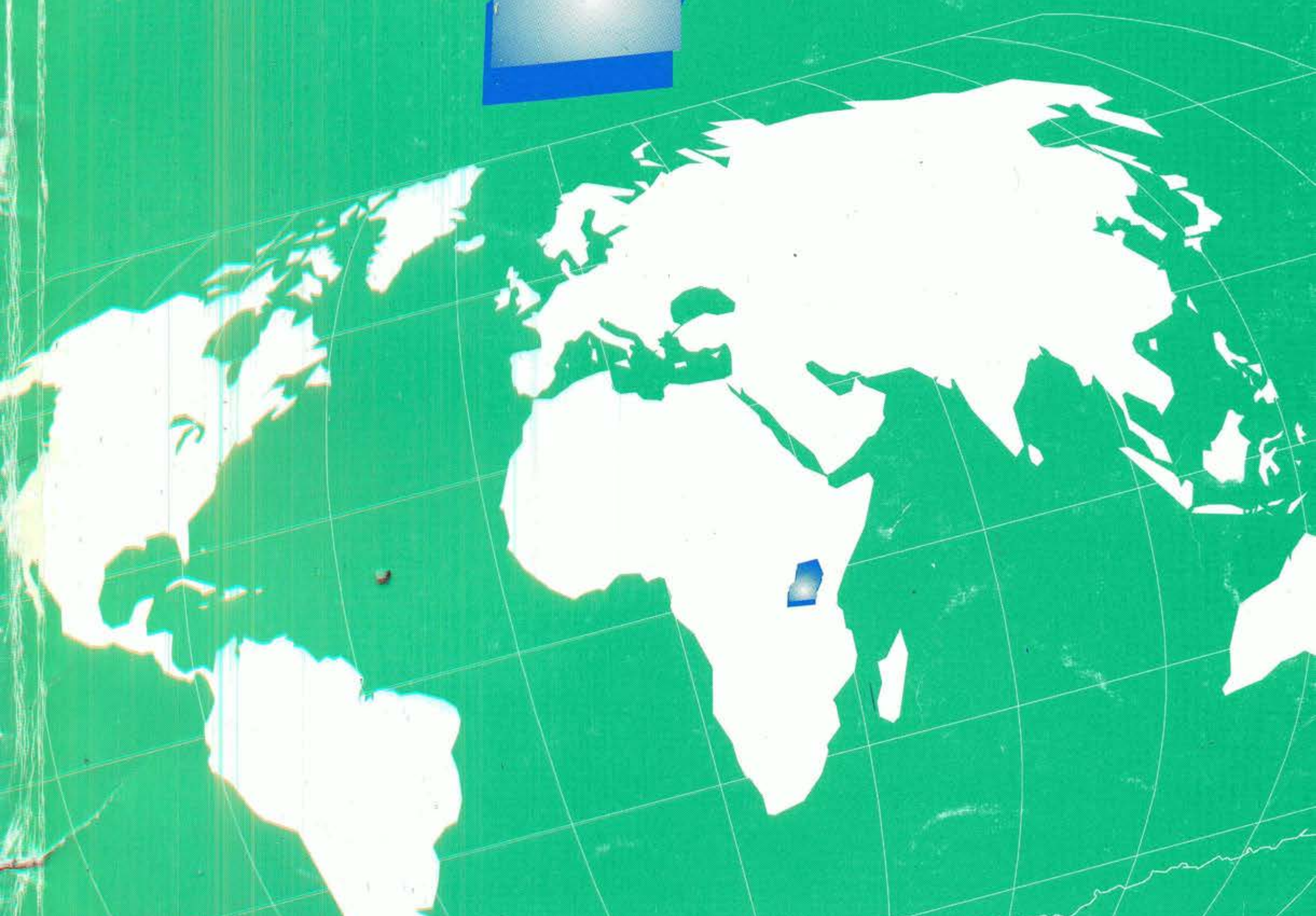
Country Case Study on Sources and Sinks of Greenhouse Gases in Uganda

Final Report



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PREFACE

In accordance with Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol using comparable methodologies to be agreed upon by the Conference of the Parties.

A methodology for conducting such inventories was developed by the OECD Environment Directorate, the International Energy Agency (IEA), and the IPCC Working Group I Technical Support Unit and was proposed as the standard methodology as required under the Convention.

In order to test and further refine the method, the UNEP Atmosphere Unit, working in collaboration with the UNEP Global Environment Facility (GEF), implemented a series of nine complementary national studies using these "IPCC Guidelines for National Greenhouse Gas Inventories".

This report is one of the nine technical reports resulting from this effort. Based partly on this study and on a series of regional workshops sponsored by UNEP under the GEF funded programme and with the assistance of experts from a number of countries, an improved version of the IPCC Guidelines was prepared and approved at the Tenth Plenary Session of the IPCC in Nairobi (November 1994).

The First Conference of the Parties to the UNFCCC (Berlin, April 1995) also adopted the IPCC methodology as the recommended standard to be employed by all Parties in making their inventories in accordance with Article 4.

It is hoped that this report will assist other country study teams in the development and updating of future inventories of greenhouse gases.

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SOURCES AND SINKS OF GREENHOUSE GASES IN UGANDA

A UNEP/GEF SPONSORED PROJECT

Final Report

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August 1994

Kampala

CONTENTS

THE NATIONAL INVENTORY OF ANTHROPOGENIC SOURCES AND SINKS OF GREENHOUSE GASES IN THE REPUBLIC OF UGANDA

SUMMARY

This report presents an inventory of sources and sinks of greenhouse gases in the Republic of Uganda for the year 1990. Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOC) are described by source and sector categories.

1. Energy Combustion Activities

Uganda's per capita energy consumption is estimated to be 0.19, tons of oil equivalent originating from:

a. Petroleum products - 4%
b. Hydro-power (electricity) - 1%
c. Wood-fuel (includes household use) -95%

Emissions of GHGs due to energy combustion are clearly dominated by fuel wood combustion. Wood fuel use is as follows: Households 75%, commercial 10%, industry 5% and charcoal production 10%.

Emissions from use of petroleum products, electricity generation, as well as from road, rail, marine and air transport were calculated.

GHG emissions due to energy combustion activities were as follows: CO_2 - 708.6 Gg, CH_4 - 74.6 Gg, N_2O - 8.7 Gg, NO_x -23 Gg, CO - 849.7 Gg and NMVOC - 5 Gg.

2. Energy production, Transmission, Storage and Distribution

Emissions from these sources are minimal as there is no production of oil or natural gas and nor is there coal mining.

3. Other Industrial Processes

Industrial activity is relatively low and the main emissions are from cement production which is about 5% of installed capacity. Total installed capacity from the only two factories is 400,000 tonnes/annum.

Total emissions due to industrial processes amounted to 43.5 Gg of CO_2.

4. **Agriculture**

CH_4 Emissions have been calculated from livestock enteric fermentation, livestock manure and rice cultivation while emissions of N_2O were determined from the use of fertilizers. The use of fertilizers is very low and therefore N_2O emissions from this source are hardly significant. There were other trace gases emissions determined from agricultural waste burning and savanna burning. Total methane emissions from grazing cattle, goats, sheep, pigs and poultry amounted to 204.45 Gg for the year 1990 while rice cultivation accounted for 23.54 Gg. Emissions from agricultural crop-waste burning amounted to 3.55 Gg of CH_4, 0.38 Gg of N_2O, 8.54 Gg of NO_x and 61.85 Gg of CO. Emissions due to savanna burning were 960 Gg of CH4, 40 Gg of N20, 1,165 Gg of NOx and 16,830 Gg of CO.

5. **Land-use Change and Forestry**

CO_2 emissions were considered from on-site and off-site immediate burnings, decay and soil carbon released due to forest clearing while managed forests were looked at for carbon sinks/emissions. CO_2 emissions and CH_4 uptake reduction due to conversion of grasslands into croplands were also looked at. Total emissions from this sector were as follows: CO_2 - 8.874.76 Gg, CH_4 - 6 Gg, N_2O - 0.014 Gg, NO_x - 0.32 Gg and CO - 17.24 Gg.

6. **Wastes**

CH_4 emissions from landfills, sewage treatment and pit latrines were considered. Most of the landfills are shallow and open and hence the decomposition is mainly under aerobic conditions which produce small amounts of methane. Methane release for Kampala city was 1.292 Gg while for the whole country it was 2.460 Gg during 1990.

7. **Biomass and Biofuel Characterisation**

Biomass and biofuels vary in their carbon and nitrogen contents depending on the climate and soil type. This variation therefore influences the net heating values as well as their intensity of GHG emissions. Samples of grass and agricultural crops were collected by stratifying areas according to vegetation and the common biofuels used. These samples were then subjected to laboratory investigation. Also sixteen samples of woodfuel and seven samples of charcoal from known trees were investigated and the carbon content of fuelwood and charcoal as well as the calorific values for different types of woodfuel were determined.

8. Summary of Results

A detailed summary of results of GHG emissions by source and sector categories is given below in Minimum Data Table 6 A (Parts 1 and 2).

Table 6 A: Summary Report for National Greenhouse Gas Inventories (Part 1)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (PART 1) (Gg)						
GREENHOUSE GASE SOURCE AND SINK CATEGORIES	CO2	CH4	N20	N0x	CO	NMVOC
Total (Net) National Emission						
1 All Energy (Fuel Combustion + Fugitive)						
A Fuel Combustion	* 708.6100					
Energy & Transformation including	--	--	--	--	--	--
Industry (ISIC)	--	0.2070	0.0532	--	--	--
Transport	507.1500	0.1260	3.9500	0.5400	27.2700	4.9900
Commercial/Institutional	63.0000	--	--	--	--	--
Residential	114.1400	--	--	--	--	--
Agriculture/Forestry	0.9788	0.0010	0.0135	0.0000	0.0060	0.0020
Other (UEB Generators)	1.4830	0.0002	0.0000	0.0204	0.0100	0.0036
Biomass Burned for Energy	13.7630	74.5200	4.7040	22.8100	822.9300	--
B Fugitive Fuel Emission						
Oil and Natural Gas Systems						
Coal Mining						
2 Industrial Processes	--	--	--	--	--	--
A Iron and Steel	--	--	--	--	--	--
B Non-Ferrous Metals						
C Inorganic Chemicals						
D Organic Chemicals						
E Non-Metallic Mineral Products	43.4300					
F Other (Foam)	0.0700					
3 Solvent Use						
A Paint Application	--	--	--	--	--	--
B Degreasing and Dry Cleaning	--	--	--	--	--	--
C Chemical Products Manufacture/Processing	--	--	--	--	--	--
D Other	--	--	--	--	--	--
4 Agricutlure						
A Enteric Fermentation	--	197.4000	--	--	--	--
B Animal Wastes	--	7.0500	--	--	--	--
C Rice Cultivation	--	23.5360	--	--	--	--
D Agriculture Soils (Fertilizer Use)			0.0021			
E Agricultural Waste Burning	# 264.5000	3.5500	0.3800	8.5400	61.8500	--
F Savanna Burning	# 72,130.0000	960.0000	40.0000	1,165.0000	16,830.0000	--
5 Land Use Change and Forestry						
A Forest clearing & On-Site Burning of Cleared Forests	2,834.7500	1.9710	0.0140	0.3190	17.2430	--
B Grassland Conversion	6,641.9000	4.0150	--	--	--	--
C Abandonment of Managed Lands	--	--	--	--	--	--
D Managed Forests	-1,354.0000	--	--	--	--	--
6 Waste						
A Landfills	--	2.5000	--	--	--	--
B Wastewater	--	--	--	--	--	--
C Other (Pit Latrines)	--	1.6000	--	--	--	--

* - Total emission

- Part of the natural cycle

ACKNOWLEDGEMENTS

1. The methodology used to determine the sources and sinks of greenhouse gases was developed by Working Group I of the Intergovernmental Panel on Climate Change (IPCC) working in collaboration with the Organisation for Economic Co-operation and Development (OECD).

Financial support for the inventory was provided by the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF).

Many individuals have contributed in various ways to the study. Mr. Jan Feenstra of the Institute of Environmental Studies in The Netherlands who was the consultant for the inventory; Mr. Michael Short, UNEP Programme Officer, who was responsible for overall administration of the country case studies. Mr. B.Z. Dramadri, Permanent Secretary in the Ministry of Natural Resources and also Chairman of the National Steering Committee responsible for supervising and guiding the study; Dr. Aryamanya-Mugisha, Director of Environment Protection.

A lot of experience was also gained from the Tanzania national study team during the exchange visits by the two sides which took place in the course of the project.

The National Study Team was composed of the following:

a. Bwango-Apuuli of the Department of Meteorology who was the Project Co-ordinator and to whom all enquiries regarding the study should be directed at P.O. Box 7025, Kampala, Uganda or Internet: Bapuuli@Mukla.gn.apc.org

b. G. Turyahikayo of the Department of Energy who, together with S.A.K. Magezi of the Department of Meteorology and A.R. Tibaturanwa, determined the emissions from the Energy Sector;

c. A.W. Majugu of the Department of Meteorology who, together with Professor J.T. Nyangababo of Makerere University (Chemistry Department) and E. Werabe of the Department of Environment Protection, determined the emissions from Industry, Solvents and Wastes;

d. M.S.Z. Nkalubo of the Department of Meteorology who, together with W. Otage of the Ministry of Agriculture, Animal Industry and Fisheries, determined emissions from Agriculture;

e. I. Oluka-Akileng and P. Drichi both from Forestry Department who, together with F.D.K. Bagoora of the Department of Environment Protection and J.B. Magezi-Akiiki of the Department of Meteorology, determined the sources and sinks associated with Land-use Change

and Forestry;

f. Professor J.O. Ilukor and S.O. Oluka both of Makerere University (Physics Department) who carried out the biomass and biofuel characterisation in the Laboratory and who also calculated the emissions from savanna burning.

g. Olwero V.G.M. - Secretary who spent a lot of word-Processing time on the Report.

A number of other experts who participated in the Steering Committee Meetings, National and Regional Workshops made invaluable comments and recommendations which have been incorporated in the report. Summaries of the recommendations from the meeting and the National Workshop are given in Appendix 2.

THE NATIONAL INVENTORY OF ANTHROPOGENIC SOURCES AND SINKS OF GREENHOUSE GASES IN THE REPUBLIC OF UGANDA

INTRODUCTION

BACKGROUND

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

In September 1992, the United Nations Environment Programme (UNEP) approved a pilot project to conduct 11 country case studies on sources and sinks of GHG emissions. Uganda is one of the countries which participated in this project. This series of country studies are to develop national inventories based on the IPCC methodology and enable a larger number of national scientists and administrators to contribute further to its refinement.

The Department of Meteorology, within the Ministry of Natural Resources, was the lead agency and contact point for this national study.

1. OBJECTIVES OF THE PROJECT

a. Long-Term Objectives

i. To have a more complete understanding of the role of GHG emissions and sinks in global climate change with respect to human and natural events.

ii. To identify policies and technologies which countries might incorporate into national planning with the aim of minimising GHG emissions.

b. Short-Term Objectives

i. To increase both the quantity and quality of base line data available in order to further scientific understanding of the relationship of GHG emissions to climate change.

ii. To enhance the ability of environmental agencies in Uganda to estimate, monitor and report national inventories of GHG emissions and sinks.

iii. To promote the exchange of information related to climate change, national policy options and technology choices that could lead to the eventual reduction of GHG emissions worldwide.

iv. To promote the establishment of permanent links between national environment agencies in Uganda and international institutions for the exchange of scientific, technological and policy information related to the effects of GHG emissions on global climate change.

2. ORGANISATIONAL FRAMEWORK

a. The study was carried out by a national team under the supervision of a Project Co-ordinator from the Department of Meteorology and other members of the study team were drawn from the following Departments/Institutions:

i. Department of Energy.

ii. Department of Environment Protection/National Environmental Action Plan.

iii. Department of Forestry/National Biomass Project.

iv. Department of Meteorology.

v. Makerere University, Kampala.

(1) Department of Physics.
(2) Department of Chemistry.

vi. Ministry of Agriculture, Animal Industry and Fisheries.

3. THE RESPONSIBLE AUTHORITY

The Permanent Secretary,
Ministry of Natural Resources,
P.O. Box 7270,
KAMPALA, Uganda.

A National Steering Committee was formed to co-ordinate and advise on the conduct and implementation of the study and its composition was as follows:

a. The Permanent secretary, Ministry of Natural Resources - Chairman.

b. The Permanent Secretary/Secretary to the Treasury, Ministry of finance and Economic Planning.

c. The Permanent Secretary, Ministry of Foreign Affairs.

d. The Director of Environment Protection.

e. The Director of Agriculture.

f. The Commissioner of Meteorology.

g. The Commissioner of Lands and Surveys.

h. The Commissioner of Statistics.

i. The Chief Transport Economist, Ministry of works, Transport and Communications.

j. The Commissioner for Forestry.

4. **WORK-PLAN**

The bulk of the work was carried out under five Task Forces, each looking into different sources of emissions viz:

a. Energy Consumption, storage, transmission and distribution as well as fuel-wood use both domestic and commercial.

b. Land-use change and Forestry, i.e. forestry clearing, abandonment of managed lands, conversion of grasslands to agricultural lands, and determination of types and number of sinks.

c. Animal husbandry, rice cultivation, fertilizer use, agricultural waste, crop biomass and savanna burning.

d. Industrial processes and public utilities, i.e. chemical plants, soap factories, landfills, steel production, medicinal factories, cement industries and sewage plants.

e. Bio-fuel characterisation, i.e. laboratory determination of C:N ratio and the determination of biomass of agricultural crops.

For a study of this kind it is acknowledged that there are still many uncertainties and gaps surrounding some of the emissions estimates. Further work may be necessary to ensure that all potential sources are identified and the existing source estimates verified.

5. A GENERAL OVERVIEW OF UGANDA

Uganda spans almost 236,000 km^2 and has a population of nearly 17 million. Climate is considered as one of the major resources. In general, the country experiences two rain seasons but there are inter-annual variations in both the onset and the total amounts. Rainfed agriculture is the mainstay of the economy accounting for about 70% of GDP and over 95% of the merchandise exports and therefore the growth of the agricultural sector greatly determines the performance of the economy. It provides employment for about 80% of the population and is the economic base for much of the manufacturing and service industries. Negative climate change would therefore adversely affect the economy. National policies must therefore be evolved to tackle the problem of global warming associated with greenhouse gas emissions. They key impacts of climate change are likely to strongly affect the following sectors:

a. Agriculture;
b. Forestry;
c. Natural Ecosystems and wildlife;
d. Water Resources;
e. Fisheries;
f. Human settlements;
g. energy;
h. Transport and Industry;
i. Human Health; and
j. Air quality and changes in ultra violet intensities.

CHAPTER ONE

1.0 ESTIMATION OF GREENHOUSE GASES EMISSIONS FROM ENERGY ACTIVITIES

1.1 INTRODUCTION

1.1.1. Background

The energy sector in Uganda is predominantly dependent on wood-fuel. It is estimated that wood-fuel accounts for as much as 95% of the country's total energy consumption, while petroleum products and hydropower account for about 4% and 1% respectively (NEAP Background doc. 1993). For the base year 1990, wood-fuel accounted for 94.5%, while petroleum products and hydropower accounted for 5.0% and 0.5% respectively (World Bank energy balance 1990). Uganda has also one of the lowest per capita energy consumption in the world with commercial energy utilisation accounting for about 10% of the total energy consumption.

This low level of commercial energy consumption, coupled with the country's over dependence on wood-fuel, implies that Uganda is not expected to be a major net contributor of GHGs into the atmosphere, on the basis of fossil fuel combustion. There is, however, indication of systematic reduction in the carbon dioxide sink due to continued deforestation. It was estimated (Openshaw, 1982) that in 1980 sustainable supply of wood energy was less than demand by about 17%.

1.1.2 Data Sources

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

(i) Estimation of CO_2 Emissions from petroleum products:

Data on annual sales of petroleum products: Department of Energy, Ministry of Natural Resources.

(ii) Estimation of GHGs from Mobile Combustion:

Data on road transport and agricultural machinery (tractors): Transport Policy and Planning Project (TPPP), Ministry of Transport, Communications and Works.

Data on other Non-road Transport:

Aviation: Uganda Civil Aviation Authority.

Water Transport:

Uganda Railways Corporation and Department of Fisheries (Ministry of Agriculture, Animal Industry and Fisheries).

Rail Transport: Uganda Railways Corporation.

Estimation of GHGs from non-mobile combustion:

Thermal power generation:

Uganda Electricity Board.

Biomass combustion: Department of Forestry (Ministry of Natural Resources) Bagasse.

1.1.3 Methodology

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

CO_2 emissions from petroleum products were estimated for each fuel type using the IPCC Methodology employing the MINERGG Package and a hand calculator and the results compared.

For non-CO_2 GHGs emission estimates for both stationary and mobile sources were made using the following basic formula (GHG Inventory Reference Manual, 1991).

Emissions = Summation (EF_{abc} x $Activity_{abc}$)

where:

(i) For Stationary sources

EF = Emission Factor (g/GJ)

Activity = Energy input (GJ)

a = Fuel type;
b = Sector-activity;
c = Technology type; and

(ii) For mobile sources

EF = Emission Factor (g/GJ)

Activity = amount of energy consumed or distance travelled for a given mobile source activity.

a = transport mode (rail, road, air, water, etc.).

b = fuel type (diesel, gasoline, LPG, bunker, etc.).

c = vehicle type (e.g. passenger, light duty or heavy for road vehicles).

The same formula was also used to estimate CO_2 emissions from stationary combustion, and for mobile combustion for the various transport modes.

1.2 CARBON DIOXIDE EMISSIONS FROM FOSSIL FUELS

1.2.1 Background

All fossil fuels consumed in Uganda are secondary forms of petroleum. Uganda's own reserves of crude oil and peat are of unknown potential and are not yet exploited. Apart from lubricants and plastics, the imported petroleum products are all used for energy production in the transport, household, industry and commercial sectors.

The petroleum importation is carried out by several multinational oil companies, although the Government also procures its own strategic stocks of gasoline (petrol), gas oil (diesel) and kerosene. The Government stocks have been used on loan basis, by the oil companies, whenever there is a shortage. Otherwise the oil company stocks, at any particular time, can last for approximately one week only.

Information on imports and sales of petroleum products can be obtained from the Department of Energy (Ministry of Natural Resources), the Department of Statistics (Ministry of Finance and Economic Planning) and the Oil Companies. Examination of available sets of data from the various sources showed that the Department of Energy had the most reliable data, especially on petroleum sales. Due to the relatively high domestic prices of petroleum fuels compared to the neighbours, only negligible quantities are re-exported. However, this high price scenario has facilitated continued smuggling of petroleum products into the country. Estimates (Department of Energy) show alarmingly high figures of smuggled fuel, thus:

1990 - 15 million litres (approx. 5% of legal sales);
1991 - 42 million litres;
1992 - 55 million litres; and
1993 - 55 million litres.

Smuggled fuel is now estimated at 10% of the market {ESMAP/World Bank Mission aide Momoire (1994)}.

These figures have been ignored in the calculation of emissions in order to avoid double counting with Kenya, since Kenya would naturally have them in their sales statistics.

Table 1.1. shows annual sales of petroleum products, which gives the raw data used in the calculation of CO_2 emissions for Uganda. It is assumed that the total sales represent total local consumption.

TABLE 1.1

ANNUAL SALES OF PETROLEUM PRODUCTS IN METRIC TONNES (MT) FOR THE PERIOD 1988 - 1992

FUEL TYPE	YEAR				
	1988	1989	1990	1991	1992
Gasoline	81,148	89,748	87,148	79,843	78,024
Kerosene	34,207	37,178	35,726	27,254	23,349
Jet Fuel	17,049	25,154	33,444	N/A	13.954
Gas oil	82,063	91,205	83,021	78,007	71,821
Residual fuel oil (furnace oil)	14,175	12,185	20255	11,884	12,073
LPG	779	562	139	79	582
Industrial Diesel Oil	205	125	169	0	0
Total Quantity	230,287	256,155	259,902	197,079*	199,804

N/A = Not Available

Source:

Department of Energy, Ministry of Natural Resources. Data on lubricants is not available from this source, although import figures (Bank of Uganda) have tentative data for lubricants. Unfortunately, these figures do not always tally with actual fuel importation figures because they only show intention to import depending on availability of foreign currency. There is no indication of actual amount imported, if any.

Table 1.1 shows that there has been a systematic decrease in the consumption of kerosene since 1989. This can be attributed to the high cost of kerosene on the domestic market, which has resulted into increased substitution of wood-fuel for kerosene for cooking.

1.2.2 Stock Changes:

There are no significant stocks in the country because Oil Companies prefer to keep their stocks in neighbouring Kenya. At most, stocks in the country are expected to last five days.

Importation of industrial diesel oil virtually ceased after 1990 because of its relatively high cost as compared to residual fuel oil or diesel.

1.2.3 Estimation of CO_2 Emissions

Sales data for 1990, which represents apparent consumption, was used to calculate CO_2 emissions. Fuel consumption in Giga joules was obtained by using the conversion factors given in the IPCC's GHG Inventory Workbook (Table 1.2).

TABLE 1.2

FUEL CONSUMPTION IN GIGA JOULES FOR 1990

FUEL TYPE	APPARENT CONSUMPTION (MT)	CONVERSION FACTOR (GJ/MT)	APPARENT CONSUMPTION (GJ)
Gasoline	87,148	44.80	3.904.203.40
Kerosene	35,726	44.75	1,598,738.50
Jet Fuel	33,444	44.59	1,491,267.96
Gas oil	83,021	43.33	3.597,299.93
Residual Fuel Oil	20,255	40.19	814.048.45
LPG	139	47.31	6,576.09
Industrial diesel Oil	169	40.19	6,792.11
Total	259,902		11,418,926.44

The bulk of gasoline and gas oil are consumed in the surface transport sub-sector, kerosene and LPG in the household sub-sector, while industrial fuel oil, residual fuel oil and a small proportion of gas oil are consumed in the industry and commercial sub-sector. Therefore, surface transport (mainly road transport) is expected to be the main contributor of CO_2 from fossil fuels.

Carbon emission factors given in the IPCC's GHG Inventory Workbook were used to calculate the carbon content of the fuels (Uganda does not have her own country specific values).

In the calculation for CO_2 emissions, it is assumed that 99% of the carbon is oxidised. The carbon content for each fuel type was then multiplied by the molecular weight ratio of CO_2 to carbon (44/12) to obtain CO_2 emissions. Estimations were made using the MINERGG[1] Module (Table 1.3).

TABLE 1.3

CO_2 EMISSIONS FROM PETROLEUM PRODUCTS

FUEL TYPE	APPARENT CONSUMPTION (GJ)	EMISSION FACTOR (KgC/GJ)	CARBON CONTENT/ACTUAL CARBON EMISSIONS (GgC)	ESTIMATED EMISSIONS (Gg CO_2)
Gasoline	3,904,230.40	18.90	73.79	269.85
Kerosene	1,598,738.50	19.60	31.18	113.74
Jet Fuel	1,491,267.96	19.50	29.83	105.50*
Gas Oil	3,597,299.93	20.20	72.67	263.77
Residual Fuel Oil	814,048.45	21.10	17.18	62.35
LPG	6,576.09	17.20	0.11	0.40
Industrial Diesel Oil	6,792.11	21.10	0.14	0.50
Total CO_2 Emissions from fossil fuel combustion (excluding jet fuel)				708.61

1.3 GREENHOUSE GAS EMISSIONS FROM STATIONARY COMBUSTION

1.3.1 Background

GHG emissions from stationary combustion in Uganda comprise the following sources:

(i) Combustion of petroleum products in households for cooking and lighting (mainly kerosene and LPG) and industries for process heat (residual

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1 MINERGG *is a software package developed by IPCC/OECD*

fuel oil and industrial diesel);

(ii) Diesel (or diesel/fuel oil blend) combustion for electric power generation: and

(iii) Biomass consumption in households, the commercial sector and rural industries;

Due to the relatively low level of industrialisation in Uganda, the major emissions are from fuel-wood combustion for domestic activities.

The following problems were encountered during data collection, and some of them may need further study to resolve them.

They include:

(i) Data on wood-fuel consumption could not be disaggregated into the various sectors, although attempts in the "Background to the Budget (1992)" (Ministry of Finance and Economic Planning Document) on disaggregation had been made. The data set does not comply with the recommendations of the National Biomass Study, (i.e. the total wood-fuel consumed is radically different from the figure agreed on by the NBS). It is therefore being further scrutinised.

(ii) No reliable information is available on consumption of the various fuels in households.

(iii) Data collection on the use of fuel oil in industries is not complete yet. The Oil Companies could not, in most cases, divulge information on their sales to individual industries.

(iv) The Uganda Electricity Board (UEB), which has the mandate to register all electric power activities in Uganda, has records about its own generators only. Records of imported generators and other diesel driven stationary engines from the Uganda Revenue Authority were of no help either, as no consumption figures were available. It has, therefore, been difficult to estimate total emissions from this type of fuel combustion. Nevertheless, this consumption is considered small because most of the other generators are standby and operate on an adhoc basis.

1.3.2 GHG Emissions from Fuel Oil Combustion in Industry

Up to 1990 both residual fuel oil and industrial diesel oil were being used for firing boilers and furnaces in industries in Uganda. However, since 1991 no more industrial diesel oil has been imported because of its much higher cost. Most rural industries had also switched from furnace oil to firewood boilers due to costs. Data obtained was only on residual fuel oil in some of the industries. More inventory on industries using fuel oil is yet to be done. In this report data used was obtained from the brewing, cement, textile, tobacco, milling and paper industries, as indicated in Table 1.4.

The following conversion and emission factors have been used in the calculations (Ref. IPCC Inventory Reference Manual):

Mass/weight to energy: 40.19 GJ/MT
Volume to weight: 0.91×10^{-3} Tonnes/L

Emission factors:

Carbon : 21.1 kg C/GJ
CH_4 : 0.7 g/GJ
CO : 15 g/GJ
NO_x : 201 g/GJ
N_2O : Not available.

Emission estimates were calculated for the base year of 1990.

Below is Table 1.4 which gives GHG Emission Estimates from Fuel Oil Combustion. These emissions cover only those industries surveyed.

TABLE 1.4

GHG EMISSION ESTIMATES FROM FUEL OILCOMBUSTION (1990)

	CONSUMPTION			EMISSIONS (Gg)				
	MT	GJ	CARBON	CO2	CH4	CO	N2O	NxO
Tororo Cement	1296.25	52098.096	1.09926980	4.0306559	0.0003650	0.00078150	0.0104717	N/A
Hima Cement	860.86	34597.963	0.73017010	2.6772903	0.0000242	0.00051900	0.0095420	N/A
Uganda Breweries	1516.97	60967.024	1.28640420	4.7168153	0.0000427	0.00091450	0.0122544	N/A
Nile Breweries	299.12	12021.512	0.25365390	0.9300642	0.0000084	0.00000490	0.0000601	N/A
Papco	226.14	9088.366	0.19176452	0.7031365	0.0000064	0.00000030	0.0000455	N/A
Nyanza Textiles	2585.19	103896.000	2.19220000	8.0380000	0.0000727	0.00155000	0.0207700	N/A
BAT,Jinja	109.51	4401.097	0.09280000	0.3405000	0.0000031	0.00000660	0.0000088	N/A
Grain Milling Industr.	38.64	1552.902	0.03270000	0.1201000	0.0000011	0.00000023	0.0000031	N/A
Chillington Industr.	109.20	4388.638	0.09260000	0.3395000	0.0000031	0.00000660	0.0000088	N/A
Mulbox Industr.	13.65	548.570	0.01150000	0.0424000	0.0000008	0.00000080	0.0000011	N/A
TOTAL GHG EMISSIONS	7055.52			21.9384622	0.0005275	0.00378443	0.0531655	N/A

Total Aggregate Gas Emissions: 13.108 Gg

The total quantity of 7055.567 MT consumed in these Industries is only 35% of the total residual fuel oil imported into the country in 1990. Work is on-going to survey all the

other industries.

1.3.3 GHG Emissions from Thermal Power Generation

Uganda's electricity is almost exclusively produced from Hydropower. The major power station at the Owen Falls Dam is currently generating 160 MW, with an additional 6 MW (approximately) generated by smaller stations (UEB). Out of this, 30 MW is for export, mainly to Kenya and the rest for domestic use. The target is to produce 180 MW at the current Owen Falls Station (Power II) while work on another 200 MW plant has just started at the same place (Power III). Data obtained from UEB indicates that thermal production of power in Uganda may be about 5 MW only; contributing less than 3% of the total power generation.

Data used here in emissions estimates was obtained from UEB for one year, covering the period September 1992 to August 1993. There was no organised consumption data for the period before this.

The uncontrolled level of emissions has been assumed and estimated emission factors for heavy duty diesel engines assumed. The generators use a blend of diesel and fuel oil.

Total diesel consumed = 528,000 litres
= 459.36 Metric Tonnes (MT)
= 19904 GJ

Total fuel Oil consumed = 8,820 litres
= 8.03 MT
= 322.57 GJ

Due to the low fuel oil to diesel ratio (1.6%) a total activity of 20226.57 GJ has been assumed and the emission factors applicable to diesel used for estimating emissions (Reference Table 1.5).

TABLE 1.5		
TOTAL EMISSIONS FROM UEB THERMAL GENERATORS		
TYPE OF GAS	EMISSION FACTORS (g/MJ)	EMISSION Gg C or N
CO_2	73.3	1.483
N_2O	0.0019	0.0000384
CO	0.51	0.010
CH_4	0.01	0.000199
NO_x	1.01	0.0204
NMVOC	0.18	0.003583
TOTAL GAS EMISSIONS (Gg)		
Note: Consumption by the generators totalled approximately 20,226.57 GJ of diesel.		

1.4 ESTIMATION OF GHG EMISSIONS FROM MOBILE COMBUSTION

1.4.1 Mobile Combustion Categories

Data was collected and analysis done on the following major categories of mobile combustion:

(i) Road mobile vehicles and off road agricultural tractors;

(ii) Motor boats;

(iii) Other unspecified mobile vehicles;

(iv) Locomotives; and

(v) Jet aircrafts and piston engine aircrafts.

There were, however, constraints in achieving the objectives set - the chief among them included:

data was difficult to access;
non-availability of data;
unreliable data; and
limited literature;

Despite the above constraints, estimates of emissions have been arrived at. As stated earlier, the basic IPCC methodology was used to estimate mobile sources emissions.

1.4.2 Emissions from Motor Vehicles (Gasoline and Diesel)

1.4.2.1 Data Source:

The data used was obtained from the Transport Policy and Planning Project (TPPP), Ministry of Works, Transport and Communications. Provisional data of TPPP has been used covering the year 1990. This is the only source of this type of data in the country. The same data is being used to evolve the transport policy and planning guidelines.

1.4.2.2 Methodology

The vehicles are grouped according to their weight and type of fuel consumed. It is also assumed that the combustion is uncontrolled. Hence the emission factors used are those of uncontrolled combustion. There could also be inherent errors in using these emission factors derived using USA standards.

The raw data given was in kilometres and fuel consumption rate for each mode of transport. The IPCC methodology was used to determine the emissions content as displayed in Tables 1.6 to 1.7 below.

TABLE 1.6

GHG EMSSIONS FOR ROAD AND AGRICULTURAL VEHICLES USING GASOIL (DIESEL)

TRANSPORT CLASS	TOTAL DIST. TRAVELLED (Km)	FUEL CONSUMED (LITRES)	FUEL CONSUMED (TONES)	ENERGY CONSUMED (GJ)	EMISSION FACTORS (G/MJ) N2O	METHANE	NMVOC	CO	NOx	CO2	GREEN HOUSE GAS EMISSIONS (Gg) N2O	METHANE	NMVOC	CO	NOx	CO2
Car	3,193,200	255,456	215.37	9,331.9	140	1	73	150	1.9	73,300	0.0013	0.0000	0.0007	0.0014	0.0000	0.6840
Pickup	72,014,900	6,481,341	5,464.23	236,765.1	170	0	100	190	1.9	73,000	0.0403	0.0000	0.0237	0.0450	0.0004	17.3549
4Wheel Drive	26,110,000	2,611,000	2,201.26	95,380.5	170	0	100	190	1.9	73,000	0.0162	0.0000	0.0095	0.0181	0.0002	6.9914
Minbus	56,568,000	5,091,120	4,292.17	185,479.9	170	0	100	190	1.9	73,000	0.0316	0.0000	0.0186	0.0353	0.0004	13.6323
Medium Bus	54,060,000	10,595,760	8,932.98	387,065.8	170	0	100	190	1.9	73,000	0.0658	0.0000	0.0387	0.0735	0.0007	28.3719
Bus	20,520,000	5,130,000	4,324.95	187,400.2	1010	10	180	510	1.9	73,000	0.1893	0.0019	0.0337	0.0956	0.0004	13.7364
2Axle Truck	156,804,200	37,789,812	31,859.49	1,380,471.6	1010	10	180	510	1.9	73,000	1.3943	0.0138	0.2485	0.7040	0.0026	101.1886
3Axle Truck	44,250,000	11,283,750	9,513.00	412,198.3	1010	10	180	510	1.9	73,000	0.4163	0.0041	0.0742	0.2102	0.0008	30.2141
Truck Trailer	9,410,000	3,764,000	3,173.32	137,499.9	1010	10	180	510	1.9	73,000	0.1389	0.0014	0.0247	0.0701	0.0003	10.0787
Articulator	9,780,000	4,449,900	3,751.58	162,556.0	1010	10	180	510	1.9	73,000	0.1642	0.0016	0.0293	0.0829	0.0003	11.9154
Agric. Tractor	988,000	365,560	308.19	13,354.0	1010	10	180	510	1.9	73,000	0.0135	0.0001	0.0024	0.0068	0.0000	0.9788
Others	4,190,000	1,257,000	1,059.74	45,918.5	1010	10	180	510	1.9	73,000	0.0464	0.0005	0.0083	0.0234	0.0001	3.3658
Totals	457,888,300	89,074,699	75,096.28	3,253,421.7							2.5181	0.0234	0.5123	1.3663	0.0062	238.5123

NB: DATA SOURCE: Transport Policy and Planning Project (UGA/90/018)

TABLE 1.7

GHG EMSSIONS FOR ROAD TRANSPORT AND AGRICULTURAL VEHICLES USING GASOLINE

TRANSPORT CLASS	TOTAL DIST. TRAVELLED (Km)	FUEL CONSUMED (LITRES)	FUEL CONSUMED (TONES)	ENERGY CONSUMED (GJ)	EMISSION FACTORS (G/MJ) N2O	METHANE	NMVOC	CO	NOx	CO2	GREEN HOUSE GAS EMISSIONS (Gg) N2O	METHANE	NMVOC	CO	NOx	CO2
Car < 1300kg	193,100,000	16,690,416	12,305.80	551,299.8	390	31.4	1140	7330	0.9	69,300	0.215	0.0173	0.628	4.041	0.000496	38.205
Car 1300–1900kg	132,300,000	16,573,937	12,219.96	547,454.2	390	31.4	1140	7330	0.9	69,300	0.213	0.0172	0.624	4.013	0.000490	37.939
Car > 1900kg	28,000,000	3,983,870	2,937.31	131,591.5	410	26.9	1320	6890	0.9	69,300	0.054	0.0035	0.150	0.906	0.000120	9.119
Pickup	72,200,000	31,029,503	22,878.05	1,024,934.4	410	26.9	1320	6890	0.9	69,300	0.420	0.0275	1.353	7.062	0.000920	71.028
4Wheel Drive	26,100,000	9,036,061	6,662.26	298,470.1	410	26.9	1320	6890	0.9	69,300	0.122	0.0080	0.393	2.056	0.000270	20.683
Minbus	170,200,000	28,898,812	21,307.09	954,557.6	410	26.9	1320	6890	0.9	69,300	0.391	0.0260	1.260	6.577	0.000860	66.151
Motorcycle	52,300,000	1,129,313	832.64	37,302.3	410	26.9	1320	6890	0.9	69,300	0.015	0.0010	0.049	0.257	0.000030	2.585
TOTALS	674,200,000	107,341,912	79,143.13	3,545,609.9							1.430	0.1005	4.457	24.912	0.003186	245.710

NB: DATA SOURCE: Transport Policy and Planning Project (UGA/90/018)

1.4.3 EMISSIONS FROM MOTOR BOATS

1.4.3.1 Data Source:

The data used was obtained from the Department of Fisheries, Ministry of Animal Industry and Fisheries, Entebbe.

Fisheries Department provided the number of boats and their respective horse powers. The horse powers ranged from one to eighty-five. These boats are found on Lakes Victoria, Albert, George, Kyoga, and Edward. This data does not include boats on smaller lakes and rivers. There is a possibility that there could be some motor boats not registered with the Department of Fisheries especially those originating from neighbouring countries along shared lakes. A sample survey was conducted on four sites on lake Victoria with the users of motor boats. On the basis of this survey estimates of fuel used and mileage covered for each motor boat were made.

1.4.3.2 METHODOLOGY

The motor boats were grouped according to their horse powers, taking into account the time they spent on fishing trips. The emission estimates were done following the IPCC Procedure. Table 1.8 below gives the motor boat categorisation.

TABLE 1.8

CATEGORISATION OF MOTOR BOATS

HORSE POWER	AVERAGE CONSUMPTION Km/LITRE	NO. OF BOATS	DISTANCE TRAVELLED Km/PER DAY	FUEL CONSUMPTION IN 1990 (LITRES)
1 - 15	6	1378	18	1,500,910
16 - 30	5	327	36	859,356
31 - 60	4	80	72	525,600
61 - 85	3	28	120	408,800
Total				3,294,666

The total annual fuel consumption of 3,294,666 litres translates to 108,829 GJ of energy consumption (see Table 1.9 below).

1.4.4 EMISSIONS FROM LOCOMOTIVES[2]

Year 1990.

1.4.4.1 Data Source:

The data used was obtained from the Uganda Railways Corporation.

Data was extracted from the actual fuel consumed by the locomotives. Data could not be obtained for fuel consumption by small trains used for repair of rails. For the purposes of emission estimates, fuel consumed by the small maintenance trains is assumed to be insignificant; otherwise the rest of the data is reliable.

1.4.4.2 METHODOLOGY

As in previous estimations, the IPCC method for mobile combustion was used. The total consumption of 2,533,969 litres was transformed into 90047 GJ of energy consumption as displayed in Table 1.9 below.

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2 *It was found out that locomotives did not cross national borders but only the coaches were exchanged at the borders hence the issue of bunkers fuels did not arise.*

TABLE 1.9

TYPE	FUEL CONSUMED METRIC TONNES	ENERGY (GJ)	EMISSION ESTIMATES FROM NON-ROAD TRANSPORT — EMISSION FACTOR (g/GJ): NITROGEN OXIDE NOx	METHANE	NMVOC	CARBON MONOXIDE	NITROUS OXIDE N2O	CARBON DIOXIDE	EMISSION ESTIMATES Gg OF FULL MASS POLLUTANT: NITROGEN OXIDE NOx	METHANE	NMVOC	CARBON MONOXIDE	NITROUS OXIDE N2O	CARBON DIOXIDE
Emission from Motor Boats	20,721.169	108,828.64	1,600.00	5	110	500	2.0	73,300	0.17400	0.000544	0.000544	0.0120	0.000218	7.9800
Emission from Locomotive	2,135.500	92,529.90	1,800.00	6	130	610	2.0	73,300	0.16700	0.000600	0.012000	0.5600	0.001900	6.7800
Emission from Marines	2,078.000	90,043.00	2,100.00	N/A	N/A	46	2.0	77,400	0.18900	N/A	N/A	0.0041	0.000180	6.9700
Emissions Aircrafts (local)	38.850	1,740.00	80.00	60	540	25,000	0.9	69,300	0.00139	0.001040	0.009000	0.4180	0.000020	1.2058

N/A = Not Available

Data Source: Department of Energy, Ministry of Natural Resources,
Uganda Railways Corporation, Department of Fisheries and Civil Aviation Authority

TABLE 1.10

TYPE	FUEL CONSUMED METRIC TONNES	ENERGY GJ	EMISSIONS FROM COMBUSTION OF FUEL FROM AIRCRAFTS FOR INTERNATIONAL AIR TRANSPORT (APPROACH 4 TAKE OFF ONLY) — EMISSION FACTOR (g/GJ): NITROGEN OXIDE	METHANE	NMVOC	CARBON MONOXIDE	NITROUS OXIDE	CARBON DIOXIDE	EMISSION ESTIMATES Gg OF FULL MASS POLLUNTANT: NITROGEN OXIDE	METHANE	NMVOC	CARBON MONOXIDE	NITROUS OXIDE	CARBON DIOXIDE
Jet	2,808.0	125,208.72	290	2	18	120	N/A	71,500	0.0360	0.0003	0.0023	0.015	N/A	8.95
Piston	1,411.2	83,221.76	80	60	540	24,000	0.9	69,300	0.0005	0.0038	0.0340	1.520	0.00006	4.38

N/A = Not Available

Data Source: Civil Aviation authority, Uganda and Uganda Airlines.

1.4.5 EMISSIONS FROM COMBUSTION OF FUEL FROM MARINE VESSELS

1.4.5.1 Data Source:

The data was obtained from the Uganda Railways Corporation for the year 1990. It is to be noted, here that fuel data for Uganda Railways Corporation's ships was available. This fuel is consumed in Uganda although ships ply throughout the Lake Victoria zone covering all the three countries (Uganda, Kenya and Tanzania). This fuel data was not segregated enough to indicate what percentage was used as bunker fuel.

1.4.5.2 METHODOLOGY

As in previous estimations, the IPCC method for mobile source emissions was used to estimate the emissions. The total combustion of 2.078 metric tonnes was translated into 90,043 GJ of energy consumption as displayed in Table 1.9.

1.4.6 EMISSIONS FROM PISTON ENGINE AIRCRAFTS (LOCAL FLIGHTS)

1.4.6.1 Data Source

The data was obtained from the Soroti Flying School for 1990. These are the main operators of piston aircrafts in the country. Most of their fuel, 47,600 litres, was supplied in drums to the School, while about 10% of this was uplifted from Entebbe Airport directly. The total amount of fuel was 52,360 litres which translates to 1740 GJ of energy consumed. Emissions estimates from this source are displayed in Table 1.9.

1.4.6.2 Margin of Error

There are a few occasional flights by private fliers between Entebbe and Arua. This data could not be obtained and is assumed to be insignificant. In view of this, emissions estimates for local flights may be slightly less than the actual figures by about 5% - 10%.

1.4.6.3 METHODOLOGY

The same Methodology as for mobile combustion was used. The results are contained in Table 1.10.

1.4.7 EMISSIONS FROM AIRCRAFTS (JET ENGINES AND PISTON ENGINES), FOR INTERNATIONAL AIR TRANSPORT (BUNKERS)

1.4.7.1 Data Source

The data was obtained from Civil Aviation Authority and Uganda Airlines for the year 1990.

It is to be noted that emission factors have been developed for most commercial aircraft types. These are expressed in terms of emissions per landing and take off cycle. One problem with these factors is that they include only emissions in the immediate vicinity of the airport. Emissions under cruise conditions are not included. According to IPCC, data on cruise emissions is being developed by the USA Federal Aviation Administration and is not available at this time. The factors for jet turbine aircraft were developed by Radian (1990) based on emissions from Platt and Whitley JT-17 Engine. The emission factors for small gasoline fuelled piston aircraft were developed by Radian (1990) based on cessna Engine.

1.4.7.2 METHODOLOGY

As in previous estimates the IPCC method for mobile source emissions was used to estimate the emissions. The total combustion of 2,808 metric tonnes of jet fuel was translated into 125,208.72 GJ of energy consumption as displayed in Table 1.10; also 1411.2 metric tonnes of gasoline fuel was translated into 63221.76 GJ of energy consumption which is also displayed in Table 1.10.

1.5 COMPARISON OF CO_2 EMISSION ESTIMATES BETWEEN THE PRIMARY METHODOLOGY AND SECTOR ACTIVITY APPROACHES

A comparison of emissions as derived from the sector activity approach and primary methodology was done for the secondary fuels. In the case of emissions from petroleum and diesel there was a general agreement between the two. The comparison results are given in Tables 1.11 and 1.12 below.

1.6 CO_2 EMISSIONS ACCOUNTING FROM GASOIL (TO COMPARE WITH BASE YEAR 1990)

TABLE 1.11		
GASOIL EMISSIONS ACCOUNTING		
ACTIVITY	PRIMARY METHODOLOGY EMISSIONS (Gg)	ACTIVITY EMISSIONS (Gg)
Total Emissions from Gasoil	263.77	N/A
Emissions from Thermal Generators	N/A	1.48
Emissions from road Transport	N/A	238.51
Emissions from Locomotives	N/A	6.78
Emissions from Marines, Vessels	N/A	6.97
Total	263.77	253.74
Emissions unaccounted for are 10.3 Gg which is approximately 4% of the CO_2 Emissions from Gasoil.		

1.7 CO_2 EMISSIONS ACCOUNTING FROM GASOLINE (TO COMPARE WITH BASE YEAR 1990)

TABLE 1.12		
EMISSIONS DUE TO GASOLINE		
ACTIVITY	PRIMARY METHODOLOGY EMISSIONS (Gg)	ACTIVITY EMISSIONS (Gg)
Total Emissions from Gasoline	269.85	N/A
Emissions from road Transport	N/A	245.709
Emissions from Motor Boats	N/A	7.980
Emissions from Piston Aircrafts	N/A	1.2058
Total	269.85	254.90
Emissions unaccounted for are 15.05 Gg which is approximately 6% of the CO_2 Emissions from Gasoline.		

1.8 ACTIVITY EMISSIONS FOR OTHER FUELS

The other primary fuels utilised for energy are kerosene, furnace oil, jet-fuel and fuel-oil. Unfortunately, the utilisation of these fuels has not been disaggregated. It is therefore not possible to estimate emissions from individual activities.

1.9 ESTIMATION OF GHG EMISSIONS FROM BIOMASS BASED FUELS

1.9.1 Data Sources

Various data sources on wood-fuel utilisation are scrutinised. These include the National Biomass Study (on-going in the Department of Forestry) and publications by:

UNDP/World Bank (1990);

R.A. Plumtree and J. Carvalho (1991); and

P.C. Howard (1991).

It was found that there were significant variations in these data sets. It was, however, decided that the National Biomass Study Project offered the most reliable information. The following assumptions have been made to estimate wood-fuel utilisation.

The urban population, including those with facilities for electricity/LPG, use charcoal for domestic cooking.

All rural people use firewood.

The percentage of urban people using other fuels (electricity/LPG) is offset by that of rural people using charcoal.

1.9.2 Total Wood-fuel consumption.

Uganda's per capita charcoal consumption is estimated at 150 kg (National Biomass Study, 1992) in urban areas, while the urban population is 1,882,600 (1991 National Census). This brings total charcoal consumption (1991) to 282.39 Kilo tonnes (kt). On the other hand, per capita consumption of air-dry biomass is estimated at 750 kg (National Biomass Study, 1992). Uganda's rural population (1991) was estimated to be 14.7 million, bringing the total consumption of firewood to 11,025 Kilo Tonnes (kt). These figures are inclusive of dry-biomass used in biomass burning industries, e.g. brick-making, jaggeries, tea and tobacco curing, fish drying, etc.

1.9.3 Wood to Charcoal Conversion factors

In Uganda, wood conversion to charcoal is done through the use of earth kilns. Some limited surveys and estimates have given conflicting figures on the efficiency of these kilns, in the range of 10 - 15% (by weight). On the other hand, the National Biomass Study Team (1992) after considering a number of factors on the Uganda wood-to-charcoal conversion scene, adopted an average conversion factor from charcoal to air dry biomass of 6.6 (i.e. approximately 15.2% wood to charcoal efficiency by weight). The consumption factor of 6.6 has been used.

Total carbon released in conversion of wood to charcoal was calculated as follows:

Produced charcoal = 282.39 kt.
Expansion factor = 6.6
Wood used for charcoal burning = 282.39 x 6.6
= 1863.77 kt
Carbon content of wood = 0.3310 KT
Carbon content of charcoal = 0.8473
Carbon in wood = 0.3310 x 1863.77 = 616.90 kt
Carbon in charcoal = 0.8473 x 282.39 = 239.27 kt
Carbon released in the conversion is therefore 616.90 - 239.27 = 377.63 kt.

1.9.4 EMISSION FACTORS AND ERROR MARGIN

Country specific figures for the carbon content, nitrogen content, C/N and N/C ratios were determined experimentally. These figures have been used in the emissions calculations (Ref. Tables 1.13 and 1.16). It should be noted that there is quite a wide range in both the carbon and nitrogen contents. Both these figures have been used in the determination of the emissions to arrive at a reasonable margin of error. It has been found that the range is quite big, in excess of +/-20%, for the total emissions due to bio-fuels combustion (see Chapter Seven for details of study).

TABLE 1.13					
CARBON RELEASED IN WOOD FUEL COMBUSTION					
TYPE OF BIOMASS	TOTAL BIOMASS CONSUMED (kt)	BURNING EFFICIENCY (%)	BIOMASS BURNED (kt)	C-CONTENT OF BIOMASS Kg C/Ton	TOTAL C RELEASED (kt)
Wood	11025.00	87.0	9592.00	0.3310	3165.0
Charcoal	282.39	88.0	248.00	0.8473	211.0
Wood burned to provide charcoal	1863.77	N/A	1863.77	N/A	377.63
Total			11703.77		3753.63

TABLE 1.14						
CALCULATION OF TRACE GAS EMISSIONS FROM CARBON EMISSION ESTIMATES FROM WOOD-FUEL						
TOTAL C RELEASED (kt)	NITROGEN CONTENT OF BIOMASS kgN/Ton	TOTAL N RELEASED (KT)	TRACE GAS EMISSIONS RATIO	TRACE GAS EMISSIONS: (kt C OR N)	CONVERSION FACTORS	TRACE GAS EMISSIONS (kt GAS)
3,165.00			0.01 (CH4)	31.65 (CH4)	16/12	42.198 (CH4)
			0.10 (CO)	316.500 (CO)	28/12	738.489 (CO)
	0.01475	47.475	0.007 (N_2O)	0.332 (N_2O)	44/28	0.521 (N_2O)
			0.1210 (NO_X)	5.744 (NO_X)	30/14	12.308 (NO_X)

NOTE: CO_2: C = 44:12.

Then, CO_2 emission is given by: 3,165.0 x 44/12 = 11,605.42 kt.

TABLE 1.15						
CALCULATION OF TRACE GAS EMISSIONS FROM CARBON EMISSION ESTIMATES FROM CHARCOAL						
TOTAL C RELEASED (kt)	NITROGEN CONTENT OF BIOMASS	TOTAL N RELEASE D (kt)	TRACE GAS EMISSION S RATIO	TRACE GAS EMISSION S: (kt C OR N)	CONVERSI ON FACTORS	TRACE GAS EMISSIONS (kt GAS)
211.0			0.0014 (CH4)	0.295 (CH4)	16/12	0.393 (CH4)
			0.060 (CO)	12.66 (CO)	28/12	29.539 (CO)
	0.010	2.11	0.007 (N_2O)	0.015 (N_2O)	44/28	0.023 (N_2O)
			0.1210 (NO_X)	0 .255 (NO_X)	30/14	0.546 (NO_X)
NOTE: CO_2: C = 44:12. Then, CO_2 emission is given by: 211.0 x 44/12 = 773.67 kt.						

TABLE 1.16						
CALCULATION OF TRACE GAS EMISSIONS FROM CARBON EMISSION ESTIMATES FROM WOOD-FUEL FOR CHARCOAL						
TOTAL C RELEASED (kt)	NITROGEN CONTENT OF BIOMASS	TOTAL N RELEASE D (kt)	TRACE GAS EMISSION S RATIO	TRACE GAS EMISSION S: (kt C OR N)	CONVERSI ON FACTORS	TRACE GAS EMISSIONS (kt GAS)
377.63			0.063 (CH4)	23.79 (CH4)	16/12	31.72 (CH4)
			0.060 (CO)	22.65 (CO)	28/12	52.86 (CO)
	0.01475	2.43	0.007 (N_2O)	2.64 (N_2O)	44/28	4.15 (N_2O)
			0.1210 (NO_X)	4.569 (NO_X)	30/14	9.79 (NO_X)
NOTE: CO_2: C = 44:12. Then, CO_2 emission is given by: 377.63 x 44/12 = 1384.64 kt.						

1.9.5 EMISSIONS FROM BAGASSE

Bagasse is used to fire boilers to produce process heat in the two operational sugar industries, i.e. Sugar Corporation of Uganda Limited (Lugazi) and Kakira Sugar Works (Jinja). Data on bagasse consumption was obtained from these two sugar industries. The third industry, Kinyara Sugar Works, is not yet operational and is awaiting rehabilitation.

The CO_2 emissions have been estimated using the IPCC module for the years 1988 - 1992. The result obtained was 31.82 kt of CO_2 for 1988 using the IPCC default values. This result was checked by ordinary calculation using the bagasse to CO_2 National conversion figure of 75.2% as determined by the Sugar Corporation of Uganda (SCOUL). The result was 32.09 kt of CO_2, which compares very well with the IPCC methodology result. For the base year 1990, the two results were 75.97 kt and 76.59 kt respectively.

Table 1.17 shows GHG emissions from bagasse combustion. It can be seen that the proportion of CO_2 emissions from bagasse was only 0.57% of the total bio-fuels CO_2 emissions. Considering that there is a margin of error of +/-20% in emission estimates, the results from bagasse may not be worth considering.

The Table 1.17 below shows GHG Emissions from Bagasse.

TABLE 1.17

GREENHOUSE GAS EMISSIONS FROM BAGASSE COMBUSTION

YEAR	TOTAL BAGASSE BURNED	BURNING EFFICIENCY %	BIOMASS BURNED IN kt	CARBON CONTENT BAGASSE	TOTAL CARBON RELEASED BY BAGASSE kt	NITROGEN CONTENT OF BAGASSE	TOTAL NITROGEN RELEASED FROM BAGASSE kt
1988	42.67	90	38.4	0.226	8.679	0.01475	0.56
1989	89.22	90	80.3	0.226	18.147	0.01475	1.18
1990	101.86	90	91.67	0.266	20.72	0.01475	1.35
1991	127.93	90	115.14	0.266	26.02	0.01475	1.69
1992	173.71	90	156.34	0.266	35.33	0.01475	2.30

TABLE 1.17 "CONTINUED"

YEAR	CH_4 RELEASED IN kt	CO RELEASED IN kt	N_2O RELEASED IN kt	NOX RELEASED IN kt	CO2 RELEASED IN kt	TOTAL MASS OF ALL GASES RELEASED FROM BAGASSE (kt)
1988	0.0868	0.0868	0.0039	0.068	31.82	33.11
1989	0.1815	1.815	0.0083	0.141	66.54	69.86
1990	0.207	2.07	0.0095	0.162	75.97	*79.77
1991	0.260	2.6	0.0119	0.203	95.41	99.92
1992	0.353	3.53	0.016	0.275	129.54	135.67

NOTES: * In 1988, only the Sugar Corporation of Uganda, Lugazi (SCOUL) burned bagasse to the tune of 42,670 Tonnes. From 1989 onwards, both SCOUL and Kakira Sugar Works burned bagasse as indicated above.

1.9.6 EMISSIONS FROM OTHER BIOMASS

In Uganda, other types of biomass combusted for energy include agricultural wastes and biogas from cow-dung. The statistics on the former are not available. Although several small projects in bio-gas technology have been initiated, it is not likely that more than ten digesters are in full time operation. Moreover, those in operation would combust most of the CH_4 produced, with insignificant amounts of CO_2 released into the atmosphere. A small amount of CH_4 may get lost into the atmosphere.

Summary of total emissions from bio-fuels with error margins. Bagasse emissions have been excluded in view of the error limits.

CO_2	....	12,973	kt +/-20%
CH_4	....	56	kt +/-45%
CO	....	790	kt +/-40%
N_2O	....	0.57	kt +/-50%
NO_x	....	13.5	kt +/-45%

Total GHG gas emissions (excluding bagasse) = 13,833.07 kt +-20%

(If bagasse is included for 1991, the total GHG emissions are: = 13,913.1 kt +-20%).

The summary of results is given below in the Minimum Data Tables 1 A (Part 1 to 3) and 1 A 8.

MINIMUM DATA TABLES I ENERGY

I A Energy Fuel Combustion Activities (Part I)

SOURCE AND SINK CATEG	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSIONS FACTORS					
Sector Specific Data (units)	A Apparent Consumption (Pj)	B (Gg of full mass of pollutant)						C (kg (pollutant)/Gj) C=B/A					
		CO2	CH4	N2O	NOx	CO	NM VOC	CO2	CH4	N2O	NOx	CO	NM VOC
I A Fuel Combustion Activities													
Oil	9.921083	708.2					N/A	71.38					N/A
Gas	0.006576	0.4					N/A	60.82					N/A
Coal		N/A	N/A				N/A						
Biomass	125.539	13763	74.52	4.704	22.81	822.93	N/A	109.6	0.594	0.037	0.182	6.56	
Other (specify)													
I A 1 Energy & Transformation Activities													
Oil													
Gas													
Coal													
Biomass													
Other (specify)													
I A 2 Industry (ISIC)													
Oil													
Gas													
Coal													
Biomass													
Other (specify)													

I A Energy Fuel Combustion Activities (Part 2)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSIONS FACTORS					
Sector Specific Data (units)	A Apparent Consumption (Pj)	B (Gg of full mass of pollutant)						C (kg (pollutant)/Gj) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NM VOC	CO_2	CH_4	N_2O	NO_x	CO	NM VOC
I A 3 Transport													
Oil	7.092173	507.15	0.126	3.95	0.54	27.27	4.99	71.50	0.017	11.042	0.076	3.845	0.703
Gas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biomass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other (specify)													
I A 4 Commercial/ Institutional													
Oil	1.18972479	63.00						53.00					
Gas													
Coal													
Biomass													
Other (specify)													
I A 5 Residential													
Oil	1.5987385	113.74						71.14					
Gas	0.006576	0.40						60.80					
Coal													
Biomass													
Other (specify)													

I A Energy Fuel Combustion Activities (Part 3)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSIONS FACTORS					
Sector Specific Data (units)	A Apparent Consumption (Pj)	B (Gg of full mass of pollutant)						C (kg (pollutant)/Gj) C=B/A					
		CO2	CH4	N2O	NOx	CO	NM VOC	CO2	CH4	N2O	NOx	CO	NM VOC
I A 6 Agriculture/ Forestry													
Oil	0.013354	0.9788	0.0001	0.0135	0.00	0.006	0.002	73.29	0.007	1.01	0.00	0.509	0.179
Gas													
Coal													
Biomass													
Other (specify)													
I A 7 Other													
Oil													
Gas													
Coal													
Biomass													
Other (specify)													

I A 8 Optional Reporting Format for Traditional Biomass Burned for Energy

	ACTIVITY DATA	EMISSION ESTIMATES					AGGREGATE EMISSIONS FACTORS				
Sector Specific Data	A Apparent Consumption (kt dm)	B (Gg)					C (t/t dm) C=B/A				
		CH4	N2O	NOx	CO	NM VOC	CH4	N2O	NOx	CO	NM VOC
Fuelwood	3165.00	42.198	0.521	12.308	738.459	N/A	0.01330	0.00016	0.00380	0.2330	N/A
Charcoal Production	377.63	31.720	4.150	9.790	52.860	N/A	0.08390	0.01090	0.02590	0.1399	N/A
Charcoal Consumption	211.00	0.393	0.023	0.546	29.539	N/A	0.00186	0.01090	0.00258	0.1399	N/A
Dung											
Agricultural residues											
Bagasse	20.72	0.207	0.010	0.162	2.070	N/A	0.00990	0.00040	0.00780	0.0990	N/A
Other (specify)											

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7. Department of Fisheries, Ministry of Agriculture, Animal Industry and Fisheries: Unpublished Data on fishing vessels (1988 and 1980).

8. Uganda Electricity Board: Unpublished Data on Thermal Generators (1992 - 1993).

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19. Uganda Airlines Corporation.

CHAPTER TWO

2. GHG EMISSIONS FROM INDUSTRIAL PROCESSES

2.1 CEMENT

Uganda has got two Cement Factories - Tororo and Hima. The following report is from available information obtained from the two factories and also from the Headquarters of the Uganda Cement Industry in Kampala. The Uganda cement Industry co-ordinates national cement production and importation. Records were also obtained from the 1993 budget survey from the Statistics Department based in Entebbe.

2.1.1 Tororo

Tororo Cement Factory has an installed capacity of 150,000 tonnes annually. By 1969 the factory was producing above capacity at 170,224 tonnes per annum. However, production started declining significantly from 1973 when production dropped to about 45% of the installed capacity and reached the lowest level since installation of about 4% during the civil war of 1979. Since then production has fluctuated from about 9% to 3% of the installed capacity. The 1993 production was only about 3%.

2.1.2 Hima

Hima Cement Factory has got an installed capacity of 250,000 tonnes annually but has never worked efficiently. In the recent years production has just been around 3%. Table 2.1 below gives Annual Cement Production figures based on Factory Records.

TABLE 2.1

ANNUAL CEMENT PRODUCTION FIGURES BASED ON FACTORY RECORDS

YEAR	TORORO FACTORY TONNES	HIMA FACTORY TONNES	TOTAL TONNES	CO_2 TONNES	ERROR MARGIN
1988	5,718	9,842	15,560	7,756	+/-4%
1989	11,223	5,577	16,800	8,375	+/-3%
1990	8,903	22,014	30,917	15,412	+/-14%
1991	6,341	25,097	31,438	15,672	+/-15%
1992	4,841	43,978	48,819	24,336	+/-25%

2.1.3 Conversion Factor

The conversion factor used to convert from tonnes of cement to tonnes of CO_2 is 0.4985. This arises out of taking the pure lime conversion factor as 0.785 and an average lime cement content of 63.5% as recommended in the IPCC guidelines.

2.1.4 Error Margin

Error margin

$$= \frac{\text{Factory figures} - \text{Headquarters figures}}{1/2(\text{Factory figures} + \text{Headquarters figures.})}$$

The error margin is calculated using the difference in the figures as given at the factories and as recorded at the Uganda Statistics Department, Entebbe and published in the annual budget survey booklets. The 1993 budget survey booklet was used to get historic data for the calculations. Except for 1989, the figures reported in the budget survey booklet were lower than those obtained directly from the factories.

The error margin, according to the figures for the years 1988 - 1991, ranges from 3 - 15% as shown in the above Table, the figure of 25% for 1992 seems to be due to incomplete returns at the Statistics Department.

2.2 LIME

Data on lime production was obtained from the Cement Factories and the privately operated kilns around Tororo and Hima.

2.2.1 Tororo Area

The Tororo Cement Factory was producing lime in addition to cement but production ceased since 1988. Lime production at the factory reached a peak in 1970 when production was about 19,000 tonnes but this dropped to zero in 1976 due to lack of charcoal. As a result of the Cement Factory ceasing lime production, locally operated kilns emerged, using firewood as fuel and presently 15 of them are operating. Production from the kilns is not well known since each individual one operates almost independently with production being very much influenced by demand.

Estimate of lime production from the private kilns:

(i) Estimated weekly kiln production = 20 tonnes.

(ii) Estimated production per kiln for three working weeks of the month = 20 x 3 tonnes

(iii) Estimated monthly production for the 15 kilns = 20 x 3 x 15 tonnes

(iv) Estimated annual production for eight working months = 20 x 3 x 15 x 8 tonnes = 7,200 tonnes

(i) CO_2 released assuming CaO content of about 56% and a conversion factor of 0.785, i.e. = 7,200 x 0.56 x 0.785 = 3,165 tonnes

2.2.2 LIME PRODUCTION IN KASESE DISTRICT

There are three main centres of lime production in the Kasese District:

(i) At Hima, Kilembe Mines Lime Works where the lime produced contains 57% pure CaO.

(ii) At Equator Lime Company Limited, the lime produced contains 55% pure CaO.

(iii) At NEC Lime, Dura Limited the lime produced contains 57% pure CaO.

Table 2.2 below gives annual CO2 emissions due to lime production.

TABLE 2.2

(PURE CaO) - CO_2 EMISSIONS DUE TO LIME PRODUCTION

YEAR	HIMA LIME TONNES	EQUATOR LIME TONNES	NEC LIME TONNES	LIME TONNES	TOTAL TONNES	CO_2 TONNES
1988	465	-	-	-	465	367
1989	705	-	10,260	4,032	14,997	11773
1990	876	-	30,780	4,032	35,688	28,015
1991	677	247.5	61,560	4,032	66,517	52,216
1992	1259	27.5	68,400	4,032	73,719	57,870
Conversion factor for lime = 0.785						

2.2.3 LIME PRODUCTION IN OTHER AREAS OF THE COUNTRY

There are other secondary areas of lime production to the south-western and north-western areas of the country which were not visited due to limited time and resources. These are estimated to contribute 10% - 20% of the national lime production.

2.3 FOAM MATTRESS INDUSTRIES

The process of foam making is summarized as follows:

Polyol)
H_2O)
Amine) mixed in one tank
Silicon)
Stannate-octate)

Toluene - Di-Isocyanate (TDI) is contained in another tank.

These two tanks are programmed to release calculated proportions into a shaped container where the chemical reactions take place forming foam which takes the shape of the container. During the reactions carbon dioxide is also released.

The Vitafoam Factory, Jinja gave an empirical conversion factor of 8% of the weight of the raw materials used as the amount of CO_2 released. Since the production processes in the other factories is similar this conversion factor has been used for all the foam factories in the country.

Table 2.3 below, gives the amount of raw materials used in tons and corresponding amount of CO_2 released:

TABLE 2.3

CO_2 EMISSIONS DUE TO FAOM PRODUCTION

YEAR	VITAFORM INDUSTRY (TONNES)	UGANDA FOAM INDUSTRY (TONNES)	NEC FOAM INDUSTRY (TONNES)	TOTAL (TONNES)	CO_2 (TONNES)
1988	410	475	33	918	73
1989	510	475	33	1,018	81
1990	370	475	33	878	70
1991	460	475	33	968	77
1992	390	475	33	898	71

It is estimated that 8% of the weight of the raw materials used is released as CO_2.

2.4 METHANE PRODUCTION

There is no industry producing significant amounts of methane.

A Summary of the results is given below in the Minimum Data Table 2 - Industrial Processes.

Minimum Data Tables 2 Industrial Processes

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Production quantity (t)	B (full mass of pollutant) (Gg)						C Pollutant per tonne of product (kg or t/t) C=B/A					
		CO	CO2	CH4	N2O	NOx	NM VOC	CO	CO2	CH4	N2O	NOx	NM VOC
2 INDUSTRIAL PROCESSES													
A. Iron and Steel													
B. Non-ferrous Metals													
Aluminium Production													
Other													
C. Inorganic Chemicals (excepting solvent use)													
Nitric Acid													
Fertilizer Production													
Other													
D. Oganic Chemicals													
Adipic Acid													
Other													
E. Non-Metalic Mineral Products													
Cement	30917		15.4						2007.59				
Lime	35688		28.0						1274.57				
Other (FOAM)	878		0.1						8780.00				
F. Other (ISIC)													

References:

1. OECD (Organisation for Economic Co-operation and Development) (1991), Estimation of Greenhouse Gas Emissions and Sinks, Final Report from the OeCD expert meeting, 18 - 21 February 1991, Paris, France.

2. Budget survey report (1993). Ministry of Finance and economic planning Statistics Department.

CHAPTER THREE

3. GHG EMISSIONS FROM SOLVENTS

3.1 PAINT

Production of Paint from local industries is shown in Table 3.1 below:

TABLE 3.1						
ANNUAL PRODUCTION OF PAINT						
YEAR	1986	1987	1988	1989	1990	1991
ACTUAL PRODUCTION x 1000 LITRES	288	170	176	315	148	311
CAPACITY UTILISATION (%)	6.7	3.9	4.1	7.3	3.4	7.7
INSTALLED CAPACITY (LITRES)						4.311.000
AMOUNT OF SOLVENT, (21.9%) OF PAINT						944.109

3.1.1 Source: Budget Survey Report 1993 (Ministry of Finance and Economic Planning).

Local paint production is still very low with the factory capacity utilisation below 10%. To make up for the installed capacity or national demand, paint is imported mainly from Kenya. However, data on the amount of imported paint could not be obtained readily. At the moment we can only assume that the import is about equal to the difference between the installed factory capacity and what is produced locally.

3.1.2 PERCHLOROETHYLENE

There are about ten main dry cleaning companies in Uganda. The common dry cleaning agent used is the perchloroethylene. A sample of the dry cleaning companies indicated that they use between 200 to 300 litres of the solvent, that is an average of 250 litres per month. For a year for the ten companies = 250 x 12 x 10 = 30,000 litres.

3.1.3 CARBON TETRACHLORIDE

From a report of a UNEP Sponsored National Case Studies on Ozone of 1993, small quantities of carbon tetrachloride were found to be imported for use as solvents, mainly in laboratories. The users of carbon tetrachloride identified through the survey were Universities, School Laboratories and textile industries. The total import is less than 1 ton per year.

3.1.4 CONCLUSION

The total amount of non-methane volatile organic compounds (NMVOC) arising out of Solvent use is approximately 1.000 tonnes mainly out of paint use. The error associated with this figure is estimated to be between 20% - 30% due to the poor records of imported paint. Imported paint accounts for about 90% of the market demand due to the present low capacity production of the local industries.

References:

1. Report of a UNEP Sponsored National Case study on Ozone depleting substances (July 1993) undertaken by the Department of Environment Protection.

2. Budget Survey report 1993. Ministry of Finance, Statistics Department.

CHAPTER FOUR

4. GREENHOUSE GAS (GHG) EMISSIONS FROM AGRICULTURE AND SAVANNA BURNING

4.1 METHANE EMISSIONS FROM LIVESTOCK

4.1.1 BACKGROUND

Of domesticated animals, ruminant animals (cattle, buffalo sheep, goats and camels) are the major source of methane emissions with cattle being the most important source globally.

Methane is produced as part of the normal fermentative digestive process of animals. Ruminant animals are characterized by a large "fore-stomach" or rumen. Within the rumen microbial fermentation breaks down feed into soluble products which together with the digestion products are utilized by the animal. The microbial fermentation that occurs in the rumen enables ruminant animals to digest complex plant carbohydrates which monogastric animals including humans cannot digest.

Methane is produced in the rumen by bacteria as a by-product of the fermentation process. This methane is eructated and exhaled by the animal.

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

4.1.2 EMISSION INVENTORY METHOD

In order to estimate emissions of methane from livestock, the OECD (1991) Report recommends the following steps:

(a) Enumerate the number of animals by species.

(b) Characterise the population of each animal species and divide the population into reasonably homogeneous categories, e.g. age, size, feeding and production level; and management system.

(c) Estimate methane emission factors for each category of animal by:

(i) estimating the animal feed energy intake for each animal representative of the category.

(ii) estimating the portion of the feed energy intake that will be converted to methane.

(iii) estimating the emission factor by multiplying the feed intake by the portion of the feed energy converted to methane.

(d) Estimate total methane emissions by multiplying the emissions factor by the number of animals for each category and summing across categories.

4.1.2.1 **Enumeration**

The National Census of Agriculture and Livestock was undertaken as a joint effort between the Government of Uganda, UNDP as the funding agency and FAO as the executing agency in 1990 - 1991. (Vol I Methodology of Census). However, the main livestock area of Karamoja and districts of Gulu, Kitgum, Kumi and Soroti were excluded due to the then prevailing insurgency in the region. Kampala District which is predominantly urban was also excluded from the census coverage. The National Census gave the cattle numbers as 4.332, 4.560, 4.800 million for 1988, 1989, and 1990 respectively. According to FAO AGROSTAT PC[3] however, the cattle position stood as 4.26 million minimum and 4.738 million mean in 1988 with a national herd growth of 5%.

The projection therefore would give cattle numbers as indicated below:

	Minimum	Mean
1988	- 4.260 million	4.734 million
1989	- 4,473 million	4.975 million
1990	- 4.699 million	5.224 million
1991	- 4.932 million	5.485 million

Projection for other domestic animals were as follows in millions:

Year	Sheep	Goats	Pigs	Poultry
1988	0.74	3.1	0.90	11.1
1989	0.79	3.5	0.77	12.3
1990	0.84	3.8	0.76	13.7
1991	0.9	4.1	0.80	15.2

---

3 *The FAO AGROSTAT PC is a statistical Package which gives figures of production and consumption for the whole world, country by country and sub-sector by sub-sector in the fields of livestock, crops and fisheries.*

4.1.2.2. Domestic Animals Categorisation

Uganda's National herd mainly comprises of indigenous cattle. The average mature weight is 220 kg and the average milk production is two litres per day (source, Ministry of Agriculture, Animal Industry and Fisheries).

4.1.2.3 Estimation of Methane Emission Factors

Efforts are being made to get country specific factors required to determine methane emission factors of Uganda cattle. This report contains default factors which will be replaced as soon as country specific factors are determined. The method of determining the methane emission factors is outlined in Section 4.1.2.

4.1.2.3.1 Feed Intake Level

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

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

Assuming that Uganda's national sward is also of 50 percent digestibility and taking the average live weight to be 220 kg, the average daily feed intake should be 1.9 percent of 220 kg per animal which is close to 4 kg. Because the cattle that consume mostly low quality forage in tropical regions have relatively low rates of growth and milk production, estimates of the efficiency of energy retention for growth or milk production do not contribute significantly to the estimate of total feed intake. Using more recent work performed in Australia, the following activity factors are recommended for the energy required for grazing (Michael J. Gibbs, et al 1993).

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

Animals grazing good quality pasture; 17 percent of NEm and Animals grazing over very large areas 37 percent of NEm.

where NEm is the net energy required for maintenance in Megajoules (MJ/day).

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

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

$NEm\ (MJ/day) = 0.322 \times (220)^{0.75} = 18.4$

Because of grazing over very large areas 37 percent of NEm will be required which is $\frac{37}{100} \times 18.4 = 6.8$ MJ/day

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

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

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

Where:

GE = Gross-feed energy intake

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

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

$NE/DE = 0.298 + 0.0035 \times DE\%$

DE = 60% (default value)

Therefore: NE/DE = 0.499

NE_g = Net energy required for growth (negligible)

Therefore, ignoring the term NE_g, the above equation gives: GE = 84.17 MJ/day.

4.1.2.4 <u>Conversion of feed intake to methane</u>

OECD (1991) recommends the statistical relationship developed by Balaxter and Clappeton (1965) to estimate the portion of feed intake that will be converted to methane in well balanced forage diets and mixed with forage/grain diets as found in temperate agriculture systems.

To simplify matters somewhat for poor quality tropical agriculture diets, a general assumption that 6.0 percent of feed energy is converted to methane is used.

Therefore:

$$\frac{6.0 \times (84.19)}{100} = 5.05 \text{ MJ/day}$$ gives the energy converted to methane.

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

5.05 MJ/day x 365 days = 1843.32 MJ/head/year. 55.65 MJ is equivalent to 1 kg of CH_4.

Therefore, 1843.32 x 0.018 = 33.2 kg CH4/head/year.

4.1.3 METHANE EMISSIONS FROM RUMINANT AND PSEUDO RUMINANTS

The simple method based on emission factor per animal has been adopted here. An Emission factor for cattle in Uganda has been calculated as above. Emission factors as calculated by Crutzen et al (1986) from mean animal masses and mean intake of feed will be used for goats, sheep and pigs. (See Table 4.1 below).

TABLE 4.1

Animal Type	Number	Emission Factor Kg-CH4/Head/Year	Total CH4 Emission Gg CH4
1988			
Grazing Cattle	4,734,000	33.20	157.17
Goats	3,100,000	5.00	15.50
Sheep	740,000	5.00	3.70
Pigs	70,000	1.00	0.07
Total			176.44
1989			
Grazing Cattle	4,975,000	33.20	165.17
Goats	3,500,000	5.00	17.50
Sheep	790,000	5.00	3.95
Pigs	730,000	1.00	0.73
Total			187.35
1990			
Grazing Cattle	5,224,000	33.20	173.44
Goats	3,800,000	5.00	19.00
Sheep	840,000	5.00	4.20
Pigs	760,000	1.00	0.76
Total			197.40
1991			
Grazing Cattle	5,485,000	33.20	182.10
Goats	4,100,000	5.00	20.50
Sheep	900,000	5.00	4.50
Pigs	800,000	1.00	0.80
Total			207.90

4.2 METHANE EMISSIONS FROM LIVESTOCK MANURE

4.2.1 BACKGROUND

Manure is primarily composed of organic material and therefore the potential for methane emissions is great. The portion of this emission potential which is actually realised is a function of the manure management system. Anaerobic conditions will result in much methane production whereas manure kept in contact with oxygen (e.g. spread on fields) produces little amounts of methane. Other principal determinants of methane production from livestock manure are characterisation of the manure and the climate (Gibbs M.S., et al 1993).

Uganda's national herd mainly comprises of indigenous cattle and the manure management system is by deposits on pastures and ranges. The exotic cattle population is considered insignificant compared to the indigenous cattle. The composition of livestock manure which is primarily a function of the animal species and diet, determines its maximum methane producing capacity. In the tropics cattle are mainly fed on roughage diet which will produce less bio-degradable manure containing more complex organic substances such as hemi-cellulose, cellulose and lignin. On the other hand however, because of less digestibility of the pastures, cattle will take in a lot and produce much manure.

The climatic parameters like temperature and rainfall will affect both the rate and total amount of methane production in manure. A warm and moist environment promotes methane production. Uganda whose annual rainfall varies between 2500 mm -700 mm and mean maximum temperature 30^0C - 25^0C has favourable conditions for methane production from animal manure although the manure management system produces minimal emissions

4.2.2 METHODOLOGY FOR ESTIMATING EMISSIONS FROM LIVESTOCK MANURE

The major steps of the methodology recommended in the OECD (1991) Report are as follows:

(i) Estimate the amount of volatile solid produced for each animal type (VS) using published statistics on animal populations, animal sizes and manure generation rates.

(ii) Estimate the maximum methane producing capacity for the manure from each animal type (Bo).

(iii) Define the manure management systems in use and for each system estimate its methane producing potential (MCF).

(iv) Estimate methane emissions for each animal type and manure management system (TM) by multiplying the amount of volatile solids produced by the animal type (VS) by the methane producing capacity of the manure Bo and by the methane producing capacity potentials of the manure management system (MCF).

(v) Total methane emission will be the sum over all animals types and all manure systems.

4.2.3 Calculation of Emissions

Total Methane emissions for each animal type for one year may be calculated with the following formula recommended by OECD 1991.

$$TM = VS \times Bo \times MCF \times 365 \times \text{Density of } CH_4/10^9$$

Density of Methane = 0.662 kg/m^3.

The estimates of VS, Bo, MCF were recently modified by the US Environment Protection Agency EPA 1993 (Gibbs M.J. et al 1993) -see Table 4.2 below.

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

For Waste Production in cattle, the Tanzania figures, where experiments have been carried out, will be used since they are more representative of the region. These figures are given in the Tanzania preliminary report on sources and sinks of greenhouse gases.

TABLE 4.2

DESCRIPTION	CATTLE	SHEEP	GOATS	PIGS	POULTRY
VS kg/head/day	1.7	0.37	0.49	0.41	0.02
B_0 (m^3 CH_4/kg VS)	0.10	0.13	0.13	0.29	0.24
Manure Management System	Pasture Range and Paddock (PRP)	PRP	PRP	Solid Storage and Drylot	PRP
MCF at 30^0c	2%	2%	2%	5%	2%
MCF at 20^0C	1.5%	1.5%	1.5%	1.5%	1.5%

Using the animal population figures given in 1.2.1 and MCF at 30^0C, the following emissions were obtained - see Table 4.3 below.

TABLE 4.3

Animal Type	Animal Population	Waste Production Kg/d/TAM	Volatile Solids Production Kg/head/day	Emissions Potentials Bo (M ^ 3/Kg Vs)	MCF at 30 C	Total Ch4 Gg/year
1988 (MINIMUM)						
Grazing Cattle	4,260,000	5.00	1.70	0.10	0.02	3.50
Pigs	700,000	4.10	0.41	0.29	0.05	1.01
Sheep	740,000	1.60	0.37	0.13	0.02	0.17
Goats	3,100,000	1.80	0.49	0.13	0.02	0.95
Poultry	11,100,000	0.12	0.02	0.24	0.02	0.26
Total						5.89
1989 (MINIMUM)						
Grazing Cattle	4,473,000	5.00	1.70	0.10	0.02	3.67
Pigs	700,000	4.10	0.41	0.29	0.05	1.01
Sheep	740,000	1.60	0.37	0.13	0.02	0.17
Goats	3,100,000	1.80	0.49	0.13	0.02	0.95
Poultry	11,100,000	0.12	0.02	0.24	0.02	0.26
Total						6.06
1990 (MEAN)						
Grazing Cattle	5,224,000	5.00	1.70	0.10	0.02	4.28
Pigs	760,000	4.10	0.41	0.29	0.05	1.09
Sheep	840,000	1.60	0.37	0.13	0.02	0.19
Goats	3,800,000	1.80	0.49	0.13	0.02	1.17
Poultry	13,700,000	0.12	0.02	0.24	0.02	0.32
Total						7.05
1990 (MINIMUM)						
Grazing Cattle	4,699,000	5.00	1.70	0.10	0.02	3.85
Pigs	760,000	4.10	0.41	0.29	0.05	1.09
Sheep	840,000	1.60	0.37	0.13	0.02	0.19
Goats	3,800,000	1.80	0.49	0.13	0.02	1.17
Poultry	13,700,000	0.12	0.02	0.24	0.02	0.32
Total						6.62
1991 (MEAN)						
Grazing Cattle	5,485,000	5.00	1.70	0.10	0.02	4.50
Pigs	800,000	4.10	0.41	0.29	0.05	1.15
Sheep	900,000	1.60	0.37	0.13	0.02	0.21
Goats	4,100,000	1.80	0.49	0.13	0.02	1.26
Poultry	15,200,000	0.12	0.02	0.24	0.02	0.35
Total						7.47
1991 (MINIMUM)						
Grazing Cattle	4,932,000	5.00	1.70	0.10	0.02	4.04
Pigs	800,000	4.10	0.41	0.29	0.05	1.15
Sheep	900,000	1.60	0.37	0.13	0.02	0.21
Goats	4,100,000	1.80	0.49	0.13	0.02	1.26
Poultry	15,200,000	0.12	0.02	0.24	0.02	0.35
Total						7.01

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

kg/head/year

Sheep	0.21
Goats	0.22
Poultry	0.023
Cattle	1.00
Pigs	2.00

These figures are for developing countries with warm climates. Comparing the emissions using the default emission factors and the emissions as computed above for 1990 (mean).

	DEFAULT	COMPUTED
Cattle	0.005 Tg	0.019 Tg
Sheep	0.00018 Tg	0.00031 Tg
Poultry	0.00032 Tg	0.000038 Tg
Goats	0.001 Tg	0.002 Tg
Pigs	0.0015 Tg	0.004 Tg

Apart from poultry whose results differ by an order of magnitude, the rest are comparable.

4.3 METHANE FROM RICE PRODUCTION

4.3.1 Background

Of the wide variety of sources for atmospheric CH_4, rice paddy fields are considered an important source because of the recent increase in their harvested area in the world. There are large temporal variations of CH_4 fluxes at various locations of the world. The fluxes differ markedly with soil type, application of organic matter and mineral fertilizer. The wide variations in CH_4 fluxes also indicate that the fluxes are critically dependent upon several factors including climate, characteristics of soils and paddy and agriculture practices.

The Intergovernmental Panel on Climate Change estimated the global emission rate from paddy fields to be ranging from 20 -150 Tg/year with an average of 60 Tg/year. This is about 5% - 30% of the total emissions from all sources (Katsuyuki Minami 1993). This significant percentage necessitates investigating emissions from rice paddies. The distribution of the harvested area of rice in the world is as follows:

Asia	129.011×10^6 ha
America	9.609×10^6 ha
Africa	4.755×10^6 ha
Rest	1.156×10^6 ha

Africa's harvested area is 3.3% of the world's (Katsuyuki Minami 1993).

4.3.2 RICE GROWING IN UGANDA

Paddy Rice is grown in reclaimed swamps. Uganda has a swamp area of about 520,000 hectares. Paddy rice is mainly grown in two districts namely Iganga at Kibimba Rice Scheme and Tororo at Doho. (Nkalubo M.S.Z. 1990).

Gulu District grows mainly upland rice. At Kibimba Rice Scheme about 520 hectares are under rice cultivation. Two crops are planted a year; the first crop planted during February/March is harvested in June/July. The second crop planted during August/ September is harvested in December/ January. The type of rice grown is Indica varieties K23 and K264 in the local coding. All the breeds are imported mainly from Philippines. The cultivation period is 120 days and the active flooding period is 90 days. Water supply for the crop is by irrigation which is supplemented by the seasonal rainfall (1400 mm per year) which comes in two seasons, March - May and September - November. Flash irrigation is done at germination. Two-three weeks after germination permanent flooding is done with flood depth being increased with growth of the rice up to a maximum of 10 - 15 cm. The area of paddy rice harvested in 1990 in all districts was given as 40349 ha and 7101 ha for upland rice grown in Gulu (source Ministry of Agriculture Monthly Reports). In 1991, there was 5.5% increase in the harvested area to 51934 ha; with 32904 ha under paddy rice and 19030 under upland rice.

4.3.3 RECOMMENDED METHODOLOGY OF CH4 EMISSION FROM RICE Cultivation

Base year: 1990 as average over 1990 - 1991.

Area of rice under flooded region A($m^{2)}$.

Emission factor for flooded condition E($Tg/m^2/day$).

Number of days under cultivation (season length) = D(days/year).

Calculate flux (flooded) = A x B x C.

Area of rice under flooded regimes for the two crops in the year for 1990 is 40349 ha.

Emission factors for flooded conditions are obtained from flux standards corrected for temperature as given by Katsuyuki Minami 1993 who divided the world's harvested area of rice paddies into 12 Climatic regions. Uganda fits better in the Malay-Northern Borneo Region which has a temperature of 27^{0}C and a minimum flux of 0.25 $g/m^2/day$ and a maximum of 0.82 $g/m^2/day$.

Number of days under cultivation is 120.

Low Estimate for 1990

CH_4 Gg = (Area in hectares x Number of days/year (when flooded) x Emission factor $10^4 m^2$/hectare x 10^{-9}) = 40,349 hectares x 120 days/year x 0.25 g/m^2/day x $10^4 m^2$/hectares x 10^{-9} = 12.129.

Low estimate for 1991

CH_4 Gg = 32,904 hectares x 120 days/year x 0.25 g/m^2/day x $10^4 m^2$/hectares x 10^{-9} = 9.907.

Average Low estimate = 11.018 Gg CH_4

High Estimate for 1990

CH_4 Gg = 40,349 hectares x 120 days/year x 0.82 g/m^2/day x $10^4 m^2$/hectares x 10^{-9} = 39.693 Gg CH_4.

High Estimate for 1991

CH_4 Gg = 32,904 hectares x 120 days/year x 0.82 g/m^2/day x $10^4 m^2$/hectares x 10^{-9} = 32.413

Average High Estimate = 36.053 Gg CH_4.

The IPCC Final Draft Greenhouse Gas Inventory Workbook, Volume 2 gives default activity data for harvested rice throughout the world. The default figures given for Uganda, however, differ from those used in this report. Since the figures used in this report are country specific measurements by the Ministry of Agriculture, Animal Industry and Fisheries, they should be considered more accurate.

4.4 NITROUS OXIDE EMISSIONS FROM FERTILIZER USE

4.4.1 FERTILIZER CONSUMPTION IN UGANDA

The majority of Uganda farmers, except for large estates like sugar and tea, have not taken use of fertilizers seriously. The other important crop to use fertilizer (Urea especially) is pineapples. Otherwise the overall national demand is low hence its supply is also low (Ministry of Agriculture, Animal Industry and Fisheries).

Up to 1975, the country had the capacity to produce phosphate fertilizers. Now fertilizers come into the country through donations and by direct importation through Bank of Uganda.

Because agricultural activities fluctuate from year to year due to economic, climatic and other variables, emission estimates based on a specific year of fertilizer consumption data could result into misrepresentative estimates. IPCC/OECD methodology recommends that an average of three years of fertilizer consumption centred on 1988 can be used. The data of fertilizers used in 1990 - 1992 is given in the Table 4.4 below.

TABLE 4.4

ANNUAL FERTILIZER USE (METRIC TONNES)

YEAR	NPK	UREA	CAN	ASN
1990	500	150	N/A	20
1991	620	200	10	N/A
1992	1880	N/A	N/A	N/A
TOTAL	2920	350	10	20
Average	973	180	10	20

where:

NPK - Nitrogen Phosphorous Potassium
CAN - Calcium Ammonium Nitrates
ASN - Ammonium Sulphate Nitrate
N/A - Not available

4.4.2 <u>N_2O Emission Methodology</u>

The OECD (1991) methodology is based on the amount of each type of fertilizer consumed and nitrogen content. An emission co-efficient for the fraction of applied N that is released as N_2O-N for each fertilizer type, and a factor used to convert the emissions for N_2O-N to N_2O should be determined. The emissions of N_2O-N are estimated for each fertilizer type, summed over all types and then converted to units of N_2O.

N_2O Emissions (tonnes N_2O-N) = Summation ($F_f \times E_f$)

where F = Annual Fertilizer Consumption (tonnes N)

E = Emission Co-efficient (tonnes N_2O-N) released/ (tonnes N applied).

f = Fertilizer type

N_2O Emissions (tonnes N_2O) = N_2O-N Emissions (tonnes N_2O-N) x 44/28.

4.4.3 EMISSIONS RESULTS

Table 4.5 below gives the emissions calculated using the above methodology.

TABLE 4.5							
FERTILIZER	AVERAGE AMOUNT CONSUMED (TONNES N)	N_2O-EMISSION (TONNES N_2O-N)			N_2O EMISSIONS (TONNES N_2O)		
		MEDIUM	LOW	HIGH	MEDIUM	LOW	HIGH
NPK	973	1.07	0.010	66.6	1.68	0.02	104.6
UREA	180	0.20	0.13	0.27	0.31	0.20	0.42
CAN	10	0.03	0.004	0.17	0.05	0.006	0.27
ASN	20	0.05	0.008	0.34	0.8	0.13	0.13
TOTAL	1.185	1.35	0.15	67.38	2.12	0.24	105.42

Emission Co-efficient as given by OECD (1991) on page 5 - 50 in % N_2O-N produced are shown in Table 4.6.

TABLE 4.6		
	MEDIUM	RANGE
NPK	0.11	0.001 - 6.84
UREA	0.11	0.07 - 1.5
CAN	0.28	0.04 - 1.71
ASN	0.20	0.04 - 1.71

4.5 CARBON DIOXIDE RELEASED DUE TO BURNING OF AGRICULTURAL CROP WASTES

4.5.1 BACKGROUND

The basis for the determination of greenhouse gas emissions from burning of agricultural wastes is on the amount of carbon burned and the emission ratios of CH_4, CO, N_2O and NO_x to CO_2 measured in the smoke fires (Crutzen and Andrea, 1990).

To determine the total carbon burned in agricultural wastes, six parameters for each crop type were determined through both field, and laboratory experiments and measurements:

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

4.5.2 DETERMINATION OF CARBON BURNED

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

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

It should be noted however that some of the agricultural residues could be burnt for energy purposes. In such cases, the fraction burnt for energy purposes should be determined and its emissions estimated under the energy sector.

The results are shown in Table 4.7 below.

TABLE 4.7

CARBON DIOXIDE RELEASED FROM BURNING OF AGRICULTURAL CROP WASTES

CROP TYPE	CROP PRODUCTION X 10^3 TONNES	RESIDUE/CROP RATIO	RESIDUE BURNED (%)	DRY MATTER CONTENT (%)	CARBON CONTENT (TONNES C/TONNES DRY MATTER)	TOTAL CARBON BURNED X 10^3 (TONNES C)	CO_2 RELEASED = 0.9 X TOTAL CARBON X 10^3 BURNED (t-c)
Banana	7293	0.4	15	45	0.312	61.4	55.26
Finger Millet	578	1.1	20	85	0.326	35.2	31.68
Maize	400	1	30	75	0.329	32.6	29.34
Sorghum	344	1.2	40	80	0.284	52.2	46.98
Rice	23	1.4	60	85	0.248	4.1	3.69
wheat	13	1.2	40	90	0.314	1.8	1.62
Sweet Potatoes	1716	0.3	5	40	0.365	3.8	3.42
Irish Potatoes	190	0.4	5	40	0.345	0.52	0.47
Cassava	3271	0.3	5	50	0.332	8.1	7.29
Beans	330	0.7	5	80	0.297	2.8	2.52
Field Peas	12	0.6	5	80	0.297	0.09	0.08
Cow Peas	38	0.6	5	80	0.293	0.27	0.24
Pigeon Peas	42	0.7	5	80	0.299	0.35	0.32
(Pea Nuts) Groundnuts	134	1	60	76	0.296	18.1	16.30
Soya Beans	14	0.7	5	88	0.335	0.14	0.13
Simsim	36	5.1	95	73	0.189	24.1	21.7
Sugar cane	351.4	0.3	95	90	0.347	291.9	28.17

TABLE 4.7							
CARBON DIOXIDE RELEASED FROM BURNING OF AGRICULTURAL CROP WASTES							
Coffee (A&R)	174	0.8	30	42	0.381	6.7	6.03
Cotton	3.2	12.5	95	80	0.342	10.4	9.36
						293.9	264.5 (264.8)
						294	265

NOTES:
1. The Crop Production figures are for 1988.
2. The sugar cane production includes an approximate 10% out-growers production used for molasses production.
3. Source of crop production figures is Ministry of Agriculture, Animal Industry and Fisheries. The rest of the factors are from Laboratory analysis, Makerere University.

TABLE 4.8: GREENHOUSE GAS EMISSIONS FROM BURNING OF AGRICULTURAL CROP WASTES IN UGANDA

CO_2 RELEASED $X10^3$ (t-C)	CH_4 -C Emissions x 10^3(t-C)		CH_4 Emission x 10^3(tonnes)		CO -C Emission x 10^3(t-C)		CO-Emission x 10^3 (Tonnes)	
	Low	High	Low	High	Low	High	Low	High
265	1.85	3.45	2.5	4.6	19.9	33.1	46.4	77.3

TABLE 4.8 "CONTINUED"

N_2O -N Emission x 10^3(t-N)		N_2O Emission x 10^3 (Tonnes)		NO_x-N Emission x 10^3(t-N)		NO_x Emission x 10^3(Tonnes)	
Low	High	Low	High	Low	High	Low	High
0.03	0.45	0.05	0.71	0.55	7.4	1.18	15.9

4.5.3 GREENHOUSE GAS EMISSION RATIOS

The emissions of CH_4, CO, N_2O and NO_x were then calculated based on the methodology in Crutzen and Andreae (1990). In the calculation of CH_4 and CO emissions due to crop residue burning, the amount of carbon burning is multiplied by 0.9 to account for approximately 10% of the carbon that remains on the ground (Seilar and Crutzen, 1980; Crutzen and Andreae, 1990 - cited IPCC Methodology).

The resulting figure which is the amount of CO_2 released instantaneously measured in units of carbon, was then multiplied by the ratios of emissions of CH_4 and CO relative to CO_2 (See Appendix 1) to yield emissions of CH_4 and CO in units of carbon. The emissions of CH_4 and CO are then multiplied by 16/12 and 28/12, respectively, to convert to full molecular weights.

The emissions of N_2O and NO_x due to burning of crop residue were calculated by multiplying the total carbon burned (in equation (I) by the N/C ratio of the fuel by weight to calculate the total amount of nitrogen released. A range of (0.02 - 0.17) was adopted to give the low and high emission scenarios based on the laboratory results of the crop-type N/C values. The details of these ratios, together with other emission factors used in this Chapter, are given in Chapter Seven of this report.

The total N released was multiplied by the ratios of emission of N_2O and NOx relative to the N content of the fuel (see Appendix 1) to yield emissions of N_2O and NOx in units of N. The emissions of N_2O and NOx were converted to full molecular weights by multiplying their emissions by 44/28 and 30/14 respectively.

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

CH_4 - C emissions (low) = (carbon burned) x (0.90) x (0.007)
CH_4 - C emissions (high) = (carbon burned) x (0.90) x (0.013)
CH_4 emissions (low, high) = CH_4 - C emissions (low, high) x 16/12
CO - C emissions (low) = (carbon burned) x (0.90) x (0.075)
CO - C emissions (high) = (carbon burned) x (0.90) x (0.125)
CO emissions (low, high) = CO - C emissions (low, high) x 28/12
N_2O - N emissions (low = (carbon burned) x (0.02) x (0.005)
N_2O - N emissions (high) = (carbon burned) x (0.17) x (0.009)
N_2O - N emissions (low, high) = N_2O - emissions (low, high) x 44/2
NO_x - N emissions (low) = (carbon burned) x (0.02) x (0.094)
NO_x - N emissions (high) = (carbon burned) x (0.17 x (0.148)
NO_x - emissions (low, high) = NO_x - N emissions (low, high) x 30/14

These results are displayed in Table 4.8 above.

APPENDIX I

Emission Ratios for Biomass Burning Calculations	
Compound	Ratios
CH_4	0.007 - 0.013
CO	0.075 - 0.125
N_2O	0.005 - 0.009
NO_x	0.094 - 0.148

4.5.4 **Source:** Crutzen and Andreae, 1990.

4.5.5 **Notes:**

(i) Ratios for CH_4 and CO are mass of Carbon Compound released in units of C relative to mass of CO_2 released from burning (in units of C).

(ii) Ratios for N_2O and NO_x are expressed as the ratios of emissions relative to the nitrogen content of the fuel.

4.6 GREENHOUSE GAS EMISSIONS FROM SAVANNA BURNING

Greenhouse gas emissions from savanna burning was determined on the basis of the quantity of carbon dioxide released instantaneously due to the burning.

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

4.6.1 CARBON DIOXIDE RELEASED DUE TO SAVANNA BURNING

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

(i) $B_b = A_s * P_b * (AGB)$

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

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

where: $(CO_2)_{LM}$ = CO_2 Released from Live Material (t CO_2 - C)

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

(iii) $(CO_2)_{DM} = B_b * (DP) * (BE)_{DP} * (C-C)_{DM}$

where: $(CO_2)_{DM}$ = Carbon dioxide released from dead material (t CO_2 - C)

(DP) = Dead Portion of Biomass (%)
$(BE)_{DP}$ = Burning Efficiency of Dead Portion (%)
$(C-C)_{DM}$ = Carbon Content of Dead Biomass (t C/t biomass).

(iv) Total CO_2 Released (t CO_2 - C) = $(CO_2)_{LM} + (CO_2)_{DM}$

Results are shown in Table 4.9 below.

4.6.2. GREENHOUSE GAS EMISSION RATIOS

The emissions of CH_4, CO, N_2O and NO_x were calculated based on the IPCC methodology according to Crutzen and Andreae (1990).

The total amount of CO_2 - C released due to savanna burning was multiplied by the emission ratios of CH_4 and CO relative to emissions of CO_2 (as per Appendix 1 attached and Summary below) to obtain emissions of CH_4, and CO, each is expressed in units of carbon. The emissions of CH_4 and CO were multiplied by 16/12 and 28/12, respectively, to convert to full molecular weights.

The emissions of N_2O, NO_x were determined by first multiplying the total CO_2 - C released by the estimated N/C ratio of the biomass (as per results of the biomass characterisation) to yield the total amount of nitrogen (N) released. The total N released was then multiplied by the ratios of emissions of N_2O and NO_x relative to the N-content of the biofuel/or biomass (as per Appendix 1 attached and Summary below) to yield emissions of N_2O and NO_x, expressed in units of N. The emissions of N_2O and NO_x were converted to full molecular weights by multiplying emissions by 44/28 and 30/14 respectively.

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

CH_4 - C emissions (low) = (CO_2 - C Released) x (0.007)
CH_4 - C emissions (high) = (CO_2 - C released) x 0.013)
CH_4 - emissions (low, high)-CH_4-C Emissions (low, high) x 16/12
CO - C emissions (low) = (CO_2 - C Released) x (0.075)
CO - C emissions (high) = CO_2 - C Released) x (0.125)

CO emission (low, high) = CO - C emissions (low, high) x (28/12

N_2O - N emissions (low) = (CO_2 - C released) x (0.0625) x (0.005)

N_2O - N emissions (high) = (CO_2 - C released) x (0.0625) x (0.009)

N_2O emissions (low, high) = N_2O - N emissions (low, high) x (44/28)

NO_x - N emissions (low) = (CO_2 - C Released) x (0.0625) x (0.094)

NO_x - N emissions (high) = (CO_2 - C Released) x (0.0625) x (0.148)

NO_x emissions (low, high) = NO_x - N emissions (low, high) x 30/14

Results are shown in Table 4.10 below.

TABLE 4.9

CARBON DIOXIDE RELEASED DUE TO SAVANNA BURNING

Savanna	Area x 10^4 (ha)	Portion Burned (%)	Above ground Biomass density exposed to burning (t - biomass/ha)	Biomass burned x 10^6 (t-biomass)	Live portion (%)	Live Burning Efficiency (%)
Permanent Swamp	92.04	5	200	9.2	100	20
Seasonal Swamp	186.44	44	54	44.3	5	70
Savanna Woodland	82.11	48	.26	10.25	10	70
Savanna Grassland	1073.8	50	36	193.3	5	70
Dry Thicket	177	56	4	3.96	-	-

TABLE 4.9 "CONTINUED"

Savanna	C-Content of live Biomass (t-c/t Biomass)	CO_2 Released from live material x 10^3 (t CO_2 - C)	Dead Portion (%)	Dead Portion Burning Efficiency (%)	C-Content of Dead Biomass	CO2 Released from Dead Material x 10^6 (t CO_2 - C)	Total CO_2 Released x 10^6 (t CO2 - C)
Permanent Swamp	0.1020	36.82	-	-	-	-	0.037
Seasonal Swamp	0.020	31.01	95	100	0.77	11.66	11.67
Savanna Woodland	0.026	18.65	90	100	0.306	22.82	2.84
Savanna Grassland	0.026	175.89	95	100	0.306	56.19	56.36
Dry Thicket	-	-	100	100	0.306	1.21	1.21
							72.13

NOTE:	The figures of the area of savanna burned are from the Ministry of Agriculture, Animal Industry and Fisheries. The rest of the factors are from the Laboratory Analysis, Makerere University.

TABLE 4.10

GREENHOUSE GAS EMISSIONS DUE TO SAVANNA BURNING

CO_2 Released	CH_4 - C Emission x 10^6(t - c)		CH_4 - Emission x 10^6 (Tonnes)		CO-C Emission x 10^6 (t - c)		CO-Emission x 10^6 (Tonnes)	
	Low	High	Low	High	Low	High	Low	High
72.13	0.50	0.94	0.67	1.25	5.41	9.02	12.62	21.04

TABLE 4.10 "CONTINUED"

CO_2 Released	N_2O-N Emission x 10^6 (t - N)		N_2O Emission x 10^6 (Tonnes)		NOx-N Emission x 10^6 (t - N)		NOx Emission x 10^6 (Tonnes)	
	Low	High	Low	High	Low	High	Low	High
72.13	0.023	0.041	0.035	0.064	0.42	0.67	0.91	1.42

NOTE: Average of N/C ratio for biomass - 0.0625 is adopted in the determination of N_2O and NO_x emissions. N/C ratio varies significantly from the IPCC default value of 0.006. This variation could have arisen from a number of factors: in particular, the presence of some mineral ions in the soil e.g. calcium is known to greatly increase uptake of Nitrogen by plants.

The Summary of results is given below in the Minimum Data Tables 4A - 4C.

MINIMUM DATA TABLES 4: AGRICULTURE

4 A & B: Enteric Fermentation & Animal Wastes

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES		AGGREGATE EMISSION FACTOR	
	A	B		C	
Sector Specific Data (units)	Number of Animals (1000)	Enteric fermentation (Gg CH4)	Animal Wastes	Enteric Fermentation (kg CH4 per animal)	Animal Wastes
4 AGRICULTURE				C = (B/A) X 1000	
A & B Enteric Fermentation & Wastes					
1 Cattle	5,224	173.44	4.28	33.2	0.819
i Beef					
ii Dairy					
2 Goats	3,800	19.00	1.17	5.0	0.308
3 Sheep	840	4.20	0.19	5.0	0.226
4 Pigs	760	0.76	1.09	1.0	1.434
5 Horses/Mules/Asses					
6 Buffalo					
7 Camels and Llamas					
8 Other (Poultry)	13,700		0.32		0.023

4 C: Rice Cultivation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES	AGGREGATE EMISSIONS FACTOR
Sector Specific Data (Units)	A Area cultivated in hectares (Mha)	B Hectare-Days of Cultivation (Mha-days)	C Emission of CH4 (Gg CH4)	D CH4/N20 Average emission Factor (kg CH4 per ha day) D = C/B
C Rice Cultivation				
'1 Flooded Regime	0.0403	3.6314	23.536	6.481
'2 Intermittent Regime				
'3 Dry Regime				

References:

1. OECD - (Organisation for economic Cooperation and Development - 1991). *Estimation of Greenhouse Gas Emission and Sinks.* Final Report from the OECD Experts' Meeting, 18 - 21 February 1991.

2. Vol. 1 Methodology of Census - Report on Uganda *National Census of Agriculture and Livestock (1987 - 1992)*, Ministry of Agriculture, Animal Industry and Fisheries.

3. Michael J. Gibbs et all (1993) - Methane Emission from Livestock: *Methane and Nitrous* Oxide methods in National Emissions Inventories and options for control. Proceedings 8 : 73 - 79.

4. Gibbs M.J. et al 1989 - *Methane Emission from Livestock. Manure.* Methane and Nitrous Oxide Methods in National Emission Inventories and options for control. Proceedings 9 : 81 - 86

5. Katsunyuki Minami 1993 - *Methane from Rice production.* Methane and Nitrous Oxide Methods in National emissions Inventories and options for control. Proceedings 13 : 143 - 162

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CHAPTER FIVE

5.0 GREENHOUSE GASES (GHG) EMISSIONS FROM LAND-USE CHANGE AND FORESTRY

5.1 INTRODUCTION

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

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

Forest area statistics have been normally assessed, updated and stored as Departmental Records by the Department of Forestry but these records are mainly concerned with the gazetted areas. Even so these area statements of the Forest Estate are now outdated. Therefore, an up to date inventory of all the Forest Reserves is urgently required. As for the forested areas outside the forest reserves, there is hardly any data. There has been a gradual but serious reduction of the forest estate both within and outside the gazetted areas and the rate of deforestation in Uganda is currently not known except for estimates made by various institutions both in and outside the country.

Fortunately, the National Biomass Study which is currently in its final year of implementation is expected to come up with more accurate estimates of Uganda's woody biomass situation with proper estimates of the present area of the land-use/cover types. From this information and with the use of the earlier area estimates of the forest and other land-use cover types in the country, a more realistic rate of degradation or deforestation shall be arrived at.

In light of the above background, it should be noted that for the estimation of the GHG emissions, especially for the reference year of 1990, no current information exists, other than data from woody biomass growing stocks from the National Biomass Study Report. Therefore, earlier estimates near the reference year are used in this report.

The Section is organised according to the following categories as outlined in the IPCC Inventory workbooks:

A **Forest Clearings**

(i) CO_2 emissions from immediate burnings
(ii) CO_2 emissions from decay
(iii) CO_2 emissions from soil carbon release
(iv) Total emissions from forest clearings

B Section B looks at the emissions due to conversion of grasslands to croplands. The emissions are estimated under these sub-sections:

(i) Methane uptake reduction.

(ii) Carbon Dioxide emissions due to a decrease in above ground biomass.

(iii) Loss of soil carbon due to oxidation.

C **Carbon sinks/emissions from managed forests**

D **Biomass burning modules**

5 A FOREST CLEARING

5 A 1 CO_2 FROM BURNING ABOVE-GROUND BIOMASS

(i) Area Estimates

Data which is available on Uganda's forest estate is mainly confined to the gazetted areas. This implies that outside the gazetted areas there is hardly any reliable data.

The following Table illustrates the areas of the forest estate by type and their sources:

Tropical High Forests

Source and Year	Area (ha)	Type
Langdale Brown (1958)	1,117,600	Total Tropical and moist forest cover
Atlas of Uganda (1967)	689,000	Tropical high forest
	73,000	Bamboo
Lockwood consultants (1973)	732,000	Tropical high forest
Forest Department (1987)	729,865	Tropical high forest
FAO	765,000	Tropical high forest

In the above Table the Forestry Department estimate though reliable does not take into account the area of forest which was lost due to encroachment since 1972 and the additional forest land on private/public lands.

Langdale Brown's estimate in 1958 which covers all forest types based on the aerial photography of 1950s is a reasonable one as this is taken to be the earliest estimates of forest cover in the country ever since.

(ii) Woodlands

Very little information exists on Savannah Woodlands. Recent area estimates vary much and are as follows:

Atlas of Uganda (1967)	699,000 ha
Lockwood Consultants (1973)	776,000 ha
FAO (1985)	5,250,000 ha
Forestry Department (1987)	680,000 ha

(iii) Plantation

According to Forestry Department Records of 1987, the areas of plantations by then were as follows:

Softwood Plantations	13.4 kha
Eucalyptus plantations	14.35 kha
Eucalyptus Plantations (Tobacco CO.)	10.56 kha

(iv) Rate of Deforestation

In the calculation of the rate of deforestation over a period of 25 years, Langdale's estimate (for tropical and moist forests only) was taken as a base year and that of the Forestry Department in 1987 is taken as the nearest reference year for the GHG emissions estimate. The loss, therefore, of the **Tropical High Forest Area** over a period of 29 years is, 387,735 Ha, giving an annual deforestation rate of 13,400 Ha. Since no reliable data exists for areas outside forest reserves, it was difficult to estimate the rate of deforestation outside the gazetted areas. However FAO in 1990 estimated the rate of deforestation in Uganda over a ten year period based on the interpretation of multi-date Landsat MSS imageries (1980 and 1990), covering four sample areas of Uganda. From their estimates, the annual rate of deforestation in Uganda over the last ten years was 64,500 Ha. This figure was considered to be rather too high and therefore not used. Since no data is available and we did not want to leave out an important part of the estimate of deforestation, the same figures used for gazetted areas have been used for the deforestation outside the gazetted areas. One has to keep in mind, however, that this figure is solely based on expert judgement and should be handled with extreme caution.

(v) <u>Growing Stock</u>

The following Table shows the data on growing stock from the National Biomass Study:

Standing Stock	Tropical High Forest	Open Forest
Before	202 t dm/ha	32 t dm/ha
After	59.46 t dm/ha	10 t dm/ha
Loss	143 t dm/ha	22 t dm/ha

Source: National Biomass Study, Forestry Department, Kampala.

(vi) <u>FOREST CLEARING: IPCC METHODOLOGY</u>

Below is an outline of the steps used in the calculation as recommended by the IPCC Methodology:

Burning of Above-ground Biomass

Estimate area of cleared Forest.

Estimate the standing stock before and after burning.

Estimate net loss.

Reduce the Quantity by 0.5.

Convert to Carbon Equivalent by multiplying by 0.45.

Convert the above to CO_2 Released assuming that (0.87 is CO_2 and 0.13 is left as charcoal.

Repeat Steps 1 to 6 for each Forest Type.

5 A 2 On-Site Burning of cleared forests: Trace Gases

Emission

5 A 3 Decay of Above-ground Biomass

Same as in (vi) above except annual rate is based on a ten year period.

5 A 4 Soil Carbon Release.

Forest Type: Tropical High Forest excluding Open Forests - area multiplied by amount of soil carbon.

The Summary of the results is given below in Table 5 A 1.

Table 5 A 1 Forest Clearing: CO2 Released from Burning of Above-ground Biomass

Source and sink categories			Activity Data			Emissions Estimates	Aggregate Emissions Factor
			A Area cleared k ha	B Total Biomass change kt dm	C Quantity of Biomass Burned (on and off-site) kt dm	D Quantity of Carbon Released Gg CO_2	E Mg CO_2/kt dm burned
							E=D/C
Tropical	Closed Forests	Undisturbed					
	Bread-leaf	Logged	13.4	143	371	391.79	1.05
	Closed Forests	Undisturbed					
	Conifers	Logged					
		Unproductive					
	Closed Forests	Sub-Total					
	Open Forests	Productive					
		Unproductive	13.4	22	57	60.21	1.05
		Sub-Total	26.8	83*	428	451.6	1.05*

* mean of the two values

5 A 2 On-Site Burning of Cleared Forests: Trace Gases Emissions

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS ESTIMATE			
	A Carbon Release Gg	B Nitrogen Release Gg	C Emissions Estimate Gg			
			CH_4	CO	N_2O	NO_x
On Site Burning of Cleared Forests	123.166	1.232	1.971	17.243	0.014	0.319

5 A 2 On-Site Burning of Cleared Forests "Continued"

Source and Sink Categories	AGGREGATE EMISSION RATIOS			
	D Aggregate Emission Ratios			
	D = C/A		D = C/B	
	CH_4	CO	N_2O	NO_x
On-Site Burning of Cleared Forests	0.016	0.139	0.01	0.258

Sources: Extracts from the results of the computation of MINERGG - software. Column A is from the burning of above-ground biomass and columns B and C are from the Summary Report as computed by the software for the on site burning of above-ground biomass.

5 A 3 FOREST CLEARING: CO_2 REALISED FROM DECAY OF ABOVE-GROUND BIOMASS

(i) Area Estimates

The area estimates of annual rate of deforestation were obtained from **UNEP 1988** where it was estimated that between 1977 and 1987, i.e. over a ten year period over 100,000 ha of Forests were cleared-annual rate is 10,000 ha. As for the Open Forests (Woodlands) data was obtained from The FAO 1990 Forest Assessment (see above).

(ii) Growing Stock

Standing Stock before and after were initially got from the Table 6 -1 from the IPCC worksheet as default values whereby Tropical High Forest was given as 260 t dm/ha undisturbed closed broadleaf and 210 t dm/ha logged. For the open forests which, in Uganda's case, is woodlands, the default values given were 45 ha t dm/ha and 10 t dm/ha. However, the national data from the National Biomass Study are now available and they have been used in the calculations as follows: Tropical high forest undisturbed 202 t dm/ha and disturbed (encroached) is 59.46 t dm/ha. Open forest (woodlands) 32 t dm/ha and 10 t dm/ha.

The results of the calculations are summarised in the Minimum Data Table 5 A 3 below:

Table 5 A 3 Forest Clearing: CO2 Released from Decay of Above-ground Biomass

Source and sink categories			Activity Data			Emissions Estimates	Aggregate Emissions Factor
			A 10-Year Average area cleared k ha	B 10-Year Average Actual Loss of Biomass kt dm	C Average Quantity of Biomass to Decay kt dm	D CO_2 Emissions Gg CO_2	E Emission Factor Mg CO_2/kt dm
							E=D/C
Tropical	Closed Forests	Undisturbed					
	Bread-leaf	Logged	10	143	71	86.51	1.2
	Closed Forests	Undisturbed					
	Conifers	Logged					
		Unproductive					
	Closed Forests	Sub-Total					
	Open Forests	Productive					
		Unproductive	10	22	11	13.31	1.2
		Sub-Total	20	83	825	99.82	1.2

5 A 4 FOREST CLEARING: SOIL CARBON RELEASE

The sources of data in this section are obtained from worksheet 1.1 using the default values as in the worksheet. The details of the calculations are summarised in Table 5 A 4 below:

Table 5 A 4 Forest clearing: Soil Carbon Release

Source and sink categori es	Activity Data		Emissions Estimates	Aggregate Emissions Factor
Forest Types	A Ave. ann. forest converted to pasture or crop over 25 years	B Soil carbon content of land before clearing t C/ha	C CO_2 released from soil Gg CO_2	D Aggregate emissions factor from soil carbon Mg/ha D=C/A
Tropical	13.4	100	2.383.33	177.86

5 A 5 FOREST CLEARING: TOTAL EMISSION FROM FOREST CLEARING

The Table below is a summary of the total emissions from forest clearings.

Table 5 A 5 Total CO_2 Emission From Forest Clearings

Category	Emissions (Gg)
CO_2 from burning of cleared biomass	451,6
CO_2 from decay of cleared biomass	99.82
CO_2 from soil carbon release	2.283.33
Total	2.834.75

5 B CH_4 UPTAKE REDUCTION AND NET CO_2 EMISSIONS DUE TO CONVERSION OF GRASSLANDS TO CULTIVATED LANDS

5 B 1 BACKGROUND INFORMATION

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

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

5 B 2 ABANDONMENT OF MANAGED LANDS

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

5 B 3 NET EMISSIONS DUE TO SHIFTING CULTIVATION

This step could not be calculated because no data is available about the rate at which managed lands are abandoned. It was however noted that due to the high rate of population increase, there is a very high pressure on the arable land and therefore shifting cultivation is hardly practised. This implies that skipping this step may not introduce a significant error.

5 B 4 CH_4 UPTAKE REDUCTION AND NET CO_2 EMISSIONS DUE TO CONVERSION OF GRASSLANDS TO CULTIVATED LANDS.

5 B 4.1 NOTE:

Here, the grasslands were supposed to be considered separately by type. However, no data was available in which the area conversion was given by grassland type. So from the available data, an average annual rate of conversion for all grassland types considered together was computed. A value of 941 x 10^3 x ha/year was got as shown below:

YEAR	TOTAL GRASSLAND AREA UNDER CULTIVATION	SOURCE
1958	26,600 km^2 (13%)	MacMaster 1962
1967	34,297 km^2 (17%)	Langlands (1967)
1989	55,000 km^2	Ministry of Agriculture, Animal Industry and Fisheries

Therefore:

(i) Between 1958 to 1967 is a period of nine years and a total area of 7,697 km^2 of grassland was converted to cropland. This gives an annual conversion rate of 7,697/9 = 855.2 km^2/year.

(ii) Between 1967 and 1989 is a period of 22 years and a total of 20,703 km^2 of grassland was converted into cropland. This gives an annual conversion rate of 20,203/22 = 941 km^2/year.

From the available literature and the explanation of the methods used in the area estimations it was found that the 1967 and 1989 estimates were more reliable so the annual conversion rate of 941 km^2/year was adopted.

5 B 4.2 No value is available for the average annual CH_4 uptake in Uganda and also no country specific data was available for Uganda and hence the default value for Gambia was used.

5 B 4.3 Default values for the annual CO_2-C emissions per unit area of grasslands before and after conversion as given in the Gambia report were also adopted.

CH_4 Uptake Reduction = Area converted x (Average Annual CH_4 Uptake per unit area before conversion) x 0.40 x 16/12.

Area converted = 941 x 10^3 ha/year.

Average annual CH_4 uptake = 0.8 g CH_4-C/m^2 - (default value from the Gambia Report).

Therefore, CH_4 uptake reduction = 941 x 10^3 x (0.8 x 10^4 g CH_4-C/ha) x 0.4 x 16/12 = 4.015 x 10^9 g CH_4 = 4.015 - Gg CH_4

CO_2 emissions = Area converted x {(Annual CO_2 - C emission per unit area before conversion) x (Annual CO_2 - C emission per unit area after conversion)} x 44/12 = 941 x 10^3 x (7.3 - 6.0) x 44/12 = 4.485.4 Gg CO_2.

5 B 5 Loss of soil carbon

TABLE 5 B 2 : LOSS OF SOIL CARBON			
A 25 year Total conversion of grasslands to cultivated land (000) ha	B	C = A x B x 0.025 x 44/12	D = C/A
941 x 25	98.7	2,156.6	0.09

B = Soil carbon content of grasslands in Tonnes/ ha. It should be noted that no default value was available so six soil samples were collected from the six major grassland types in Uganda and they were tested in the laboratory for their carbon content. An average value of the six samples was then used in the calculation. The results of the laboratory analysis are given below.

TABLE 5 B 3: SOIL - CARBON CONTENT		
SOIL - CARBON CONTENT RESULTS		
GRASSLAND TYPE	LOCATION	SOIL CARBON CONTENT (t/ha)
Mixed Savanna	Arua, Nebbi	67.2
Butyrospermum Savanna	Lira, Gulu	94.5
Combretum Savanna	Nakasongola, Masindi	82.2
Dry Acacia Savanna	Sembabyule, Masaka	86.6
Grass-Hemeda Savanna	Mbarara	103.9
Moist Acacia Savanna	Bushenyi	151.2
	Average	98.7

C = Total carbon dioxide released from the twenty five year historic conversion in kt - CO_2 (Gg).

D = Average Emission Factor in Mg/ha.

5 D <u>MANAGED FORESTS</u>

(i) <u>Area Estimates</u>

Sources of data on Plantations (Eucalyptus and Mixed Softwood) and Tropical High Forests are mainly from Forestry Department. As for the closed Forests the data was obtained from Howard P.C. 1991 "Nature Conservation in Uganda's Tropical High Forest Reserves IUCN". According to Howard the productive Forest Cover for Uganda's twelve principal Reserved Tropical High Forests were about 384,200 ha. For the plantation areas and woodlands, the Forestry Department estimates of 1987 were used.

(ii) <u>Annual Growth Rates</u>

The annual growth rates were obtained from the Tables 6 - 5 and 6 - 6 as default values. Currently, the data on annual growth rate from the National Biomass Study is being worked on and if finished, it shall be incorporated into the national figures. The annual harvest figures were derived from the Forestry Department Records and the removals from the open forests area are assumed to be mainly wood-fuels. A little caution must be given here - that not all fuel-wood removed comes from Managed Forest Reserves. In actual fact a lot of wood-fuel comes from nearby farmland areas and open forests and bushlands outside the gazetted forested areas. Therefore in interpreting the sinks and emissions one should be aware of this fact.

5 D 1 STEPS OF CALCULATION AND SUMMARY OF RESULTS

Annual Growth

Area of Managed Forest (k Ha)

Growth rate t dm/Ha
Biomass Increment (kt dm)
Carbon Content of Dry Biomass
Total Carbon Increment

5 D 2 HARVESTS

(i) Annual Harvests

(ii) Commercial Harvests

Commercial Harvest Round-wood (180 Km^3 Forest Department sources 1988)

Commercial Harvest (131.4 kt dm)

Fuel-wood

Population = 16.5 million

Per capita fuel-wood Consumption 0.66 kt dm/1000 persons = 11.025 kt.

The following Tables are the summaries of the calculations:

Table 5 D 1 Managed Forests: Annual Growth Increment

Source and sink categories			Activity Data	Emissions/sink estimates
Forest Type			A Area of managed forests k ha	B CO_2 removal Gg C
Tropical	Plantations (specify type)	Eucalyptus	24.915	163.125
		Mixed Conifers	13.038	84.825
	Logged	Closed broadleaf	384.002	1900.008
		Closed conifers		
		Open forests	680.000	2,019.600
	Total		1064.000	4,168.000

Table 5 D 2 Managed Forests: Harvest

Source and Sink Categories	Activity Data	Emissions Estimates	Aggregate Emissions Factor
	A Amount of Biomass Harvested kt dm	B CO2 Emission/Sink Estimates Gg C of full mass pollutant	C CO2 Emission Factors Mg/t dm
			C = B/A
Commercial Timber	126	56.7	0.45
Fuel-wood	11,025	4,961.25	0.45
Other (specify)			

Table 5 D 3 **Managed Forests: Net Emissions/Removals (Summary)**

Category	Emissions/Removals (Gg)
Total Growth Increment	4,168
Total Harvest	5,522
Net Emissions(+) or Removals (-)	1,354

5 D 4 WEAKNESSES AND STRENGTHS OF THE METHODOLOGY

(i) Classification System

The classification system of the IPCC Methodology is rather limiting and does not allow for any changes in the software. It also assumes that all Forests are managed and that sinks and removals also take place only in these type of forests. But in reality a lot of carbon is being fixed even in areas which are not traditionally looked at as forests.

However, for Uganda's case, there is currently an on-going project the National Biomass Study. In this study, a country-wide mapping of the Land-use/cover and the assessment (inventory) of the woody biomass (growing stock per unit area and annual increment) is being done. Monitoring of the woody biomass dynamics in the country is also being established as part of this study.

Here below is a full extract of the classification of the Land-use/cover adopted in the National Biomass Study. This classification should be the one to be used for Managed Forests for Uganda's case, if a reliable estimate of sinks and emissions of carbon is to be achieved.

(ii) Table XII -Land-use/Land Cover Classes

Plantations and woodlots - deciduous trees/broadleaves ("hardwood").

Plantations and woodlots - coniferous trees ("softwood").

Tropical high forest - normally stocked.

Tropical high forest - depleted/encroached.

Woodland - trees and shrubs (average height > 4 m).

Bushland - bush, thickets, scrubs (average

height < 4 m). (Some shrubs and scattered trees may occur).

Grassland, rangelands, pasture land, open savannah. (Some scattered trees, shrubs, scrubs and thickets may occur).

Wetland vegetation, swamp areas, papyrus.

Subsistent, mixed farmland recently used or in use - with/without scattered trees, agricultural fallow areas.

Uniform, mono-cropped, non-seasonal farmland without any trees and shrubs - e.g. tea and sugar estates.

Urban or rural built up area, bare rock, miscellaneous impediment.

Water - larger rivers, ponds and lakes.

(iii) Some types of vegetation mentioned in this Chapter need further explanation. There appears to be a lot of confusion and disagreement in general regarding the understanding and definition of bush, shrub, scrub and thicket. In this study, the following definitions were used:

(a) *Shrub:* branchy "tree" without a clear/straight bole/stem, mainly 4 - 10 m high.

(b) *Scrub:* without a defined bole/stem, less than 4 m high, mainly one species isolated in a cluster.

(c) *Thicket:* many non-defined stem growths of a number of species growing in clusters, mainly less than 7 m high.

(d) *Bush:* continuous wide spread growing scrub and thicket.

Comments and explanations of the classification system are found below:

(iv) Plantations

These are the man-made tree plantations. Young generation woodlots are dominant in this class in the project areas.

(a) Class 1 consists of deciduous, broad-leaved trees mainly of *Eucalyptus spp.*, *Maesopsis emimii*, *Acacia mearnsii* (Black Wattle) and some *Markhamia Platycalyx*.

(b) Class 2 includes the *Conifers; Pine spp.* and *Cypress spp.*

(v) Tropical High Forest

These natural forests with a high variety of species were divided into two classes:

(a) Class 3 is normally stocked **Tropical High Forest (THF)**. This was found both in the form of large forests (e.g. Mabira Forest in the Jinja Project

Area) and in smaller patches.

(b) Class is depleted/degraded/encroached and has a reduced richness of species composition. The understorey is dominated by secondary bush and shrubs, in particular *Solanum spp.*

(vi) Woodland, Bushland and Grassland

This group covers all intermediate land-use/cover classes from bare grassland to densely stocked woodland:

(a) Class 5 represents the most woody areas where trees and shrubs are the predominant cover. There is both a wet type occurring as a zone along wetlands (riverine forest) and a dry type appearing on dry, grass-covered areas. *To qualify as woodland the average height of the trees must exceed 4 m.*

(b) Class 6 refers to vegetation dominated by bush, scrubs and thickets growing together as an entity, but not exceeding an average height of 4 m.

This class may have different origins. In dry, grass-covered areas it appears to be permanent, including for example normally taller growing species which have been arrested from their potential by persistent fires and/or other biotic factors; (for example *Acacia hockii* in Mbarara and *Commiphora africana* in Moroto).

This class also occurs on abandoned farmland in the form of a late fallow with rapid impetus of mainly *Lantana camara*. On clear cut abandoned forest land the vegetation is rapidly progressing to bush comprising many different pioneer species as the first phase of succession.

(a) Class 7: Grazing grounds, whether rangelands, improved pastures or natural savannah grassland are all grouped together in this class. Various trees - bush/woody vegetation frequently occur on this land, but grass cover dominates the scene.

(vii) Wetlands

class 8 comprises both permanent wetland - usually with papyrus and reeds - and some seasonally flooded areas. These are found along lake shores and in valleys with impeded drainage, where the vegetation shows clear symptoms of frequent high water table. Various vegetation may occur, but the most dominant is wet grass. Among the indicator trees are *Acacia siberiana* and palms such as *Phoenix reclinata*.

(viii) Farmland Area

(a) Class 9: Included in this class are all the small-holder subsistence farm units. All kinds of cropping systems are found: mixed cropping, multiple cropping and shifting cultivation combined within small areas. Scattered trees/tree clusters are also frequently found, especially in the near vicinity of the homesteads. These are mostly fruit trees and various multipurpose trees as support to and integrated in the farming system (agroforestry). *The biomass coverage displays a wide range from bare ground to almost closed forest.*

(b) Class 10: These are large scale commercial farms such as tea and sugar estates, especially found in Jinja Project Area.

(ix) Impediment Area

Areas grouped here were for various reasons thought to be mainly non-productive.

(a) Class 11 includes towns, village trading centres, quarries, homesteads, school compounds, roads, bare rock and recreational grounds. However, most of the class 11 areas encountered were built-up areas and here considerable biomass was recorded; in particular as various compound trees and multiple use trees growing close to be homesteads. As can be easily seen in Chapter 11.10, the total amount of biomass per ha exceeded the amount per ha in class 9 for most project areas.

(b) Class 12 comprises open water, like large rivers, ponds and lakes. The boundary between open water and surrounding wetland with a permanent high water table is sometimes difficult to draw. In considered a main problem in the nine project areas, though.

When the results of the national Biomass Study are released later this year and based on the above classification, the results of the GHG Inventory will have to be refined accordingly.

(x) <u>Harvesting</u>

The harvested commercial volume which is used in the calculation is derived from the Forestry Department while fuel-wood consumption was derived from the estimates made by the National Biomass Study, which was also based on a number of sources and their own estimates for urban and rural consumption. The software only allows for two entries to be made, i.e. per capita consumption and total population of the country. It does not take into account the fact that per capita consumption of wood-fuel is only for that fraction of the population which relies on wood-fuel Besides this problem, the country data is normally broken down into fire-wood and charcoal. In order to facilitate the calculations, the per capita estimates as made by the National Biomass Study had to be adjusted from 0.75 tons (for firewood) to 0.668 tonnes and the population figure of 16.5 million (1991 census) were used - refer to Chapter One on Total Woodfuel Consumption.

(xi) Abandonment of Managed Lands (previous 20 years)

After a careful consideration of the worksheet, the following decisions were made:

(a) All emissions of GHGs from forests are covered in the other worksheets on land-use.

(b) Uganda does not have managed lands abandoned over the previous 20 years because of the ever increasing population pressure which demands more land for agriculture.

(xii) <u>GENERAL CONCLUSION</u>

In the calculations of Annual Growth and harvesting, it has been assumed that all fuel-wood comes from Managed Forests (in Uganda's case gazetted Forest Reserves). But in reality fuel-wood originates from scattered trees in farm land areas. So, if it is assumed that half of the firewood does not come from Managed Forests and that the increment of farm trees, etc. compensates the other half of the fuelwood consumed, Uganda will be a net sink rather than a net emitter as the preliminary results show.

However, when the final results from the National Biomass Study come out later this year, an amendment to the inventory shall be made.

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CHAPTER SIX

6. GHG EMISSIONS FROM WASTES

6.1 ESTIMATES OF METHANE PRODUCTION FROM MUNICIPAL GARBAGE

Quantities of Municipal garbage collected for dumping were obtained from the City and Municipal Records. The expected waste generation in Kampala from a study carried out in 1989 and released in 1990 by Engineering Section of the City Council is as follows:

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

However, several organisations, including the World Bank, have complained that the rate of 1.15 kg/head/ day is unreliable and most likely too high. The City Council has confirmed that several complaints have been raised before and the study is to be redone. Their view is that the rate is most likely between 0.6 and 0.7 kg/head/day.

6.1.1 Management Practices

6.1.1.1. Dumping

The Municipal solid wastes in the main towns of Uganda are dumped in valleys or shallow pits originally used for extraction of marram for road construction. The wastes end up in relatively shallow, open piles decomposing mainly under aerobic conditions to produce carbon dioxide and a small amount of methane. Typical dumping sites in Kampala City cover an area up to about 50,000 sq. metres. The garbage is heaped in isolated heaps of up to five metres high. The heaps overlap over time to form some kind of hillocks.

6.1.1.2 Composition

The garbage collected in most of the towns is over 90% vegetable matter/agricultural waste products. In one of the studies carried out for Kampala City Council and Jinja Municipal Council by the World Bank, the composition was found to be as given in Table 6.1 below.

TABLE 6.1		
COMPOSITION OF MUNICIPAL GARBAGE (%)		
	KAMPALA	JINJA
Vegetable matter	73.8	93.0
Paper	5.4	3.0
Plastic	1.6	1.0
Metal	3.1	0.5
Glass	0.9	1.1
Street debris	5.5	1.4
Tree cuttings	8.0	-
Sawdust	1.7	-

6.1.2 Estimation of Methane Emissions

Since the Municipal Solid Wastes are virtually not land-filled it is difficult to use some of the formulae suggested. Some estimates have however been made based on the conversion factor of 21.5 kg of methane per tonne of garbage suggested by Orlich (1990) for Municipal garbage from developing countries. This conversion factor is 50% of the average methane recovery determined for the USA using an empirical model based on landfill gas recovery data. Due to limited basic data from developing countries, the range of default values of 25% to 75% of the USA mean recovery value, is suggested for the developing countries. The lower conversion factor for developing countries is due to differences in garbage composition factor and management practices. Most of the landfills in developing countries, including Uganda, are open dumps. This situation tends to suppress anaerobic decomposition while enhancing aerobic decomposition where much of the methane formed is oxidised.

However due to the high content of vegetable matter (about 90%) in the Uganda garbage, the methane recovery potential is most likely higher than the average value being used in the calculations.

Table 6.2 below gives a summary of Municipal Garbage Collection and Methane Emissions from the Garbage.

TABLE 6.2								
MUNICIPAL GARBAGE COLLECTION AND METHANE RELEASE (TONNES)								
YR.	1988		1989		1990		1991	
NAME	GARBAGE	METHANE	GARBAGE	METHANE	GARBAGE	METHANE	GARBAGE	METHANE
KAMPALA	43139	928	56870	1238	60087	1292	66591	1432
JINJA	19934	429	22485	483	24985	537	27485	590
TORORO	1384	30	1456	31	1528	33	1600	34
MBALE	3921	84	4214	91	4507	97	4800	103
MASAKA	12067	259	9905	213	13770	296	1600	344
MBARARA	8506	183	9016	194	9526	205	10036	216
TOTAL	88951	1913	103948	2250	114403	2460	126512	2720

Source of Data: From City/Town Council Records

6.1.3 Error Margins

There seems to be large differences between the expected waste generation and the actual waste collected for dumping. When the figures of garbage collected in Kampala are compared with the expected waste generation of 1.15 kg/head/day it is found that the garbage collected is about a quarter of that expected to have been generated. Even if 1.15 kg/ head/day is too high, half of it is still less than 50% of the garbage is collected for communal dumping. However, in the majority of cases the garbage is disposed of locally in shallow pits where it decomposes aerobically.

6.2 SANITATION FACILITIES

The following sanitation facilities exist in the country:

(1) Water borne - use of sewer lines or septic tanks.

(2) VIP Latrine - a recent innovation mostly being introduced by NGOs and UNICEF.

(3) Bucket latrine system - though a very old method and out-dated some towns. e.g. Arua and Kabale still maintain this system.

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

(5) None at all.

The Table 6.3 below based on the 1991 housing and population census summarises the use of toilets:

TABLE 6.3			
PERCENTAGE USE OF SANITATION FACILITIES			
TOILET	KAMPALA	OTHER URBAN	RURAL AREAS
Water borne, not shared	8.5	8.7	0.08
Water borne shared	5.6	11.6	0.04
Pit latrine not shared	11.5	13.6	52.6
Pit Latrines shared	71.1	61.3	22.6
None	2.6	4.5	24.5
Others	0.7	0.3	0.7
Population	773,000	1,103,000	14,707,000
Population using pit latrines	643,136	826,147	11,059,664
Total	12,528,947		

From Table 6.3 above, it is very clear that use of pit latrines is the most prevalent in the country, being about 75% in the urban and rural areas and about 83% in the city of Kampala. Calculation of methane released from sanitation facilities will at the moment only take into account release from pit latrines. However, some statistics concerning urban water borne toilet facilities are given first.

6.2.1 Urban water borne toilet facilities

The urban population estimated to be using water borne toilet facilities is about 332,900 people which is about 0.02% of the total national population. The majority of the population as pointed out before use pit latrines. The results of a survey carried out by members of the task force in the major towns regarding use of water borne toilet facilities is given in Table 6.4. below.

TABLE 6.4	
STATION	AVAILABLE RECORDS
Kampala	None - files misplaced.
Jinja	Uses sewage lagoons and septic tanks
Mbale	Two sewage lagoons in use for the inner town while neighbouring areas use septic tanks. From the Water and Sewerage Corporation, Mbale, there are about 2,000 family accounts with about six people per family, that is 12,000 people.
Masaka	Almost full records were available from 1990 - 1992. The records are as follows: 1990 - 69.3 metric tons 1991 - 65.7 metric tons 1992 - 76.7 metric tons
Mbarara	Two sewerage lagoons available but not in much use, presently septic tanks are being used.
Tororo	Two sewerage lagoons in use for inner town, neighbouring areas use septic tanks. Out of the town's 26,000 people it is estimated that 25% is connected to the sewerage lagoons.

6.2.2 Methane release from pit latrines

To calculate the methane released from pit latrines the formula recommended (for sewage treatment facilities) in the proceedings of the International IPCC Workshop on Methane and Nitrous oxide in national emissions inventories and options for control (February 1993) was adapted.

In this formula,

Emissions (kg CH_4/year)

= Population x kg BOD/Capita/day x 365 x Production Potential kg CH_4/kg BOD x Fraction anaerobically digested.

Where:

Population using pit latrines = 12.529×10^6;

Kg BOD/Capita/day = 0.037 (default value for Africa);

6.2.3 Production Potential

In an experiment by a Tanzanian GHG Inventory Team to determine the CH_4 and CO_2 emission factors from septic tanks, pit latrines and anaerobic ponds using the five day bio-chemical oxygen demand for Dar-es-Salaam the following results were obtained.

WASTE SYSTEM	PRODUCTION POTENTIAL (grammes/litre) (g/l)	PRODUCTION POTENTIAL kg/CH_4/kg BOD
Septic Tanks	18	0.0857
Anaerobic pounds	10	0.0769
Pit Latrines	5	0.0227

6.2.4 Source of Data:

Tanzanian National GHG Inventory Report
1994

The production potential for the pit latrines is taken as 0.0227 kg CH_4/kg BOD;

6.2.5 Fraction Anaerobically digested

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

Substituting for these factors,

therefore, Emissions (kg CH_4/year)

$= 12.529 \times 10^6 \times 0.037 \times 365 \times 0.0227 \times 0.417$ kg
$= 1.60167 \times 10^6$ kg
$= 1.602$ Gg

If calculations are made using a methane production potential of 5 g/l and an average excreta density of 1.464 kg/l as estimated by the Tanzanian's, the methane release of about 1.6×10^6 kg/year would imply an average excreta generation of about 100 g/person/day which I think is not unreasonable.

This implies that the calculated emission of 1.60 Gg/year for pit latrines is within reasonable limits.

The summary of results is given below in Minimum Data Tables 6A and 6B.

MINIMUM DATA TABLES 6 WASTE

6 A Waste: Landfills

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES	AGGREGATE EMISSIONS FACTORS	
Weste Type	A Total MSW (kg per year)	B MSW Landfilled (kg)	C CH4 Emission (kg)	D Emission Factor (kg CH4/kg MSW landfilled)	E Qty of Ch4 recovered (kg CH4)
				D=C/B	
Municipal Garbage					
A Landfills	114.4x10^6	N/A	2.5x10^6	N/A	

NB: Open dumping practiced. Conversion factor of 21.5 kg / tonne garbagge used

6 B Weste: Sewage Treament

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES		AGGREGATE EMISSIONS FACTORS	
Weste Type	A Quantity BOD in Westewater (kg)	B Quantity of CH4 anaerobically digested (kg CH4)	C CH4 Emissions (kg)	D Emission Factor (kg CH4/kg BOD)	E Qty of CH4 recovered (kg CH4)
				D=C/B	
B Wastewater Municipal					
Industrial					
C Other (Pit Latrines)	178.4x10^6	74.4x10^6	1.60x10^6	0.02	

References

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CHAPTER SEVEN

7. BIOMASS AND BIO-FUEL CHARACTERISATION[4]

Biomass and Bio-fuels vary in their carbon and nitrogen contents depending on the climate and soil-type in a given region. This variation therefore influences the net-heating values of the bio-fuels as well as their intensity of the GHG emission.

A variety of species of biomass commonly combusted during bush clearing by fires were collected through a process of stratified sampling, where the spatial distribution as per ecosystem was the basis for stratification. Twelve samples of grass as well as thirty six samples of agricultural crops in Uganda were collected by stratifying areas in the country according to vegetation and the common bio-fuels used. These samples were subjected to laboratory investigation. A total of sixteen samples of wood-fuel and seven samples of charcoal from known trees of origin, were investigated.

Bio-gas from cow-dung arising from anaerobic digestion in a digester with a retention time of 60 days or more, was also examined. While this is not strictly the concern of the current study, its future potential as a viable bio-fuel makes a worthy investigation for completeness. In any case the materials from which the biogas may be generated would have known C/N ratios. Finally, the heating values of all the biomass and bio-fuel samples were also determined.

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[4] *To be published as:*

1. *"Greenhouse Gas Emissions from agricultural Residue Burning". To be presented at the UNESCO/IPPS Regional Conference on Capacity Building in Physics, Nairobi, Kenya, 19th - 23rd September 1994.*

2. *To be published in the Proceedings under UNESCO African Network of Scientific and Technological Institutions as presented in (1) above.*

3. *"Characterisation of Agricultural Crops for Estimation of Energy and Greenhouse gases released in Burning of their Residues" in the African Journal of Science and Technology UNESCO/ANSTI, Nairobi, Kenya.*

7.1 DETERMINATION OF CARBON CONTENT

Carbon is oxidized at a temperature of approximately 120 degrees celsius by adding a potassium dichromat solution and concentrated sulphuric acid to a given biomass/bio-fuel sample in powder form. The excess of potassium dichromat, not reduced by the organic matter of the sample, is determined by titration with ferrous sulphate and with diphenylamine-4-sulphonic acid Ba-salt as an indicator. Phosphoric acid is added to form a complex with ferric iron providing a sharper colour change of the indicator. The carbon content of a sample was then determined from the equation:

$$C\ \% = \{[3(b - s)]/b/W\} \times M \times 100$$

where

b = ml of FeSo4 used for the blank determination
s = ml of FeSod used for the sample determination
3 = equivalent weight of carbon
W = weight of sample
M = moisture correction factor

7.2 DETERMINATION OF NITROGEN CONTENT

Compounds containing Nitrogen in the Biomass/Bio-fuels are reduced to ammonium compounds by Kjeldal digestion procedure making use of sulphuric acid, selenium, copper sulphate and sodium sulphate.

Sulphuric acid is a dehydrating as well as an oxidizing agent whereas Se and $CuSo_4$ are catalytic agents. The Na_2So_4 increases the boiling temperature. After the digestion is completed, a sub-sample is taken out to which an excess of NaOH is added. Ammonia, NH_3 is subsequently distilled over into boric acid and then titrated with potassium bi-iodate. The Nitrogen content of sample is then calculated from the equation:

$$N\% = [(s - b)M/W] \times 14 \times (50/V \times M \times 100$$

where

S = ml of $KH(IO_3)_2$ used for sample titration
b = ml of $KH(IO_3)_2$ used for blank titration
m = molarity of the $KH(IO_3)_2$

14 = atomic weight of N
50 = volume of digestion tube
V = ml used of the digest
100 = conversion factor for %
W = weight of sample
M = moisture correction factor

7.3 THE C- AND N- CONTENT OF BIO-GAS

The carbon content of Bio-gas was determined using the composition analysis by Orsat Chemical absorption Apparatus. The main contribution to C- is CO_2 and CH_4. The CO and other trace gases are in minute quantities and in any case including CO would give double counting. Contribution to N- (which is near zero) is largely from NO^x and NH_3 which appear only in traces and hence C/N ratio has not been made. In actual fact, it is really the C.N ratio of the materials digested to produce Bio-gas which is of cardinal importance. In the Orsat Chemical Absorption Apparatus, the constituent gases of Bio-gas are absorbed separately one after the other in different absorption vessels containing various chemicals.

7.4 NET HEATING VALUE OF BIO-FUEL

Measured quantities of the bio-fuel samples were each completely burned in a combustion chamber. The net heating values (equal to the gross heating value less the heat carried away by the products of combustion) estimated over the heat gained by measured quantities of water in a light calorimeter of known mass.

In the case of Bio-gas, the gross heating value is given. This is obtained through a calculation based on the composition components which are mainly CH_4 and CO_2. The high heating value, therefore, assumes that all Bio-gas is made up of CH_4 with only traces of CO_2.

7.5 OTHER PARAMETERS

Wet or dry matter weights and related quantities, as well as product to residue ratio, were determined by simple measurements on the biomass samples when wet and dry. The residue of any sample of biomass is actually the part which is considered waste for example, the peels of bananas or potatoes and the husks of grain crops, etc. The carbon content per tonne of dry matter is obviously much higher than that of wet matter and hence, most measurements adopted are those of dry matter. For wet wood, the values are 0.030 to 0.055 compared to 0.380.

The above-ground mass of the biomass was determined by specific field measurements and extrapolations based on vegetation distribution and on site samples of common bush clearing by fire.

The summary of results for the Biomass/Bio-fuel characterisation are shown in the Table 7.1 and 7.2 at the end of this description.

7.6 ESTIMATION OF ERRORS

The errors obtainable in the tabulated results are from the experimental measurements. The intrinsic qualities like water content of the raw material, dry or wet, are also a source of uncertainty in the final results. It is considered sufficient to give possible error limits for C-, N- contents and the derived ratios at 5%. The heating values have error limits of the order of 2% whereas the residue/product is about 5% on the average.

TABLE 7.1					
BIOMASS/FUEL EXPERIMENTAL PARAMETERS					
BIO-FUEL	C- CONTENT (TONNES OF C PER TONNE OF DRY MATTER)	N- CONTENT (TONNES OF N PER TONNE OF DRY MATTER)	C/N RATIO	N/C RATIO	ENERGY OUTPUT NET HEATING VALUE (GJ/t)
WOOD	0.272 TO 0.388	0.0098 to 0.0197	13.9 to 39.6	0.0253 to 0.0720	9.3 to 11.6
CHARCOAL	0.794 to 0.901	-	-	-	25.2 to 29.4
BIO-GAS (68.4%) CH_4)	8% FROM CO_2 48% FROM CH_4 = 56% c-	-	(HIGH)	(NEAR ZERO)	LOW 26.6 HIGH 42.0 MJ/CUBIC M (GROSS)

TABLE 7.2						
BIOMASS/BIO-FUEL EXPERIMENTAL PARAMETERS FOR CROP RESIDUES						
CROP WASTE	C-CONTENT (tonne of C/tonne (Dry Matter)	N-CONTENT (tonne of N/tonne (Dry Matter)	C/N	N/C	ENERGY OUTPUT (GJ/t)	RES/PRODUCT RATIO
Bananas	0.312	0.009	34.7	0.0288	7.6	0.4
Finger Millet	0.326	0.016	20.4	0.0491	8.4	1.1
Maize	0.329	0.0053	62.1	0.0161	8.9	1.0
Sorghum	0.284	0.011	25.8	0.0387	8.3	1.2
Rice	0.248	0.012	20.7	0.0484	8.1	1.4
Wheat	0.314	0.014	22.4	0.0446	7.2	1.2
Sweet Potato	0.365	0.0123	29.7	0.0337	7.9	0.3
Irish Potato	0.345	0.0175	19.7	0.0507	7.6	0.4
Cassava	0.332	0.023	14.4	0.0693	8.3	0.3
Beans	0.297	0.007	42.4	0.0236	7.7	0.7
Field Peas	0.297	0.033	9.0	0.1111	7.6	0.6
Cow Peas	0.293	0.0245	12.0	0.0836	7.7	0.6
Pigeon Peas	0.299	0.034	8.8	0.1137	7.6	0.7
Groundnuts	0.296	0.014	21.1	0.0473	8.3	1.0
Soya Beans	0.335	0.021	16.0	0.0627	7.8	0.7
Simsim	0.189	0.033	5.7	0.1746	8.3	5.1
Sugar cane	0.347	0.0035	99.1	0.0100	8.8	0.3
Coffee	0.381	0.0175	21.8	0.0459	8.9	0.8
Cotton (Stalk)	0.342	0.0192	17.8	0.0561	9.1	12.5
Mixed grass	0.305	0.0183	16.7	0.0600	7.9	-

Elephant Grass	0.269	0.014	19.2	0.0520	8.0	-
Swamp Grass	0.277	0.018	15.4	0.0650	7.4	-
Savanna Grass	0.306	0.019	6.1	0.0621	7.6	-
Papyrus Grass	0.314	0.0099	31.7	0.0315	7.3	-

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GLOSSARY AND ACRONYMS USED IN THE REPORT

ASN	= Ammonium Sulphate Nitrate
BOD	= Bio-chemical oxygen demand
CAA	= Civil Aviation Authority
CAN	= Calcium Ammonium Nitrate
CaO	= Calcium Oxide
CFCs	= Chlorofluorocarbons
CH_4	= Methane
CIDA	= Canadian International Development Agency
CO_2	= Carbon Dioxide
ESMAP	= Energy Sector Management/Assessment Program (World Bank)
FCCC	= Framework Convention on Climate Change
FUELWOOD	= Firewood
g	= gramme
GDP	= Gross Domestic Product
GEF	= Global Environment Facility
Gg	= Giga grammes (10^9g)
GHG	= Greenhouse Gases
INC	= Intergovernmental Negotiating Committee
IPCC	= Intergovernmental Panel on Climate Change
kg	= Kilogramme
l	= litre
LPG	= Liquid Petroleum Gas
MW	= Mega (Million) Watts
N_2O	= Nitrous Oxide
NBS	= National Biomass Study
NEAP	= National Environment Action Plan
NEC	= National Enterprises Corporation
NGO	= Non-Governmental Organisation
NMVOC	= Non-Methane Volatile Organic Compounds
NO_x	= Oxides of Nitrogen
NPK	= Nitrogen Phosphates Potassium
OECD	= Organisation for Economic Co-operation and development
SCOUL	= Sugar Corporation of Uganda Limited
Tg	= Tera grammes (10^{12}g)
TOE	= Tonnes of Oil Equivalent
TPPP	= Transport Policy and Planning Project
UEB	= Uganda Electricity Board
UN	= United Nations
UNCED	= United Nations Conference on Environment and Development
UNEP	= United Nations Environment Programme
UNICEF	= United Nations Children's Fund
URC	= Uganda Railways Corporation
WOOD-FUEL	= Charcoal and Firewood

APPENDIX 1

COMMENTS ON THE IPCC METHODOLOGY

Sector specific comments on the IPCC Methodology have been given in the main Report under the various sectors. A few more comments are given here below:

1. The recommended Methodology for the conversion of wood-fuel to charcoal was found to give erroneous results. So a simplified Methodology was adopted as can be seen in Section 1.9.3.

2. Conversion of grasslands to cultivated lands results in a reduction of the above ground Biomass. A Methodology for estimating the CO_2 emissions due to this reduction in Biomass should therefore be developed.

3. The sanitation facilities used by the majority of the population in developing countries is pit latrines. It is therefore necessary to develop a methodology which can be used to estimate methane emissions from these sanitation facilities.

APPENDIX 2

This Appendix I contains the resolutions and recommendations from the Steering Committee Meetings and the National Workshop.

1. STEERING COMMITTEE MEETING

1.1 POLICY OPTIONS AND VIEWS

The following are the Policy Options and Recommendations from the proceedings of the Steering Committee Meeting on the National Inventory of Anthropogenic Sources and Sinks of Greenhouse Gases which was held on 7 March 1994 in Kampala.

a. Participants agreed that even a small country like Uganda contributes GHG emissions to the atmosphere. Therefore, it was argued that these studies should be supported and Environmental Research should receive more support.

b. Members noted that more work ought to be done on land-use as it could be the key to GHG issues and other related activities. This is especially so considering that this inventory will be used in formulating further policy options in other aspects of environmental management.

c. Noted that efficient utilisation of fuels made good economic sense and was good for the environment. It was therefore essential to adapt cleaner and more efficient fuels.

d. Re-afforestation was recommended as a policy except that it should always follow appropriate research to ensure the right species for maximum absorption.

e. On emission permits and regulations, the meeting noted that subsidies and taxation may be difficult to implement and that such policies should be adapted after ascertaining the capacity to implement them. For example licensees may often be the culprits (due to taxation) and hence will fail to implement policies due to different interest groups. It was therefore necessary to look at other alternatives as incentives within the natural resources sector. For example, tax reductions could be incentives.

f. It was noted that awareness was still a problem and the members recommended that environment awareness should be made a major policy of government. If taxes, for example, are imposed, people should be well informed so as to understand the role of taxation.

g. Most members were of the view that Uganda is not a net emitter. They felt that data used was rather scattered and hence the GHG estimate was not accurate. They recommended further research and fine-tuning through increased data collection.

h Participants called for more research before suggesting policies which should have a legal framework. They noted that most policies are hurriedly put in place without ensuring implementation capacity.

At policy level, investment objectives should be synchronised with the environmental management objectives. This will call for more coordination with the various sub-sectors.

1.2 RECOMMENDATIONS AND POLICY IMPLICATIONS

The meeting endorsed the strategies as recommended s which were as follows:

a. **Strategies to limit GHG emissions**

i. Improving energy efficiency so as to reduce demand for energy and hence the amount of CO2 generated during energy production - thus improving economic performance, reducing other pollutant emissions and increasing energy security.

ii. Using cleaner energy sources and technologies - this reduces emissions of CO_2 and pollutants that cause acid rain and other environmental problems.

iii. Improving forest management and expanding forest areas thus increasing the size of a major global carbon sink.

iv. Adapting agricultural practices which reduce emissions of CH_4 and N_2O, e.g. improving livestock waste management, reducing the nitrogen content of fertilizer and improving rice cultivation techniques.

b. **Strategies to reduce the impacts of climate change.**

i. developing emergency and disaster preparedness policies and programmes;

ii. Improving the efficiency of natural resource use to minimise the impact of climate change on e.g. food security, water supplies and bio-diversity.

c. **Strategies to help society to adapt to new climatic conditions.**

i. research to reduce scientific and socio-economic uncertainties about climate change;

ii. expansion in ocean/lake observation and monitoring;

iii. development of new technologies in the fields of energy, industry and agriculture, e.g. efficient cook stoves;

iv. reviews of planning in the fields of energy, industry and agriculture, e.g. drought resistant crops.

v. Public information programmes advocating changes in behaviour, e.g. reduction in the use of private transport.

d. **Limitation and adaptation policies can be implemented through channels such as:**

i. Regulations and economic mechanisms, e.g. emission fees, fuel subsidies; emission permits and regulations can encourage industry to adopt low emission fuels and technologies;

ii. Technology development and transfer;

iii. International agreements, e.g. Montreal Protocol UNFCCC, etc.

Finally, it was agreed that the polluter pays principle should be encouraged. This should be applied selectively first covering only those who are supposed to know and can afford it, e.g. Industrialists and Institutions.

2 THE NATIONAL WORKSHOP

The following are recommendations on policy and technological options from the proceedings of the National Workshop on Sources and Sinks of Greenhouse Gases held in Kampala from 31 May to 1 June 1994.

2.1 WORKING GROUP ONE: ENERGY, INDUSTRY AND WASTES

a. **Energy Sector**

i. That use of large Transit Transport Systems be adopted instead of the cars and minibuses which are costly, cause congestion and give high emissions;

ii. That there is need for capacity building for handling emissions of greenhouse gases;

iii. That Governments should handle (estimate) their own local aviation emissions but where this is not possible, then an international opinion be sought, e.g. overflying planes; and

iv. That regional co-operation in fuel taxation should be encouraged so as to harmonise fuel prices and thus combat smuggling.

b. <u>Industry Sector</u>

i. that bodies like the Uganda Manufacturers Association (UMA) Uganda Investment Authority (UIA) and Uganda Natural Bureau of Standards (UNBS) should work jointly in setting up standards for industrial products so as to standardise their quality;

ii. that institutions which use wood-fuels be encouraged to have their own raw material sources, (i.e. tree plantations);

iii. adoption of appropriate and cost effective technology which suits the environmental requirements should be encouraged.

c. <u>Solvents and Waste</u>

i. that the Department of Environment should be requested to set up standards on the use of Solvents;

ii. that recycling of industrial and Domestic Waste be encouraged;

iii. that proper waste disposal facilities be set up so as to enable methane harvest; and

iv. that the use of bio-degradable paper bags as packaging material should be encouraged as opposed to the use of plastic bags.

2.2 <u>WORKING GROUP TWO: AGRICULTURE AND SAVANNA BURNING</u>

i. That for a complete inventory, the role of fruit trees and shrubs as sinks of CO_2 should be put under consideration;

ii. That the populace should be sensitized on the adverse effects of bush burning and that the existing laws against indiscriminate bush burning should be reinforced;

iii. That the emissions from wild-game especially those confined in zoos and National Parks should be considered;

iv. That proper use of some agriculture wastes as mulches or animal feed should be encouraged instead of burning;

v. That conversion of some agricultural wastes into energy through bio-degradation should be encouraged;

vi. That the growth of upland rice be encouraged so as to reduce the growth of paddy rice which results in CH_4 production;

vii. That the use of organic manure should be promoted as opposed to inorganic manure;

viii. That these given recommendations and other relevant environment education aspects should be included in the school syllabi; and

ix. That extension workers should be given refresher courses about greenhouse gases from time to time so as to encourage continuous monitoring of emissions from agricultural practices.

2.3 WORKING GROUP THREE: LAND-USE CHANGE AND FORESTRY

i. That fresh clearance of forests and grasslands for agriculture and other purposes should be discouraged;

ii. That the existing legislation covering the gazetted forest areas should be strengthened and that a new legislation to cover forests outside the gazetted areas should be established so as to enable the proper monitoring of changes in the privately owned forests;

iii. That the use of proper agricultural practices which reduce the rate of forest and grassland clearing should be encouraged;

iv. That to the extent possible, the use of wetlands for agricultural purposes should be discouraged and in cases where this is not possible then sustainable use of the wetlands should be encouraged;

v. That forestry programmes which result into re-afforestation should be enhanced;

vi. That the population should be sensitized on the sustainable use of forestry resources;

vii. That agro-forestry should be encouraged;

viii. That funding (both local and external), transfer of appropriate technology, capacity building, public awareness, research and development should be encouraged.

APPENDIX 3

MINERGG SOFTWARE

Copies of the MINERGG Software outputs have been attached for comparison with the results in the main reports. Please take note of the comments made about the short-comings and possible improvements of the software.

Fuel Type Fuel	Apparent Consumption (GJ)	x Emission Factor (kg C/GJ) =	Carbon Fraction (Gg C)	- Carbon Stored (Gg C)
Liquid Fuel				
Crude Oil	.00000E+0	20.0000	.00000E+0	.00000E+0
Natural Gas Liquids	.00000E+0	15.2000	.00000E+0	.00000E+0
LPG	.65760E+4	17.2000	.11310E+0	.00000E+0
Gasoline	.39042E+7	18.9000	.73789E+2	.00000E+0
Kerosene	.15987E+7	19.6000	.31335E+2	.00000E+0
Jet Fuel	.14912E+7	19.5000	.29079E+2	.00000E+0
Gas/Diesel Oil	.35972E+7	20.2000	.72665E+2	.00000E+0
Residual Fuel Oil	.81404E+6	21.1000	.17176E+2	.00000E+0
Naphtha	.00000E+0	20.0000	.00000E+0	.00000E+0
Bitumen	.00000E+0	22.0000	.00000E+0	.00000E+0
Lubricants	.00000E+0	20.0000	.00000E+0	.00000E+0
Petroleum Coke	.00000E+0	27.5000	.00000E+0	.00000E+0
Refinery Feedstocks	.00000E+0	20.0000	.00000E+0	.00000E+0
Other Oil Products	.67921E+4	20.0000	.13584E+0	.00000E+0
TOTAL Liquid Fuel	.11418E+8		.22429E+3	.00000E+0
Solid Fuel				
Coking Coal	.00000E+0	25.8000	.00000E+0	.00000E+0
Steam Coal	.00000E+0	25.8000	.00000E+0	.00000E+0
Lignite (Brown Coal)	.00000E+0	27.6000	.00000E+0	.00000E+0
Sub-bituminous Coal	.00000E+0	26.2000	.00000E+0	.00000E+0
Peat	.00000E+0	28.9000	.00000E+0	.00000E+0
Coke	.00000E+0	29.5000	.00000E+0	.00000E+0
BKB/Patent Fuels	.00000E+0	25.8000	.00000E+0	.00000E+0
TOTAL Solid Fuel	.00000E+0		.00000E+0	.00000E+0
Natural Gas				
Natural Gas (Dry)	.00000E+0	15.3000	.00000E+0	.00000E+0
TOTAL Natural Gas	.00000E+0		.00000E+0	.00000E+0
Biomass				
Biomass—Solid	.00000E+0	29.9000	.00000E+0	.00000E+0
Biomass—Liquid	.00000E+0	20.0000	.00000E+0	.00000E+0
TOTAL Biomass	.00000E+0		.00000E+0	.00000E+0
Oil Bunkers				
Jet Fuel Bunkers	.00000E+0	19.5000	.00000E+0	.00000E+0
Gas/Diesel Oil Bunkers	.00000E+0	20.2000	.00000E+0	.00000E+0
Resid. Fuel Oil Bunkers	.00000E+0	21.1000	.00000E+0	.00000E+0
"Other Oil" Bunkers	.00000E+0	20.0000	.00000E+0	.00000E+0
TOTAL Oil Bunkers	.00000E+0		.00000E+0	.00000E+0
TOTAL (excl. Biomass, Bunkers)	.11418E+8		.22429E+3	.00000E+0

Net Emissions = (Gg C)	x	Carbon Oxidized (fract)	=	Actual Emissions (Gg C)	Actual Emissions (Gg CO2)
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.11310E+0		0.990		.11197E+0	.41058E+0
.73789E+2		0.990		.73052E+2	.26785E+3
.31335E+2		0.990		.31021E+2	.11374E+3
.29079E+2		0.990		.28788E+2	.10555E+3
.72665E+2		0.990		.71938E+2	.26377E+3
.17176E+2		0.990		.17004E+2	.62350E+2
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.13584E+0		0.990		.13448E+0	.49310E+0
.22429E+3				.22205E+3	.81419E+3
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0		0.980		.00000E+0	.00000E+0
.00000E+0				.00000E+0	.00000E+0
.00000E+0		0.995		.00000E+0	.00000E+0
.00000E+0				.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0				.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0		0.990		.00000E+0	.00000E+0
.00000E+0				.00000E+0	.00000E+0
.22429E+3				.22205E+3	.81419E+3

Biofuel	Carbon Released (kt C)	x	Emission Ratio (C-CH4/C,C-CO/C)	=	Emissions (Gg C)	x	Conversion Factor
Wood	4,603		CH4 0.0120		55.236		16/12
			CO 0.0600		276.180		28/12
Charcoal Consumption	215		CH4 0.0014		0.301		16/12
			CO 0.0600		12.900		28/12
Charcoal Production	162		CH4 0.0630		10.206		16/12
			CO 0.0600		9.720		28/12
Agricultural Residues	0		CH4 0.0050		0.000		16/12
			CO 0.0600		0.000		28/12
Dung	0		CH4 0.0170		0.000		16/12
			CO 0.0600		0.000		28/12
Other	0		CH4 0.0100		0.000		16/12
			CO 0.0600		0.000		28/12
Total All Biofuels	4,980				65.743		
					298.800		

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Emissions = (Gg CH4,CO)	Nitrogen Released (kt N) x	Emission Ratio (N-N2O/N, N-NOx/N) =	Emissions (Gg N) x	Conversion Factor =	Emissions (Gg N2O,NOx)
73.646	46.030	N2O 0.0070	0.322	44/28	0.506
644.411		NOx 0.1210	5.570	30/14	11.936
0.401	0.000	N2O 0.0070	0.000	44/28	0.000
30.100		NOx 0.1210	0.000	30/14	0.000
13.608	1.620	N2O 0.0070	0.011	44/28	0.017
22.680		NOx 0.1210	0.196	30/14	0.420
0.000	0.000	N2O 0.0070	0.000	44/28	0.000
0.000		NOx 0.1210	0.000	30/14	0.000
0.000	0.000	N2O 0.0070	0.000	44/28	0.000
0.000		NOx 0.1210	0.000	30/14	0.000
0.000	0.000	N2O 0.0070	0.000	44/28	0.000
0.000		NOx 0.1210	0.000	30/14	0.000
87.655	47.650		0.333		0.523
697.191			5.766		12.356

Cement Production (kt)	x	Emission Factor (t CO2/t Cement)	=	CO2 Emissions (Gg C)	(Gg CO2)
30.91		0.4985		4.20	15.41

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Data Notes

The mean margin error between 1988 and 1992 based on production figures from the factories and from the central Government cement corperation is about 10%.

Significant amounts of lime as a finished product are made mainly for the road construction.For the year 1990 about 35.7Gg of lime were produced.The carbon-dioxide release was culculated by determining the pure CaO content of the lime and then multiplied by a conversion factor of 0.785. A value of 28.0Gg was obtained.

Animal	Enteric Fermentation: Population (1000 head) x	Emission Factor (kg CH4/head) =	Emissions (Gg CH4)	Population (1000 head)
Dairy Cows	0	0.00	0.00	0
Other Cattle	5,224	33.20	173.44	5,224
Buffalo	0	0.00	0.00	0
Sheep	840	5.00	4.20	840
Goats	3,800	5.00	19.00	3,800
Camels	0	0.00	0.00	0
Horses and Mules	0	0.00	0.00	0
Swine	760	1.00	0.76	760
Poultry	13,700	0.00	0.00	13,700
TOTAL			197.40	

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-Manure Management- Emission Factor x (kg CH4/head)	= Emissions (Gg CH4)	Total (Manure + Fermentation) (Gg CH4)
0.00	0.00	0.00
0.82	4.28	177.72
0.00	0.00	0.00
0.23	0.19	4.39
0.31	1.18	20.18
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.76
0.02	0.27	0.27
	5.92	203.32

Cultivation Type	Cultivated Area (Mha) x	Cropping Cycles per year x	Growing Season (days/ cycle) x	Emission Factor (kg/ ha/day) =	Methane Emissions (Gg CH4)
Wet (Totally flooded)	0	1.00	120	0.49	23.70
Intermittently flooded	0	0.00	0	0.00	0.00
Other	0	0.00	0	0.00	0.00
TOTAL	0	1.00	120	0.49	23.70

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		Biomass		Combustion		Biomass		Carbon		Carbon
x	Fraction Living or Dead	=	Burned (kt dm)	x	Efficiency (fraction)	=	Oxidized (kt dm)	x	Carbon Content (fract)	=	Carbon Released (Gg C)

Fraction Living or Dead		Biomass Burned (kt dm)	Combustion Efficiency (fraction)	Biomass Oxidized (kt dm)	Carbon Content (fract)	Carbon Released (Gg C)
LIVING	1.00	920.00	0.20	184.00	0.10	18.40
DEAD	0.00	0.00	1.00	0.00	0.40	0.00
LIVING	0.05	2,214.43	0.70	1,550.10	0.02	31.00
DEAD	0.95	42,074.21	1.00	42,074.21	0.77	32,397.14
LIVING	0.10	1,024.61	0.70	717.23	0.03	21.52
DEAD	0.90	9,221.47	1.00	9,221.47	0.31	2,858.66
LIVING	0.00	0.00	0.00	0.00	0.00	0.00
DEAD	1.00	3,964.80	1.00	3,964.80	0.31	1,229.09
LIVING	0.05	9,664.20	0.70	6,764.94	0.03	202.95
DEAD	0.95	183,619.80	1.00	183,619.80	0.31	56,922.14
LIVING	0.05	13,823.24	0.67	9,216.27	0.03	273.87
DEAD	0.95	238,880.28	1.00	238,880.28	0.39	93,407.03
		252,703.52		248,096.55	·	93,680.90

Savanna Category	Area Burned (kha)	x	Biomass Density (t dm/ha)	=	Biomass Exposed to Burning (kt dm)	x	Actually Burned (fract)	=	Actually Burned (kt dm)
Permanent swamp	920		20.0		18,400.0		0.05		920.00
seasonal swamp	1,864		54.0		100,656.0		0.44		44,288.64
Savanna woodland	821		26.0		21,346.0		0.48		10,246.08
Dry thicket	1,770		4.0		7,080.0		0.56		3,964.80
Savanna grassland	10,738		36.0		386,568.0		0.50		193,284.00
Total All Categories	16,113		33.1		534,050.0		0.47		252,703.52

Total Living and Dead

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Data Notes

The biomass density for 'permanent swamp' is 200 and not 20.0 so the result should be multiplied by a factor of 10. The software should be adjusted so as to take more than two places of whole number digits as well as a few more decimal places.

Crop	Annual Production (kt Biomass crop)	x	Residue to Crop Biomass Ratio	=	Residue (kt biomass)	x	Dry Matter Content (fract)	=	Dry Residue (kt dm)
Banana	7,293		0.4		2,917.2		0.45		1,312.7
Finger millet	578		1.1		635.8		0.85		540.4
Maize	400		1.0		400.0		0.75		300.0
Sorghum	344		1.2		412.8		0.80		330.2
Rice	23		1.4		32.2		0.85		27.3
Wheat	13		1.2		15.6		0.90		14.0
Sweet Potatoes	1,716		0.3		514.8		0.40		205.9
Irish Potatoes	190		1.4		266.0		0.40		106.4
Cassava	3,271		0.3		981.3		0.50		490.6
Beans	330		0.7		231.0		0.80		184.8
Field Peas	12		0.6		7.2		0.80		5.7
Cow Peas	38		0.6		22.8		0.80		18.2
Pigeon Peas	42		0.7		29.4		0.80		23.5
Ground Nuts	134		1.0		134.0		0.76		101.8
Soya Beans	14		0.7		9.8		0.88		8.6
Simsim	36		5.1		183.6		0.73		134.0
Sugar Cane	351		0.3		105.3		0.90		94.7
Coffee(A&R)	174		0.8		139.2		0.42		58.4
Cotton	3		1.2		3.6		0.80		2.8
Total All Crops	14,962		0.5		7,041.6		0.56		3,960.7

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Data Notes

The residue/crop ratio for cotton is 12.5 but the software can take only 1.2. A few more decimal places are required.

	Burned in Fields x (fract)	x Combustion Efficiency (fraction)	= Biomass Burned (kt dm)	x Carbon Fraction of Residue	= Carbon Released (Gg C)	x Nitrogen-Carbon Ratio	= Nitrogen Released (Gg C)
4	0.15	0.90	177.22	0.3120	55.29	0.095	5.253
3	0.20	0.90	97.28	0.3260	31.71	0.095	3.012
0	0.30	0.90	81.00	0.3290	26.65	0.095	2.532
4	0.40	0.90	118.89	0.2840	33.76	0.095	3.207
7	0.60	0.90	14.78	0.2480	3.67	0.095	0.349
4	0.40	0.90	5.05	0.3140	1.59	0.095	0.151
2	0.05	0.90	9.27	0.3650	3.38	0.095	0.321
0	0.05	0.90	4.79	0.3450	1.65	0.095	0.157
5	0.05	0.90	22.08	0.3320	7.33	0.095	0.696
0	0.05	0.90	8.32	0.2970	2.47	0.095	0.235
6	0.05	0.90	0.26	0.2970	0.08	0.095	0.008
4	0.05	0.90	0.82	0.2930	0.24	0.095	0.023
2	0.05	0.90	1.06	0.2990	0.32	0.095	0.030
4	0.60	0.90	54.99	0.2960	16.28	0.095	1.547
2	0.05	0.90	0.39	0.3350	0.13	0.095	0.012
3	0.95	0.90	114.60	0.1890	21.66	0.095	2.058
7	0.95	0.90	81.03	0.3470	28.12	0.095	2.671
6	0.30	0.90	15.78	0.3810	6.01	0.095	0.571
8	0.95	0.90	2.46	0.3420	0.84	0.095	0.080
1	0.23	0.90	810.07	0.2977	241.18	0.095	22.913

Forest Type	Area Cleared Anually (kha) x	Biomass Before Clearing [(t dm/ha) -	Biomass After Clearing (t dm/ha) =	Net Change in Biomass (t dm/ha)] =
Tropical Closed Forest				
Broadleaf:	0	0	0	0
Broadleaf: Logged	13	202	59	143
Conifer: Undisturbed	0	0	0	0
Conifer: Logged	0	0	0	0
Unproductive	0	0	0	0
Total Tropical Closed	13	202	59	143
Tropical Open Forest				
Productive	0	0	0	0
Unproductive	13	32	10	22
Total Tropical Open	13	32	10	22
Temperate Evergreen				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Temperate	0	0	0	0
Temperate Deciduous				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Temperate	0	0	0	0
Boreal				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Boreal	0	0	0	0
Other	0	0	0	0
Total ALL FORESTS	26	117	35	83

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Forest Clearing: Aboveground
CO2 Released from On-Site Burning

Annual Loss of Biomass (kt dm) x	Burned On-Site (fract) =	Biomass Burned On-Site (kt dm) x	Combustion Efficiency (fraction) x	Carbon Content of Aboveground Biomass Burned On-Site (fraction) =	Carbon Released (Gg C)	(Gg CO2)
0	0.00	0	0.90	0.45	0.00	0.00
1,859	0.20	371	0.87	0.33	106.74	391.39
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
1,859	0.20	371	0.87	0.33	106.74	391.39
0	0.00	0	0.90	0.45	0.00	0.00
286	0.20	57	0.87	0.33	16.42	60.21
286	0.20	57	0.87	0.33	16.42	60.21
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
2,145	0.20	429	0.87	0.33	123.16	451.60

Forest Type	Area Cleared Anually (kha) x	Biomass Before Clearing [(t dm/ha) -	Biomass After Clearing (t dm/ha) =	Net Change in Biomass (t dm/ha)] =
Tropical Closed Forest				
Broadleaf:	0	0	0	0
Broadleaf: Logged	13	202	59	143
Conifer: Undisturbed	0	0	0	0
Conifer: Logged	0	0	0	0
Unproductive	0	0	0	0
Total Tropical Closed	13	202	59	143
Tropical Open Forest				
Productive	0	0	0	0
Unproductive	13	32	10	22
Total Tropical Open	13	32	10	22
Temperate Evergreen				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Temperate	0	0	0	0
Temperate Deciduous				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Temperate	0	0	0	0
Boreal				
Primary	0	0	0	0
Secondary	0	0	0	0
Total Boreal	0	0	0	0
Other	0	0	0	0
Total ALL FORESTS	26	117	35	83

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Annual Loss of Biomass (kt dm) x	Burned Off-Site (fract) =	Biomass Burned Off-Site (kt dm) x	Combustion Efficiency (fraction) x	Carbon Content of Aboveground Biomass Burned Off-Site (fraction) =	Carbon Released (Gg C)	Carbon Released (Gg CO2)
0	0.00	0	0.90	0.45	0.00	0.00
1,859	0.00	0	0.87	0.33	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
1,859	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
286	0.00	0	0.87	0.33	0.00	0.00
286	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.00	0.00	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
0	0.00	0	0.90	0.45	0.00	0.00
2,145	0.00	0	0.00	0.00	0.00	0.00

Forest Type	Area Cleared Anually (kha)	x	Biomass Before Clearing [(t dm/ha)	-	Biomass After Clearing (t dm/ha)	=	Net Change in Biomass (t dm/ha)]
Tropical Closed Forest							
Broadleaf:	0		0		0		0
Broadleaf: Logged	10		202		59		143
Conifer: Undisturbed	0		0		0		0
Conifer: Logged	0		0		0		0
Unproductive	0		0		0		0
Total Tropical Closed	10		202		59		143
Tropical Open Forest							
Productive	0		0		0		0
Unproductive	10		32		10		22
Total Tropical Open	10		32		10		22
Temperate Evergreen							
Primary	0		0		0		0
Secondary	0		0		0		0
Total Temperate	0		0		0		0
Temperate Deciduous							
Primary	0		0		0		0
Secondary	0		0		0		0
Total Temperate	0		0		0		0
Boreal							
Primary	0		0		0		0
Secondary	0		0		0		0
Total Boreal	0		0		0		0
Other	0		0		0		0
Total ALL FORESTS	20		117		35		83

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Annual Loss of Biomass = (kt dm) x	Decayed (fract) =	Biomass Decayed (kt dm) x	Carbon Content of Aboveground Biomass Decayed (fraction) =	Carbon Released (Gg C)	(Gg CO2)
0	0.00	0	0.45	0.00	0.00
1,430	0.05	71	0.33	23.59	86.51
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.45	0.00	0.00
1,430	0.05	71	0.33	23.59	86.51
0	0.00	0	0.45	0.00	0.00
220	0.05	11	0.33	3.63	13.31
220	0.05	11	0.33	3.63	13.31
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.00	0.00	0.00
0	0.00	0	0.00	0.00	0.00
0	0.00	0	0.00	0.00	0.00
0	0.00	0	0.45	0.00	0.00
0	0.00	0	0.45	0.00	0.00
1,650	0.05	82	0.33	27.22	99.82

Data Notes

The annual rate of deforestation over 25 years was calculated from Langdale's estimate as a base year and the Forestry department estimates of 1987 (over 29 years), where the annual rate for Tropical Forests was calculated to be 13,400 ha. For areas outside the gazetted areas, such as open woodlands, there was no reliable data. So in order to fill this gap the estimate for the Tropical High Forest was also used for the Open forests.
As for the ten year rate of deforestation for the decay, estimates were obtained from UNEP 1988 (1977-1987) where it was estimated that a total of 100,000 ha of Forest were cleared making an average of 10,000 ha being removed annually.

The growing stock before and after was National data from the National Biomass Study Phase I results.

The rest of the data such as fraction of carbon released or burnt and Carbon equivalents was based on the Tanzanian country specific data i.e about 75 % of the total cleared biomass is collected as fuelwood and 20 % of the above ground biomass is burnt in fields (10 % of the burnt carbon remains on the ground as charcoal, the remaining clearedbiomas which is 5 % of the above ground biomass such as foliage, twigs and humus decays in fields over an average of ten years releasing one tenths of its carbon content on dry weight basis annually. While this could be true for the Tanzanian case, the expert opinion for Uganda could be different because of differences of fuelwood supply and agricultural practises. In Uganda in areas where fuelwood could easily be obtained from the neighbourhood of the homesteads, farmers normally burn the cleared aboveground biomass in order to open up the area for agriculture and the rest is left to rot as manure. It is however not easily quantifiable as to how much is burnt immediately and how much is left to rot.

25 Year Total Conversion of Grasslands to Cultivation (kha)	x	Soil Carbon Content of Grasslands (t C/ha)	x	Annual Rate of Carbon Release from Soil (fraction)	=	Total Annual Soil Carbon Release from Grassland Conversion (Gg C)	(Gg CO2)
235		98.7		0.025		579.86	2,126.16

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Data Notes

Conversion of Grasslands to cultivated lands results in a reduction of above ground Biomass. A methodology for estimating the CO2 emissions due to this reduction in Biomass should therefore be incoporated in the Software.

Using the following values from the Gambia report:

_ Grassland Biomass density before conversion = 7.3t\ha
_ Grassland Biomass density after conversion = 6.0t\ha,
gives CO2 emissions of 4,485.4Gg.

This MINERGG software does not take into consideration the CH4 uptake
reduction due to conversion of Grasslands to cultivated lands.
Using the Emission Factors from the Gambia report gives:

_ CH4 uptake reduction = 4.015Gg.

Forest Type	Area of Managed Forest (kha)	x	Growth Rate (t dm/ ha)	=	Biomass Increment (kt dm)	x	Carbon Content (fract)	=	Total Carbon Increment (Gg C)
Tropical Plantations									
Acacia spp.	0		15.0		0.0		0.45		0.000
Eucalyptus spp.	25		14.5		362.5		0.45		163.125
Tectona grandis	0		8.0		0.0		0.45		0.000
Pinus spp.	0		11.5		0.0		0.45		0.000
Pinus caribaea	0		10.0		0.0		0.45		0.000
Mixed Hardwoods	0		6.8		0.0		0.45		0.000
Mixed Fast-Growing	0		12.5		0.0		0.45		0.000
Mixed Softwoods	13		14.5		188.5		0.45		84.825
Total Tropical	38		14.5		551.0		0.45		247.950
Tropical Logged									
Closed Broadleaf	384		11.0		4,224.0		0.45		1,900.800
Closed Condiferous	0		0.0		0.0		0.45		0.000
Open	680		6.6		4,488.0		0.45		2,019.600
Total Tropical Logged	1,064		8.2		8,712.0		0.45		3,920.400
Tropical Other	0		6.6		0.0		0.45		0.000
Temperate Plantations									
Douglas Fir	0		6.0		0.0		0.45		0.000
Loblolly pine	0		4.0		0.0		0.45		0.000
Total Temperate	0		0.0		0.0		0.00		0.000
Temperate Commercial									
Evergreen	0		0.0		0.0		0.45		0.000
Deciduous	0		0.0		0.0		0.45		0.000
Total Temperate	0		0.0		0.0		0.00		0.000
Temperate Other	0		0.0		0.0		0.45		0.000
Boreal	0		0.0		0.0		0.45		0.000
	Number of Trees (1000's of trees)		Growth Rate (kt dm/ 1000 trees)						
Afforestation Programs	0		0.0		0.0		0.45		0.000
Village & Farm Trees	0		0.0		0.0		0.45		0.000

Forest Type	Area of Managed Forest (kha)	x	Growth Rate (t dm/ ha)	=	Biomass Increment (kt dm)	x	Carbon Content (fract)	=	Total Carbon Increment (Gg C)
Total ALL FORESTS					9,263.0		0.45		4,168.350

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Data Notes

1. Area data on plantations and tropical high forests are mainly from forest department records. As for the closed forests the data was obtained from Howard, P.C (Nature Conservation in Uganda's Tropical High Forest).

2. The rest of the data is default data from the IPCC workbook.

Total Biomass Removed in Commercial Harvest (kt dm)	+	Total Fuelwood Consumed (kt dm)	+	Other Wood Use (kt dm)	=	Total Biomass Consumption (kt dm)	-	Wood Removed from Forest Clearing (kt dm)	=	Total Biomass Consumption from Managed Forests (kt dm)
126.00		12,146		0		12,272.00		0.00		12,272.00

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Data Notes

The harvest figure was obtained from the Forestry department records of 1989. Conversion factor was obtained from FAO yearbook of forest Statistics.

Annual Carbon Uptake (Gg C)	-	Annual Carbon Release (Gg C)	=	Net Annual Removal (Gg C)	(Gg CO2)
4,168.35		5,522.40		-1,354.05	-4,964.85

NOTE: The Net Annual Removal is negative, thus, a positive Emission of Carbon.

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x	Carbon Content (fraction)	=	Annual Carbon Release (Gg C)
	0.45		5,522.40

Landfill Type	MSW Landfilled (Gg MSW)	x	Fraction DOC (Gg DOC/ Gg MSW)	=	DOC Landfilled (Gg DOC)	x	Fraction which Actually Degrades	=
All Landfills	34.32		0.14		4.80		0.75	

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Data Notes

It was assumed that 30% of the total MSW generated was. under land-filled conditions.This was based on the fact that most of the MSW is open-dumped. However,it is necessary to carry out case studies so as to determine a more appropriate fraction.

C Released as Biogas (Gg C)	Fraction CH4 (Gg C-CH4/ x Gg C-Biogas) =	Emissions (Gg C-CH4)	(Gg CH4) -	CH4 Recovered (Gg CH4) =	Net Emissions (Gg CH4)
3.60	0.50	1.80	2.40	0.00	2.40

Population (1000 persons)	12,529
x BOD Generation Rate (Gg BOD5/1000 persons/year)	0.0135
= BOD Generated (Gg BOD5)	169.14
x Fraction Anaerobically Treated	0.04
= BOD Treated Anaerobically (Gg BOD5)	6.77
x Emission Factor (Gg CH4/Gg BOD5)	0.22
= Emissions (Gg CH4)	1.49
- CH4 Recovered (Gg CH4)	0.00
= Net Emissions (Gg CH4)	1.49

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Data Notes

The sanitation facilities used by the majority(about 75%) of the population is pit Latrines. Provisional culculations were made using assumed values of BOD and the fraction anaerobically digested.It is therefore very necessary to carry out case studies to determine the appropriate conversion factors.Even the equation for methane released from pit Latrines may be different from the one for the water-borne sanitation facilities.

UGANDA GREENHOUSE GAS EMISSIONS 08/24/94

Data Year: 1990

Module / Submodule	Data Year	CO2 (Gg CO2)	CH4 (Gg CH4)	N2O (Gg N2O)	NOx (Gg NOx)	CO (Gg CO)
Energy						
Combustion						
CO2 from Energy	1990	814				
Biomass (non-CO2)	1990		87.7	0.5	12.4	697
Fugitive						
Oil and Gas Systems	1990		0.0			
Coal Production	1990		0.0			
Energy Subtotal		814	87.7	0.5	12.4	697
Industry						
Cement Production	1990	15				
Agriculture						
Livestock	1990		203.3			
Rice Cultivation	1990		23.7			
Savanna Burning	1990		961.8	40.8	1164.8	16,831
Agricultural Residues	1990		3.2	0.3	5.9	56
Agriculture Subtotal			1192.0	41.1	1170.7	16,887
Land Use Change & Forestry						
Forest Clearing						
Aboveground	1990	551				
Soils	1990	2,383				
On-Site Burning	1990		2.0	0.0	0.3	17
Grassland Conversion	1990	2,126				
Aband. of Managed Lands	1990	0				
Managed Forests						
Annual Growth	1990	-4,168				
Biomass Harvest	1990	5,522				
Land Use Subtotal		6,415	2.0	0.0	0.3	17
Waste						
Landfills	1990		2.4			
Wastewater						
Industrial	1990		0.0			
Municipal	1990		1.5			
Waste Subtotal			3.9			
TOTAL EMISSIONS		7,245	1285.5	41.6	1183.4	17,602

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