1 Data Collection and Analysis

Data has been sourced from LEMP and is indicated in table 2.3. The data was entered in worksheets 1-1 and 1-3.

2.4 Comments on IPCC/OECD Methodology

IPCC guidelines were the source of other fuels properties, carbon emission factors, carbon content and fraction of carbon oxidised. The details are presented in sheets 1, 2 and 3. Please note that for all liquid fuels the original units are (m^3). While for coal and biofuels the units are (t) and (Kt) respectively.

Worksheet 1-1

Column A

Lesotho does not produce fossil fuels. As a result these column is not applicable to the Lesotho situation.

Column C

Lesotho does not export any fuels.

Column D

Lesotho has no bunkers

Column E

It is assumed that there is no stock pile since imported fuels are all consumed within few days.

Column G

Conversion factor of the total biomass fuels was estimated as the arithmetic mean (15.5TJ/Kt) of individuals as given in SADCC energy statistics (In GJ/t) firewood (17.5), agricultural residues (16.4) and dung (12.6).

Column N

Oxidation factor of the total biomass fuels was estimated as the arithmetic mean of oxidation factors (as given in IPCC) of individual biofuels.

		MODULE	**ENERGY**					
		SUBMODULE	**CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)**					
		WORKSHEET	**1-1**					
		SHEETS	**1 OF 5**					
		COUNTRY	**LESOTHO**					
		YEAR	**1994**					
			STEP 1					
			A	B	C	D	E	F
			Production	Imports	Exports	International	Stock Change	Apparent
						Bunkers		Consumption
FUEL TYPES								F=(A+B-C-D-E)
Liquid Fossil	Primary Fuels	Crude Oil						0.00
		Orimulsion						0.00
		Natural Gas Liquids						0.00
	Secondary Fuels	Gasoline		63809				63,809.00
		Jet Kerosene		101				101.00
		Other Kerosene		54332				54,332.00
		Shale Oil						0.00
		Gas / Diesel Oil		40928				40,928.00
		Residual Fuel Oil						0.00
		LPG		3125				3,125.00
		Ethane						0.00
		Naphtha						0.00
		Bitumen						0.00
		Lubricants						0.00
		Petroleum Coke						0.00
		Refinery Feedstocks						0.00
		Other Oil						0.00
Liquid Fossil Totals								
Solid Fossil	Primary Fuels	Anthracite [a]						0.00
		Coking Coal						0.00
		Other Bit. Coal		87943				87,943.00
		Sub-bit. Coal						0.00
		Lignite						0.00
		Oil Shale						0.00
		Peat						0.00
	Secondary Fuels	BKB & Patent Fuel						0.00
		Coke Oven/Gas Coke						0.00
Solid Fuel Totals								
Gaseous Fossil		Natural Gas (Dry)						0.00
Total								
Biomass total								
		Solid Biomass	1478.14					1,478.14
		Liquid Biomass						0.00
		Gas Biomass						0.00

		MODULE	ENERGY					
		SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)					
		WORKSHEET	1-1					
		SHEETS	2 OF 5					
		COUNTRY	LESOTHO					
		YEAR	1994					
			STEP 2	STEP 3				
			G[b]	H	I	J	K	
			Conversion	Apparent	Carbon Emission	Carbon Content	Carbon Content	
			Factor	Consumption	Factor			
			(TJ/Unit)	(TJ)	(t C/TJ)	(t C)	(Gg C)	
				FUEL TYPES				
Liquid Fossil	Primary Fuels	Crude Oil		0.00		0.00	0.00	
		Orimulsion		0.00		0.00	0.00	
		Natural Gas Liquids		0.00		0.00	0.00	
	Secondary Fuels	Gasoline	0.0326	2,080.17	18.9	39,315.28	39.32	
		Jet Kerosene	0.035	3.54	19.5	68.93	0.07	
		Other Kerosene	0.035	1,901.62	19.6	37,271.75	37.27	
		Shale Oil		0.00		0.00	0.00	
		Gas / Diesel Oil	0.037	1,514.34	20.2	30,589.59	30.59	
		Residual Fuel Oil		0.00		0.00	0.00	
		LPG	0.045	140.63	17.2	2,418.75	2.42	
		Ethane		0.00		0.00	0.00	
		Naphtha		0.00		0.00	0.00	
		Bitumen		0.00		0.00	0.00	
		Lubricants		0.00		0.00	0.00	
		Petroleum Coke		0.00		0.00	0.00	
		Refinery Feedstocks		0.00		0.00	0.00	
		Other Oil		0.00		0.00	0.00	
Liquid Fossil Totals			5,640.29			109,664.30	109.66	
Solid Fossil	Primary Fuels	Anthracite[a]		0.00		0.00	0.00	
		Coking Coal		0.00		0.00	0.00	
		Other Bit. Coal	0.0293	2,576.73	25.8	66,479.63	66.48	
		Sub-bit. Coal		0.00		0.00	0.00	
		Lignite		0.00		0.00	0.00	
		Oil Shale		0.00		0.00	0.00	
		Peat		0.00		0.00	0.00	
	Secondary Fuels	BKB & Patent Fuel		0.00		0.00	0.00	
		Coke Oven/Gas Coke		0.00		0.00	0.00	
Solid Fuel Totals	2,576.73				66,479.63	66.48		
Gaseous Fossil		Natural Gas (Dry)		0.00		0.00	0.00	
Total				8,217.02		176,143.93	176.14	
Biomass total				22,911.17		685,043.98	685.04	
		Solid Biomass	15.5	22,911.17	29.9	685,043.98	685.04	
		Liquid Biomass		0.00		0.00	0.00	
		Gas Biomass		0.00		0.00	0.00	

		MODULE	ENERGY					
		SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)					
		WORKSHEET	1-1					
		SHEETS	3 OF 5					
		COUNTRY	LESOTHO					
		YEAR	1994					
			STEP 4	STEP 5	STEP 6			
			L	M	N	O	P	
			Carbon Stored	Net Carbon Emissions	Fraction of Carbon Oxidised	Actual Carbon Emissions	Actual CO_2 Emissions	
			(Gg C)	(Gg C)		(Gg C)	(Gg CO_2)	
			FUEL TYPES					
Liquid Fossil	Primary Fuels	Crude Oil		0.00		0.00	0.00	
		Orimulsion		0.00		0.00	0.00	
		Natural Gas Liquids		0.00		0.00	0.00	
	Secondary Fuels	Gasoline	0	39.32	0.99	38.92	142.71	
		Paraffin	0	37.27	0.99	36.90	135.30	
		Other Kerosene		0.00		0.00	0.00	
		Shale Oil		0.00		0.00	0.00	
		Diesel Oil	0.00	30.59	0.99	30.28	111.04	
		Residual Fuel Oil		0.00		0.00	0.00	
		LPG	0.00	2.42	0.995	2.41	8.82	
		Ethane	0.00	0.00		0.00	0.00	
		Naphtha	0.00	0.00		0.00	0.00	
		Bitumen	0.00	0.00		0.00	0.00	
		Lubricants	0.00	0.00		0.00	0.00	
		Petroleum Coke		0.00		0.00	0.00	
		Refinery Feedstocks		0.00		0.00	0.00	
		Jet Fuel	0	0.07	0.99	0.07	0.25	
Liquid Fossil Totals			0.00	109.66		108.58	398.13	
Solid Fossil	Primary Fuels	Anthracite [a]		0.00		0.00	0.00	
		Coking Coal	0.00	0.00		0.00	0.00	
		Other Bit. Coal		66.48	0.98	65.15	238.88	
		Sub-bit. Coal		0.00		0.00	0.00	
		Lignite		0.00		0.00	0.00	
		Oil Shale		0.00		0.00	0.00	
		Peat		0.00		0.00	0.00	
	Secondary Fuels	BKB & Patent Fuel		0.00		0.00	0.00	
		Coke Oven/Gas Coke	0.00		0.00	0.00		
Solid Fuel Totals			0.00	66.48		65.15	238.88	
Gaseous Fossil		Natural Gas (Dry)	0.00	0.00		0.00	0.00	
Total			**0.00**	**176.14**		**173.73**	**637.01**	
Biomass total			0.00	684.98		595.93	2,185.08	
		Solid Biomass		684.98	0.87	595.93	2,185.08	
		Liquid Biomass		0.00		0.00	0.00	
		Gas Biomass		0.00		0.00	0.00	

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**3 OF 16 MANUFACTURING INDUSTRIES AND CONSTRUCTION**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
		STEP 1		**STEP 2**		**STEP 3**
	A	B	C	D	E	F
MANUFACTURING	Consumption	Conversion	Consumption	Carbon Emission	Carbon	Carbon
INDUSTRIES AND		Factor	(TJ)	Factor	Content	Content
CONSTRUCTION		(TJ/Unit)		(t C/TJ)	(t C)	(Gg C)
			C=(AxB)		E=(CxD)	F=(E/1000)
Crude Oil [a]			0.00		0.00	0.00
Natural Gas Liquids			0.00		0.00	0.00
Gasoline	0		0.00		0.00	0.00
Paraffin	0		0.00		0.00	0.00
Other Kerosene			0.00		0.00	0.00
Diesel Oil	3192.4	0.03743	119.49	20.2	2,413.73	2.41
Residual Fuel Oil			0.00		0.00	0.00
LPG	0		0.00		0.00	0.00
Jet fuel	0		0.00		0.00	0.00
Naphtha			0.00		0.00	0.00
Lubricants			0.00		0.00	0.00
Petroleum Coke			0.00		0.00	0.00
Refinery Gas			0.00		0.00	0.00
Anthracite			0.00		0.00	0.00
Coking Coal			0.00		0.00	0.00
Other Bituminous Coal	7035.44	0.02927	205.93	25.8	5,312.93	5.31
Sub-Bituminous Coal			0.00		0.00	0.00
Lignite			0.00		0.00	0.00
Peat			0.00		0.00	0.00
Patent Fuel			0.00		0.00	0.00
Brown Coal Briquettes			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
Gas Coke			0.00		0.00	0.00
Gas Works Gas			0.00		0.00	0.00
Coke Oven Gas			0.00		0.00	0.00
Blast Furnace Gas			0.00		0.00	0.00
Natural gas			0.00		0.00	0.00
Municipal Solid Waste			0.00		0.00	0.00
Industrial Waste			0.00		0.00	0.00
		0.00		0.00	0.00	
		0.00		0.00	0.00	
		Total	**325.42**			

Memo items:						
Wood/Wood Waste			0.00		0.00	0.00
Charcoal			0.00		0.00	0.00
Other Solid Biomass			0.00		0.00	0.00
Liquid Biomass			0.00		0.00	0.00
Gaseous Biomass			0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**4 OF 16 MANUFACTURING INDUSTRIES AND CONSTRUCTION**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 4	STEP 5	STEP 6			
	G	H	I	J	K	L
MANUFACTURING	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
INDUSTRIES AND	Carbon Stored[a]	(Gg C)[a]	Emissions	Carbon Oxidised	Emissions	Emissions
CONSTRUCTION	(Gg C)		(Gg C)	(Gg CO_2)		
			H=(FxG)	I=(F-H)		K=(IxJ)
L=(Kx[44/12])						
Crude Oil[a]		0.00	0.00		0.00	0.00
Natural Gas Liquids		0.00	0.00		0.00	0.00
Gasoline		0.00	0.00		0.00	0.00
Paraffin		0.00	0.00		0.00	0.00
Other Kerosene		0.00	0.00		0.00	0.00
Diesel Oil		(b) 0.00	2.41	0.99	2.39	8.76
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		(b) 0.00	0.00		0.00	0.00
Jet fuel		(b) 0.00	0.00		0.00	0.00
Naphtha		(b) 0.00	0.00		0.00	0.00
Lubricants	(c)	0.00	0.00		0.00	0.00
Petroleum Coke		0.00	0.00		0.00	0.00
Refinery Gas		0.00	0.00		0.00	0.00
Anthracite		0.00	0.00		0.00	0.00
Coking Coal		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	5.31	0.98	5.21	19.09
Sub-Bituminous Coal		0.00	0.00		0.00	0.00
Lignite		0.00	0.00		0.00	0.00
Peat		0.00	0.00		0.00	0.00
Patent Fuel		0.00	0.00		0.00	0.00
Brown Coal Briquettes		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
Gas Coke		0.00	0.00		0.00	0.00

Gas Works Gas0.00	0.00		0.00	0.00		
Coke Oven Gas0.00	0.00		0.00	0.00		
Blast Furnace Gas0.00	0.00		0.00	0.00		
Natural gas			(b)	0.00	0.00	0.00
0.00						
Municipal Solid Waste0.00	0.00		0.00	0.00		
Industrial Waste0.00	0.00		0.00	0.00		
0.00	0.00		0.00	0.00		
0.00	0.00		0.00	0.00		
			Total	**27.85**		
Memo items:						
Wood/Wood Waste0.00	0.00		0.00	0.00		
Charcoal0.00	0.00		0.00	0.00		
Other Solid Biomass0.00	0.00		0.00	0.00		
Liquid Biomass0.00	0.00		0.00	0.00		
Gaseous Biomass0.00	0.00		0.00	0.00		
			Total Biomass	**0.00**		

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**5 OF 16 TRANSPORT**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 1	**STEP 2**			**STEP 3**	
	A	B	C	D	E	F
TRANSPORT	Consumption	Conversion	Consumption	Carbon	Carbon Content	Carbon Content
		Factor	(TJ)	Emission Factor	(t C)	(Gg C)
		(TJ/Unit)		(t C/TJ)		
			C=(AxB)		E=(CxD)	F=(E/1000)
Domestic Aviation [a]						
Gasoline			0.00		0.00	0.00
Jet fuel	101	0.035	3.54	19.5	68.93	0.07
			0.00		0.00	0.00
		Subtotal	**3.54**			
Road Transport						
Natural Gas			0.00		0.00	0.00
LPG			0.00		0.00	0.00
Gasoline	63809	0.0326	2,080.17	18.9	39,315.28	39.32
Diesel	28650	0.037	1,060.05	20.2	21,413.01	21.41
			0.00		0.00	0.00
		Subtotal	**3,140.22**			
Rail Transport						
Gas/Diesel Oil			0.00		0.00	0.00
Residual Fuel Oil			0.00		0.00	0.00
Anthracite			0.00		0.00	0.00
Other Bituminous Coal			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
			0.00		0.00	0.00
		Subtotal	**0.00**			
National Navigation [a]						
Gasoline			0.00		0.00	0.00
Gas/Diesel Oil			0.00		0.00	0.00
Residual Fuel Oil			0.00		0.00	0.00
Lubricants			0.00		0.00	0.00
Sub-Bituminous Coal			0.00		0.00	0.00
			0.00		0.00	0.00
		Subtotal	**0.00**			
Pipeline Transport						
Natural Gas			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Subtotal	**0.00**			
		Total Transport [a]	**3,143.76**			
Memo items:						
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**6 OF 16 TRANSPORT**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 4	STEP 5	STEP 6
	G	H	I	J	K	L
TRANSPORT	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
	Carbon Stored	(Gg C)	Emissions	Carbon Oxidised	Emissions	Emissions
		(Gg C)		(Gg C)	(Gg CO_2)	
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Domestic Aviation [a]						
Gasoline		0.00	0.00		0.00	0.00
Jet fuel		0.00	0.07	0.99	0.07	0.25
		0.00	0.00		0.00	0.00
					Subtotal	**0.25**
Road Transport						
Natural Gas		0.00	0.00		0.00	0.00
LPG		0.00	0.00		0.00	0.00
Gasoline		0.00	39.32	0.99	38.92	142.71
Diesel	0	0.00	21.41	0.99	21.20	77.73
		0.00	0.00		0.00	0.00
					Subtotal	**220.44**
Rail Transport						
Gas/Diesel Oil		0.00	0.00		0.00	0.00
Residual Fuel Oil		0.00	0.00		0.00	0.00
Anthracite		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Subtotal	**0.00**
National Navigation [a]						
Gasoline		0.00	0.00		0.00	0.00
Gas/Diesel Oil		0.00	0.00		0.00	0.00
Residual Fuel Oil		0.00	0.00		0.00	0.00
Lubricants	(b)	0.00	0.00		0.00	0.00
Sub-Bituminous Coal		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Subtotal	**0.00**
Pipeline Transport						
Natural Gas		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Subtotal	**0.00**
					Total Transport [a]	**220.69**

Memo items:						
Liquid Biomass		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**9 OF 16 COMMERCIAL / INSTITUTIONAL SECTOR**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 1	**STEP 2**	**STEP 3**			
	A	B	C	D	E	F
COMMERCIAL /	Consumption	Conversion	Consumption	Carbon Emission	Carbon	Carbon
INSTITUTIONAL		Factor	(TJ)	Factor	Content	Content
SECTOR		(TJ/Unit)		(t C/TJ)	(t C)	(Gg C)
			C=(AxB)		E=(CxD)	F=(E/1000)
Gasoline			0.00		0.00	0.00
Jet Kerosene			0.00		0.00	0.00
Other Kerosene			0.00		0.00	0.00
Diesel	492	0.037	18.20	20.2	367.72	0.37
Residual Fuel Oil			0.00		0.00	0.00
LPG			0.00		0.00	0.00
Anthracite			0.00		0.00	0.00
Other Bituminous Coal	792	0.0293	23.21	25.8	598.70	0.60
Lignite			0.00		0.00	0.00
Brown Coal Briquettes			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
Gas Works Gas			0.00		0.00	0.00
Coke Oven Gas			0.00		0.00	0.00
Natural gas			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Total	**41.41**			
Memo items:						
Wood/Wood Waste			0.00		0.00	0.00
Charcoal			0.00		0.00	0.00
Other Solid Biomass			0.00		0.00	0.00
Liquid Biomass			0.00		0.00	0.00
Gaseous Biomass			0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**10 OF 16 COMMERCIAL / INSTITUTIONAL SECTOR**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 4	STEP 5	STEP 6
	G	H	I	J	K	L
COMMERCIAL /	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
INSTITUTIONAL	Carbon Stored	(Gg C)	Emissions	Carbon Oxidised	Emissions	Emissions
SECTOR			(Gg C)		(Gg C)	(Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Gasoline		0.00	0.00		0.00	0.00
Jet Kerosene		0.00	0.00		0.00	0.00
Other Kerosene		0.00	0.00		0.00	0.00
Diesel		0.00	0.37	0.99	0.36	1.33
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		0.00	0.00		0.00	0.00
Anthracite		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	0.60	0.98	0.59	2.15
Lignite		0.00	0.00		0.00	0.00
Brown Coal Briquettes		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
Gas Works Gas		0.00	0.00		0.00	0.00
Coke Oven Gas		0.00	0.00		0.00	0.00
Natural gas		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Total	**3.49**
Memo items:						
Wood/Wood Waste		0.00	0.00		0.00	0.00
Charcoal		0.00	0.00		0.00	0.00
Other Solid Biomass		0.00	0.00		0.00	0.00
Liquid Biomass		0.00	0.00		0.00	0.00
Gaseous Biomass		0.00	0.00		0.00	0.00
					Total Biomass	**0.00**

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**11 OF 16 RESIDENTIAL SECTOR**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 1	**STEP 2**	**STEP 3**			
	A	B	C	D	E	F
RESIDENTIAL	Consumption	Conversion	Consumption	Carbon Emission	Carbon	Carbon
SECTOR		Factor	(TJ)	Factor	Content	Content
		(TJ/Unit)		(t C/TJ)	(t C)	(Gg C)
			C=(AxB)		E=(CxD)	F=(E/1000)
Gasoline			0.00		0.00	0.00
Other Kerosene	54332	0.035	1,901.62	19.6	37,271.75	37.27
Gas/Diesel Oil			0.00		0.00	0.00
Residual Fuel Oil			0.00		0.00	0.00
LPG	3125	0.045	140.63	17.2	2,418.75	2.42
Anthracite			0.00		0.00	0.00
Other Bituminous Coal	78533	0.0293	2,301.02	25.8	59,366.24	59.37
Sub-Bituminous Coal			0.00		0.00	0.00
Lignite			0.00		0.00	0.00
Peat			0.00		0.00	0.00
Patent Fuel			0.00		0.00	0.00
Brown Coal Briquettes			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
Gas Works Gas			0.00		0.00	0.00
Coke Oven Gas			0.00		0.00	0.00
Natural gas			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Total	**4,343.26**			
Memo items:						
Wood/Wood Waste			0.00		0.00	0.00
Charcoal			0.00		0.00	0.00
Other Solid Biomass			0.00		0.00	0.00
Liquid Biomass			0.00		0.00	0.00
Gaseous Biomass			0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**12 OF 16 RESIDENTIAL SECTOR**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 4	STEP 5	STEP 6
	G	H	I	J	K	L
RESIDENTIAL	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
SECTOR	Carbon Stored	(Gg C)	Emissions	Carbon Oxidised	Emissions	Emissions
			(Gg C)		(Gg C)	(Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Gasoline		0.00	0.00		0.00	0.00
Other Kerosene		0.00	37.27	0.99	36.90	135.30
Gas/Diesel Oil		0.00	0.00		0.00	0.00
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		0.00	2.42	0.995	2.41	8.82
Anthracite		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	59.37	0.98	58.18	213.32
Sub-Bituminous Coal		0.00	0.00		0.00	0.00
Lignite		0.00	0.00		0.00	0.00
Peat		0.00	0.00		0.00	0.00
Patent Fuel		0.00	0.00		0.00	0.00
Brown Coal Briquettes		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
Gas Works Gas		0.00	0.00		0.00	0.00
Coke Oven Gas		0.00	0.00		0.00	0.00
Natural gas		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Total	**357.44**
Memo items:						
Wood/Wood Waste		0.00	0.00		0.00	0.00
Charcoal		0.00	0.00		0.00	0.00
Other Solid Biomass		0.00	0.00		0.00	0.00
Liquid Biomass		0.00	0.00		0.00	0.00
Gaseous Biomass		0.00	0.00		0.00	0.00
					Total Biomass	**0.00**

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**13 OF 16 AGRICULTURE / FORESTRY / FISHING**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 1	STEP 2	STEP 3
	A	B	C	D	E	F
AGRICULTURE /	Consumption	Conversion	Consumption	Carbon Emission	Carbon	Carbon
FORESTRY / FISHING		Factor	(TJ)	Factor	Content	Content
		(TJ/Unit)		(t C/TJ)	(t C)	(Gg C)
			C=(AxB)		E=(CxD)	F=(E/1000)
Mobile						
Gasoline			0.00		0.00	0.00
Jet Kerosene			0.00		0.00	0.00
Other Kerosene			0.00		0.00	0.00
Diesel	8472	0.037	313.46	20.2	6,331.97	6.33
Residual Fuel Oil			0.00		0.00	0.00
LPG			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Total Mobile	**313.46**			
Stationary						
Gasoline			0.00		0.00	0.00
Other Kerosene			0.00		0.00	0.00
Gas/Diesel Oil			0.00		0.00	0.00
Residual Fuel Oil			0.00		0.00	0.00
LPG			0.00		0.00	0.00
Anthracite			0.00		0.00	0.00
Coking Coal			0.00		0.00	0.00
Other Bituminous Coal			0.00		0.00	0.00
Lignite			0.00		0.00	0.00
Patent Fuel			0.00		0.00	0.00
Brown Coal Briquettes			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
Gas Works Gas			0.00		0.00	0.00
Natural gas			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Total Stationary	**0.00**			
Memo items:						
Mobile						
Liquid Biomass			0.00		0.00	0.00
Stationary						
Wood/Wood Waste			0.00		0.00	0.00

Charcoal			0.00		0.00	0.00
Other Solid Biomass			0.00		0.00	0.00
Liquid Biomass			0.00		0.00	0.00
Gaseous Biomass			0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**14 OF 16 AGRICULTURE / FORESTRY / FISHING**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 4	STEP 5	STEP 6			
	G	H	I	J	K	L
AGRICULTURE /	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
FORESTRY / FISHING	Carbon Stored [a]	(Gg C)	Emissions	Carbon Oxidised	Emissions	Emissions
			(Gg C)		(Gg C)	(Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Mobile						
Gasoline		0.00	0.00		0.00	0.00
Jet Kerosene		0.00	0.00		0.00	0.00
Other Kerosene		0.00	0.00		0.00	0.00
Diesel		0.00	6.33	0.99	6.27	22.99
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
	Total Mobile	**22.99**				
Stationary						
Gasoline		0.00	0.00		0.00	0.00
Other Kerosene		0.00	0.00		0.00	0.00
Gas/Diesel Oil		0.00	0.00		0.00	0.00
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		0.00	0.00		0.00	0.00
Anthracite		0.00	0.00		0.00	0.00
Coking Coal		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	0.00		0.00	0.00
Lignite		0.00	0.00		0.00	0.00
Patent Fuel		0.00	0.00		0.00	0.00
Brown Coal Briquettes		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
Gas Works Gas		0.00	0.00		0.00	0.00

Natural gas		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
	Total Stationary	**0.00**				
Memo items:						
Mobile						
Liquid Biomass		0.00	0.00		0.00	0.00
Stationary						
Wood/Wood Waste		0.00	0.00		0.00	0.00
Charcoal		0.00	0.00		0.00	0.00
Other Solid Biomass		0.00	0.00		0.00	0.00
Liquid Biomass		0.00	0.00		0.00	0.00
Gaseous Biomass		0.00	0.00		0.00	0.00
	Total Biomass	**0.00**				

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**15 OF 16 OTHER (GOVERNMENT SECTOR)**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 1	**STEP 2**	**STEP 3**
	A	B	C	D	E	F
OTHER	Consumption	Conversion	Consumption	Carbon Emission	Carbon	Carbon
(NOT ELSEWHERE			Factor	(TJ)	Factor	Content
Content						
SPECIFIED)			(TJ/Unit)		(t C/TJ)	(t C)
(Gg C)						
C=(AxB)		E=(CxD)	F=(E/1000)			
Crude Oil						
			0.00		0.00	0.00
Natural Gas Liquids			0.00		0.00	0.00
Gasoline			0.00		0.00	0.00
Jet Kerosene			0.00		0.00	0.00
Other Kerosene			0.00		0.00	0.00
Diesel	123	0.037	4.55	20.2	91.93	0.09
Residual Fuel Oil			0.00		0.00	0.00
LPG			0.00		0.00	0.00
Ethane			0.00		0.00	0.00
Naphtha			0.00		0.00	0.00
Lubricants			0.00		0.00	0.00
Petroleum Coke			0.00		0.00	0.00
Refinery Gas			0.00		0.00	0.00
Anthracite			0.00		0.00	0.00

Coking Coal			0.00		0.00	0.00
Other Bituminous Coal	1671	0.0293	48.96	25.8	1,263.18	1.26
Sub-Bituminous Coal			0.00		0.00	0.00
Lignite			0.00		0.00	0.00
Peat			0.00		0.00	0.00
Patent Fuel			0.00		0.00	0.00
Brown Coal Briquettes			0.00		0.00	0.00
Coke Oven Coke			0.00		0.00	0.00
Gas Coke			0.00		0.00	0.00
Gas Works Gas			0.00		0.00	0.00
Coke Oven Gas			0.00		0.00	0.00
Blast Furnace Gas			0.00		0.00	0.00
Natural gas			0.00		0.00	0.00
Municipal Solid Waste			0.00		0.00	0.00
Industrial Waste			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
			0.00		0.00	0.00
		Total	**53.51**			
Memo items:						
Wood/Wood Waste			0.00		0.00	0.00
Charcoal			0.00		0.00	0.00
Other Solid Biomass			0.00		0.00	0.00
Liquid Biomass			0.00		0.00	0.00
Gaseous Biomass			0.00		0.00	0.00
		Total Biomass	**0.00**			

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER1)**					
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**					
SHEETS	**16 OF 16 OTHER (GOVERNMENT SECTOR)**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
				STEP 4	STEP 5	STEP 6
	G	H	I	J	K	L
OTHER	Fraction of	Carbon Stored	Net Carbon	Fraction of	Actual Carbon	Actual CO_2
(NOT ELSEWHERE	Carbon Stored	(Gg C)	Emissions	Carbon Oxidised	Emissions	Emissions
SPECIFIED) (Gg C)		(Gg C)	(Gg CO_2)			
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Crude Oil		0.00	0.00		0.00	0.00
Natural Gas Liquids		0.00	0.00		0.00	0.00
Gasoline		0.00	0.00		0.00	0.00
Jet Kerosene		0.00	0.00		0.00	0.00
Other Kerosene		0.00	0.00		0.00	0.00
Diesel		0.00	0.09	0.99	0.09	0.33
Residual Fuel Oil		0.00	0.00		0.00	0.00
LPG		0.00	0.00		0.00	0.00
Ethane		0.00	0.00		0.00	0.00
Naphtha		0.00	0.00		0.00	0.00
Lubricants		0.00	0.00		0.00	0.00
Petroleum Coke		0.00	0.00		0.00	0.00
Refinery Gas		0.00	0.00		0.00	0.00
Anthracite		0.00	0.00		0.00	0.00
Coking Coal		0.00	0.00		0.00	0.00
Other Bituminous Coal		0.00	1.26	0.98	1.24	4.54
Sub-Bituminous Coal		0.00	0.00		0.00	0.00
Lignite		0.00	0.00		0.00	0.00
Peat		0.00	0.00		0.00	0.00
Patent Fuel		0.00	0.00		0.00	0.00
Brown Coal Briquettes		0.00	0.00		0.00	0.00
Coke Oven Coke		0.00	0.00		0.00	0.00
Gas Coke		0.00	0.00		0.00	0.00
Gas Works Gas		0.00	0.00		0.00	0.00
Coke Oven Gas		0.00	0.00		0.00	0.00
Blast Furnace Gas		0.00	0.00		0.00	0.00
Natural gas		0.00	0.00		0.00	0.00
Municipal Solid Waste		0.00	0.00		0.00	0.00
Industrial Waste		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
		0.00	0.00		0.00	0.00
					Total	**4.87**

Memo items:						
Wood/Wood Waste		0.00	0.00		0.00	0.00
Charcoal		0.00	0.00		0.00	0.00
Other Solid Biomass		0.00	0.00		0.00	0.00
Liquid Biomass		0.00	0.00		0.00	0.00
Gaseous Biomass		0.00	0.00		0.00	0.00
					Total Biomass	**0.00**

		MODULE	**ENERGY**						
		SUBMODULE	**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**						
		WORKSHEET	**1-3**						
		SHEETS	**1 OF 3**						
		COUNTRY	**LESOTHO**						
		YEAR	**1994**						
									STEP 1
						A			
						Fuel Consumption			
						(TJ)			
			A1	A2		A3	A4	A5	A6
	ACTIVITY		Coal	Natural Gas		Oil	Wood / Wood	Charcoal	Other Biomass
							Waste		& Wastes
Energy Industries									
Manufacturing Industries and									
Construction			205.93			118.12			
Transport	Domestic Aviation[a]				3.54				
					Gasoline	Diesel			
	Road				2080.17	1060.04			
	Railways								
	National Navigation[a]								
Other	Commercial/Institutional		23.17			18.2			
Sectors	Residential		2298.72	140.63		1901.27	14889.15		8021.99
	Agriculture/Forestry/Stationary								
	Fishing	Mobile				313.47			
Other (not elsewhere specified)		48.91			4.54				
Total [a]			**2,576.73**	**140.63**		**5,499.35**	**14,889.15**	**0.00**	**8,021.99**
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									
(a) Excludes international bunkers.									

		MODULE	**ENERGY**						
		SUBMODULE	**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**						
		WORKSHEET	**1-3**						
		SHEETS	**2 OF 3 CH_4**						
		COUNTRY	**LESOTHO**						
		YEAR	**1994**						
						STEP 2			
						B			
						Emission Factors (kg/TJ)			
			B1	B2		B3	B4	B5	B6
	ACTIVITY		Coal	Natural Gas	Oil	Wood / Wood Waste	Charcoal	Other Biomass and Wastes	**Energy**
Industries									
Manufacturing Industries and									
Construction			10			2			
Transport	Domestic Aviation[a]				0.5				
					Gasoline	Diesel			
	Road				20	5			
	Railways								
	National Navigation[a]								
Other	Commercial/Institutional		10			10			
Sectors	Residential		300	5		10	300		300
	Agriculture/Forestry/Stationary								
	Fishing	Mobile							
Other (not elsewhere specified)	10				10				
Total[a]									
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									

		MODULE	**ENERGY**							
		SUBMODULE	**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**							
		WORKSHEET	**1-3**							
		SHEETS	**3 OF 3 CH_4**							
		COUNTRY	**LESOTHO**							
		YEAR	**1994**							
							STEP 3			
						C				D
				Emissions by Fuel (kg)					Total	
										Emissions (Gg)
			C=(AxB)							
			C1	C2	C3	C4	C5	C6	D= sum	
	ACTIVITY		Coal	Natural Gas	Oil	Wood / Wood Waste	Charcoal	Other Biomass and Wastes	(C1..C6) / 1	000 000
Energy Industries			0.00	0.00		0.00	0.00	0.00	0.00	0.00
Manufacturing Industries and										
Construction		2,059.30	0.00		236.24	0.00	0.00	0.00	0.00	**Transport**
Domestic Aviation[a]				1.77					0.00	
Gasoline	Diesel									
	Road			0.00	41,603.40	5,300.200.05				
	Railways		0.00			0.000.00				
	National Navigation[a]		0.00			0.000.00				
Other	Commercial/Institutional		231.70	0.00		0.00	0.00	0.00	0.00	0.00
Sectors	Residential		689,616.00	703.15		0.00	4,466,745.00	0.00	2,406,597.00	7.56
	Agric/Forestry/Stationary		0.00	0.00		0.00	0.00	0.00	0.00	0.00
	Fishing	Mobile		0.00		0.000.00				
Other (not elsewhere specified)		489.10	0.00		0.00	0.00	0.00	0.00	0.00	Total [a]
		692,396.10	703.15		47,141.61	4,466,745.00	0.00	2,406,597.00	7.61	
Memo: International Marine Bunkers		0.00		0.00	0.00				0.00	Memo: International
Aviation Bunkers			0.00	0.00				0.00		

		MODULE	**ENERGY**						
		SUBMODULE	**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER1)**						
		WORKSHEET	**1-3**						
		SHEETS	**2 OF 3 N_2O**						
		COUNTRY	**LESOTHO**						
		YEAR	**1994**						
						STEP 2			
						B			
						Emission Factors (kg/TJ)			
			B1	B2		B3	B4	B5	B6
	ACTIVITY		Coal	Natural Gas	Oil	Wood / Wood Waste	Charcoal	Other Biomass and Wastes	
Energy Industries									
Manufacturing Industries and									
Construction		1.4			0.6				
Transport	Domestic Aviation[a]		2						
					Gasoline	Diesel			
	Road				0.6	0.6			
	Railways								
	National Navigation[a]								
Other	Commercial/Institutional		1.4			0.6			
Sectors	Residential		1.4	0.1		0.6	4		4
	Agriculture / Forestry/								
	Stationary								
	Fishing	Mobile				0.6			
Other (not elsewhere specified)			1.4			0.6			
Total[a]									
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									

		MODULE	ENERGY							
		SUBMODULE	NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)							
		WORKSHEET	1-3							
		SHEETS	3 OF 3 N_2O							
		COUNTRY	LESOTHO							
		YEAR	1994							
						STEP 3				
						C				D
						Emissions by Fuel (kg)				Total
										Emissions (Gg)
			C=(AxB)							
			C1	C2		C3	C4	C5	C6	D= sum
	ACTIVITY		Coal	Natural Gas	Oil	Wood / Wood Waste	Charcoal	Other Biomass and Wastes	(C1..C6) /	1 000 000
Energy Industries			0.00	0.00		0.00	0.00	0.00	0.00	0.00
Manufacturing Industries and										
Construction			288.30	0.00		70.87	0.00	0.00	0.00	0.00
Transport	Domestic Aviation[a]					7.08				0.00
					Gasoline	Diesel				
	Road			0.00	1,248.10	636.02				0.00
	Railways		0.00			0.00				0.00
	National Navigation[a]		0.00			0.00				0.00
Other	Commercial/Institutional		32.44	0.00		10.92	0.00	0.00	0.00	0.00
Sectors	Residential		3,218.21	14.06		1,140.76	59,556.60	0.00	32,087.96	0.10
	Agriculture / Forestry /		Stationary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fishing	Mobile		0.00		188.08				0.00
Other (not elsewhere specified)			68.47	0.00		2.72	0.00	0.00	0.00	0.00
Total[a]			3,607.42	14.06		3,304.57	59,556.60	0.00	32,087.96	0.10
Memo: International Marine Bunkers			0.00		0.00	0.00				0.00
Memo: International Aviation Bunkers					0.00	0.00				0.00

		MODULE	ENERGY						
		SUBMODULE	NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)						
		WORKSHEET	1-3						
		SHEETS	2 OF 3 CO						
		COUNTRY	LESOTHO						
		YEAR	1994						
						STEP 2			
						B			
						Emission Factors (kg/TJ)			
			B1	B2		B3	B4	B5	B6
ACTIVITY			Coal	Natural Gas	Oil	Wood /	Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries									
Manufacturing Industries and									
Construction		150			10				
Transport	Domestic Aviation[a]		100						
					Gasoline	Diesel			
	Road				8000	1000			
	Railways								
	National Navigation[a]								
Other	Commercial/Institutional		2000			20			
Sectors	Residential		2000	50		20	5000		5000
	Agric/Forestry/Stationary								
	Fishing	Mobile	1000						
Other (not elsewhere specified)			2000			20			
Total[a]									
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									

MODULE			**ENERGY**							
SUBMODULE			**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**							
WORKSHEET			**1-3**							
SHEETS			**3 OF 3 CO**							
COUNTRY			**LESOTHO**							
YEAR			**1994**							
						STEP 3				
						C				D
			Emissions by Fuel (kg)			Total Emissions (Gg)				
			C=(AxB)							
			C1	C2	C3	C4	C5	C6	D= sum	
ACTIVITY			Coal	Natural Gas	Oil	Wood /	Wood Waste	Charcoal	Other Biomass and Wastes	(C1..C6) / 1 000 000
Energy Industries			0.00	0.00		0.00	0.00	0.00	0.00	0.00
Manufacturing Industries and										
Construction		30,889.50	0.00		1,181.20	0.00	0.00	0.00	0.03	
Transport	Domestic Aviation[a]	354.000.00								
	Gasoline	Diesel								
	Road			0.00	16,641,360.00	1,060,040.00	17.70			
	Railways		0.00			0.000.00				
	National Navigation[a]		0.00			0.000.00				
Other	Commercial/Institutional		46,340.00	0.00		364.00	0.00	0.00	0.00	0.05
Sectors	Residential		4,597,440.00	7,031.50		38,025.40	74,445,750.00	0.00	40,109,950.00	119.20
	Agric/Forestry/Stationary		0.00	0.00		0.00	0.00	0.00	0.00	0.00
	Fishing	Mobile		0.00		313,470.000.31				
Other (not elsewhere specified)			97,820.00	0.00		90.80	0.00	0.00	0.00	0.10
Total [a]			**4,772,489.50**	**7,031.50**		**18,054,885.40**	**74,445,750.00**	**0.00**	**40,109,950.00**	**137.39**
Memo: International Marine Bunkers			0.00		0.00	0.00				0.00
Memo: International Aviation Bunkers					0.00	0.00				0.00

MODULE	**ENERGY**								
SUBMODULE	**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**								
WORKSHEET	**1-3**								
SHEETS	**2 OF 3 NMVOC**								
COUNTRY	**LESOTHO**								
YEAR	**1994**								
						STEP 2			
						B			
						Emission Factors (kg/TJ)			
			B1	B2		B3	B4	B5	B6
ACTIVITY			Coal	Natural Gas	Oil	Wood / Wood Waste	Charcoal	Other Biomass and Wastes	**E n e r g y**
Industries									
Manufacturing Industries and									
Construction			20			5			
Transport	Domestic Aviation[a]								
					Gasoline	Diesel			
	Road				1500	200			
	Railways								
	National Navigation[a]								
Other	Commercial/Institutional	200			5				
Sectors	Residential		200	5		5	600		600
	Agric/Forestry/Stationary								
	Fishing	Mobile				200			
Other (not elsewhere specified)									
Total[a]			200			5			
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									

MODULE			**ENERGY**							
SUBMODULE			**NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)**							
WORKSHEET			**1-3**							
SHEETS			**3 OF 3 NMVOC**							
COUNTRY			**LESOTHO**							
YEAR			**1994**							
					STEP 3					
					C					D
					Emissions by Fuel (kg)		Total Emissions (Gg)			
							4C=(AxB)			
			C1	C2	C3		C4	C5	C6	D= sum
ACTIVITY			Coal	Natural Gas	Oil		Wood/Wood Waste	Charcoal	Other Biomass and Wastes	(C1..C6)/
										1 000 000
Energy Industries			0.00	0.00		0.00	0.00	0.00	0.00	0.00
Manufacturing Industries and										
Construction			4,118.60	0.00		590.60	0.00	0.00	0.00	0.00
Transport	Domestic Aviation[a]				0.00					0.00
					Gasoline	Diesel				
	Road			0.00	3,120,255.00	212,008.003.33				
	Railways		0.00			0.00				0.00
	National Navigation[a]		0.00			0.00				0.00
Other	Commercial/Institutional		4,634.00	0.00		91.00	0.00	0.00	0.00	0.00
Sectors	Residential		459,744.00	703.15		9,506.35	8,933,490.00	0.00	4,813,194.00	14.22
	Agric/Forestry/Stationary		0.00	0.00		0.00	0.00	0.00	0.00	0.00
	Fishing	Mobile		0.00	62,694.00	0.00			0.06	
Other (not elsewhere specified)			0.00	0.00		0.00	0.00	0.00	0.00	0.00
Total[a]			468,496.60	703.15		3,405,144.95	8,933,490.00	0.00	4,813,194.00	17.62
Memo: International Marine Bunkers			0.00		0.00	0.00				0.00
Memo: International Aviation Bunkers					0.00	0.00				0.00

TABLE 1 SECTORAL REPORT FOR ENERGY

(Sheet 1 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total Energy	635.99	7.63	0.10	4.92	137.08	17.57	0.00
A Fuel Combustion Activities (Sectoral Approach)	**635.99**	**7.63**	**0.10**	**4.92**	**137.08**	**17.57**	**0.00**
1 Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00
a Public Electricity and Heat Production							
b Petroleum Refining							
c Manufacture of Solid Fuels and Other Energy Industries							
2 Manufacturing Industries and Construction	27.87	0.00	0.00	0.09	0.03	0.00	0.00
a Iron and Steel							
b Non-Ferrous Metals							
c Chemicals							
d Pulp, Paper and Print							
e Food Processing, Beverages and Tobacco							
f Other (please specify)							

TABLE 1 SECTORAL REPORT FOR ENERGY

(Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
3 Transport	**220.69**	**0.05**	**0.00**	**2.10**	**17.70**	**3.33**	**0.00**
a Civil Aviation	0.25	0.00	0.00	0.00	0.00	0.00	
b Road Transportation	220.44	0.05	0.00	2.10	17.70	3.33	
c Railways	0.00	0.00	0.00	0.00	0.00	0.00	
d Navigation	0.00	0.00	0.00	0.00	0.00	0.00	
e Other (please specify)	0.00						
Pipeline Transport	0.00						
4 Other Sectors	**382.55**	**7.58**	**0.10**	**2.73**	**119.25**	**14.22**	**0.00**
a Commercial/Institutional	2.15	0.00	0.00	0.00	0.05	0.00	
b Residential	357.42	7.58	0.10	2.72	119.20	14.22	
c Agriculture/Forestry/Fishing	22.99	0.00	0.00	0.01	0.00	0.00	
5 Other (please specify)	**4.87**	**0.00**	**0.00**	**0.00**	**0.10**	**0.01**	
B Fugitive Emissions from Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Solid Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Coal Mining		0.00					
b Solid Fuel Transformation							
c Other (please specify)							
2 Oil and Natural Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Oil		0.00		0.00	0.00	0.00	0.00

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3.0 AGRICULTURE

3.1 Overview of the Agriculture Sector

Agriculture in Lesotho is the key sector and a major source of employment within the country. Approximately 85 percent of the population lives in rural areas and about 60 to 70 percent of the country's labour force obtains supplemental income from agriculture. However, Lesotho's agriculture is characterised by low and declining production. The contribution of agriculture to GNP declined from 22 percent in 1971 to 11 percent in 1988 (Bureau of Statistics, 1992). Similarly the contribution of agriculture to GDP decreased from 50 percent in 1974 to 22 percent in 1984 (Government of Lesotho, 1987). In the period 1990 – 1995 the share of agriculture in GNP averaged 11 percent.

The agricultural sector is increasingly being dominated by livestock (Table 3.1). In 1966 crop production contributed approximately 60 percent of the value of agricultural output with livestock contribution 40 percent. By 1984 crop production contribution had declined to 22 percent while livestock contribution increased to 78 percent. The contribution of crop production in the agricultural sector peaked in 1990/91 because of favourable weather conditions. The contribution of livestock to agriculture peaked in 1992/93 while crop contribution was the lowest. The drop in crop contribution was mainly due to drought.

Year	Crops	Livestock
1996	60.0	40.0
1973/74	47.2	52.8
1977/78	56.0	44.0
1980/81	42.7	57.3
1983/84	22.4	77.6
1987/88	43.8	56.2
1988/89	43.1	56.9
1989/90	36.5	63.5
1990/91	50.1	49.9
1991/92	38.9	61.1
1992/93	17.3	82.7
1993/94	24.0	76.0
1994/95	37.3	62.7

Table 3.1: Share of Crops and Livestock in Agricultural Output (Percent)
Source : Bureau of Statistics and Ministry of Agriculture (1996).

Major field crops include maize, sorghum, beans, peas, winter wheat, and horticultural crops. An estimated one-third of agricultural output, in particular livestock products, enters the market, with the larger proportion going to household subsistence. The sector is dominated by small holders who, by and large, are unable to meet their subsistence requirements on account of the adverse conditions facing agriculture in general, the poor quality of technology, and the small size of agricultural holdings. Many have found farming to be relatively unattractive and have consequently reduced the time, organization and other resources devoted to it. Nevertheless, Agriculture continues to dominate the domestic economy, with the highest percentage of the population engaged in this sector. However, in recent years, agriculture's contribution to GDP at current market prices averaged over 40 percent. This relative decline in agriculture can be partly attributed to the faster growth of other sectors of the domestic economy [LASR, 1994]. However, the major causes of decline seem to, be among others, the following: reduction in the area under cultivation; decline of soil fertility and continuing erosion; poor cultivation and management practices.

Livestock production and acquisition is an important component of the domestic economy. Sheep and goats have an additional value as producers of wool and mohair. There is a poultry industry (eggs and broilers), a small dairy industry and a pig industry being developed steadily. Horses and donkeys are also a major component of the rural transport system especially in the mountain regions.

Livestock production is generally sustained by communal grazing in the rangelands. There is general agreement that there has been widespread and serious deterioration in the condition of Lesotho's grassland.

There has also been detrimental changes in floristic composition of the grasslands. Among these changes are a decrease in the more palatable climax vegetation and an increase in bare ground including bushes encroachment by semi-woody shrubs.

The traditional systems of animal husbandry has evolved around what would seem to be a well ordered pattern of transhumans between the lowlands (winter) and the mountain grazing areas (summer). At the beginning of spring all stock with the exception of milking cows and transport animals must move from the village grazing areas to the mountain cattle posts. Stock remaining in the village must either be kraaled or confined to allocated pastures. In the winter months, the animals are brought back to the summer grazing area around the villages including the communal grazing of crop residues.

These agricultural activities contribute directly to emissions of greenhouse gases through a variety of different processes. These include methane emissions from enteric fermentation in domestic animals, animal wastes, and non-CO_2 emissions from indiscriminate burning of rangelands and a much more rare burning of agricultural wastes. The latter are communally grazed and the remaining stocks are collected for fuel in the villages. Each of these activities is considered here and the results are provided in the worksheets.

3.2 Enteric Fermentation from animal manure & Manure Management

Methane is emitted in herbivores as a by product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. Both ruminant and some non-ruminant (e.g. pigs, horses) animals produce methane, although ruminants are the largest source since they are able to digest cellulose due to the presence of specific

microorganisms in their digestive tracts. The amount of methane released is dependent on the animal category, age, weight, the quality and quantity of feed, and the energy expenditure of the animal. In Lesotho, the ruminant population of livestock is mainly cattle, sheep and goats.

Methane from the management of animal manure occurs as the result of its decomposition under anaerobic conditions. These conditions often occur when a large number of animals are managed in a confined area (e.g. dairy farms, beef feedlots, swine and poultry farms). In Lesotho most of the animals are managed in free range systems in communal grazing areas. Animals are only confined in kraals overnight. The upcoming dairy industry is made up of small scale systems of no more than three cows on average per farm. The poultry farms have an average of 300 chickens while swine farms have two or three pigs on average (Data estimated by expert opinion). The foregoing analysis testifies to the fact that the domestic livestock management systems are not conducive to high emissions.

3.2.1 Data Collection and Analysis

The data used in the estimation of emissions from animals and animal manure are obtained from the scientific survey of the agricultural sector conducted annually by the Bureau of Statistics (BOS). Some data compiled by the Livestock and Range Management Division of the Ministry of Agriculture were used to augment the statistical data from BOS. Although the IPCC manual recommends that the country values be used in calculating the emissions the default value factors from the manuals have been used because of a lack of documented country specific values. Entries and results are indicated in Worksheet 4-1 of the Agriculture Module summarized here as Table 3.2.

		Actual	Emissions	
Animal Type	Population (1000s)	Enteric	Manure	Total[2] (Gg)
		(CH_4 Yr^{-1})	(CH_4 Yr^{-1})	CH4/yr
Dairy cows	4	0.14	0.003	0.147
Non-dairy	593	18.91	0.593	19.50
Sheep	1110	5.55	0.178	5.73
Goats	764	3.82	0.130	3.95
Horses & Mules	102	1.74	0.163	2.003
Swine	63	0.06	0.378	0.441
Poultry	2000	0.00	0.04	0.04
Total		30.22	1.485	31.811

Table 3.2. Methane Emissions from Domestic Livestock Enteric Fermentation and manure Management submodule. Agriculture Module.

3.3 Emission of Non CO_2 Trace Gases from Savanna Burning

Savannas are tropical and subtropical vegetation formations with a predominately continuous grass cover occasionally interrupted by trees and shrubs. Most of the growth occurs during the wet season. In the dry

season the grasses wither and die hence fires are frequent. The Lesotho grasslands are different from the savanna ecosystems. There is almost a complete absence of woody vegetation in Lesotho. Small semi-woody shrubs have spread very widely during this century in the grasslands at medium and higher altitudes. The most dominant are the **Chrysocoma tenuifolia** and **Aster filifolius.** Both of these shrubs adversely affect the grazing potential. Small amounts of Chrysocoma are gathered for fuel.

General descriptions of the vegetation[3] and broad ecological zones have been identified [Bawden et al, 1968]. The distribution of plants is correlated with altitude and modified by effects of slope aspect on soil development. In the high mountain area, thin stony soils are colonized by **Helichyrysum spp., Danthonia disticha.** The basalt soils are colonized by **Festuca rubra and F. caprina.** Earlier workers have described the grassland on north facing slopes and at lower altitudes as **Themida triandra** dominant. The growth cycle of the grassland is controlled by seasonal variations in temperature and moisture. Most of the grasses become dormant during the cold and dry winter season and makes it susceptible to burning. Grassland burning results in instantaneous gross emissions of CO_2 emissions. However, the same amount will be taken up in the regrowth so net emission is zero. Emissions of these other gases are net transfers from the biosphere to the atmosphere.

Some accurate estimates of extensive grassland burning are usually obtained by remote sensing techniques using low resolution satellite imagery. In Lesotho prescribed burning of grassland is rare. Almost all incidences of burning occur as indiscriminate burning of rangeland. This is also normally not a very serious problem. As a result there is no concerted effort to monitor the occurrence of fires. The best estimate of rangeland burning was established on the basis of areas frequently burned each year in the districts and particularly in the Range Management Areas and reports of burning in forest reserves. We have thus estimated that a total of 37,000 ha is burned annually as an average of all categories (grassland and forest reserves). Estimates are derived from annual repots from the Department of Range and Livestock services and Forestry Annual report. These are occurrences of annual indiscriminate burning reported by Range officers and Forestry personnel (unpublished data). The entries and results of burning are shown in Worksheet 4-3 of the Agriculture Module summarized in table 3.3.

Category All[1]	Area (Kha)	Total Carbon	Non-CO_2 Emissions (Gg)			
burned	burned	released	CH_4	CO	N_2O	NO_x
3.37	37	72.09	0.19	6.72	0.003	0.13

Table 3.3. Prescribed and/or indiscriminate burning of grasslands and trees in forests reserves in Lesotho. Agriculture Module. Submodule for Prescribed burning of Savannas.

3.4 Burning of Agricultural Residues

Large quantities of agricultural wastes are produced from farming systems. The burning of these wastes to clear remaining straw and stubble after harvest and to prepare the field for the next cycle may potentially

produce large quantities of carbon. Like the burning of savannas, the burning of crop residues in not a net source of CO_2 because the carbon released to the atmosphere is reabsorbed during the next growing season. Similarly, crop residue burning makes a significant contribution to the CH_4, CO, NO_x and N_2O pool of trace gases. In Lesotho there is a very insignificant level of crop residue burning due to grazing of the residues by livestock and subsequent gathering of the stover for fuel. The latter component is reported in Chapter 2 under energy sector.

3.5 Agricultural Soils

Agricultural soils may emit or remove nitrous oxide, carbon dioxide and/or methane. In Lesotho, major inputs into agricultural soils include synthetic fertilizers, nitrogen from animal wastes, biological fixation and mineralization of organic matter.

Data for synthetic fertilizers with nitrogen compounds were derived from annual compilation of fertilizer imports into Lesotho (Co-op Lesotho, Ministry of Agriculture). Crop residue and estimates of biological fixation by legume crops was estimated from annual production estimates (LASR, 1994). The relevant calculations are provided in the worksheet 4-5 in the appendix.

3.6 Comments on IPCC/OECD Methodology

Worksheet 4-1

- **Column A**
  Livestock data used here came from the Bureau of Statistics Annual Reports 1993-95 and Department Livestock Service reports. The BOS reports do not separate horses and mules statistics hence in this report the combined total population is used. As a result, it is not possible to calculate the more accurate weighted average.
- **Column B**
  In this column we have used the average emissions factor for horses and mules.
- **Column C**
  In this column we have used the average emissions factor for horses and mules in temperate zones of developing countries.
- **Column D**
  Default factors for temperate regions of developing countries have been used.

1.2 Worksheet 4-1 Supplemental

Others include sum of goats, horses and mules.

1.3 Worksheet 4-1 Sheet 2

Pasture range and paddock have been accounted for in the sector for agricultural soils. N_2O emissions from waste management systems other than pasture range and paddocks and solid storage and drylot are insignificant and are therefore assumed to be zero.

Worksheet 4-1 Nitrous Oxide Emissions

Pasture range and paddock

During the winter and spring months animals roam to graze the crop residues in the cropland. This effect will be confounded in the direct soil emissions from agricultural fields after spreading.

Worksheet 4-3

- **Column A**
  The area burned is based on annual occurrence of indiscriminate fires in the range management areas, district estimates and burning within forest reserves (Annual Reports of Range and Forestry Departments, Ministry of Agriculture).
- **Column B**
  Maximum density is assumed in accordance with Menant etal 1991. Table 4-14 Revised 1996 IPCC Guidelines Reference Manual.

Worksheet 4-3 Sheet 3

Column O

Lower limit of the range given in the default tables.

MODULE	**AGRICULTURE**					
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK**					
	ENTERIC FERMENTATION AND MANURE MANAGEMENT					
WORKSHEET	**4-1**					
SHEET	**1 OF 2 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC**					
	FERMENTATION AND MANURE MANAGEMENT					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
	STEP 1		**STEP 2**	**STEP 3**		
	A	B	C	D	E	F
Livestock Type	Number of Animals	Emissions Factor for Enteric Fermentation	Emissions from Enteric Fermentation	Emissions Factor for Manure Management	Emissions from Manure Management	Total Annual Emissions from Domestic Livestock
	(1000s)	(kg/head/yr)	(t/yr)	(kg/head/yr)	(t/yr)	(Gg)
			C = (A x B)		E = (A x D)	F =(C + E)/1000
Dairy Cattle	4	36	144.00	1	4.00	0.15
Non-dairy Cattle	593	32	18,976.00	1	593.00	19.57
Buffalo			0.00		0.00	0.00
Sheep	1110	5	5,550.00	0.16	177.60	5.73
Goats	764	5	3,820.00	0.17	129.88	3.95
Camels			0.00		0.00	0.00
Horses and mules	124	14	1,736.00	1.25	155.00	1.89
Mules & Asses			0.00		0.00	0.00
Swine	63	1	63.00	6	378.00	0.44
Poultry	2000	0	0.00	0.018	36.00	0.04
Totals			30,289.00		1,473.48	31.76

MODULE	AGRICULTURE			
SUBMODULE	METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK			
	ENTERIC FERMENTATION AND MANURE MANAGEMENT			
WORKSHEET	4-1 (SUPPLEMENTAL)			
SPECIFY AWMS	PASTURE RANGE AND PADDOCK			
SHEET	NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM			
COUNTRY	LESOTHO			
YEAR	1994			
	A	B	C	D
Livestock Type	Number of Animals	Nitrogen Excretion	Fraction of Manure	Nitrogen Excretion
		Nex	Nitrogen /AWMS 100%	per AWMS, Nex
	(1000s)	(kg//head/(yr)	(fraction)	(kg/N/yr)
D = (A x B x C)				
Non-dairy Cattle	593	40	96	2,277,120.00
Dairy Cattle	4	60	83	19,920.00
Poultry	2000	0.6	81	97,200.00
Sheep	1110	12	99	1,318,680.00
Swine	63	16	0	0.00
Others	880	40	99	3,484,800.00
			TOTAL	7,197,720.00

MODULE	AGRICULTURE			
SUBMODULE	METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK			
	ENTERIC FERMENTATION AND MANURE MANAGEMENT			
WORKSHEET	4-1 (SUPPLEMENTAL)			
SPECIFY AWMS	SOLID STORAGE AND DRYLOT			
SHEET	NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM			
COUNTRY	LESOTHO			
YEAR	1994			
	A	B	C	D
Livestock Type	Number of Animals	Nitrogen Excretion	Fraction of Manure	Nitrogen Excretion
		Nex	Nitrogen /AWMS 100%	per AWMS, Nex
	(1000s)	(kg//head/(yr)	(fraction)	(kg/N/yr)
D = (A x B x C)				
Non-dairy Cattle	593	40	3	71,160.00
Dairy Cattle	4	60	0	0.00
Poultry	2000	0.6	0	0.00
Sheep	1110	12	1	13,320.00
Swine	63	16	93	93,744.00
Others	880	40	0	0.00
		TOTAL	178,224.00	

MODULE	**AGRICULTURE**		
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC**		
	FERMENTATION AND MANURE MANAGEMENT		
WORKSHEET	**4-1**		
SHEET	**2 OF 2 NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION**		
	EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS (AWMS)		
COUNTRY	**LESOTHO**		
YEAR	**1994**		
		STEP 4	
	A	B	C
Animal Waste	Nitrogen Excretion	Emission Factor For	Total Annual Emissions
Management System	$Nex_{(AWMS)}$	AWMS	of N_2O
(AWMS)		EF_3	
	(kg N/yr)	(kg N_2O–N/kg N)	(Gg)
			C=(AxB)[44/28] / 1 000 000
Anaerobic lagoons	0.00		0.00
Liquid systems	0.00		0.00
Daily spread	0.00		
Solid storage & drylot	178,224.00	0.02	0.01
Pasture range and paddock	7,197,720.00		
Other	0.00		0.00
Total	7,375,944.00	**Total**	0.01

	MODULE	AGRICULTURE					
	SUBMODULE	BURNING OF SAVANNAS					
	WORKSHEET	4-3					
	SHEET	1 OF 3					
	COUNTRY	LESOTHO					
	YEAR	1994					
		STEP 1				STEP 2	
A	B	C	D	E	F	G	H
Area Burned	Biomass	Total Biomass	Fraction	Quantity	Fraction of Living	Quantity of Living	Quantity
by Category (specify)	Density of Savanna	Exposed to Burning	Actually Burned	Actually Burned	Biomass Burned	Biomass Burned	of Dead Biomass
(k ha)(t dm/ha)	(Gg dm)		(Gg dm)		(Gg dm)	(Gg dm)	
		C = (A x B)		E = (C x D)		G = (E x F)	H = (E - G)
37	6	222.00	0.85	188.70	0.45	84.92	
							103.79
		0.00		0.00		0.00	
							0.00
		0.00		0.00		0.00	
							0.00
		0.00		0.00		0.00	
							0.00
		0.00		0.00		0.00	
							0.00
		0.00		0.00		0.00	
							0.00
		0.00		0.00		0.00	
							0.00

MODULE	**AGRICULTURE**				
SUBMODULE	**BURNING OF SAVANNAS**				
WORKSHEET	**4-3**				
SHEET	**2 OF 3**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
STEP 3					
	I	J	K	L	
	Fraction	Total Biomass	Carbon Fraction	Total Carbon	
	Oxidised of living	Oxidised	of Living & Dead	Released	
	and dead biomass		Biomass		
		(Gg dm)		(Gg C)	
		Living: J = (G x I)	*Dead:* J = (H x I)	L = (J x K)	
Living	0.8	67.93	0.45	30.57	
Dead	1	103.79	0.4	41.51	
Living		0.00		0.00	
Dead		0.00		0.00	
Living		0.00		0.00	
Dead		0.00		0.00	
Living		0.00		0.00	
Dead		0.00		0.00	
Living		0.00		0.00	
Dead		0.00		0.00	
Living		0.00		0.00	
Dead		0.00		0.00	
Living		0.00		0.00	
Dead		0.00		0.00	
Total				72.08	

		MODULE	**AGRICULTURE**			
		SUBMODULE	**BURNING OF SAVANNAS**			
		WORKSHEET	**4-3**			
		SHEET	**3 OF 3**			
		COUNTRY	**LESOTHO**			
		YEAR	**1994**			
		STEP 4			STEP 5	
L	M	N	O	P	Q	R
Total Carbon Released	Nitrogen-Carbon Ratio	Total Nitrogen Content	Emissions Ratio	Emissions	Conversion Ratio	Emissions from Savanna Burning
(Gg C)	(Gg N)		(Gg C **or** Gg N)		(Gg)	
	N = (L x M)		P = (L x O)		R = (P x Q)	
		0.002	0.14	16/12	CH_4	0.19
		0.04	2.88	28/12	CO	6.73
72.08 0.006	0.43		P = (N x O)		R = (P x Q)	
		0.005	0.00	44/28	N_2O	0.00
		0.094	0.04	46/14	NO_x	0.13

MODULE	**AGRICULTURE**		
SUBMODULE	**AGRICULTURAL SOILS**		
WORKSHEET	**4-5**		
SHEET	**1 OF 5 DIRECT NITROUS OXIDE EMISSIONS FROM**		
	AGRICULTURAL FIELDS, EXCLUDING CULTIVATION OF HISTOSOLS		
COUNTRY	**LESOTHO**		
	YEAR 1994		
STEP 1			**STEP 2**
	A	B	C
Type of N input to soil	Amount of N	Factor for	Direct Soil
	Input	Direct Emissions	Emissions
EF_1			
	(kg N/yr)	(kg N_2O–N/kg N)	(Gg N_2O-N/yr)
			C = (A x B)/1 000 000
Synthetic fertiliser (F_{SN})			
Animal waste (F_{AW})	3,909,250.32	0.0125	0.05
N-fixing crops (F_{BN})	359574.6	0.0125	0.00
Crop residue (F_{CR})			
		Total	0.05

	MODULE	**AGRICULTURE**			
	SUBMODULE	**AGRICULTURAL SOILS**			
	WORKSHEET	**4-5A (SUPPLEMENTAL)**			
	SHEET	**1 OF 1 MANURE NITROGEN USED**			
	COUNTRY	**LESOTHO**			
	YEAR	**1994**			
A	B	C	D	E	F
Total Nitrogen	Fraction of Nitrogen	Fraction of Nitrogen	Fraction of Nitrogen	Sum	Manure Nitrogen Used
Excretion	Burned for Fuel	Excreted During	Excreted Emitted as		(corrected for NO_x and
		Grazing	NO_x and NH_3		NH_3 emissions), F_{AW}
(kg N/yr)	(fraction)	(fraction)	(fraction)	(fraction)	(kg N/yr)
				F = 1 - (B + C + D)	F = (A x E)
7,375,944.00	0.25	0.02	0.2	0.53	3,909,250.32

	MODULE	**AGRICULTURE**				
	SUBMODULE	**AGRICULTURAL SOILS**				
	WORKSHEET	**4-5B (SUPPLEMENTAL)**				
	SHEET	**1 OF 1 NITROGEN INPUT FROM CROP RESIDUES**				
	COUNTRY	**LESOTHO**				
	YEAR	**1994**				
A	B	C	D	E	F	G
Production	Fraction of	Production of	Fraction of	One minus the	One minus the	Nitrogen Input
of non - N -	Nitrogen of	Pulses and	Nitrogen in N-	Fraction of	Fraction of	from Crop
Fixing Crops	non - N -	Soybeans	Fixing Crops,	Crop Residue	Crop Residue	Residues,
	Fixing Crops,			Removed From	Burned	F_{CR}
				Field,		
(kg dry Biomass/yr)	(kg N/kg dry	(kg dry biomass)	(kg N/kg dry			
biomass)	biomass/yr)		(fraction)	(fraction)	(kg N/yr)	
						G = 2 x (A x B +
						C x D) x E x F
61892720	0.015	359574.6	0.03	0.55	0.75	774,821.88

MODULE	**AGRICULTURE**			
SUBMODULE	**AGRICULTURAL SOILS**			
WORKSHEET	**4-5**			
SHEET	**2 OF 5 DIRECT NITROUS OXIDE EMISSIONS FROM CULTIVATION OF HISTOSOLS**			
COUNTRY	**LESOTHO**			
YEAR	**1994**			
STEP 3	**STEP 4**			
	D	E	F	G
	Area of	Emission Factor for	Direct Emissions	Total Direct
	Cultivated	Direct Soil	from Histosols	Emissions of
	Organic Soils	Emissions		N_2O
	F_{OS}	EF_2		
	(ha)	(kg N_2O–N/ha/yr)	(Gg N_2O–N/yr)	(Gg)
		F=(D x E)/1 000 000	G = (C+F)[44/28]	
Subtotal	0	5	0.00	0.08

MODULE	**AGRICULTURE**		
SUBMODULE	**AGRICULTURAL SOILS**		
WORKSHEET	**4-5**		
SHEET	**3 OF 5 NITROUS OXIDE SOIL EMISSIONS FROM GRAZING ANIMALS -**		
	PASTURE RANGE AND PADDOCK		
COUNTRY	**LESOTHO**		
YEAR	**1994**		
STEP 5			
A	B	C	
Animal Waste	Nitrogen Excretion	Emission Factor for	Emissions Of N_2O from
Management System	$Nex_{(AWMS)}$	AWMS	Grazing Animals
(AWMS)		EF_3	
(kg N/yr)	(kg N_2O–N/kg N)	(Gg)	
			C = (A x B)[44/28]/1 000 000
Pasture range & paddock	7,197,720.00	0.02	0.23

MODULE	**AGRICULTURE**							
SUBMODULE	**AGRICULTURAL SOILS**							
WORKSHEET	**4-5**							
SHEET	**4 OF 5 INDIRECT NITROUS OXIDE EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NH_3 AND NO_x**							
COUNTRY	**LESOTHO**							
YEAR	**1994**							
				STEP 6				
	A	B	C	D	E	F	G	H
Type of	Synthetic	Fraction of	Amount of	Total N	Fraction of	Total N Excretion	Emission Factor	Nitrous Oxide
Deposition	Fertiliser N	Synthetic	Synthetic N	Excretion by	Total Manure N	by Livestock that	EF_4	Emissions
	Applied to	Fertiliser N	Applied to Soil	Livestock	Excreted that	Volatilizes		
	Soil, N_{FERT}	Applied that	that Volatilizes	N_{EX}	Volatilizes			
		Volatilizes			$Frac_{GASM}$			
		$Frac_{GASFS}$						
	(kg N/yr)	(kg N/kg N)	(kg N/kg N)	(kg N/yr)	(kg N/kg N)	(kg N/kg N)	(kg N_2O–N/kg N)	(Gg N_2O–N/yr)
			C = (A x B)			F = (D x E)		H = (C + F) x G /1 000 000
Total	1097799.9	0.1	109,779.99	7,375,944.00	0.2	1,475,188.80	0.01	0.02

Table 4. Sectoral Report For Agriculture (Sheet 1 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)					
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
Total Agriculture	31.95	0.44	0.13	6.73	0.00
A Enteric Fermentation	30.29				
1 Cattle	19.12				
2 Buffalo	0.00				
3 Sheep	5.55				
4 Goats	3.82				
5 Camels and Llamas	0.00				
6 Horses	1.74				
7 Mules and Asses	0.00				
8 Swine	0.06				
9 Poultry	0.00				
10 Other (please specify)					
B Manure Management	1.47	0.01			
1 Cattle	0.60				
2 Buffalo	0.00				
3 Sheep	0.18				
4 Goats	0.13				
5 Camels and Llamas	0.00				
6 Horses	0.16				
7 Mules and Asses	0.00				
8 Swine	0.38				
9 Poultry	0.04				

Table 4 Sectoral Report For Agriculture (Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)					
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
B Manure Management (cont...)					
10 Anaerobic		0.00			
11 Liquid Systems		0.00			
12 Solid Storage and Dry Lot		0.01			
13 Other (please specify)		0.00			
C Rice Cultivation	0.00				
1 Irrigated	0.00				
2 Rainfed	0.00				
3 Deep Water	0.00				
4 Other (please specify)					
D Agricultural Soils		0.43			
E Prescribed Burning of Savannas	0.19	0.00	0.13	6.73	
F Field Burning of Agricultural Residues [1]	0.00	0.00	0.00	0.00	
1 Cereals					
2 Pulse					
3 Tuber and Root					
4 Sugar Cane					
5 Other (please specify)					
G Other (please specify)					

3.7 References

- Bureau of Statistics (BOS) Annual Reports, 1993-1995. Government of Lesotho
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4.0 LAND USE AND FORESTRY

4.1 Overview of Land Use Change and Forestry

The natural vegetation of Lesotho is dominated by grassland, and by indigenous shrubs in some mountain areas. Although the present vegetation is regarded as a sub climax resulting from human interference and modification, according to May (1992), it is highly unlikely that large areas of Lesotho were ever covered by forests or woodland. However, patches of bush and small evergreen trees that occur on rocky slopes of sheltered valleys suggest that forest cover was previously more extensive than at present [GOL, 1996]. Bawden and Carrol (1968) have also suggested that Lesotho's climatic conditions are too dry and frosty for tree growth.

Only about 24 percent of Lesotho's GDP is derived from natural resources. While forest resources do not presently appear to contribute significantly to the national economy, their potential for import-saving (at the moment all processed wood consumed in Lesotho is imported) as well as the creation of new employment opportunities in rural areas could be very significant [GOL, 1995].

Present Forest Resources:

Lesotho is one of the least forested countries in Africa, tree cover is sparse and extends over a small percentage of the land. A few extremely limited areas of remnant indigenous Leucusidea woodland occur in the North, and some pockets of mixed forests and thickets are found in the river valleys. Otherwise open shrubland with isolated trees is the most dominant type with any woody biomass (These have been included under the indigenous species category on Worksheet 5-1 Sheet 1). Within this association, trees are normally found close to areas of water concentration. Although sparse and low yielding, the natural vegetation is a valuable resource to rural people. Much of the present woody biomass stock in the country result from indigenous shrubs. At the moment the gazetted Forest Areas cover approximately 12,000 ha while the rest of the planted stocks are privately owned. The distribution of woodlots by districts is given on Table 4.1. The reader should note that this gazetted hectarage is not necessarily all covered with trees, but declared to be used for formal tree planting. For example, the total stocked area (6173ha) in table 4.1 is part of the 12000ha gazetted area.

District	Stocked area (1995/96) (ha)	No. Woodlots 0-20 ha	No. Woodlots 21-50 ha	No. Woodlots >50 ha	Total Woodlots
Maseru	1619	89	22	3	114
Berea	827	63	3	2	68
Leribe	1799	55	14	7	76
Butha-Buthe	513	15	4	1	20
Mokhotlong	17	13	0	0	13
Thaba Tseka	50	15	0	0	15
Qacha's Nek	174	21	0	0	21
Quthing	429	71	1	0	72
Mohale's Hoek	290	40	10	1	51
Mafeteng	457	31	6	0	37
Total	6173	413	60	14	487

Table 4.1: Distribution of Woodlots according to districts in Lesotho
Source: Woodlot Inventories carried out in 1995/96 by Forestry Division (Unpublished)

In addition to the plantations, many pines, cypresses and oaks have been planted around Government building and near trading and mission stations.

Demand For Wood And Tree Products:

The energy economy in Lesotho is largely focused on collecting and consuming wood fuel (mainly wood) to satisfy the households' demand for cooking and heating. As outlined in chapter 2, section 2.1 biofuels constitute about 80 percent of the national energy consumption. Furthermore these energy carriers accounted for about 90 percent of the total household energy consumption in 1984 [GTZ, 1991]. Wood is the dominant fuel in the lowlands and foothills while shrubs and dung are more prevalent in the mountains and Senqu River Valley because of limited availability of other fuels.

Thus much of the demand for fuelwood is satisfied from deforestation of indigenous woodland and this exceeds afforestation efforts. This is not only a threat to the poorest who cannot afford alternative types of fuel but as the economy matures, deforestation is expected to grow consequently increasing emission of greenhouse gases and reducing to extinction, the supply of material traditionally available to provide energy.

Land Use Changes:

The wholesale clearance of all types of habitat for settlements as well as burning and indiscriminate gathering of fuelwood have destroyed most of Lesotho's biological diversity. A little of what remains is under threat and is likely to escalate the emissions of greenhouse gases.

4.2 Change in Forestry and other Woody Bio-mass

In Lesotho's context **acacia species** includes poplars and willow while **tropical others** mainly include indigenous forests like hardwoods. Most of these forests are under the management of the traditional authorities.

Although millions of trees have been planted since 1855 only a few have survived to a harvestable age. While it is true that some of these trees cannot withstand harsh climatic conditions, the death of many others is caused by negligence or even willful damage by the people who do not yet realise the important role of trees in soil conservation and environmental protection. Moreover, as fires sweep through the grassland every year, there has been little opportunity for tree roots and stems to coppice and for tree seedlings to survive.

The Government has been harvesting woodlots (though not commercially), since 1981/82 to produce firewood and poles. Other wood using enterprises such as furniture making mainly rely on imported timber.

The other point to be noted is the fact that in 1987 when the Woodlot Project came to an end the Government stopped recording harvesting inventories. To calculate the 1994 estimates, a 20 percent increase was applied to the 1987 figures based on the pre 1987 trends.

4.2.1 Traditional Fuelwood Consumed

The data on consumption of traditional fuelwood has been sourced from chapter 2 on Energy. The total traditional fuelwood consumption is 960.59kt comprising of fuelwood (479.51kt) with moisture content of 12.3% and shrubs (481.08kt) with moisture content of 10.5%. An average moisutre content of 11.4%

for the two fuels is assumed. The figure of 960.59kt at 11.4% moisture content has been translated into a figure of 860.69kt dry matter needed for the analysis, using the standard relation

$$\frac{W_W - W_W}{W_W} = W_c$$

$$\begin{aligned} \text{Where } W_w &= \text{wet weight} \\ W_d &= \text{dry weight} \\ M_c &= \text{moisture content.} \end{aligned}$$

In rural Lesotho, trees are used for fencing poles, firewood and for building purposes. Some indigenous shrubs are also used as ceremonial and medicinal plants. Even though Lesotho's harsh winters require extensive use of energy for space heating in addition to food preparation, in terms of the supply situation it is apparent, although to an undetermined extent, that the present rate of consumption exceeds the rate of natural regeneration. In addition to reducing the growing stock available for future consumption, this net loss of vegetation cover contributes to CO_2 emissions.

Although it is known that Basotho utilize forest products for a wide range of uses in addition to fuel, for example Hall and Green (1989) indicate that trees are wanted for fencing especially kraals while timber and poles are used for house construction etc. Data on wood consumption for these purposes are currently not available.

4.3 Forest and Grassland Conversion

4.3.1 Encroachment of croplands onto grasslands

The progressive encroachment of villages onto production grasslands and cropland and the encroachment of croplands to grasslands is a major problem in Lesotho. It has been estimated that 14 percent of the total surface area of Lesotho has been converted from rangeland to cropland within the last 12 years [IUCN, 1993].

Lesotho is also moving through some major population shifts due to urbanisation and peri-urbanisation process. These have an enormous impact on land use. For instance, thirty years ago, except for Maseru and some urbanisation around Maputsoe and Botha-Bothe, the population of Lesotho was largely a rural one. By 1995 this had changed with increasing urbanisation in the lowlands. By 2025 it is estimated that there will be urban and peri-urban settlements through much of the lowlands along the major roads adjacent to the border. By this time half of the population of Lesotho will be settled in those areas [TAMS Consultants et al, 1996].

These changes mean that more grasslands and croplands will be converted to villages and this will definitely have a significant effect on the national greenhouse fluxes. This scenario is also likely to be worsened by the fact that with these kind of conversions, the chances of biomass regrowth are very minimal.

Nevertheless, despite the importance of this phenomenon, there has been no quantitative assessment carried out to evaluate the scale and seriousness of the problem. In order to obtain realistic estimates of greenhouse gas emissions, there is a pressing need to confirm these estimates and this may be possible through the use of high resolution spot images. Preliminary results of the evaluation is indicated in worksheet 5-2.

4.4 Abandonment of Managed Lands

The data used for abandonment of managed lands is derived from the 1988 Natural Resources Inventory; 1995/96 Forest Inventories; the 1993 Environmental Synopsis of Lesotho and Land Use Planning Divisions, Present land use maps. These estimates were made on the basis of the total area of gullied and rock land. The assumption here being that these areas were originally grasslands and/or cropland and have been degraded and abandoned over time. Moreover, according to the 1993 Environmental Synopsis, 5 percent of the land has been rendered unusable due to gully formation, much of which occurred in the 1930's. Gully erosion alone may account for up to one million tonnes of soil lost per annum.

It has also been estimated that one quarter of the land is now so badly eroded as to be put out of production and estimates of soil loss to sheet erosion vary and range from 15 million tonnes per year from croplands to 23 million tonnes per year from rangelands. Nevertheless these estimates need to be confirmed and the question of whether or not they are rehabilitated needs to be studied. Preliminary results of soil carbon uptake on abandoned land regenerating are given in worksheet 5.4 sheet 1 to 3. Data entry and results of evaluation are indicated in Worksheet 5-1 sheet 1 of 3.

4.5 Change in Soil Carbon for Mineral Soils

Due to its mountainous terrain, Lesotho has little agricultural potential; 9% of the land is deemed suitable for intense cultivation, less than 20% can support only low intensity cultivation and the rest is suitable only for well managed grazing (National Conservation Plan For Lesotho, 1988). Furthermore most of the soils lack stability due to their light texture, shallowness and low amount of organic matter. Lack of inputs (improved seed, fertilizer etc.) has often been cited as a problem with crop production. The poor cannot access these inputs which are available as they cannot afford them.

Long-term cultivation with medium to low input was therefore assumed for Worksheet 5-5 sheet 1 of 4.

4.6 Comments on IPCC/OECD Methodology

Worksheet 5-1

The assumption made in this worksheet is that there is a total of 165kha of indigenous forest [National Range Inventory, 1988]. 27 Kha Acacia (includes poplars, willows and other spp including those outside forest reserves). 6 Kha Pines and Eucalyptus (mainly found in the forest reserves or gazetted areas), [source, Woodlot Inventory 1995/96]. Classification of forest types on this worksheet is based on the 1995/96 Woodlot Inventories and other sources e.g. May 1997. Although the IPCC manuals classify Eucalyptus, pines and acacia as tropical species they are in fact grown in Lesotho even though it does not have tropical climate.

- **Column B**
  The growth rate values used in Column B were taken from the Forestry Research Reports.

Worksheet 5-1 (sheet 2 of 3)

- Column F - Harvest Categories
  Data could not be classified by forest types since the available information is not categorized. Secondly, the data was given in hectares and therefore the estimates were calculated on hectare/ volume basis i.e. 8m^3/ha/year was taken as an average.

- Column G
  The default value falls within the range of given defaults for different types of forests.

- Column H - Commercial Harvesting
  Available harvest data is given in hectares and therefore the estimates were calculated on hectare/ volume basis. i.e. 8m^3 was taken as an average. The other point to be noted about harvest figures is the fact that in 1987 when the Woodlot Project came to an end Government stopped recording harvesting inventories. In order to calculate the 1994 estimates, a 20 percent increase was applied to the 1987 figures.

Worksheet 5-2

- Column A
  Data available for Grassland Conversion were obtained from the 1993 Environmental Synopsis which stated that 14% of the Grassland use had been converted to cropland within the last 12 years. The same data were used to estimate the annual convention rate.

- Column L
  In Lesotho trees are not burned off-site unless it is for fuelwood consumption which is already accounted for earlier. A default value from IPCC for grass has been used.

Worksheet 5-3

This worksheet has been omitted because there is no "On- site-burning of forests" since trees/forests are not burned on-site in Lesotho and on- site burning of grasslands has been accounted for in the Agriculture sector.

Worksheet 5-4 sheet 2

- Column A and G
  Since data for more than 20 years is unavailable, the value for first 20 years has been assumed to be constant. Abandoned land re-growing on this worksheet was estimated to be total abandoned land minus rockland, which is assumed to have no potential for re-growth.

- Column B and H
  The default value used is from the1990 National Rangeland Inventory.

Worksheet 5-5 sheet 1

- Column D
  The total land area of t and t-20 is not equal to the total land area because of the lack of detailed information on land use categories.

Worksheet 5-5 sheet 2

- Column A
  Data used on column A was obtained from the 1988 Conservation Plan for Lesotho and projection to the 1994 (base year) were made using population, soil erosion and other land use driving forces.

Worksheet 5-5 sheet 3

- Column A
  The data source for types of lime was derived from the Fertilizer Consumption Statistical Data 1994/95, from Department of Crops, Ministry of Agriculture.

		MODULE	**LAND USE CHANGE AND FORESTRY**				
		SUBMODULE	**CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS**				
		WORKSHEET	**5-1**				
		SHEET	**1 OF 3**				
		COUNTRY	**LESOTHO**				
		YEAR	**1994**				
					STEP 1		
			A	B	C	D	E
			Area of	Annual Growth	Annual Biomass	Carbon Fraction	Total Carbon
			Forest/Biomass Stocks	Rate	Increment	of Dry Matter	Uptake Increment
			(kha)	(t dm/ha)	(kt dm)		(kt C)
					C=(A x B)		E=(C x D)
Tropical	Plantations	*Acacia spp.*	27	11	297.00	0.5	148.50
		Eucalyptus spp.	3	7.8	23.40	0.5	11.70
		Tectona grandis			0.00		0.00
		Pinus spp	3	6.5	19.50	0.5	9.75
		Pinus caribaea			0.00		0.00
		Mixed Hardwoods			0.00		0.00
		Mixed Fast			0.00		0.00
		Growing Hardwoods					
		Mixed Softwoods			0.00		0.00
	Other Forests	Moist	165	3.8	627.00	0.5	313.50
		Seasonal			0.00		0.00
		Dry			0.00		0.00
	Other (specify)				0.00		0.00
Temperate	Plantations	Douglas fir			0.00		0.00
		Loblolly pine			0.00		0.00
	Commercial	Evergreen			0.00		0.00
		Deciduous			0.00		0.00
	Other				0.00		0.00
Boreal					0.00		0.00
			A	B			
Non-Forest Trees (specify type)			Number of Trees	Annual Growth			
			(kt dm/1000 trees)	Rate			
				(1000s of trees)			
					0.00		0.00
					0.00		0.00
					Total		483.45

MODULE	**LAND USE CHANGE AND FORESTRY**							
SUBMODULE	**CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS**							
WORKSHEET	**5-1**							
SHEET	**2 OF 3**							
COUNTRY	**LESOTHO**							
YEAR	**1994**							
				STEP 2				
	F	G	H	I	J	K	L	M
Harvest Categories	Commercial Harvest	Biomass Conversion	Total Biomass	Total	Total Other	Total Biomass	Wood Removed	Total Biomass
(specify)	(if applicable)	/ Expansion	Removed in	Traditional Fuelwood	Wood Use	Consumption	From Forest Clearing	Consumption
		Consumed Ratio	Commercial Harvest					From Stocks
		(if applicable)						
(1000 m^3 roundwood)	(t dm/m^3)	(kt dm)	(kt dm)	(kt dm)	(kt dm)	(kt dm)	(kt dm)	
			H = (F x G)	FAO data	K = (H + I + J)	(From column M, sheet 3)	Worksheet 5-2,	M = K - L
	7.5	0.65	4.88	851.08	0	855.96		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
			0.00			0.00		
Totals	7.50		4.88	851.08	0.00	855.96	46.80	809.16

MODULE	**LAND USE AND FORESTRY**			
SUBMODULE	**CHANGES IN FOREST AND OTHER**			
	WOODY BIOMASS STOCKS			
WORKSHEET	**5-1**			
SHEET	**3 OF 3**			
COUNTRY	**LESOTHO**			
YEAR	**1994**			
	STEP 3		**STEP 4**	
N	O	P	Q	
Carbon	Annual Carbon	Net Annual	Convert to CO_2	
Fraction	Release	Carbon Uptake	Annual Emission	
		(+) or Release (-)	(-) or Removal (+)	
	(kt C)	(kt C)	(Gg CO_2)	
	O = (M x N)	P = (E - O)	Q = (P x [44/12])	
0.5	404.58	78.87	289.20	

		MODULE	**LAND-USE CHANGE AND FORESTRY**			
		SUBMODULE	**FOREST AND GRASSLAND CONVERSION - CO_2 FROM BIOMASS**			
		WORKSHEET	**5-2**			
		SHEET	**1 OF 5 BIOMASS CLEARED**			
		COUNTRY	**LESOTHO**			
		YEAR	**1994**			
			STEP 1			
		A	B	C	D	E
Vegetation types		Area Converted Annually	Biomass Before Conversion	Biomass After Conversion	Net Change in Biomass Density	Annual Loss of Biomass
		(kha)	(t dm/ha)	(t dm/ha)	(t dm/ha)	(kt dm)
					D = (B - C)	E = (A x D)
Tropical	Wet/Very Moist				0.00	0.00
	Moist, short dry season				0.00	0.00
	Moist, long dry season				0.00	0.00
	Dry				0.00	0.00
	Montane Moist				0.00	0.00
	Montane Dry				0.00	0.00
Tropical Savanna/Grasslands		36	36	10	26.00	936.00
Temperate	Coniferous				0.00	0.00
	Broadleaf				0.00	0.00
Grasslands					0.00	0.00
Boreal	Mixed Broadleaf/ Coniferous				0.00	0.00
	Coniferous				0.00	0.00
	Forest-tundra				0.00	0.00
Grasslands/Tundra					0.00	0.00
Other					0.00	0.00
	Subtotals	36.00			26.00	936.00

		MODULE	**LAND-USE CHANGE AND FORESTRY**				
		SUBMODULE	**FOREST AND GRASSLAND CONVERSION - CO_2 FROM BIOMASS**				
		WORKSHEET	**5-2**				
		SHEET	**2 OF 5 CARBON RELEASED BY ON-SITE BURNING**				
		COUNTRY	**LESOTHO**				
		YEAR	**1994**				
			STEP 2				
			F	G	H	I	J	K
Vegegation types			Fraction of Biomass	Quantity of Biomass	Fraction of Biomass	Quantity of Biomass	Carbon Fraction	Quantity of Carbon
			Burned on Site	Burned on Site	Oxidised on Site	Oxidised on Site	of Above-	Released
(from biomass | burned)						ground Biomass	
							(burned on site)	
				(kt dm)		(kt dm)		(kt C)
				G = (E x F)		I = (G x H)		K = (I x J)
Tropical	Wet/Very Moist			0.00		0.00		0.00
	Moist, short dry season			0.00		0.00		0.00
	Moist, long dry season			0.00		0.00		0.00
	Dry			0.00		0.00		0.00
	Montane Moist			0.00		0.00		0.00
	Montane Dry			0.00		0.00		0.00
Tropical Savanna/Grasslands	0.45		421.20	0.9	379.08	0.5	189.54	
Temperate	Coniferous			0.00		0.00		0.00
	Broadleaf			0.00		0.00		0.00
Grasslands				0.00		0.00		0.00
Boreal Mixed	Broadleaf/Coniferous			0.00		0.00		0.00
	Coniferous			0.00		0.00		0.00
	Forest-tundra			0.00		0.00		0.00
	Grasslands/Tundra			0.00		0.00		0.00
Other				0.00		0.00		0.00
							Subtotal	189.54

		MODULE	**LAND-USE CHANGE AND FORESTRY**					
		SUBMODULE	**FOREST AND GRASSLAND CONVERSION - CO_2 FROM BIOMASS**					
		WORKSHEET	**5-2**					
		SHEET	**3 OF 5 CARBON RELEASED BY OFF-SITE BURNING**					
		COUNTRY	**LESOTHO**					
		YEAR	**1994**					
			STEP 3			**STEP 4**		
		L	M	N	O	P	Q	R
Vegetation types		Fraction of Biomass	Quantity of Biomass	Fraction of Biomass	Quantity of Biomass	Carbon Fraction	Quantity of Carbon	Total Carbon
		Burned off Site	Burned off Site	Oxidised off Site	Oxidised off Site	of Above-ground	Released	Released
						Biomass	(from biomass	(from on and off
						(burned off site)	burned off site)	site burning)
			(kt dm)		(kt dm)		(kt C)	(kt C)
			M = (E x L)		O = (M x N)		Q = (O x P)	R = (K + Q)
Tropical	Wet/Very Moist		0.00		0.00		0.00	0.00
	Moist, short dry season		0.00		0.00		0.00	0.00
	Moist, long dry season		0.00		0.00		0.00	0.00
	Dry		0.00		0.00		0.00	0.00
	Montane Moist		0.00		0.00		0.00	0.00
	Montane Dry		0.00		0.00		0.00	0.00
Tropical								
Savanna/Grasslands		0.05	46.80	0.9	42.12	0.5	21.06	210.60
Temperate	Coniferous		0.00		0.00		0.00	0.00
	Broadleaf		0.00		0.00		0.00	0.00
Grasslands			0.00		0.00		0.00	0.00
Boreal	Mixed Broadleaf/ Coniferous		0.00		0.00		0.00	0.00
	Coniferous		0.00		0.00		0.00	0.00
	Forest- tundra		0.00		0.00		0.00	0.00
Grasslands/Tundra			0.00		0.00		0.00	0.00
Other			0.00		0.00		0.00	0.00
		Subtotals	46.80				21.06	210.60

	MODULE	**LAND-USE CHANGE AND FORESTRY**								
	SUBMODULE	**FOREST AND GRASSLAND CONVERSION - CO_2 FROM BIOMASS**								
	WORKSHEET	**5-2**								
	SHEET	**4 OF 5 CARBON RELEASED BY DECAY OF BIOMASS**								
	COUNTRY	**LESOTHO**								
	YEAR	**1994**								
		STEP 5								
		A	B	C	D	E	F	G	H	I
Vegetation types		Average Area	Biomass	Biomass	Net Change	Average	Fraction	Quantity	Carbon Fraction	Carbon Released
		Converted	Before	After	in Biomass	Annual	Left to Decay	of Biomass	in Above- ground	from Decay
		(10 Year Average)	Conversion	Conversion	Density	Loss of Biomass		Left to Decay	Biomass	of Above-ground
										Biomass
		(kha)	(t dm/ha)	(t dm/ha)	(t dm/ha)	(kt dm)		(kt dm)		(kt C)
					D = (B-C)	E = (A x D)		G = (E x F)		I = (G x H)
Tropical	Wet/Very Moist				0.00	0.00		0.00		0.00
	Moist, short				0.00	0.00		0.00		0.00
	dry season									
	Moist, long				0.00	0.00		0.00		0.00
	dry season									
	Dry				0.00	0.00		0.00		0.00
	Montane Moist				0.00	0.00		0.00		0.00
	Montane Dry				0.00	0.00		0.00		0.00
Tropical										
Savanna/Grasslands		36	36	10	26.00	936.00	0.5	468.00	0.5	234.00
Temperate	Coniferous				0.00	0.00		0.00		0.00
	Broadleaf				0.00	0.00		0.00		0.00
Grasslands					0.00	0.00		0.00		0.00
Boreal	Mixed Broadleaf/				0.00	0.00		0.00		0.00
	Coniferous									
	Coniferous				0.00	0.00		0.00		0.00
	Forest-tundra				0.00	0.00		0.00		0.00
Grasslands/Tundra					0.00	0.00		0.00		0.00
Other					0.00	0.00		0.00		0.00
									Subtotal	234.00

MODULE	**LAND-USE CHANGE AND FORESTRY**		
SUBMODULE	**FOREST AND GRASSLAND CONVERSION - CO_2 FROM BIOMASS**		
WORKSHEET	**5-2**		
SHEET	**5 OF 5 SUMMARY AND CONVERSION TO CO_2**		
COUNTRY	**LESOTHO**		
YEAR	**1994**		
		STEP 6	
A	B	C	D
Immediate Release	Delayed Emissions	Total Annual Carbon	Total Annual CO_2
From Burning	From Decay	Release	Release
(kt C)	(kt C)	(kt C)	(Gg CO_2)
	(10-year average)		
		C = A + B	D = C x (44/12)
210.60	234.00	444.60	1,630.20

MODULE		**LAND-USE CHANGE AND FORESTRY**				
SUBMODULE		**ABANDONMENT OF MANAGED LANDS**				
WORKSHEET		**5-4**				
SHEET		**1 OF 3 CARBON UPTAKE BY ABOVEGROUND REGROWTH - FIRST 20 YEARS**				
COUNTRY		**LESOTHO**				
YEAR		**1994**				
				STEP 1		
		A	B	C	D	E
Vegetation types		20-Year Total Area Abandoned and Regrowing (kha)	Annual Rate of Aboveground Biomass Growth (t dm/ha)	Annual Aboveground Biomass Growth (kt dm) C = (A x B)	Carbon Fraction Aboveground Biomass	Annual Carbon Uptake in of Aboveground Biomass (kt C) E = (C x D)
Tropical	Wet/Very Moist			0.00		0.00
	Moist, short dry season			0.00		0.00
	Moist, long dry season			0.00		0.00
	Dry			0.00		0.00
	Montane Moist			0.00		0.00
	Montane Dry			0.00		0.00
Tropical Savanna/Grasslands		48	0.62	29.76	0.5	14.88
Temperate	Coniferous			0.00		0.00
	Broadleaf			0.00		0.00
Grasslands				0.00		0.00
Boreal	Mixed Broadleaf/Coniferous			0.00		0.00
	Coniferous			0.00		0.00
	Forest tundra			0.00		0.00
Grasslands/Tundra				0.00		0.00
Other				0.00		0.00
					Subtotal	14.88

MODULE		**LAND-USE CHANGE AND FORESTRY**				
SUBMODULE		**ABANDONMENT OF MANAGED LANDS**				
WORKSHEET		**5-4**				
SHEET		**2 OF 3 CARBON UPTAKE BY ABOVEGROUND REGROWTH - > 20 YEARS**				
COUNTRY		**LESOTHO**				
YEAR		**1994**				
				STEP 2		
		G	H	I	J	K
Vegetation types		Total Area Abandoned for more than Twenty Years (kha)	Annual Rate of Aboveground Biomass Growth (t dm/ha)	Annual Aboveground Biomass Growth (kt dm)	Carbon Fraction of Aboveground Biomass	Annual Carbon Uptake in Aboveground Biomass (kt C)
				I = (G x H)		K = (I x J)
Tropical	Wet/Very Moist			0.00		0.00
	Moist, short dry season			0.00		0.00
	Moist, long dry season			0.00		0.00
	Dry			0.00		0.00
	Montane Moist			0.00		0.00
	Montane Dry			0.00		0.00
Tropical Savanna/Grasslands				0.00		0.00
Temperate	Coniferous	152	0.62	94.24	0.5	47.12
	Broadleaf			0.00		0.00
Grasslands				0.00		0.00
Boreal	Mixed					
	Broadleaf/Coniferous			0.00		0.00
	Coniferous			0.00		0.00
	Forest tundra			0.00		0.00
Grasslands/Tundra				0.00		0.00
Other				0.00		0.00
					Subtotal	47.12

MODULE	**LAND-USE CHANGE AND FORESTRY**
SUBMODULE	**ABANDONMENT OF MANAGED LANDS**
WORKSHEET	**5-4**
SHEET	**3 OF 3 TOTAL CO_2 REMOVALS FROM ABANDONED LANDS**
COUNTRY	**LESOTHO**
YEAR	**1994**
	STEP 3
L	M
Total Carbon Uptake from Abandoned Lands	Total Carbon Dioxide Uptake
(kt C)	(Gg CO_2)
L = (E + K)	M = (L x (44/12))
62.00	227.33

	MODULE	**LAND-USE CHANGE AND FORESTRY**					
	SUBMODULE	**CHANGE IN SOIL CARBON FOR MINERAL SOILS**					
	WORKSHEET	**5-5**					
	SHEET	**1 OF 4**					
	COUNTRY	**LESOTHO**					
	YEAR	**1994**					
		STEPS 1 AND 2				**STEP 3**	
A	B	C	D	E	F	G	H
Land-use	Soil type	Soil	Land Area	Land Area	Soil Carbon	Soil Carbon	Net change in
Management		Carbon					Soil Carbon
Systems		(t)	(t-20)	(t)	(t-20)		
		(Mg C/ha)	(Mha)	(Mha)	(Tg)	(t)	(Tg per 20 yr)
						(Tg)	
					F = (C x D)	G = (C x E)	H = (G - F)
All Systems	High activity soils		0.01	0.01	0.53	0.40	-0.13
	Low activity soils		0.34	0.20	14.28	8.40	-5.88
	Sandy		0.00	0.00	0.00	0.00	0.00
	Volcanic		0.00	0.00	0.00	0.00	0.00
	Wetland (Aquic)		0.00	0.00	0.00	0.00	0.00
	Totals		0.35	0.21			-6.01

MODULE	**LAND-USE CHANGE AND FORESTRY**					
SUBMODULE	**SOIL CARBON FOR AGRICULTURALLY IMPACTED LANDS**					
WORKSHEET	**5-5A (SUPPLEMENTAL)**					
SHEET	**1 OF 1**					
COUNTRY	**LESOTHO**					
YEAR	**1994**					
A	B	C	D	E	F	G
Land-use/ Systems	Soil type	Soil Carbon under Native	Base Factor	Tillage Factor	Input Factors	Soil Carbon
under Native						in Agriculturally
Management		Vegetation				Impacted Lands
		(Mg C/ha)				(Mg C/ha)
						G = (C x D x E x F)
All Systems	High Activity Soils	70.00	0.70	1.00	0.90	44.10
	Low Activity Soils	60.00	0.70	1.00	1.00	42.00
	Sandy	15.00	0.70	1.00	1.00	10.50
	Volcanic	70.00	0.70	1.00	1.00	49.00
	Wetland (Aquic)	120.00	0.60	1.00	1.00	72.00

MODULE	**LAND-USE CHANGE AND FORESTRY**		
SUBMODULE	**CARBON EMISSIONS FROM INTENSIVELY-MANAGED ORGANIC SOILS**		
WORKSHEET	**5-5**		
SHEET	**2 OF 4**		
COUNTRY	**LESOTHO**		
YEAR	**1994**		
		STEP 4	
	A	B	C
Agricultural Use of Organic Soils	Land Area	Annual Loss Rate (Mg C/ha/yr)	Net Carbon Loss from Organic Soils
	(ha)	(Default)	(Mg/yr)
		C = (A x B)	
Cool temperate			
Upland crops			0.00
Pasture/Forest			0.00
Warm temperate			
Upland crops	16305	10	163,050.00
Pasture/Forest	105397.44	2.5	263,493.60
Tropical			
Upland crops			0.00
Pasture/Forest			0.00
		Total	426,543.60

MODULE	**LAND-USE CHANGE AND FORESTRY**		
SUBMODULE	**CARBON EMISSIONS FROM LIMING OF AGRICULTURAL SOILS**		
WORKSHEET	**5-5**		
SHEET	**3 OF 4**		
COUNTRY	**LESOTHO**		
YEAR	**1994**		
		STEP 5	
	A	B	C
Type of lime	Total Annual	Carbon Conversion Factor	Carbon Emissions from Liming
	Amount of Lime		
	(Mg)		(Mg C)
			C = (A x B)
Limestone $Ca(CO_3)$	4000	0.12	480.00
Dolomite $CaMg(CO_3)_2$	3500	0.122	427.00
	Total	907.00	

MODULE	**LAND-USE CHANGE AND FORESTRY**			
SUBMODULE	**CALCULATION OF TOTAL CO_2-C EMISSIONS FROM AGRICULTURALLY-IMPACTED SOILS**			
WORKSHEET	**5-5**			
SHEET	**4 OF 4**			
COUNTRY	**LESOTHO**			
YEAR	**1994**			
STEP 6				
	A	B	C	D
Source	Worksheet	Unit	Total Annual	Convert to Total
	values	Conversion	Carbon	Annual CO_2
		Factor	Emissions	Emission
			(Gg)	(Gg/yr)
			C = (A x B)	D= C x (44/12)
Total Net Change in Soil	-6.01	-50	300.62	1,102.26
Carbon in Mineral Soils				
Total Net Carbon Loss from	426,543.60	0.001	426.54	1,563.99
Organic Soils				
Carbon Emissions from Liming	907.00	0.001	0.91	3.33
			Total	2,669.57

Table 5 Sectoral Report For Land-Use Change And Forestry (Sheet 1 Of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO
Total Land-Use Change and Forestry	1,260.57	0.00	0.00	0.00	0.00	0.00
A Changes in Forest and Other Woody	0.00	-289.20				
Biomass Stocks						
1 Tropical Forests						
2 Temperate Forests						
3 Boreal Forests						
4 Grasslands/Tundra						
5 Other (please specify)						
B Forest and Grassland Conversion	1,630.20		0.00	0.00	0.00	0.00
1 Tropical Forests	0.00					
2 Temperate Forests	0.00					
3 Boreal Forests	0.00					
4 Grasslands/Tundra	1,630.20					
5 Other (please specify)	0.00					
C Abandonment of Managed Lands		-2,750.00				
1 Tropical Forests		0.00				
2 Temperate Forests		-896.50				
3 Boreal Forests		0.00				
4 Grasslands/Tundra		-1,853.50				
5 Other (please specify)		0.00				
D CO2 Emissions and Removals from Soil	2,669.57	0.00				
E Other (please specify)						

4.7 References

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5.0 WASTE

5.1 Overview of Waste

In general, waste has not been a subject of major concern. This can be realised by the fact that there has been no coherent policy on waste management [M.L. Mhlanga, T.Guililat, 1997]. Information on waste either has not been existing or not well been documented. This problem is more prevalent in the domestic rural sector where there are no formal institutions dealing with waste.

Regarding formal sectors waste management has received some attention. For example the first legislation on public health was passed in 1970 [M.L. Mhlanga, T. Guililat, 1997].

The growing global attention of environmental issues is expected to stimulate the process of improving waste management in the country. The country has taken a number of steps to address the subject of environment in general, the establishment of the functioning National Environment Secretariat (NES) in 1989 is the single most achievement. NES has the authority on environmental issues in the country. It is through the initiatives of NES that a reasonable comprehensive baseline study on waste management in Lesotho was completed by M.L. Mhlanga and T. Guililat, on behalf of Business Support Southern Africa (PTY) Ltd in 1997). This study contains useful information on major sources of waste which include tins/cans, organic materials, paper and plastics. The study further classifies the sources of waste in terms of sectors. Institutional and commercial establishments have paper as the main source of waste with 76% and 58% respectively of total waste. Finally in households plastics contribute the highest (47%) share of waste. Prospects for recycling paper may be investigated as a management tool in solid waste disposal. This study, however, has a limitation on the type of data, on waste water and solid waste, which is required to develop the appropriate inventory of emissions of greenhouse gases.

5.2 Methane Emission from Domestic and Commercial Wastewater and Sludge Treatment

The management of wastewater disposal in rural settlements does not exist. In urban and peri - urban areas , the issue is the responsibility of Water and Sewerage Authority (WASA). However, there are not many customers who have access to the sewerage network. About 3 to 9 percent of developed areas in the districts have the services of reticulated sewerage. These areas include public, Government and private institutions.

In Maseru, the capital city where population is much larger than in other cities, still a small percentage have access to reticulated sewerage. The balance of the city is served by dry system and ordinary pit latrines or alternatively wet systems connected to soak away's and conservancy tank systems. Water And Sewerage Authority (WASA) runs a conservancy tank emptying service. WASA is considering possibility of out sourcing the service and has policy to this regard.

WASA has two main sewage treatment plants in Maseru. These are the Industrial Lagoon system and Ratjomose Sewage Treatment Plant, the largest in the country. The Plant uses both conventional and waste stabilization pond methods to treat or purify sewerage. It is located on the South West of Maseru on the banks of the Mohokare (Caledon) river and it serves a collection area of 20sq km. The system is operated by pumping stations, installed to assist in transporting sewerage to the plant. The drainage area covers south and western inner city areas of Maseru including the industrial estates.

The sewage gravitates through two main sewerages of 1.5m diameter, which are capable of handling a flow of 22,000 m^3 per day. The plant is comprised of two small plants, the biofilter treatment plant and the Oxidation lagoon sewerage plant. These two treatment systems share the same inlet works where grit removal and coarse screening is done. The combination of two plants is designed to treat an average daily flow of 10,000 m^3 per day. Sixty percent of sewage water goes to oxidation lagoon system and the rest flows to the biofilter treatment system.

5.2.1 Industrial Waste Water

The Industrial Lagoon treatment was initially constructed to treat industrial and other waste water generated in the Maseru West area. When Ratjomose Treatment Plant was constructed, this plant was retained to be used as pretreatment system for the industrial effluents.

This Lagoon system was upgraded in 1981 to serve as pre-treatment facility for the Lesotho Brewing Company. An Anoerobic pond and a pumping station were constructed. Pumping station was to transfer the effluent from lagoon system into one of the main sewerage's terminating at the Ratjomose Sewerage Treatment Plant.

Besides these main treatment plants there are other small sewerage treatment facilities in operation in Maseru. These include Dairy Farm and Maluti Dairy, Pig breeding station, hospitals, Moshoeshoe I Airport and the abattoir.

WASA is considering the rehabilitation of all these systems except the National Abattoir sludge treatment that is maintained and operated by the abattoir.

Methane is produced by anaerobic activities and the decomposition of organic matter in sewerage facilities during treatment and disposal of waste water.

5.2.2 Data collection and analysis

The data used for waste water treated is from Water and Sewerage Authority reports (report by BKS Incorporated, Pretoria June 1996 and Greater Maseru Sanitation Project Phase II, Stage 3,1996). These reports include the amount of waste water treated and the rate of BOD per annum in Maseru and other districts. There is no data concerning emissions of methane from domestic and commercial waste water. Therefore calculations are done using the default values from IPCC guidelines.

5.3 Methane Emissions from Solid Wastes

Similar to waste water there is no management of solid waste disposal in rural settlements. In urban areas there are institutions responsible for waste disposal. In the districts, offices of the Town Clerks collect the waste for disposal. In Maseru, the capital city the responsibility is vested on Maseru City Council (MCC), which collects the waste for disposal to the open landfill site, situated at Ha Tsosane, a suburb of Maseru. The site was not originally intended to be used as a dumping place but it is an abandoned quarry site that was created by road construction. It was converted to dumping place by the MCC. The waste that is found in this landfill is composed mainly of domestic waste as well as waste from stores and supermarkets. This landfill is not well managed and it is thought that it can lead to a series of environmental pollution and health problems to the nearby households.

5.3.1 Data collection and analysis

Information on solid waste was taken from Maseru Municipal reports. In worksheet 6-1 B (supplemental) the population figure is a projection from 1986 Population Census of Lesotho by Bureau of Statistics.

5.4 Comments on IPCC/OECD Methodology

There has not been any study concerning greenhouse gas emissions from waste, default from the revised 1996 IPCC Guidelines workbook have been used.

Worksheet 6-1

- **Column B**

A default value has been used.

- **Column C**

Adopted default value of Nigeria from Table 6-1.

Worksheet 6-1 B

- Column A

  The total rural population for 1994 was estimated from the projected figures for that year. The national population in 1994 was about 1997480 (1016502 females and 980978 males) [BOS, 1994]. The BOS provided the percentages of rural and urban population to be used as 81 percent and 19 percent respectively. The total rural population was therefore estimated as 1617959 approximately 1600000 and the total urban population was about 379521 approximately 380000. The Bureau of Statistics completed a population census for 1996. However, the Census report has not been published. Therefore 380000 has been used in the analysis.

- Column B

  The given default value has been used.

Worksheet 6-3, Sheet 1

- Column A

  Data sources are National reports from each industry. Most of the reports are not documented.

- Column B

  Cannery assumed default value of bean blanching for Western Europe. Dairy products also assumed

default value for Western Europe. Bleaching and dying assumed a default value of textiles for Greece.

- Column C
  Waste water produced (m^3/tonne product) values are adopted from the IPCC guidelines. Bleaching and dying adopted rayon default values.

Worksheet 6-3, Sheet2

- Column B and C
  Default values for Africa on Table 6-8 have been used.

Worksheet 6-4

- Column A
  The recommended dietary allowance for adults is 0.8 grams of proteins per kilogram of desirable body weight [Contemporary Nutrition – Issues and Insights, 1992]. This recommended amount works out to about 56 grams of protein daily for a 70kg man and about 44 grams of protein for a 55kg woman. The above average body weight for man and woman has been used.

	MODULE	**WASTE**										
	SUBMODULE	**METHANE EMISSIONS FROM SOLID WASTE DISPOSAL SITES**										
	WORKSHEET	**6-1**										
	SHEET	**1 OF 1**										
	COUNTRY	**LESOTHO**										
	YEAR	**1994**										
	STEP 1		STEP 2				STEP 3				STEP 4	
A	B	C	D	E	F	G	H	J	K	L	M	N
Total	Methane	Fraction of	Fraction of	Fraction of	Conversion	Potential Methane	Realised	Gross	Recovered	Net Annual	One Minus	Net Annual
Annual	Correction	DOC in	DOC which	Carbon	Ratio	Generation Rate	(Country-	Annual	Methane	Methane	Methane	Methane
MSW	Factor	MSW	Actually	Released as		per Unit of Waste	specific)	Methane	per Year	Generation	Oxidation	Emissions
Disposed	(MCF)		Degrades	Methane		(Gg CH_4/Gg MSW)	Methane	Generation	(Gg CH_4)	(Gg CH_4)	Correction	(Gg CH_4)
to SWDSs							Generation	(Gg CH_4)			Factor	
(Gg MSW)							Rate per Unit					
							of Waste					
							(Gg CH_4/					
							Gg MSW)					
						G= (C x D x E x F)	H= (B x G)	J= (H x A)		L= (J - K)		N= (L x M)
55.48	0.6	0.11	0.77	0.5	16/12	0.06	0.03	1.88	0	1.88	1	1.88
					16/12	0.00	0.00	0.00		0.00		0.00
					16/12	0.00	0.00	0.00		0.00		0.00

MODULE	**WASTE**	
SUBMODULE	**QUANTITY OF MSW DISPOSED OF IN SOLID WASTE**	
	DISPOSAL SITES USING DISPOSAL RATE DEFAULT DATA	
WORKSHEET	**6-1B (SUPPLEMENTAL)**	
SHEET	**1 OF 1**	
COUNTRY	**LESOTHO**	
YEAR	**1994**	
A	B	C
Population whose Waste	MSW Disposal Rate to SWDSs	Total Annual MSW
goes to SWDSs (Urban or Total)	(kg/capita/day)	Disposed to SWDSs (Gg MSW)
(persons)		
		C = (A x B x 365)/1 000 000
380000	0.4	55.48

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER AND SLUDGE TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**1 OF 4 ESTIMATION OF ORGANIC WASTEWATER AND SLUDGE**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	STEP 1				
A	B	C	D	E	F
Region or City	Population	Degradable Organic Component	Fraction of Degradable	Total Domestic/Commercial	Total Domestic/Commercial
	(1,000 persons)	(kg BOD/1000 persons/yr)	Organic Component	Organic Wastewater (kg BOD/yr)	Organic Sludge (kg BOD/yr)
			Removed as Sludge		
				E = [B x C x (1-D)]	F = (B x C x D)
	380	13505	0	5,131,900.00	0.00
				0.00	0.00
				0.00	0.00
				0.00	0.00
			Total:	5,131,900.00	0.00

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**2 OF 4 ESTIMATION OF EMISSION FACTOR FOR WASTEWATER HANDLING SYSTEMS**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	STEP 2				
A	B	C	D	E	F
Wastewater	Fraction of Wastewater	Methane Conversion	Product	Maximum Methane Producing	Emission Factor
Handling System	Treated by the Handling	Factor for the Handling		Capacity	for Domestic/Commercial
	System	System			Wastewater
				(kg CH_4/kg BOD)	(kg CH_4/kg BOD)
			D = (B x C)		F = (D x E)
LAGOON	0.05	0.8	0.04		
			0.00		
			0.00		
			0.00		
		Aggregate MCF:	0.04		0.00

SUBMODULE	**METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER AND SLUDGE TREATMENT**				
WORKSHEET	**6-2**				
SHEET	**4 OF 4 ESTIMATION OF METHANE EMISSIONS FROM DOMESTIC/COMMERCIAL WASTEWATER AND SLUDGE**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	STEP 4				
	A	B	C	D	E
	Total Organic	Emission Factor	Methane	Methane	Net Methane
	Product	(kg CH_4/kg BOD)	Emissions	Recovered	Emissions
MODULE WASTE					
	(kg BOD/yr)		Without	and/or Flared	(Gg CH_4)
			Recovery/Flaring	(kg CH_4)	
	From Worksheet	from Worksheet	C = (A x B)		E = (C - D)/1 000 000
	6-2, Sheet 1	6-2, Sheets 2 and 3			
Wastewater	5,131,900.00	0.01	51,319.00	0	0.05
Sludge	0.00	0.00	0.00		0.00
				Total:	0.05

	MODULE	**WASTE**					
	SUBMODULE	**METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER AND SLUDGE HANDLING**					
	WORKSHEET	**6-3**					
	SHEET	**1 OF 4 TOTAL ORGANIC WASTEWATER AND SLUDGE**					
	COUNTRY	**LESOTHO**					
	YEAR	**1994**					
		STEP 1					
		A	B	C	D	E	F
		Total Industrial Output (t/yr)	Degradable Organic Component (kg COD/m^3 wastewater)	Wastewater Produced (m^3/tonne product)	Fraction of Degradable Organic Component Removed as Sludge	Total Organic Wastewater from Industrial Source (kg COD/yr)	Total Organic Sludge from Industrial Source (kg COD/yr)
						E = [A x B x C x(1-D)]	F = (A x B x C x D)
Iron and Steel						0.00	0.00
Non-ferrous metals						0.00	0.00
Fertiliser						0.00	0.00
Food & Beverage	Canneries	30000	5.2	26	0	4,056,000.00	0.00
	Beer	35600	17	5	0	3,026,000.00	0.00
	Wine					0.00	0.00
	Meatpacking					0.00	0.00
	Dairy products	1800	1.5	2.8	0	7,560.00	0.00
	Sugar					0.00	0.00
	Fish processing					0.00	0.00
	Oil & grease	82100	0.3	1.6	0	39,408.00	0.00
	Coffee					0.00	0.00
	Soft drinks	9400	5	4.5	0	211,500.00	0.00
	Other					0.00	0.00
Paper & Pulp	Paper					0.00	0.00
	Pulp					0.00	0.00
	Other					0.00	0.00
Petroleum refining/Petrochemicals						0.00	0.00
	Bleaching	92300	0.09	501	0	4,161,807.00	0.00
	Dying	2900	0.09	501	0	130,761.00	0.00
	Other					0.00	0.00
Rubber						0.00	0.00
Other						0.00	0.00
					Total	11,633,036.00	0.00

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER TREATMENT**				
SOURCE	**ALL**				
WORKSHEET	**6-3**				
SHEET	**2 OF 4 ESTIMATION OF EMISSION FACTOR FOR WASTEWATER HANDLING SYSTEMS**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	STEP 2				
A	B	C	D	E	F
Wastewater	Fraction of Wastewater	Methane Conversion Factor	Product	Maximum Methane Producing	Emission Factor
Handling System	Treated by the				for Industrial Wastewater
Source	Handling System				
		(MCF)		Capacity	(kg CH_4/kg COD)
				(kg CH_4/kg DC)	
			D = (B x C)		F = (D x E)
LAGOON	0.1		0.9	0.09	
			0.00		
			0.00		
			0.00		
		Aggregate MCF:	0.09		0.00

MODULE	**WASTE**				
SUBMODULE	**METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER AND SLUDGE TREATMENT**				
WORKSHEET	**6-3**				
SHEET	**4 OF 4 ESTIMATION OF METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER AND SLUDGE**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	STEP 4				
	A	B	C	D	E
	Total Organic	Emission Factor	Methane Emissions	Methane	Net Methane
	Product	(kg CH_4/kg COD)	without	Recovered	Emissions
	(kg COD/yr)		Recovery/Flaring	and/or Flared	(Gg CH_4)
	(kg CH_4)				
	Worksheet 6-3, Sheet 1	Worksheets 6-3, Sheets 2 and 3	C = (A x B)		E = (C - D) / 1 000 000
Wastewater	11,633,036.00	0.02	267,559.83	0	0.27
Sludge	0.00	0.00	0.00		0.00
				Total:	0.27

MODULE	**WASTE**				
SUBMODULE	**INDIRECT NITROUS OXIDE EMISSIONS FROM HUMAN SEWAGE**				
WORKSHEET	**6-4**				
SHEET	**1 OF 1**				
COUNTRY	**LESOTHO**				
YEAR	**1994**				
	A	B	C	D	E
	Per Capita Protein	Population	Fraction of	Emission factor	Total Annual
	Consumption	(number)	Nitrogen in	EF_6 (kg N_2O-	N_2O Emissions
	(Protein in		Protein $Frac_{NPR}$	N/kg sewage-N	(Gg N_2O/yr)
	kg/person/yr)		(kg N/kg protein)	produced)	
					E = (A x B x C x D)
					x (44/28) / 1 000 000
Total	18.07	1997480	0.16	0.01	0.09

Table 6 Sectoral Report For Waste (Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES						
			(Gg)			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Total Waste	0.00	1.88	0.09			
A Solid Waste Disposal on Land	0.00	1.88	0.00			
1 Managed Waste Disposal on Land						
2 Unmanaged Waste Disposal Sites						
3 Other (please specify)						
B Wastewater Handling	0.00	0.00	0.09			
1 Industrial Wastewater		0.00				
2 Domestic and Commercial Wastewater		0.00	0.09			
3 Other (please specify)						
C Waste Incineration						
D Other (please specify)						

5.5 References

Report by BKS Incorporated. Pretoria, June 1996

Greater Maseru Sanitation Project - Phase II - Stage 3,1996

Contemporary Nutrition-Issues and Insights, 1992

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Achievements of the National Inventory

The process of the development of the Lesotho National Inventory has achieved the following:

- highlighted the poor state of natural resources data base in Lesotho
- illustrated the need to compile an inventory of natural resources and other relevant data in a more systematic and standardised manner
- facilitated the professional development of some officers through on-the-job-training,
- organisation of special seminars and regional workshops on climate change issues,
- integrated relevant disciplines and the contributions of various institutions
- afforded good opportunities in purposeful sharing of data, information, knowledge and know-how relating to the aims of the project
- shown the need to regularly upgrade national data collection capabilities using reliable methods

6.2 Problems in data collection and applications of the IPCC/OECD Methodology in Lesotho

Lesotho, like most developing countries is plagued by the problem of a weak data base. However, even in areas where data exists it has not necessarily been collected for 1994 (the IPCC base year) nor is it in the format required by IPCC. However in some aspects where there is regulation of activities, it has been possible to use up to date information, for example petroleum fuels. However this information was not in the format suitable for the direct application in this exercise.

This problem of data availability was not as pronounced in Agriculture as in other sectors. The only area where estimates had to be made in this sector was for the 'grassland burned'. The main reason being that the burning of grasslands in Lesotho is not managed but is done indiscriminately by the herdboys hence there hasn't been an effort to measure the size of the areas burned.

The Land Use Change and Forestry Sector, on the other hand had its share of problems as far as data collection is concerned. For instance, forestry harvesting inventories went as far as 1987. Thus, some estimates had to be made for 1994. The process of estimating was also not easy because the inconsistent and erratic nature of the pre-1987 Forest Harvest data. Again, the available harvest data was biased towards woodlots and did not include the indigenous shrubs which incidentally cover the largest area.

Data on Land Use Change was mainly derived from the 1993 Environmental Synopsis of Lesotho and the 1988 Conservation Plan. There was no data for 1994 at the time that the GHG's inventories were made. Historic data (pre-1988), also proved to be incomplete and inconsistent. Moreover, the sources for these data were scattered in different institutions that could not be easily accessed during the limited time allotted to GHG inventories.

Availability of historical data would have allowed the Inventory Team to calculate backward trends in land use/land cover change which would in turn be used to estimate future trends. Since this was not possible a comprehensive emission inventories for this sector could not be achieved.

Data used for the abandonment of managed lands was estimated from the total gullied and bare rockland. The assumption being that some areas which were formerly grasslands which were eventually abandoned. These estimates needed to be ground-truthed, with surveys, but the time and budget allotted for inventories proved to be too little for realistic, country-wide physical surveys.

The Project also experienced difficulties in obtaining data and information from the Waste Sector and had to rely heavily on the default values provided by the IPCC guidelines. There is a valid concern that the default values might not necessarily be applicable to Lesotho's situation. The other shortcoming of this sector as far as landfills are concerned is that a lot of them were unplanned in the same sense that they are either gullies or abandoned quarry sites, so their dimensions are unknown.

6.3 The Application of IPCC/OECD Methodology in Lesotho

According to IPCC/OECD methodology, abandoned managed lands are assumed to have a significant element of re-growth which would in turn affect land cover and have a significant effect on CO_2 uptake. However, in the case of Lesotho, abandoned areas are either gullies or bare rocklands which have a non-significant regrowth factor (if any). Thus, the carbon dioxide uptake calculated for the regrowth of abandoned lands is a bit unrealistic for Lesotho's situation.

The other important factors that could greatly affect the emissions in Lesotho are overgrazing, conversion of grasslands to croplands, encroachement of villages onto croplands and rangelands and urban sprawl. Yet, the IPCC guidelines do not make allowances for these changes in land use nor do they guide countries on how the present conversions (those that appear in the IPCC/OECD guidelines) could be broadened to include the above-mentioned land use changes.

6.4 Synthesis of Lesotho's National Inventory

6.4.1 Major Greenhouses Gases

Carbon dioxide has the highest quantities of emissions than any other gas in Lesotho. Tables 7A and 7B and Figure 6.1 show that 1896.56Gg of carbon dioxide were emitted followed by carbon monoxide with only 143.61Gg emitted. Methane has the next highest emissions of 41.47Gg. NMVOC and Oxides of nitrogen have small amounts of emissions and are 17.57Gg and 5.05Gg respectively. Nitrous oxide has the least emissions of 0.63Gg.

6.4.2 Major Emissions Sectors

Land use change and forestry sector is the major source of Greenhouse gases in the country. Table 7B and Figure 6.2 show that this sector emitted 1260.57Gg of Carbon dioxide equivalent which constitute 40.47%

of the total emissions of all the sectors (carbon dioxide equivalent) of 3115.06Gg. Figure 6.2 shows that Agriculture sector is the next highest with 29.69%, followed by Energy sector with 27.43% then Waste sector with 2.41%.

Although energy contributes only 27.43% of the total sectoral CO_2 emissions, considering CO_2 alone, it is the second largest emitter after Land Use Change and Forestry at about 34% while 66% is due to the latter sector. Energy is ranked in this manner since biomass fuels which are the major source of energy are assigned carbon emission factor of zero. With respect to environmental degradation in general, especially land degradation the use of biomass for energy purposes requires special attention due to inadequate land vegetation cover in the country.

In the Land Use Change and forestry, the major emissions are from Forest and Grassland Conversion and Agriculturally Impacted soils releasing Carbon dioxide. The fact that land use change and forestry sector is the largest emitter of Greenhouse gases can only be contexualised by examining the salient features of land use and management in the study area.

Lesotho is primarily a pastoral country with four agro-ecological zones designated as lowlands, foothills, mountains and the Senqu valley. There are two predominant types of land use in Lesotho, namely agricultural and non-agricultural. Agricultural land use include cultivation practiced in the lowlands, forests and livestock farming in the mountain region. Under non-agricultural land uses, settlement, is the main category. Because of limitations offered by the country's topography, the remainder of the country's land remains wastelands that cannot be put to much use. This includes escarpments, rocklands, steep and gullied lands.

Lesotho's topography has also had negative effects of land management. Its terrain is mountainous with only a narrow region in the west consisting of lowlands. The lowlands are also relatively high - the highest point being 1500m. The steepness and ruggedness of the mountain region have presented Lesotho with limited land for agriculture and settlements. Hence the competition between different land uses resulting with encroachment of non-agricultural land uses on agricultural land uses.

There are climatic differences in accordance with topographical region in Lesotho. The rainfall also varies with regions, consequently, the mountains, which are otherwise unsuitable for agriculture receive the highest rainfall, while the lowlands receive very little rainfall especially during the growing period. Drought is therefore a common phenomenon in Lesotho. Soils are also important for an agrarian country like Lesotho. However, most soils in Lesotho are highly erodible, resulting in spectacular sheet and gully erosion. Nonetheless, population pressure has meant that almost all available land (which in most cases is grassland or forested land), despite its unsuitability, is cultivated, with consequent damage to the soil resource. Another result of the population pressure has been the progressive removal of vegetation cover (grasses and indigenous shrubs) with natural regeneration being prevented by uncontrolled grazing within the communally owned rangelands and by veld fires. Lesotho's rangeland currently show the disastrous effects of adoption of systems of land management and use which are not suited to the nature of the land on which they have been imposed: soil erosion, degradation of grasslands, disappearance of indigenous shrubs. Grasslands and trees have a major role on Lesotho's climate since they circulate oxygen, nitrogen, carbon dioxide and regulate humidity and act as a sink for carbon dioxide. Their degradation and ultimate removal is thus detrimental for Lesotho's climate.

6.5 Global Warming Potential

Global Warming Potential (GWP) has been used to compare the gases carbon dioxide, methane an nitrous oxide in terms of their effectiveness in Global Warming Potential. Carbon dioxide has been used as a reference. Nitrous Oxide is 320 times more effective in global warming potential while methane is 24.5 times more effective than carbon dioxide. These indices of the gases are over a period of 100 years lifetime of carbon dioxide in the atmosphere. These indices 320, 24.5 and 1 for carbon dioxide have been used in table 7C to translate 0.63Gg nitrous oxides, 41.47Gg methane and 1896.56Gg carbon dioxide into carbon dioxide equivalent (1000 T CO_2) as follows nitrous oxide 202.55Gg, methane 1015.95Gg and carbon dioxide 1896.56Gg.

Examining the quantities of total emissions of gases in gigagrams in table 7A, Carbon dioxide emissions (1896.56 Gg) constitute 90.1% of total gas emissions (2105.09Gg), the other gases are insignificant. However, in terms of carbon dioxide equivalent, other gases become noticeable, though carbon dioxide still has the highest percentage of 60.88% and methane follows with 32.61% of total. This of course demonstrates the significance of stating greenhouse gas emissions in terms of carbon dioxide equivalents.

6.6 Recommendations

The Land Use Change and Forestry Sector is very important in the Lesotho context both economically and in the role it plays in climate change. However, the estimates made on this sector at present are not accurate and thus the emissions calculated might not be realistic. This is mainly because land use is a highly complex issue in Lesotho and the methods used to estimate the emissions do not take into consideration that complexity. It is therefore recommended that:

1. More attention be paid to this sector in the future since at present the IPCC Methodology is biased to the energy sector.

2. There is also a need to revisit the inventories in the future to update the existing data in a much more systematic manner and this can be done through:-

   a) secondary data and survey;

   b) directing donor funding to the acquisition, manipulation and application of satellite imagery to track historical land use changes in order to determine future trends and update existing data. Landsat/spot images could also be used to demarcate and calculate grasslands burned.

3. The Inventories themselves should not be viewed as a separate climate change assignment but as an integral component of the national development plans and ultimately assessment of mitigation options.

4. The question of standardizing data collection methods should also be looked into so that purposeful sharing of data regionally could be achieved in the future to avoid duplication.

Overall, some commendable successes in capacity-building and general education on climate change has been achieved by the project.

The process of estimating GHG's has been a valuable exercise, but should not be viewed as an end but rather as the beginning of a much more comprehensive study.

[1] includes machines like tractors

[1] Emissions from enteric fermentation and manure management

[2] Total annual emissions from Domestic Livestock

[3] See World Bank Report No. 3039-LSO Lesotho: Agricultural Sector Review. 1981

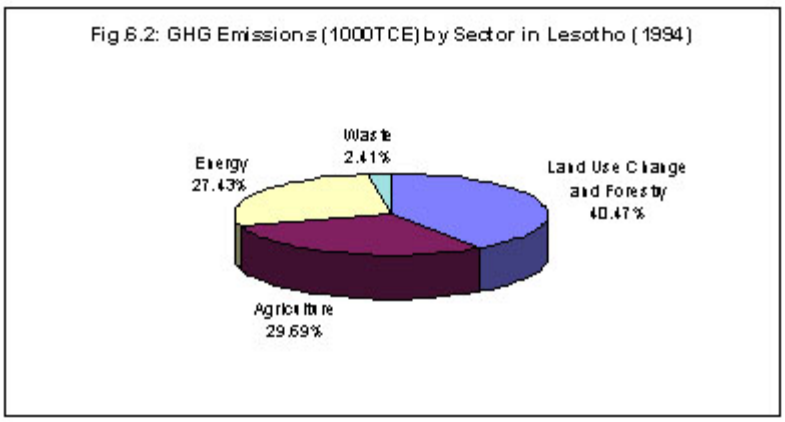

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Sheet 1 of 2)

GREENHOUSE GAS SOURCE AND SINK	CO_2	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs	PFCs	SF_6			
CATEGORIES	Emissions	Removals												
									P	A	P	A	P	A
Total National Emissions and Removals	1,896.56	0.00	41.47	0.63	5.05	143.81	17.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 Energy	635.99	0.00	7.63	0.10	4.92	137.08	17.57	0.00						
A Fuel Combustion (Sectoral Approach)	635.99		7.63	0.10	4.92	137.08	17.57							
1 Energy Industries	0.00		0.00	0.00	0.00	0.00	0.00							
2 Manufacturing Industries and														
Construction	27.87		0.00	0.00	0.09	0.03	0.00							
3 Transport	220.69		0.05	0.00	2.10	17.70	3.33							
4 Other Sectors	382.55		7.58	0.10	2.73	119.25	14.22							
5 Other (please specify)	4.87		0.00	0.00	0.00	0.10	0.01							
B Fugitive Emissions from Fuels	0.00		0.00		0.00	0.00	0.00	0.00						
1 Solid Fuels			0.00											
2 Oil and Natural Gas			0.00		0.00	0.00	0.00	0.00						
2 Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A Mineral Products	0.00					0.00	0.00	0.00						
B Chemical Industry	0.00		0.00	0.00	0.00	0.00	0.00	0.00						
C Metal Production	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D Other Production	0.00				0.00	0.00	0.00	0.00						
E Production of Halocarbons and Sulphur									0.00	0.00	0.00	0.00	0.00	0.00
Hexafluoride														
F Consumption of Halocarbons and Sulphur									0.00	0.00	0.00	0.00	0.00	0.00
Hexafluoride														
G Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00				0.00		0.00

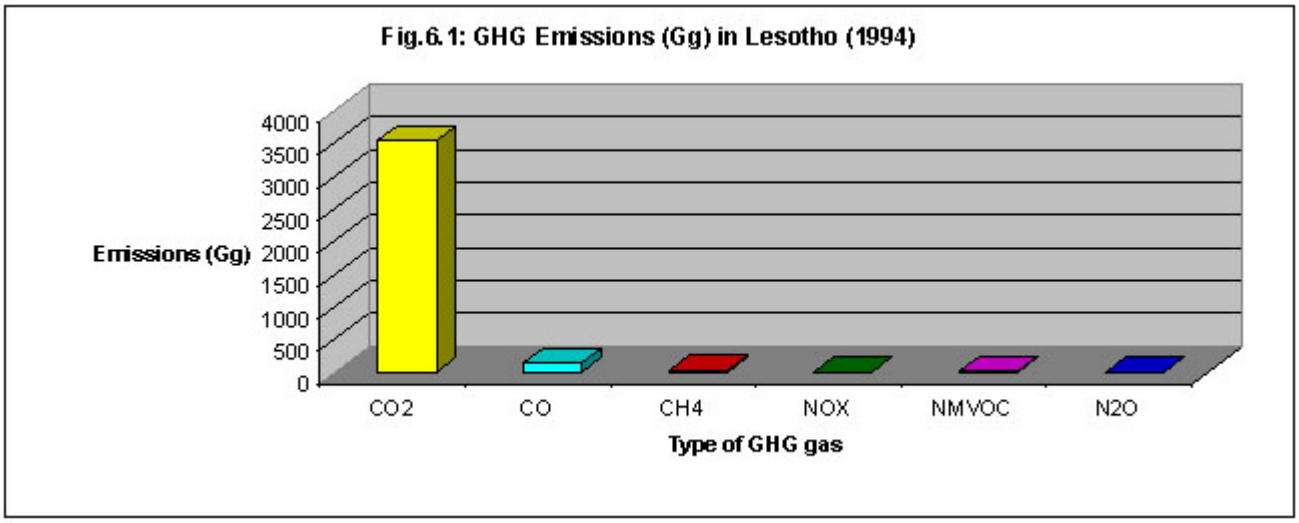
Fig.6.1: GHG Emissions (Gg) in Lesotho (1994)
Emissions (Gg)
4000
3500
3000
2500
2000
1500
1000
500
0
CO2
CO
CH4
NOX
NMVOC
N2O
Type of GHG gas

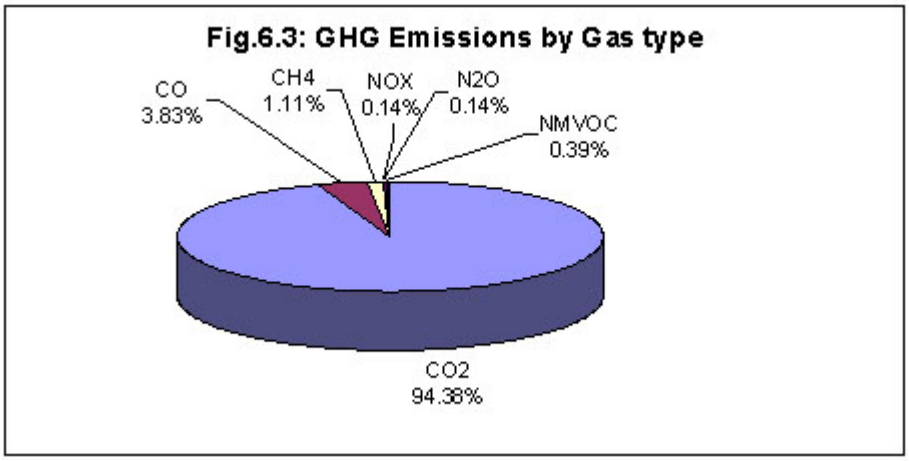
Fig.6.3: GHG Emissions by Gas type
CO
3.83%
CH4
1.11%
NOX
0.14%
N2O
0.14%
NMVOC
0.39%
CO2
94.38%