TRAINING MANUAL

ON

MEASUREMENT, REPORTING AND VERIFICATION (MRV) AND GREEN HOUSE GAS (GHG) REPORTING TO SUPPORT REDD+ IN ZAMBIA

MAY 2012

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This report has been prepared by Centre for Energy, Environment and Engineering Zambia (CEEEZ) for the UN REDD Programme for Zambia

ACRONYMS

CH_4 - Methane

CO - Carbon monoxide

CO_2 - Carbon dioxide

COP – Conference of Parties

DoE - Department of Energy

EFDB - Emission Factor Database

EPA - Environmental Protection Agency

GHG - Greenhouse Gases

GL - Guidelines

IPCC - Intergovernmental Panel on Climate Change

LUCF- Land Use Change and Forestry

LULUCF- Land Use, Land Use Change and Forestry

NAMA - Nationally Appropriate Mitigation Actions

N_2O - Nitrous oxide

NO_X - Nitrogen oxides

NMVOC- Non-methane volatile organic compound

UNFCCC - United Nations Framework Convention on Climate Change

SUMMARY OF MANUAL

This training manual on Greenhouse Gas (GHG) Reporting to support REDD+ in Zambia includes an overview of the science of climate change and forest carbon, the role of forest in the carbon cycle, and forest degradation. It then covers an overview of National GHG Inventories and reporting format focusing on requirements, legal, institutional and procedural arrangements, objectives of the inventory, GHG reporting gases, estimation methodology and reporting format. It finally elaborates on the IPCC land use, land use change and forestry methodologies aimed at estimating emissions and removals from this category to include; Revised IPCC1996 methodology, IPCC Good Practice Guidance 2003 for land use, land use change and forestry, and introduces 2006 IPCC Guidelines Agriculture Forestry and Land Use (AFOLU).

1.0 BACKGROUND ON GLOBAL WARMING AND CLIMATE CHANGE AND LINKAGE TO FOREST CARBON

1.1 Definition and Causes of Global Warming

Global warming is the observed and projected increases in the average temperature of Earth's atmosphere and oceans. The Earth's average temperature rose about 0.6° Celsius in the 20th century (Figure1.1).

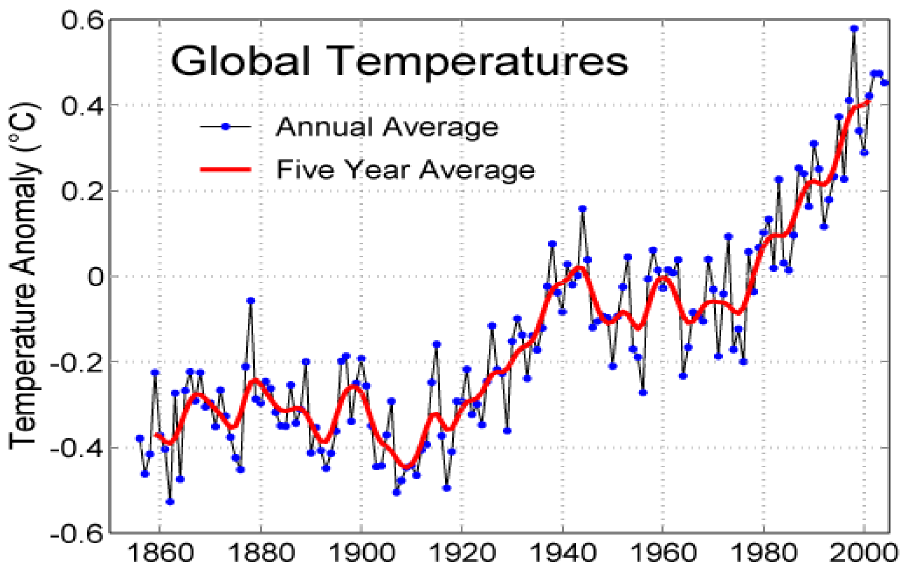


Fig 1.1: Definition for global warming

According to different assumptions about the future behaviour of mankind, a projection of current trends as represented by a number of different scenarios gives temperature increases of about 3° to 5° C by the year 2100 or soon afterwards(Figure 1.2).

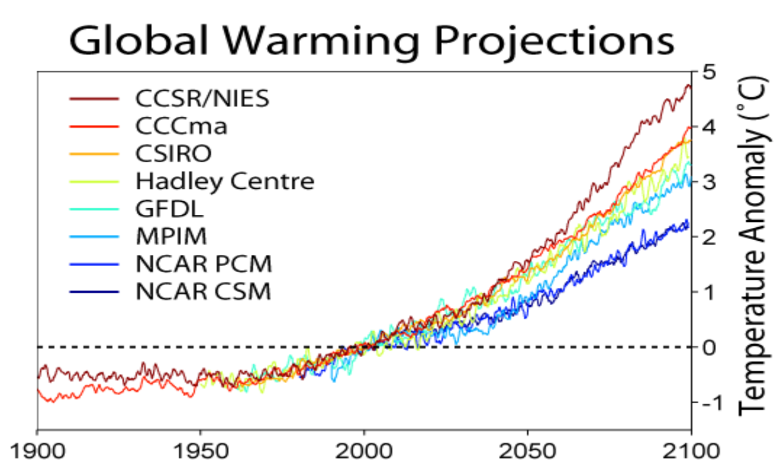


Fig 1.2: Definition for global warming: Temperature increase until the year 2100.

Almost 100% of the observed temperature increase over the last 50 years has been due to the increase in the atmosphere of greenhouse gas concentrations like carbon dioxide (CO_2), methane and nitrous oxide (N_2O). The largest contributing source of greenhouse gas is the burning of fossil fuels leading to the emission of carbon dioxide.

The greenhouse effect

When sunlight reaches Earth's surface, some is absorbed and warms the earth and most of the rest is radiated back to the atmosphere at a longer wavelength than the sun light. Some of these longer wavelengths are absorbed by greenhouse gases in the atmosphere before they are lost to space (Figure 1.3).

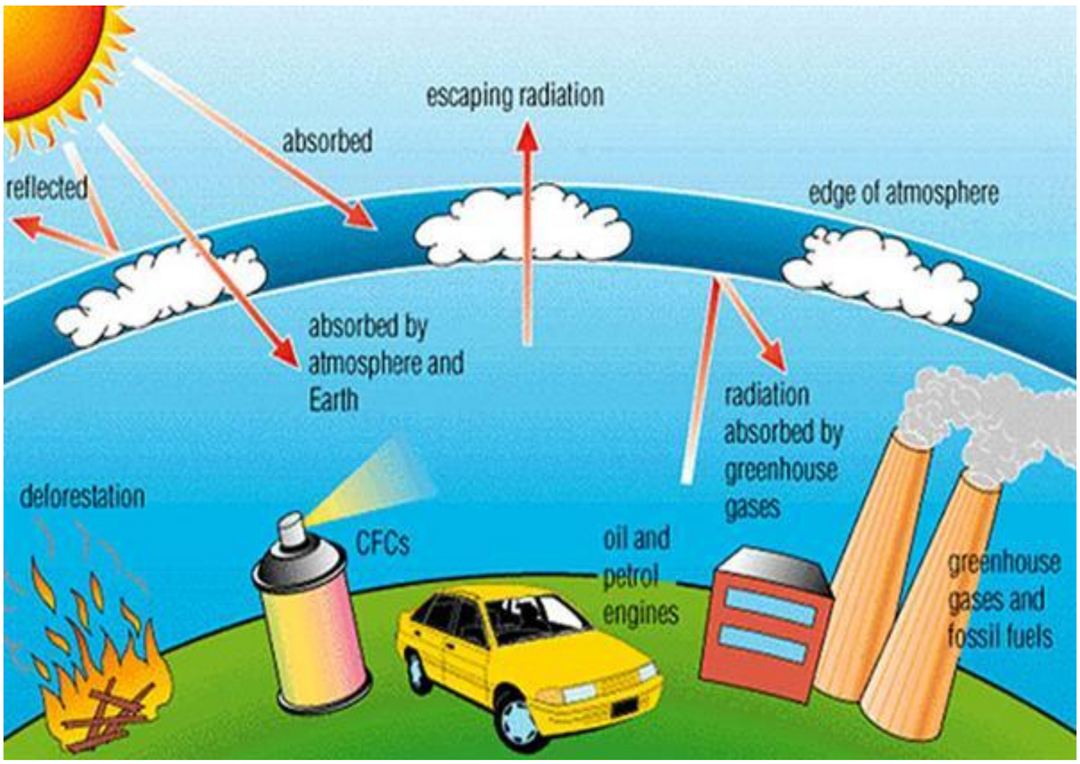


Figure 1.3 Greenhouse effect

The absorption of this long wave radiant energy warms the atmosphere. These greenhouse gases act like a mirror and reflect back to the Earth some of the heat energy which would otherwise be lost to space. The reflecting back of heat energy by the atmosphere is called the "greenhouse effect".

Effects of Global Warming

There are two major effects of global warming and these are;

- Increase of temperature on the earth by about 3° to 5° C by the year 2100.
- Rise of sea levels by at least 25 meters by the year 2100.

Increasing global temperatures are causing a broad range of changes. Sea levels are rising due to thermal expansion of the ocean, in addition to melting of land ice. Amounts and patterns of precipitation are changing. The total annual power of hurricanes has already increased markedly since 1975 because their average intensity and average duration have increased (in addition, there has been a high correlation of hurricane power with tropical sea-surface temperature).

Changes in temperature and precipitation patterns increase the frequency, duration, and intensity of other extreme weather events, such as floods, droughts, heat waves, and tornadoes. Other effects of global warming include higher or lower agricultural yields, further glacial retreat, reduced summer stream flows, species extinctions. As a further effect of global warming, diseases like malaria are returning into areas where they have been extinguished earlier.

Climate change is a complex problem, which, although environmental in nature, has consequences for all spheres of existence on our planet. It either impacts on-- or is impacted by-- global issues, including poverty, economic development, population growth, sustainable development and resource management. It is not surprising, then, that solutions come from all disciplines and fields of research and development.

At the very heart of the response to climate change, however, lies the need to reduce emissions. In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below 2 degrees Celsius.

1.2 UNFCCC-The International Response to Climate Change

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were by then inevitable.

By 1995, countries realized that emission reductions provisions in the Convention were inadequate. The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization 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.

They launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed countries to emission reduction targets. The Protocol’s first commitment period started in 2008 and ends in 2012. At COP17 in Durban, governments of the Parties to the Kyoto Protocol decided that a second commitment period, from 2013 onwards, would seamlessly follow the end of the first commitment period. The length of the second commitment period is to be determined: it will be either five or eight years long.

There are now 195 Parties to the Convention. The UNFCCC secretariat supports all institutions involved in the international climate change negotiations, particularly the Conference of the Parties (COP), the subsidiary bodies (which advise the COP), and the COP Bureau (which deals mainly with procedural and organizational issues arising from the COP and also has technical functions).

1.3 Climate Change Science and Forest Carbon

1.3.1 Climate Change Science

Unequivocal scientific evidence based on 2007 IPCC findings shows that, since the industrial revolution, the burning of fossil fuels and the destruction of forests have caused the concentrations of heat- trapping green house gases to increase significantly in our atmosphere, at a speed and magnitude much greater than natural fluctuations would dictate (IPCC, 2007). If concentrations of greenhouse gases in the atmosphere continue to increase, the average temperature at the Earth's surface will increase from 1.8 to 4 C above 2000 levels by the end of this century (IPCC 2007c).

Impacts of climate change, many of which have already been seen, include temperature increase, sea level rise, melting of glaciers and sea ice, increased coral bleaching, changes in the location of suitable habitat for plants and animals, more intense droughts, hurricanes and other extreme weather events, increased wildfire risk and increased damage from floods and storms. People living in marginal poverty- stricken areas are most at risk of being severely and negatively impacted by climate change, as their livelihoods are closely tied to ecosystems which provide water for drinking, wildlife for hunting, fishing and medicinal plants (African Development Bank, 2003). Protecting forests can both mitigate climate change and protect the ecosystems services people depend on.

1.3.2 The Role of Forests in the Carbon Cycle

Trees absorb carbon dioxide gas from the atmosphere during photosynthesis and, in the process of growing, transform the gas to the solid carbon that makes up their barks, wood, leaves and roots. When trees are cut down and burned or left to decompose, the solid carbon chemically changes back to carbon dioxide gas and returns to the atmosphere. In the case of timber harvesting, only a fraction of the harvested tress make it into the long term wood products such as houses, chairs, and tables. For example, one study estimates that for every tree harvested using conventional logging techniques in Amazonia, 35.8 additional were damaged (Gerwing, et al, 1996). As much as 20 percent of usable timber volume that was extracted from a typical hectare was never removed and instead left to rot in the forest. Furthermore, less than 35 percent of the timber that made it to the saw-mill was actually converted into usable boards.

Hence, the majority of the forest vegetation ends up as waste, and whether burned or left to decay, emits carbon dioxide gas as it breaks down (Figure 1.1).

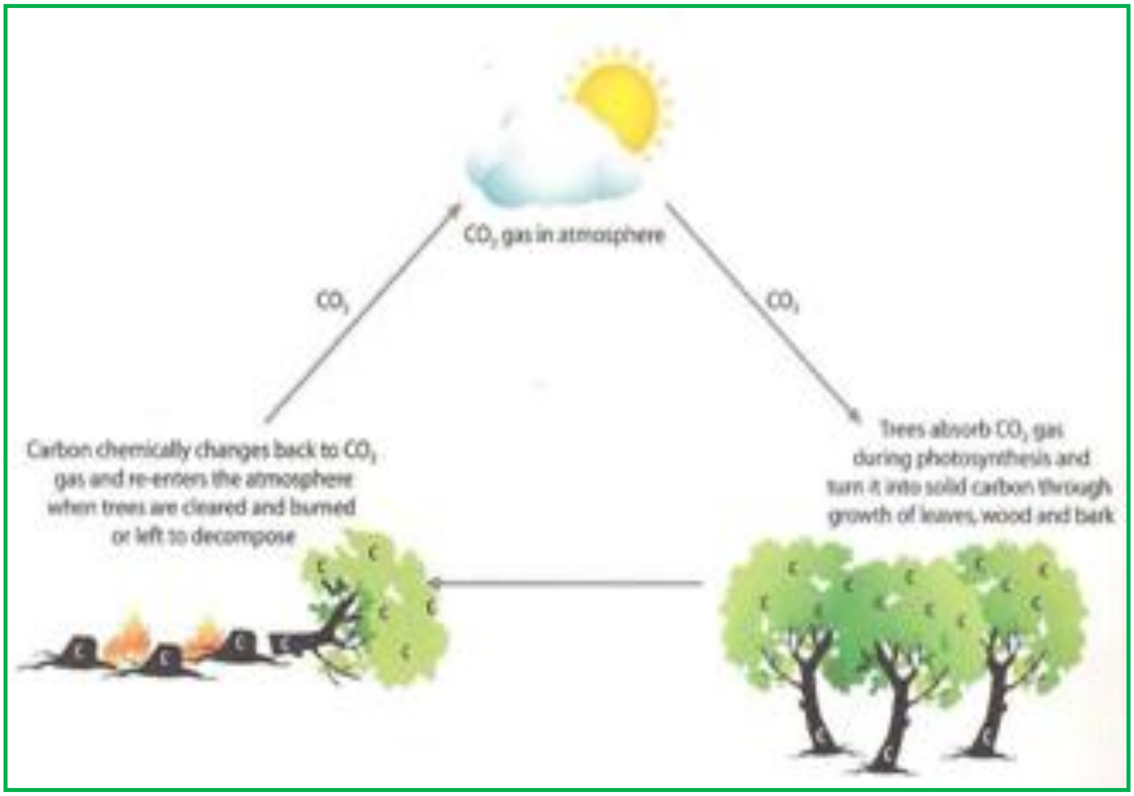


Figure 1.1: Simplistic diagram of trees and carbon cycle. Source: N.Virgilio,TNC

Forests and other terrestrial systems annually absorb approximately 2.6 gigatons of carbon (GtC), or 9.53gigatons of carbon dioxide equivalent (GtCO2e), while deforestation and degradation of forests emit approximately 1.6 GtC(5.87GtCO2e), for net absorption of 1 GtC(3.67 GtCO2e) (IPCC, 2007). Forests therefore play an important role in the global carbon cycle as both a “sink” (absorbing carbon dioxide) and a “source” (emitting carbon dioxide). The 1.6 GtC emitted by deforestation and degradation of forests accounts for 17.4 percent of total emissions from all sectors, and this is more than the emissions of the entire global transportation sector (Figure 1.2) (IPCC 2007). Thus policy and economic incentives to curb deforestation and forest damage have the potential to enhance the natural functioning of the world’s forests in sequestering, or storing, carbon and to reduce their role as a source of emissions.

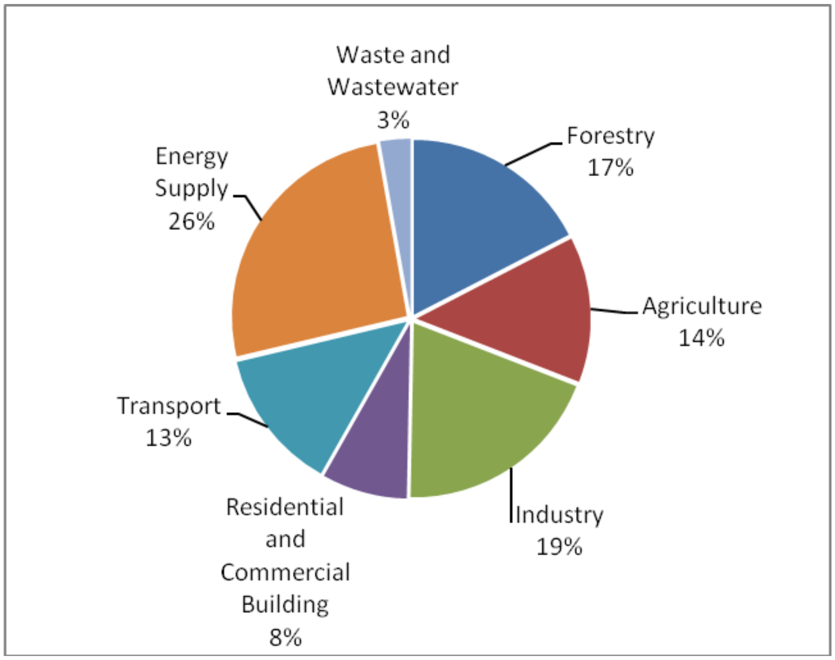


Figure 1.2 Attribution of global greenhouse gas emissions: Source IPCC 4th Assessment report for policy makers (2007)

1.3.3 Forest Degradation

While deforestation refers to the entire loss of patches of forest through clearing and conversion to other lands uses (e.g. farming, ranching and development), forest degradation refers to the loss of biomass (living vegetation) in forests through timber harvesting, fuel-wood gathering, fire and other activities which do not result in complete conversion to other land uses. In its classification of "forest", the Intergovernmental Panel on Climate Change (IPCC) uses a minimum crown cover of 10 percent. Thus, by this definition, up to 90 percent of a forest can be cleared before it is considered deforested. As such forest degradation can lead to substantial carbon emissions and is often a precursor to deforestation. For example, roads created by logging operations open up previously untouched land to conversion. Also, openings in forest canopy caused by forest degradation increase the risk of forest fire, which in turn increases the risk of conversion of land to pasture for grazing and ultimately agriculture (Figure 1.3) (Griscom,et al, 2009).

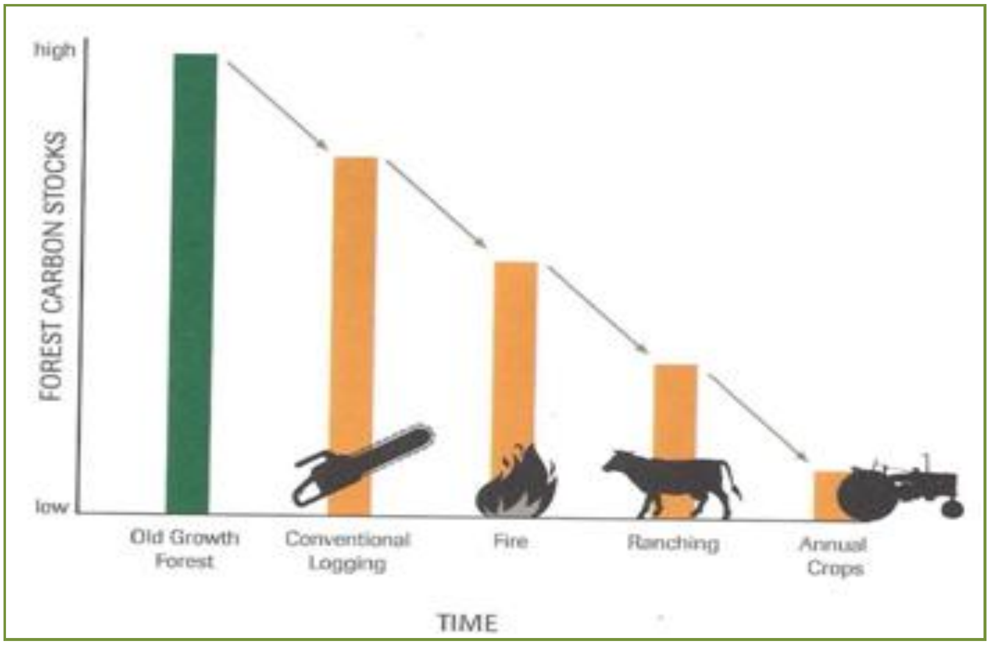


Figure 1.3: illustrative interaction between degradation and processes leading to conversion. Source: B Griscom,TNC

The IPCC estimates that from 17.4 percent of emissions from forestry, approximately 2.2 percent are a result of tropical forest degradation (from logging alone). The estimate, however, appears to substantially underestimate emissions from logging and does not consider other forms of degradation such as fuelwood harvest and fire, which depending on location can significantly add to emissions (Putz,et al. 2008 and Alencar, et al, 2006)

2.0 OVERVIEW OF NATIONAL GREENHOUSE GAS INVENTORIES AND REPORTING FORMAT

2.1 National Greenhouse Gas Inventories

All Parties to the Climate Convention (UNFCCC) must submit national reports on the implementation of the Convention to the Conference of Parties (COP). The required contents of national communications and the timetable for their submission are different for Annex I and non-Annex I Parties. This is in accordance with the principle of "*common but differentiated responsibilities*" enshrined in the Convention.

(i) Annex I Parties

Must submit an annual inventory of their GHG emissions, including data for their base year (1990) and all years since, except for the two years before submission. The inventory is annually reviewed by international review teams. In addition, Annex I Parties shall periodically submit their national communications, according to the deadlines established by the Conference of the Parties; the national communications are also reviewed by international review teams.

(ii) Non-Annex I Parties

Must report in more general terms on their actions to address climate change and to adapt to its effect. A periodic reporting as part of the national communication is required, including their GHG inventory information. No reviews are scheduled (every four years, most non-Annex I Parties are finalizing their 2nd National Communications), and some have already undertaken their 3rd National Communication Reporting.

2.2 Requirements legal, institutional and procedural arrangements

Each Party to the Convention and the Kyoto Protocol is committed to develop, publish and regularly update national emission inventories of greenhouse gases as well as formulate and implement projects to reduce these emissions. Article 5.1 of the Kyoto Protocol requires that Annex I Parties to the Convention have a *National System* in place for estimating anthropogenic GHG emissions and removals and for reporting and archiving the results.

New mechanisms for mitigation actions in non-Annex I Parties (Cancun agreements)

National Appropriate Mitigation Actions by developing country parties (NAMAs)

(i) National communications have to be enhanced including reporting every two years
(ii) Mitigation actions will be measured, reported and verified and subject to international verification in accordance with the guidelines developed under the Convention

Policy approaches and positive incentives on issues relating to REDD+

(i) To implement robust and transparent national forest monitoring system for reporting of the REDD+ activities.
(ii) To develop resulted-based actions that are fully measured, reported and verified (MRV).
(iii) To develop national strategies, policies and measures and capacity building.

2.3 Objectives of the inventory

Quantify emission levels, identify the main sources and assess the impact on health and environment through appropriate models (i) Ensure compliance with national emission limits and reduction commitments undertaken under various international contexts (ii) Develop strategies and identify abatement priorities through cost-effects analysis and integrated models (iii) Verify the effects of policies and measures undertaken to reduce emissions at different levels (sectoral, regional, national and international) (iv)Verify the interaction between sectoral policies, economic accounts and environmental impacts (v) Provide comparable and publicly available information through appropriate indicators

2.4 National Greenhouse Gas Inventories: Reporting gases

As a minimum, inventories have to include the following GHGs:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Perfluorocarbons (PFCs)
- Hydrofluorocarbons (HFCs) and
- Sulphur hexafluoride (SF_6)

Estimates should also include the following indirect GHGs: *Carbon monoxide* (CO), *nitrogen oxides* (NO_x), *non-methane organic volatile compounds* (NMVOC) and *sulphur oxides* (SO_2).

The inventory must cover the following sectors:

1. Energy
2. Industrial processes
3. Solvent and other product use
4. Agriculture
5. LULUCF (Land Use, Land-Use Change and Forestry)
6. Waste

International aviation and marine bunker fuel emissions are not to be included in national total and are reported separately. Each of these sectors is subdivided into different source/sink categories. Emissions and removals have to be reported at the most disaggregated level of each source/sink category

National Greenhouse Gas Inventories
1. Energy
A. Fuel Combustion (Sectoral Approach)

1. Energy Industries
    - *a. Public Electricity and Heat Production*
    - *b. Petroleum Refining*
    - *c. Manufacture of Solid Fuels and Other Energy Industries*
2. Manufacturing Industries and Construction
    - *a. Iron and Steel*
    - *b. Non-Ferrous Metals*
    - *c. Chemicals*
    - *d. Pulp, Paper and Print*
    - *e. Food Processing, Beverages and Tobacco*
    - *f. Other*
    - *Other non-specified*
3. Transport
    - a. Civil Aviation
    - b. Road Transportation
    - c. Railways
    - d. Navigation
    - e. Other Transportation
4. Other Sectors
    - *a. Commercial/Institutional*

b. Residential
c. Agriculture/Forestry/Fisheries
5. Other
a. Stationary
b. Mobile Other non-specified

B. Fugitive Emissions from Fuels

1. Solid Fuels
a. Coal Mining and Handling
b. Solid Fuel Transformation
c. Other
2. Oil and Natural Gas
a. Oil b. Natural Gas
c. Venting and Flaring Venting Flaring
d. Other (as specified in table 1.B.2)
e. *Flaring in Refineries*

Memo Items:
International Bunkers
Aviation
Marine Multilateral Operations
CO_2 Emissions from Biomass

National Greenhouse Gas Inventories: Industrial Processes

2. Industrial processes

A. Mineral Products
1. Cement Production
2. Lime Production
3. Limestone and Dolomite Use
4. Soda Ash Production and Use
5. Asphalt Roofing
6. Road Paving with Asphalt
7. Other

B. Chemical Industry
1. Ammonia Production
2. Nitric Acid Production
3. Adipic Acid Production
4. Carbide Production
5. Other (i.e. *Carbon Black, Ethylene, Dichloroethylene Styrene Methanol Caprolactam)*
Other non-specified (i.e. *Propylene, Titanium Dioxide Production)*

C. Metal Production
1. Iron and Steel Production
2. Ferroalloys Production
3. Aluminium Production
4. SF_6 Used in Aluminium and Magnesium Foundries
5. Other (i.e. *silicium production)*

D. Other Production
    1. Pulp and Paper
    2. Food and Drink
E. Production of Halocarbons and SF6
    1. By-product Emissions
        Production of HCFC-22
        Other
    2. Fugitive Emissions
    3. Other
F. Consumption of Halocarbons and SF6
    1. Refrigeration and Air Conditioning Equipment
    2. Foam Blowing
    3. Fire Extinguishers
    4. Aerosols/ Metered Dose Inhalers
    5. Solvents
    6. Other applications using ODS substitutes
    7. Semiconductor Manufacture
    8. Electrical Equipment
    9. Other
G. Other
HFCs used in Magnesium Foundries

National Greenhouse Gas Inventories: Solvent and product waste

3. Solvent and other product use
A. Paint Application
B. Degreasing and Dry Cleaning
C. Chemical Products, Manufacture and Processing
D. Other
    1. Use of N_2O for Anaesthesia
    2. N_2O from Fire Extinguishers
    3. N_2O from Aerosol Cans
    4. Other Use of N_2O
    5. Other (as specified in table 3.A-D)
    Domestic solvent use Fat edible and non-edible oil extraction Glass Wool Enduction Glue & Adhesives, Printing Industry, Vehicles dewaxing

National Greenhouse Gas Inventories: Agriculture
4. Agriculture
A. Enteric Fermentation
    1. Cattle
Option A: Dairy Cattle, Non-Dairy Cattle
Option B: Mature Dairy Cattle, Mature Non-Dairy Cattle Young Cattle
    2. Buffalo
    3. Sheep
    4. Goats

5. Camels and Llamas
6. Horses
7. Mules and Asses
8. Swine
9. Poultry
10. Other (*i.e. Rabbits*)

B. Manure management

1. Cattle

Option A:

Dairy Cattle

Non-Dairy Cattle

Option B:

Mature Dairy Cattle

Mature Non-Dairy Cattle Young Cattle

2. Buffalo
3. Sheep
4. Goats
5. Camels and Llamas
6. Horses
7. Mules and Asses
8. Swine
9. Poultry
10. Other livestock
11. Anaerobic Lagoons
12. Liquid Systems
13. Solid Storage and Dry Lot
14. Other AWMS

C. Rice Cultivation

1. Irrigated
2. Rainfed
3. Deep Water
4. Other

D. Agricultural Soils

1. Direct Soil Emissions
2. Pasture, Range and Paddock Manure
3. Indirect Emissions
4. Other

E. Prescribed Burning of Savannas

F. Field Burning of Agricultural Residues

1. Cereals
2. Pulses
3. Tubers and Roots
4. Sugar Cane
5. Other

G. Other

National Greenhouse Gas Inventories: Land Use, Land Use Change and Forestry
5. Land Use, Land Use Change and Forestry (LULUCF)

A. Forest Land
  1. Forest Land remaining Forest Land
  2. Land converted to Forest Land

B. Cropland
  1. Cropland remaining Cropland
  2. Land converted to Cropland

C. Grassland
  1. Grassland remaining Grassland
  2. Land converted to Grassland

D. Wetlands
  1. Wetlands remaining Wetlands
  2. Land converted to Wetlands

E. Settlements
  1. Settlements remaining Settlements
  2. Land converted to Settlements

F. Other Land
  1. Other Land remaining Other Land
  2. Land converted to Other Land

G. Other

National Greenhouse Gas Inventories: Waste
6. Waste

A. Solid Waste Disposal on Land
  1. Managed Waste Disposal on Land
  2. Unmanaged Waste Disposal Sites
  3. Other (as specified in table 6.A)

B. Waste Water Handling
  1. Industrial Wastewater
  2. Domestic and Commercial Waste Water
  3. Other (as specified in table 6.B)

C. Waste Incineration

D. Other

Compost production

Sludge spreading

2.5 Estimation Methodology

Estimates of GHG emissions from a category are calculated on the basis of activity data (indicating the magnitude of human activity that has taken place in this category) and emission factors (indicating the quantity of emissions produced from a unit of this category). Emissions from a given activity are expressed by the following general relation:

$$E_{s,a,t} = A_{a,t} * F_{s.a}$$

where:

E = emission relating to substance "s" and activity "a" during time "t"
A = magnitude of activity "a" during time "t"
F = emission factor relating to substance "s" and to activity "a".

Methodologies should be consistent with the Revised 1996 IPCC Guidelines, IPCC Good Practice Guidance, 2003 IPCC Good Practice Guidance for LULUCF and 2006 IPCC Guidelines. National emission factors can be used, and can be integrated with default EFs (IPCC, CORINAIR, EPA and IPCC Emissions Factor Database (EFDB)) in the case where national data are not available.

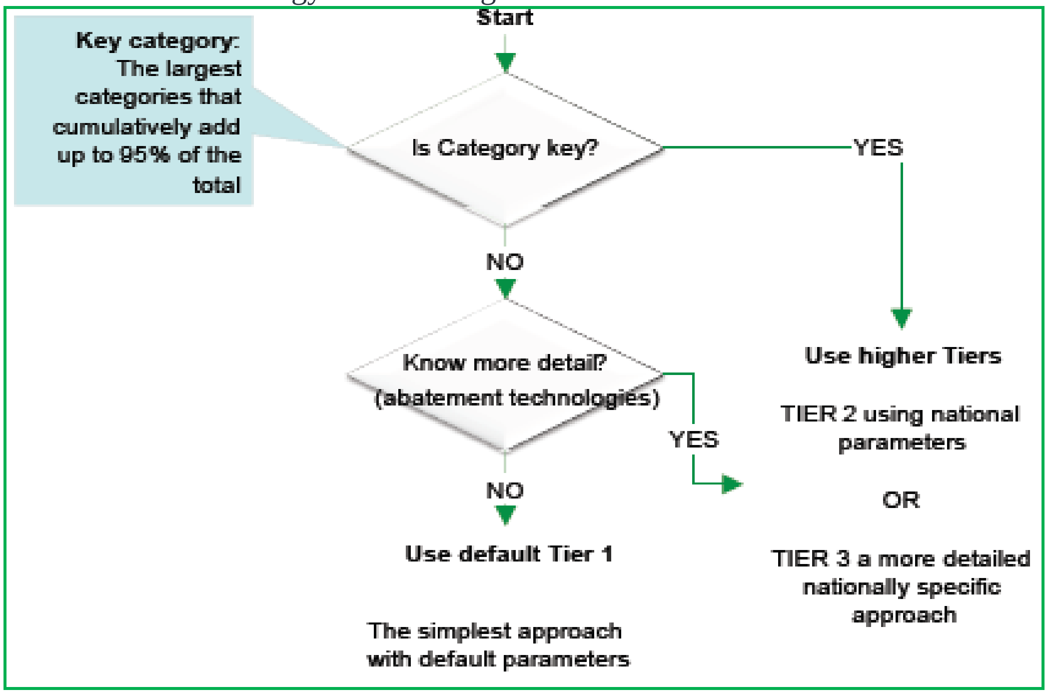
In order to promote the development of high quality national greenhouse gas inventories, a collection of methodological principles, actions and procedures were defined in the 2006 IPCC Guidelines retaining the concept of *good practice*. Inventories consistent with *good practice* are those which contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable.

Different levels of methodological complexity: **Tier 1** is the basic method, **Tier 2** intermediate and **Tier 3** most demanding in terms of complexity and data requirements. **Tier 1** methods for all categories are designed to use readily available national or international statistics in combination with the provided default emission factors and additional parameters that are provided, and therefore should be feasible for all countries

2.6 Estimation Methodology: Key Categories

Key category is used to identify the categories that have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, of trend, or uncertainty in emissions and removals. During inventory resource allocation for data collection, compilation, quality assurance/quality control and reporting, **key categories** should be prioritized, for countries.

Estimation Methodology: Methodological Choice



2.7 Reporting Format

Table 1: Summary of national emissions and removals for the year 2000.

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	HFCs	SF_6	Total
	CO_2 equiv (Gg)					
Total (Net Emissions)	35,812.42	12,648.43	5,434.33	819	4.06	54,718.24
1. Energy	1,503.42	952.15	175.8			2,631.37
2. Industrial Processes	182.47			819	4.06	1,005.53
3. Solvent and Other Product Use						
4. Agriculture		5,324.04	5,035.33			10,359.37
5. Land-Use Change and Forestry	34,126.53	6,078.45	105.4			40,310.38
6. Waste		293.79	117.8			411.59
7. Other (please specify)						
Memo Items:						
International Bunkers						
Aviation	86.85	1.68	7.44			95.97
Marine						
Multilateral Operations						

Table1.1: Detailed national emissions and removals for the year 2000.

Greenhouse Gas Source and Sink	CO_2 [(1)]	CH_4	N_2O	HFCs	SF_6	Total
Categories	CO_2 equivalent (Gg)					
Total (Net Emissions)	35,812.4 2	12,648.4 3	5,434.3 3	819.0	4.06	54,71 8
1. Energy	1,503.42	952.15	175.80			2,631
Fuel Combustion (Sectoral Approach)	1,503.42	952.15	175.80			
1. Energy Industries	18.95	0.14	0.04			
2. Manufacturing Industries and Construction	806.50	72.28	16.43			
3. Transport	583.60	0.25	0.78			
4. Other to include household , commercial and agriculture	94.37	873.60	158.10			
B. Fugitive Emissions from Fuels		2.94	0.23			
1. Solid Fuels		2.94	0.23			
2. Oil and Natural Gas						
2. Industrial Processes	182.47			819.0	4.06	1,005
A. Mineral Products	182.47					182
B. Chemical Industry						
C. Metal Production						
D. Other Production						
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6				819. 0	4.0 6	823
G. Other						
3. Solvent and Other Product Use						
4. Agriculture		5,324.04	5,035.3 3			10,35 9
A. Enteric Fermentation		2,496.56				2,496
B. Manure Management		89.61	1,550.0 0			1,639
C. Rice Cultivation		3.30				3.30
D. Agricultural Soils		0.00	2,965.1 5			2,965
E. Prescribed Burning of Savannas		2,649.62	484.84			3,134
F. Field Burning of Agricultural Residues		84.95	35.34			120
G. Other						
5. Land-Use Change and Forestry	34,126.5 3	6,078.45	105.40			40,31 0
6. Waste		293.79	117.80			411
Solid Waste Disposal on Land						
B. Wastewater Handling						
C. Waste Incineration						
D. Indirect emissions						
7. Other *(please specify)*						
Memo Items:						
International Bunkers						
Aviation	86.85	1.68	7.44			95.97

3.0 IPCC LAND USE, LAND USE CHANGE AND FORESTRY METHODOLOGIES

3.1 Introduction

IPCC methodologies for preparing GHG inventories in the Land use, land use change and forestry (LULUCF) sector include (i) Revised 1996 Guidelines for National Greenhouse Gas Inventories-Revised 1996 Guidelines, (ii) 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories-GPG 2000, (iii) Good Practice Guidance for Land Use, Land-Use Change and Forestry-GPG LULUCF, (iv) 2006 IPCC Guidelines for National Greenhouse Gas Inventories-2006 Guidelines

Definition of Key Terms

Land Use Change and Forestry (LUCF) **–** Land use is the type of activity being carried out on a unit of land, such as forest land, cropland and grassland. The IPCC 1996GL refers to sources and sinks associated with GHG emissions/removals from human activities, which:

(i) Change the way land is used (e.g., clearing of forest for agriculture, conversion of grassland to forest)
(ii) Affect the amount of biomass in existing biomass stocks (e.g., forest, village trees, savanna) and soil carbon stocks
(iii) Land Use, Land-Use Change and Forestry (LULUCF) – This includes GHG emissions/removals resulting from managed land (involving no change in use, such as forest remaining forest land) and land-use changes (involving changes in land-use, such as grassland converted to forest land or forest land converted to cropland).

Source–Any **process or activity** that releases a GHG (such as CO_2 and CH_4) into the atmosphere. A carbon pool can be a source of carbon to the atmosphere if less carbon is flowing into it than is flowing out of it.

Sink–Any process, activity or mechanism that removes a GHG from the atmosphere. A given pool can be a sink for atmospheric carbon if during a given time interval more carbon is flowing into it than is flowing out of it.

Activity data – Data on the magnitude of human activity, resulting in emissions/removals taking place during a given period of time (e.g., data on land area, management systems, lime and fertilizer use).

Emission factor – A **coefficient** that relates the activity data to the amount of chemical compound, which is the source of later emissions. Emission/removal factors are often based on a sample of measurement data, averaged to develop a representative rate of emission or removal for a given activity level under a given set of operating conditions.

Removal factor – **Rate** at which carbon is taken up from the atmosphere by a terrestrial system and sequestered in biomass and soil.

3.2 Revised 1996 IPCC Guidelines: Basic assumptions

The flux of CO_2 to/from atmosphere is assumed to be equal to changes in C-stocks in existing biomass and soils.

Changes in C-stocks can be estimated by establishing rates of change in land use and practices that bring about change in land use. Estimating C-stocks in land-use categories:

(i) That are not subjected to change

(ii) That are changed

Four default Categories in IPCC 1996GL

5A. Changes in forest and other woody biomass stocks due to

(i) *Commercial management*

(ii) *Harvest of industrial roundwood (logs) and fuelwood*

(iii) *Establishment and operation of forest plantations*

(iv) *Planting of trees in urban, village and non-forest locations*

5B. Forest and grassland conversion

The conversion of forests and grassland to pasture, cropland etc. can significantly change C-stocks in vegetation and soil

5C. Abandonment of cropland, pasture, plantation forests, or other managed lands

5D. CO_2 emissions and removals from soils

(i) *Cultivation Of Mineral Soils*

(ii) *Cultivation Of Organic Soils*

(iii) *Liming of agricultural soils*

Table 1.1: Reporting of GHG Inventory in the LUCF Sector – IPCC 1996GL

LUCF Categories	CO_2 emissions	CO_2 CH_4 N_2O removal/uptake	CO	NO_x
Changes in forest and other woody biomass stocks				
Forest and grassland conversion				
Abandonment of croplands, pastures, plantation forests, or other managed lands				
CO2 emissions and removals from soils				
Others				
TOTAL				

3.3 Revised IPCC 1996 Methodology

3.3.1 Sinks and Emissions

Forest biomass production is the major sink for carbon dioxide through photosynthesis. Re-growth of natural forests regenerating after forest clearing and/or fallow, and reforestation plantations are the main carbon sinks. Emissions under Land Use, Land Use Change and Forestry generally originate from cultivation, permanent cultivation, charcoal production, and logging in plantations, selective timber cutting, and commercial firewood cutting. Emissions also come from soil carbon stock changes during Land Use Change.

3.3.2 Methodology for estimating emissions for onsite burning

The methodology used to calculate emissions under this category is based on the 1996 IPCC revised guidelines. The priority calculations of emissions from land use and forestry focus upon the following activities:

(i) Forest clearing and on-site burning
(ii) Off-site burning (firewood and charcoal combustion)
(iii) On-site biomass decay
(iv) Carbon emissions from cultivation of organic soils
(v) Carbon emissions from cultivation of mineral soils
(vi) Carbon emissions from application of lime

CO_2 and non CO_2 emissions (CH_4, CO, N_2O and NO_X from land use change and forestry namely forest clearing and on-site burning, are calculated in accordance with IPCC methodology (1996 Guidelines). The Tier 1 method described in the Revised 1996 Guidelines for Greenhouse Gas Inventories is normally used in the absence of country emission factors. The equations that are used for the greenhouse gas inventories are presented below.

CO_2= (carbon released by forest clearing and on-site burning) kt C X 44/12

Carbon released (kt C) = (Annual loss of biomass) kt dm X (fraction of biomass burned on-site) X (fraction of biomass oxidised on-site) X (Carbon content)

(Annual loss of biomass)kt dm = (Net change in biomass density) kt dm/ha X (area converted annually) ha X (Carbon content)

(Net change in biomass density) kt dm/ha = (Biomass density before conversion) kt dm/ha – (Biomass density after conversion) kt dm/ha

Non-CO_2 emissions released from on-site burning were calculated using the expressions below in accordance with IPCC methodologies (1996).

CH_4 (tCH_4/yr) =Carbon released X Emission factor X 16/12

CO (kt CO/yr) = Carbon released X Emissions factor X 28/12

N_2O (kt N2O/yr) = (N) X (emission factor) X 44/28

where N = Total Nitrogen released

NO_X (kt NO_x/yr) = N (kt N) X emissions factor X 46/14 N (kt N) = (Carbon released kt C) X (N/C)

Where N/C =Nitrogen carbon ratio

3.3.3 Emissions from off-site burning of forest biomass (charcoal and firewood)

CO_2 emissions from off-site burning of forest biomass (charcoal and firewood) were calculated in accordance with IPCC guidelines. Non-CO_2 emissions from biomass were calculated under energy.

CO_2 = (Carbon released by biomass burnt) kt (C) X (44/12)

Carbon released kt C = (Biomass burnt/yr) X carbon content X fraction of biomass burned off-site X fraction of biomass oxidised

Biomass burnt in form of firewood and charcoal are normally obtained from energy balances

3.3.4 Emissions from biomass on-site decay (aboveground biomass)

CO2 emissions from on-site biomass decay is calculated in accordance with IPCC methodology as given below:

CO_2 (kt CO_2) = (carbon released from decay of above-ground biomass) (kt) (C) X (44/12)

Carbon released from decay of above ground biomass kt C = (Average annual loss of biomass kt dm) X (Fraction left to decay) X (Carbon fraction in aboveground biomass)

Average annual loss of biomass = (Average area converted (10-year average in hectares) X (Net change in biomass density kt dm/hectare)

3.3.5 Carbon emissions from cultivation of organic soils

CO_2(kt) = {land area of cultivated organic soils (hectares) X (annual loss rate Mg C/ha) X unit conversion factor X 3.67}/10^6

3.3.6 Carbon emissions from cultivation of mineral soils

CO_2(kt) = {land area of cultivated mineral soils (hectares) X (annual loss rate Mg C/ha) X unit conversion factor X 3.67}/10^6

3.3.6 Carbon emissions from application of lime

CO_2(kt) = {(Total amount of annual lime Mg) X (carbon conversion factor) X 3.67}/10^6

3.3.7 Greenhouse gas sinks

Re-growth natural forest regenerating after forest clearing and /or abandonment of managed cultivated lands (fallow) and reforestation plantations are the main carbon sinks

CO_2 = Carbon uptake X 44/12

Carbon uptake= (Annual biomass increment) kt dm X (carbon fraction of dry matter)

Annual biomass increment (kt dm) = (forest/biomass area abandoned over 20 years hectare) X (Annual growth rate) kt dm/ha.

3.3.7 Reporting Format

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

MODULE	LAND USE CHANGE AND FORESTRY							
SUBMODULE	CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS							
WORKSHEET	5-1							
SHEET	2 OF 3							
STEP 2								
	F	G	H	I	J	K	L	M
Harvest Categories (Species)	Commercial Harvest (if applicable) (1000 m3 roundwood)	Biomass Conversion/Expansion Ratio (if applicable) (t dm/m3)	Total Biomass Removed in Commercial Harvest (kt dm)	Total Traditional Fuelwood Consumed (kt dm)	Total Other Wood Use (kt dm)	Total Biomass Consumption (kt dm)	Wood Removed From Forest Clearing (kt dm)	Total Biomass Consumption From Stocks (kt dm)
			H = (F x G)	FAO data		K =(H + I + J)	(From columnM, Worksheet 5-2, sheet 3)	M = K - L
Totals								

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

MODULE		LAND-USE CHANGE AND FORESTRY				
SUBMODULE		FOREST AND GRASSLAND CONVERSION - CO2 FROM BIOMASS				
WORKSHEET		5-2				
SHEET		1 OF 5 BIOMASS CLEARED				
STEP 1						
Vegetation types		A Area Converted Annually (kha)	B Biomass Before Conversion (t dm/ha)	C Biomass After Conversion (t dm/ha)	D Net Change in Biomass Density (t dm/ha)	E Annual Loss of Biomass (kt dm)
					D = (B - C)	E = (A x D)
	Wet/Very Moist					
	Moist, short dry season					
	Moist, long dry season					
	Dry					
	Montane Moist					
	Montane Dry					
Tropical Savanna/Grasslands						
	Coniferous					
	Broadleaf					
Grassland						
	Mixed Broadleaf/Coniferous					
	Coniferous					
Boreal	Forest-tundra					
Grasslands/Tundra						
Subtotals						

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

MODULE		LAND-USE CHANGE AND FORESTRY						
SUBMODULE		FOREST AND GRASSLAND CONVERSION - CO2 FROM BIOMASS						
WORKSHEET		5-2						
SHEET		3 OF 5 CARBON RELEASED BY OFF-SITE BURNING						
				STEP 3				STEP 4
Vegetation types		L Fraction of Biomass Burned off Site	M Quantity of Biomass Burned off Site (kt dm)	N Fraction of Biomass Oxidised off Site	O Quantity of Biomass Oxidised off Site (kt dm)	P Carbon Fraction of Above-ground Biomass (burned off site)	Q Quantity of Carbon Released (from biomass burned off site (kt C)	R Total Carbon Released (from on and off site burning) (kt C)
			M = (E x L)		O = (M x N)		Q = (O x P)	R = (K + Q)
	Wet/Very Moist							
	Moist, short dry season							
	Moist, long dry season							
	Dry							
	Montane Moist							
	Montane Dry							
Tropical Savanna/Grasslands								
	Coniferous							
	Broadleaf							
Grassland								
Boreal	Mixed Broadleaf/ Coniferous							
	Coniferous							
	Forest-tundra							
Grasslands/ Tundra								
Subtotals								

MODULE		LAND-USE CHANGE AND FORESTRY								
SUBMODULE		FOREST AND GRASSLAND CONVERSION - CO2 FROM BIOMASS								
WORKSHEET		5-2								
SHEET		4 OF 5 CARBON RELEASED BY DECAY OF BIOMASS								
STEP 5										
		A	B	C	D	E	F	G	H	I
Vegetation types		Average Area Converted (10 Year Average) (kha)	Biomass Before Conversion (t dm/ha)	Biomass After Conversion (t dm/ha)	Net Change in Biomass Density (t dm/ha)	Average Annual Loss of Biomass (kt dm)	Fraction Left to Decay	Quantity of Biomass Left to Decay (kt dm)	Carbon Fraction in Above-ground Biomass	Carbon Released from Decay of Above-ground Biomass (kt C)
					D = (B-C)	E = (A x D)		G = (E x F)		I = (G x H)
	Wet/Very Moist									
	Moist, short dry season									
	Moist, long dry season									
	Dry									
	Montane Moist									
	Montane Dry									
Tropical Savanna/Grasslands										
	Coniferous									
	Broadleaf									
Grassland										
	Mixed Broadleaf/Coniferous									
	Coniferous									
Boreal	Forest-tundra									
Grasslands/Tundra										

Subtotals										

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

		MODULE	LAND-USE CHANGE AND FORESTRY			
		SUBMODULE	ON-SITE BURNING OF FORESTS - NON-CO2 TRACE GASES FROM BURNING BIOMASS			
		WORKSHEET	5-3			
		SHEET	1 OF 1 NON-CO2 GAS EMISSIONS			
	STEP 1			STEP 2		
A	B	C	D	E	F	G
Quantity of Carbon Released (kt C)	Nitrogen-Carbon Ratio	Total Nitrogen Released (kt N)	Trace Gas Emisions Ratios	Trace Gas Emissions (kt C)	Conversion Ratio	Trace Gas Emissions from Burning of Cleared Forests (Gg CH4, CO)
(From column K, sheet 2 of Worksheet 5-2)		C = (A x B)		E = (A x D)		G = (E x F)
			CH4		16/12	
			CO		28/12	
				kt N		Gg N2O, NOx
				E = (C x D)		G = (E x F)
			N2O		44/28	
			NOx		46/14	

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

Other						
Subtotal						

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

Other						
Subtotal						

MODULE	LAND-USE CHANGE AND FORESTRY
SUBMODULE	ABANDONMENT OF MANAGED LANDS
WORKSHEET	5-4
SHEET	3 OF 3 TOTAL CO2 REMOVALS FROM ABANDONED LANDS
STEP 3	
L	M
Total Carbon Uptake from Abandoned Lands (kt C)	Total Carbon Dioxide Uptake (Gg CO2)
L = (E + K)	M = (L x (44/12))

MODULE		LAND-USE CHANGE AND FORESTRY					
SUBMODULE		CHANGE IN SOIL CARBON FOR MINERAL SOILS					
WORKSHEET		5-5					
SHEET		1 OF 4					
		STEPS 1 AND 2				STEP 3	
A	B	C	D	E	F	G	H
Land-use/Management Systems	Soil type	Soil Carbon (t)(Mg C/ha)	Land Area (t-20) (Mha)	Land Area (t) (Mha)	Soil Carbon (t-20) (Tg)	Soil Carbon (t) (Tg)	Net chang e in Soil Carbon in Mineral Soils (Tg per 20 yr)
					F = (C x D)	G = (C x E)	H = (G - F)
High activity soils							
Low activity soils							
Sandy							
Volcanic							
Wetland (Aquic)							
Totals							
Note that land areas in columns D and E, summed over all land-use/management systems used in the inventory should be equal. Total land areas within each soil type, across all land-use systems, should also remain constant over the inventory period.							

MODULE	LAND-USE CHANGE AND FORESTRY		
SUBMODULE	CARBON EMISSIONS FROM INTENSIVELY-MANAGED ORGANIC SOILS		
WORKSHEET	5-5		
SHEET	2 OF 4		
		STEP 4	
	A	B	C
Agricultural Use of Organic Soils	Land Area (ha)	Annual Loss Rate (MgC/ha/yr) (Default)	Net Carbon Loss from Organic Soils (Mg/yr)
			C = (A x B)
Cool temperate			
Upland crops			
Pasture/Forest			
Warm temperate			
Upland crops			
Pasture/Forest			
Tropical			
Upland crops			
Pasture/Forest			
Total			

MODULE	LAND-USE CHANGE AND FORESTRY		
SUBMODULE	CARBON EMISSIONS FROM LIMING OF AGRICULTURAL SOILS		
WORKSHEET	5-5		
SHEET	3 OF 4		
STEP 5			
	A	B	C
Type of lime	Total Annual Amount of Lime (Mg)	Carbon Conversion Factor	Carbon Emissions from Liming (Mg C)
			C = (A x B)
Limestone Ca(CO3)		0.120	
Dolomite CaMg(CO3)2		0.122	
Total			

MODULE	LAND-USE CHANGE AND FORESTRY			
SUBMODULE	CALCULATION OF TOTAL CO_2-C EMISSIONS FROM AGRICULTURALLY-IMPACTED SOILS			
WORKSHEET	5-5			
SHEET	4 OF 4			
			STEP 6	
Source	A	B	C	D
	Worksheet values	Unit Conversion Factor	Total Annual Carbon Emissions (Gg)	Convert to Total Annual CO_2 Emission (Gg/yr)
			C = (A x B)	D= C x (44/12)
Total Net Change in Soil Carbon in Mineral Soils		-50		
Total Net Carbon Loss from Organic Soils		0.001		
Carbon Emissions from Liming		0.001		
Total				

3.4 GPG2003 LULUCF: Land-use Categories and Methods

3.4.1 Introduction

GPG2003 based on land-use category approach, provides a procedure to link inventory estimates of GPG2003 to IPCC 1996GL, based on Category 5A to 5D. However, the inventory estimates obtained using IPCC 1996GL **could be different** from the estimates obtained using GPG2003 due to the following reasons:

(i) *Inclusion of additional land categories, e.g. agro-forestry, coconut, coffee, tea*
(ii) *Inclusion of additional carbon pools; below-ground biomass, dead organic matter, etc.*
(iii) *Estimation of biomass increment and losses in each land category, sub-category*
(iv) *Linking of biomass and soil carbon for each land category*
(v) *Use of improved default values*

3.4.2 IPCC Good Practice Guidance 2003(Methodology) for Land Use, Land Use Change and Forestry

According to the IPCC 2003 Guidelines for LULUCF, land is classified into several categories which include, forest land, crop land, grass land, wetlands, settlements and other lands.

Table 1.2: IPCC Land Use Categories

Area in ha	**1990**	**2001**	**Diff 1990-2001**
5.A Forest Land - Total area	3,894,000	3,960,000	66,000
1. Forest Land remaining Forest Land			
productive forest	3,332,667	3,371,000	38,333
non-productive forest	546,743	577,618	30,875
2. Land converted to Forest Land	14,590	11,382	-3,208
2.1 Cropland converted to Forest Land	2,350	1,822	-528
2.2 Grassland converted to Forest Land	8,650	6,720	-1,930
2.3 Wetland converted to Forest Land	720	570	-150
2.4 Settlement converted to Forest Land	2,010	1,590	-420
2.5 Other Land converted to Forest Land	860	680	-180
5.B Cropland - total area	1,507,533	1,460,067	-47,466
1. Cropland remaining Cropland	1,474,796	1,422,183	-52,613
2. Land converted to Cropland	33,899	39,081	5,182
2.1Forest Land converted to Cropland	330	270	-60
2.2 Grassland Land converted to Cropland	33,569	38,811	5,242
5.C. Grassland - total area	1,992,764	1,957,169	-35,595
1. Grassland remaining Grassland	1,962,943	1,925,072	-37,871
2. Land converted to Grassland	29,821	32,097	2,276
2.1 Forest Land converted to Grassland	3,540	2,810	-730
2.2 Arable Land converted to Grassland	26,281	29,287	3,006

Area in ha	1990	2001	Diff 1990-2001
5 D Wetlands - total area	4,775	11,796	7,022
1. Wetlands remaining Wetlands	4,117	9,875	5,758
2. Land converted to Wetlands	658	1,921	1,263
2.1 Forest Land converted to Wetlands	200	160	-40
2.2 Arable Land converted to Wetlands	NO	NO	NO
2.3 Grassland converted to Wetlands	458	-	-458
2.4 Other Land converted to Wetlands	-	1,761	1,761
5 E Settlements - total area	323,994	449,678	125,684
1. Settlements Remaining Settlements	312,118	438,252	126,134
2. Land converted to Settlements	11,876	11,426	-450
2.1 Forest Land converted to Settlements	1,000	800	-200
2.2 Arable Land converted to Settlements	5,828	2,041	-3,787
2.3 Grassland converted to Settlements	5,048	-	-5,048
2.4 Other Land converted to Settlements	-	8,585	8,585
5 F Other Land - total area	656,991	541,346	-115,644
Waterbodies	127,498	128,678	1,180
2.1 Forest Land converted to Other Land	1,600	1,270	-330
Total Area	8,380,056	8,380,056	-

Emissions and removals of CO2 for the Land Use, Land Use Change and Forestry Sector, based on changes in ecosystem C stocks, are estimated for each land-use category (including both land remaining in a land-use category as well as land converted to another land use).

$$\Delta C = \Delta C_{FL} + \Delta C_{CL} + \Delta C_{GL} + \Delta C_{WL} + \Delta C_{SL} + \Delta C_{OL}$$

Table 1.3: Reporting of GHG Inventory in the LULUCF Sector – GPG2003

Greenhouse gas source and sink categories **5. Total land use categories**	**IPCC Guidelines**	**Net CO_2 emissions/removals**	**CH_4**	**N_2O**	**N_xO**	**CO**
5A. Forest land		Gg				
5A1. Forest land remaining forest land 5.A2 Land converted to forest land	5A, 5A, 5C.5D					
5 B. Crop land 5 B.1 Cropland remaining cropland	5A, 5D					
5.B.2 Land converted to cropland	5B,5D					
5.C Grass land	5A,5D					
5.C.1 Grassland remaining grassland	5A,5D					
5.C.2 Land converted to grassland 5.D Wetlands	5C,5D					
5.D.1 Wetlands remaining wetlands	5A,5E					
5.D.2 Land converted to Wetlands	5B,5E					

5. E Settlements						
5.E1 Settlements remaining settlements 5.E2. Land converted to settlements	5A 5B, 5E					
5.F. Other land						
5.F.1 Other land remaining other land 5.F.2 Land converted to other land	5A 5B, 5E					
5.G. Other (please specify)						
Harvested Wood products						

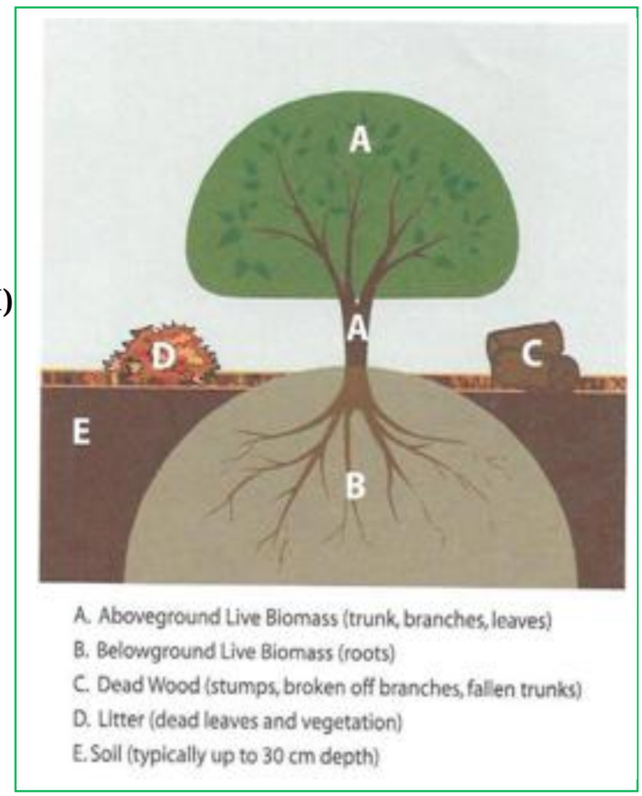
Emissions and removals from Land use change

Plant biomass constitutes a significant carbon stock in many ecosystems. Biomass is present in both aboveground and below-ground parts of annual and perennial plants. Biomass associated with annual and perennial herbaceous (i.e., non-woody) plants is relatively ephemeral, i.e., it decays and regenerates annually or every few years and therefore negligible. Thus, the methods focus on stock changes in biomass associated with woody plants and trees, which can accumulate large amounts of carbon (up to hundreds of tonnes per ha) over their lifespan (IPCC, 2006). The status of carbon pool is summarized below. Currently 5 carbon pools have to be reported under the UNFCCC

Above ground } **Biomass**
Below ground }

Dead wood } **Dead Organic Matter (DOM)**
Litter }

Soil Organic Matter (SOM) { **Mineral soils**
{ **Organic soils**



(a) Change in forest and other woody biomass stock,

The summary equation, which estimates the annual emissions or removals from land remaining in each category as well as land converted into another category is given in Equation 1.

$$\Delta CFF = (\Delta CFF_{LB} + \Delta CFF_{DOM} + \Delta CFF_{Soils}) \quad (1)$$

Where:

ΔCFF = annual change in carbon stock from forest land remaining forest land, tonnes C yr^{-1}

ΔCFF_{LB} = annual change in carbon stocks in living biomass (including above- and belowground biomass) in; tonnes C yr^{-1}

ΔCFF_{DOM} = annual change in carbon stocks in dead organic matter (includes dead wood and litter) from land remaining in each category as well as land converted into another category; tonnes C yr^{-1}

ΔCFF_{Soils} = annual change in carbon stocks in soils from land remaining in each category as well as land converted into another category; tonnes C yr^{-1}

(b) Change in carbon stocks in living biomass

Equation 2 was used to calculate annual change in carbon stocks in living biomass from land remaining in each category as well as land converted into another category.

$$\Delta CFF_{LB} = (\Delta CFF_G - \Delta CFF_L) \quad (2)$$

Where:

ΔCFF_{LB} = annual change in carbon stocks in living biomass (including above- and belowground biomass) from land remaining in each category as well as land converted into another category, tonnes C yr^{-1}

ΔCFF_G = annual increase in carbon stocks due to biomass growth, tonnes C yr^{-1}

ΔCFF_L = annual decrease in carbon stocks due to biomass loss, tonnes C yr^{-1}

(c) Annual increase in carbon stocks due to biomass increment in forest land remaining forest land

Estimation of annual increase in carbon stocks due to biomass increment from land remaining in each category as well as land converted into another category was done using Equation 3.

$$\Delta CFF_G = \sum ij\, (A_{ij} \bullet GTOTAL_{ij}) \bullet CF \quad (3)$$

ΔCFF_G = annual increase in carbon stocks due to biomass increment from land remaining in each category as well as land converted into another category by forest type and climate zone, tonnes C yr^{-1}

A_{ij} = area of from land remaining in each category as well as land converted into another category, by forest type (i = 1 to n) and climatic zone (j = 1 to m), ha

$GTOTAL_{ij}$ = average annual increment rate in total biomass in units of dry matter, by forest type (i = to n) and climatic zone (j = 1 to m), tonnes d.m. ha^{-1} yr^{-1}

CF = carbon fraction of dry mater (default = 0.5), tonnes C (tonnes d.m.) $^{-1}$

(d) Average annual increment in biomass

Equation 4 was used to estimate average annual increment in biomass.

$$G_W = I_V \bullet D \bullet BEF_1 \quad (4)$$

Where:

G_W = average annual aboveground biomass increment, tonnes d.m. ha^{-1} yr^{-1}

I_V = average annual net increment in volume suitable for industrial processing, m^3 ha^{-1} yr^{-1}

D = basic woody density, tones d.m.m^{-3}

BEF_1= biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment, dimensionless.

(e) Annual decrease in carbon stocks due to biomass loss in forest land remaining forest land

The decrease in annual carbon stock due to biomass loss from land remaining in each category as well as land converted into another category was estimated using Equation 5.

$$\Delta CFF_L = L_{felling} + L_{fuelwood} + L_{other\ losses} \quad (5)$$

Where:

ΔCFF_L = annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, tonnes C yr^{-1}

$L_{felling}$ = annual carbon loss due to commercial felling, tonnes C yr^{-1}

$L_{fuelwood}$ = annual carbon loss due to fuel wood gathering, tonnes C yr^{-1}

$L_{other\ losses}$ = annual other losses of carbon, tonnes C yr^{-1}

(f) Change in carbon stocks in dead organic matter

Equation 6 was used to estimate annual change in carbon stocks in dead organic matter in forest from land remaining in each category as well as land converted into another category.

$$\Delta CFF_{DOM} = \Delta CFF_{DW} + \Delta CFF_{LT} \quad (6)$$

Where:

ΔCFF_{DOM} = annual change in carbon stocks in dead organic matter (includes dead wood and litter) in from land remaining in each category as well as land converted into another category, tonnes C yr^{-1}

ΔCFF_{DW} = change in carbon stocks in dead wood in from land remaining in each category as well as land converted into another category, tonnes C yr^{-1}

ΔCFF_{LT} = change in carbon stocks in litter from land remaining in each category as well as land converted into another category, tonnes C yr^{-1}

(g) Carbon stocks in soils

Equations 7 and 8 was used to estimate annual change in carbon stocks in mineral soils.

$$\Delta CFF_{Minerals} = \sum_{ij} [(SOC_j - SOC_i) \bullet A_{ij}]/T_{ij} \quad (7)$$

Where:

$\Delta CFF_{Minerals}$ = annual change in carbon stocks in mineral soils from land remaining in each category as well as land converted into another category, tonnes C yr^{-1}

SOC_j = stable soil organic carbon stock, under previous state i, tonnes C ha^{-1}

SOC_i = stable soil organic carbon stock, under current state j, tonnes C ha-[1]

A_{ij}]= forest area undergoing a transition from state i, to j, ha

T_{ij} = time period of the transition from SOC_j to SOC_i, yr

$$SOC_i = SOC_{ref} \bullet f_{forest\ type}(i) \bullet f_{man\ intensity}(i) \bullet f_{dist\ regime}(i) \quad (8)$$

Where:

SOC_{ref} = the reference carbon stock, under native, unmanaged forest on a given soil, tonnes C ha-1

$f_{forest\ type}$ = adjustment factor reflecting the effects of change from the native forest to forest type in state (i), dimensionless

$f_{man\ intensity}$ (i) = adjustment factor reflecting the effect of management intensity or practices on forest in state (i), dimensionless

$f_{dist\ regime}$ (i)= adjustment factor reflecting the effect of a change in the disturbance regime to state (i) with respect to the native forest, dimemsionless

(h) Non-CO2 greenhouse gas emission

The direst N_2O emissions from managed forests was calculated using Equation 9.

$$N_2O\ direct\text{-}N_{FF} = (N_2O\ direct\text{-}N_{fertiliser} + N_2O\ direct\text{-}N_{drainage}) \qquad (9)$$

Where:

N_2O direct-N_{FF} = direct emissions of N_2O from managed forests in units of Nitrogen, Gg N

N_2O direct-$N_{fertiliser}$ = direct emissions of N_2O from forest fertilisation in units of Nitrogen, Gg N

N_2O direct-$N_{drainage}$ = direct emissions of N_2O from drainage of wet forest sols in units of Nitrogen, Gg N

The Non-CO_2 greenhouse gas emissions from biomass burning where estimated using equations 10, 11, 12, and 13.

$$CH_4\ Emissions = (carbon\ released) \bullet (emission\ ratio) \bullet 16/12 \qquad (10)$$

$$CO\ Emissions = (carbon\ released) \bullet (emission\ ratio) \bullet 28/12 \qquad (11)$$

$$N_2O\ Emissions = (carbon\ released) \bullet (N/C\ ratio) \bullet (emission\ ratio) \bullet 44/28 \qquad (12)$$

$$NO_x\ Emissions = (carbon\ released) \bullet (N/C\ ratio) \bullet (emission\ ratio) \bullet 46/14$$

3.4.3 Reporting Format Based on IPCC Good Practice

Sectoral background data for land use, land-use change and forestry-**Forestland**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA	EMISSION FACTORS					EMISSIONS/REMOVALS				
		Total area(kha)	Carbon stock change in living biomass per area (2,3)			Net carbon stock change in dead organic matter per area(3)	Net carbon stock change in soils per area (3)	Carbon stock change in living biomass(2,3)			Net carbon stock change in dead organic matter(3)	Net carbon stock change in soils (3)
Land-Use Category	Sub-division(1)		Increase	Decrease	Net change			Increase	Decrease	Net change		
					(Mg C/ha)					(Gg C)		
A. Total Forest Land		3376.44	3.18	-1.81	1.37	0.00	0.01	10742.53	-6110.53	4632.00	0.16	17.08
1. Forest Land remaining Forest Land		3365.06	3.19	-1.82	1.37	0.00	NO	10729.15	-6110.53	4618.62	0.16	NO
	Coniferous	2483.41	3.18	-1.98	1.20	0.00	NO	7896.33	-4924.24	2972.09	0.12	NO
	Deciduous	881.65	3.21	-1.35	1.87	0.00	NO	2832.81	-1186.29	1646.52	0.04	NO
2. Land converted to Forest Land(4)		11.38	1.18	IE	1.18	NO	1.50	13.38	IE	13.38	NO	17.08
2.1 Cropland converted to Forest Land		1.82	1.18	IE	1.18	NO	2.01	2.14	IE	2.14	NO	3.66
	Total	1.82	1.18	IE	1.18	NO	2.01	2.14	IE	2.14	NO	3.66
2.2 Grassland converted to Forest Land		6.72	1.18	IE	1.18	NO	0.65	7.90	IE	7.90	NO	4.34
	Total	6.72	1.18	IE	1.18	NO	0.65	7.90	IE	7.90	NO	4.34
2.3 Wetlands converted to Forest Land		0.57	1.18	IE	1.18	NO	3.04	0.67	IE	0.67	NO	1.73
	Total	0.57	1.18	IE	1.18	NO	3.04	0.67	IE	0.67	NO	1.73
2.4 Settlements converted to Forest Land		1.59	1.18	IE	1.18	NO	3.32	1.87	IE	1.87	NO	5.28
	Total	1.59	1.18	IE	1.18	NO	3.32	1.87	IE	1.87	NO	5.28
2.5 Other Land converted to Forest Land		0.68	1.18	IE	1.18	NO	3.04	0.80	IE	0.80	NO	2.07
	Total	0.68	1.18	IE	1.18	NO	3.04	0.80	IE	0.80	NO	2.07

Sectoral background data for land use, land-use change and forestry-**Crop land**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA	EMISSION FACTORS					EMISSIONS/REMOVALS				
			Carbon stock change in living biomass per area			Net carbon stock change in dead organic matter per area(3)	Net carbon stock change in soils per area (2), (3), (4)	Carbon stock change in living biomass(2), (3), (4)			Net carbon stock change in dead organic matter(3,5)	Net carbon stock change in soils (3)
Land-Use Category	**Sub-division (1)**		**Increase**	**Decrease**	**Net change**	**area(3)**		**Increase**	**Decrease**	**Net change**		
		Total area (kha)			(Mg C/ha)					(Gg C)		
B. Total Cropland		1455.45	0.05	-0.06	-0.01	NO	0.05	67.30	-83.40	-16.10	NO	76.66
1. Cropland remaining Cropland		1420.77	IE	-0.05	-0.05	NO	0.07	IE	-77.68	-77.68	NO	100.07
	Annual remaining annual	1419.89	IE	-0.04	-0.04	NO	0.07	IE	-53.54	-53.54	NO	100.04
	Annual converted to perennial	0.49	IE	-2.90	-2.90	NO	0.35	IE	-1.41	-1.41	NO	0.17
	Perennial converted to annual	0.39	IE	-58.00	-58.00	NO	-0.35	IE	-22.73	-22.73	NO	-0.14
2. Land converted to Cropland(6)		34.68	1.94	-0.16	1.78	NO	-0.68	67.30	-5.72	61.58	NO	-23.41
2.1 Forest Land converted to Cropland		0.27	IE	-21.17	-21.17	NO	-1.96	IE	-5.72	-5.72	NO	-0.53
	Total	0.27	IE	-21.17	-21.17	NO	-1.96	IE	-5.72	-5.72	NO	-0.53
2.2 Grassland converted to Cropland		34.41	1.96	IE	1.96	NO	-0.66	67.30	IE	67.30	NO	-22.88
	Total	34.41	1.96	IE	1.96	NO	-0.66	67.30	IE	67.30	NO	-22.88
2.3 Wetlands converted to Cropland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.4 Settlements converted to Cropland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.5 Other Land converted to Cropland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Sectoral background data for land use, land-use change and forestry-**Grass land**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		**ACTIVITY DATA**	**EMISSION FACTORS**					**EMISSIONS/REMOVALS**				
			Carbon stock change in living biomass per area (2), (3)			**Net carbon stock change in dead organic matter per area(2)**	**Net carbon stock change in soils per area**	**Carbon stock change in living biomass (2), (3), (4)**			**Net carbon stock change in dead organic matter(2), (5)**	**Net carbon stock change in soils (2)**
Land-Use Category	**Sub-division (1)**	**Total area** (kha)	**Increase**	**Decrease**	**Net change**			**Increase**	**Decrease**	**Net change**		
					(Mg C/ha)					(Gg C)		
C. Total Grassland		1919.60	IE,NO	-0.05	-0.05	NO	0.00	IE,NO	-98.82	-98.82	NO	6.20
1. Grassland remaining Grassland		1899.67	NO	NO	NO	NO	0.00	NO	NO	NO	NO	-3.59
	Total	1899.67	NO	NO	NO	NO	0.00	NO	NO	NO	NO	-3.59
2. Land converted to Grassland (6)		19.93	NO	-4.96	-4.96	NO	0.49	IE,NO	-98.82	-98.82	NO	9.79
2.1 Forest Land converted to Grassland		2.81	IE	-21.17	-21.17	NO	-0.57	IE	-59.48	-59.48	NO	-1.60
	Total	2.81	IE	-21.17	-21.17	NO	-0.57	IE	-59.48	-59.48	NO	-1.60
2.2 Cropland converted to Grassland		17.12	IE	-2.30	-2.30	NO	0.66	IE	-39.34	-39.34	NO	11.39
	Total	17.12	IE	-2.30	-2.30	NO	0.66	IE	-39.34	-39.34	NO	11.39
2.3 Wetlands converted to Grassland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.4 Settlements converted to Grassland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.5 Other Land converted to Grassland		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Direct N_2O emissions from N fertilization (1)

GREENHOUSE GAS SOURCE AND SINK			
	ACTIVITY DATA	**EMISSION FACTORS**	**EMISSIONS**
CATEGORIES			
	Total amount of fertilizer applied	**N2O-N emissions per unit of fertilizer**	**N2O**
Land-Use Category (2)			
	(Gg N/yr)	**(kg N2O-N/kg N)(3)**	**(Gg)**
Total for all Land Use Categories	**NO**	**NO**	**NO**
A. Forest Land (4), (5)	**NO**	**NO**	**NO**
1. Forest Land remaining Forest Land	NO	NO	NO
2. Land converted to Forest Land	NO	NO	NO
G. Other *(please specify)*			

N2O emissions from drainage of soils (1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA	EMISSION FACTORS	EMISSIONS
Land-Use Category (2)	Sub-division (3)	Area of drained soils (kha)	N2O-N per area drained (4) (kg N2O-N/ha)	N2O (Gg)
Total all Land-Use Categories		NO	NO	NO
A. Forest Land		NO	NO	NO
Organic Soil		NO	NO	NO
	Total	NO	NO	NO
Mineral Soil		NO	NO	NO
	Total	NO	NO	NO
D. Wetlands		NO	NO	NO
Organic Soil		NO	NO	NO
	Total	NO	NO	NO
Mineral Soil		NO	NO	NO
	Total	NO	NO	NO
G. Other (please specify)				

N2O emissions from disturbance associated with land-use conversion to cropland (1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION FACTORS	EMISSIONS
Land-Use Category (2)	**Land area converted**	**N2O-N emissions per area converted(3)**	**N2O**
	(kha)	**(kg N2O-N/ha)**	**(Gg)**
Total all Land-Use Categories (4)	**34.41**	**0.69**	**0.04**
B. Cropland	**34.41**	**0.69**	**0.04**
2. Lands converted to Cropland (5)	34.41	0.69	0.04
Organic Soils	NO	NO	NO
Mineral Soils	34.41	0.69	0.04
2.1 Forest Land converted to Cropland	NE,NO	NO	NE,NO
Organic Soils	NO	NO	NO
Mineral Soils	NE	NE	NE
2.2 Grassland converted to Cropland	34.41	0.69	0.04
Organic Soils	NO	NO	NO
Mineral Soils	34.41	0.69	0.04
2.3 Wetlands converted to Cropland (6)	NO	NO	NO
Organic Soils	NO	NO	NO
Mineral Soils	NO	NO	NO
2.5 Other Land converted to Cropland	NO	NO	NO
Organic Soils	NO	NO	NO
Mineral Soils	NO	NO	NO
G. Other *(please specify)*			

Carbon emissions from agricultural lime application (1)

GREENHOUSE GAS SOURCE AND SINKCATEGORIES	**ACTIVITY DATA**	**EMISSION FACTORS**	**EMISSIONS**
	Total amount of lime applied(Mg/yr)	**Carbon emissions per unit of lime**	**Carbon**
Land-Use Category			
		(Mg C/Mg)	**(Gg)**
Total all Land-Use Categories (2), (3), (4)	**205047.45**	**0.12**	**24.61**
B. Cropland (4)	**205047.45**	**0.12**	**24.61**
Limestone CaCO3	205047.45	0.12	24.61
Dolomite CaMg(CO3)2	IE	IE	IE
C. Grassland (4)	**IE**	**IE**	**IE**
Limestone CaCO3	IE	IE	IE
Dolomite CaMg(CO3)2	IE	IE	IE
G. Other *(please specify)* (4, 5)			

4.0 INTRODUCTION TO AFOLU BASED ON 2006 IPCC GUIDELINES

4.1 Background

- Process started before1991
- Revised 1996 Guidelines for National Greenhouse Gas Inventories-Revised 1996 Guidelines
- 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories - GPG 2000
- Good Practice Guidance for Land Use, Land-Use Change and Forestry -GPG LULUCF
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories-2006 Guidelines

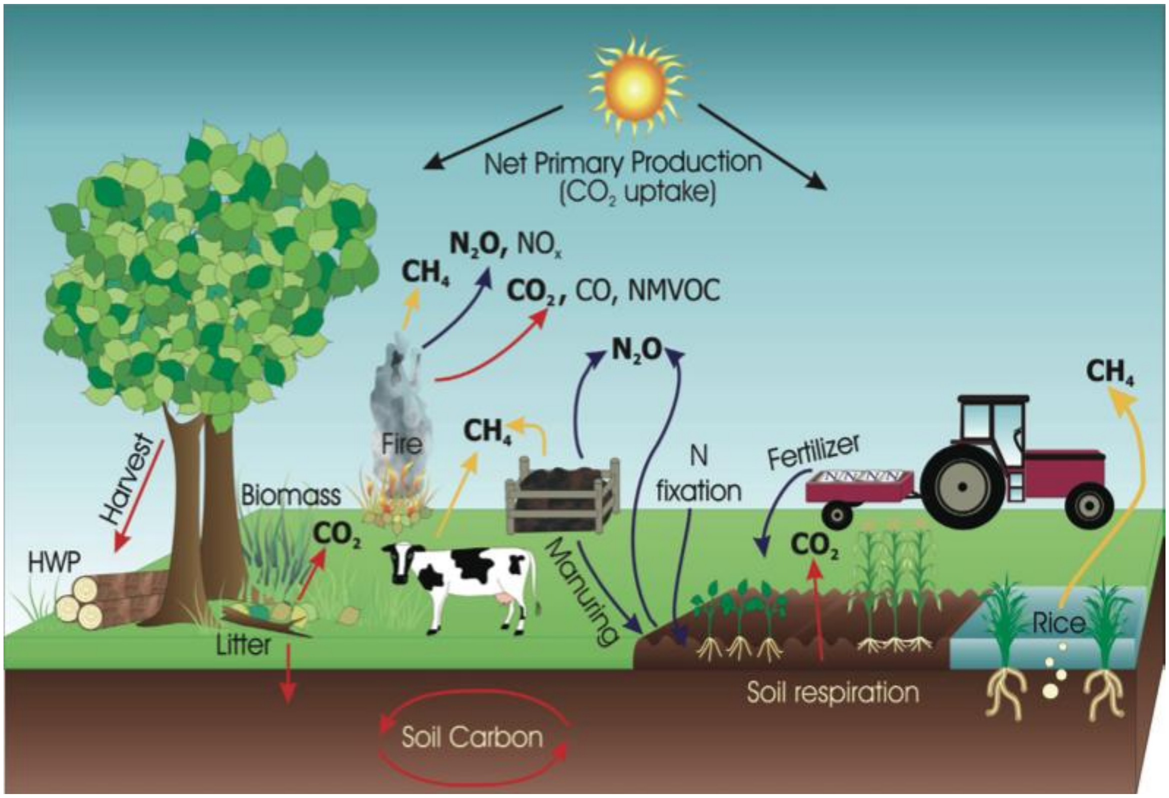
Scope

To provides guidance for preparing annual GHG inventories in the AFOLU Sector recognizing that GHG emissions and removals processes can occur across all types of land

Unique characteristic of the AFOLU sector:

- Use of "**managed land**" as a proxy for anthropogenic emissions by sources and removals by sinks.
- Only emissions from managed land have to be reported- "managed land is land where human interventions and practices have been applied to perform production, ecological or social functions."
- Definitions should be specified at the national level, described in a transparent manner, and applied consistently over time;
    - Why use Managed Land as a proxy?
- Preponderance of anthropogenic effects occurs on managed lands
- Practicality: Information needed for inventory estimation is largely confined to managed lands.
- By definition, all direct human-induced effects on GHG emissions and removals occur on managed lands only.

Main GHG emission sources/removal and processes in managed ecosystems



Key GHGs:

(i) Carbon dioxide (CO2): uptake through plant photosynthesis,release via respiration, decomposition and combustion of organic matter

(ii)Nitrous oxide (N2O): primarily emitted from ecosystems as a by-product of nitrification and denitrification

(iii)Methane (CH4): emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation, and during incomplete combustion while burning organic matter.

(iv)Other gases of interest (from combustion and from soils): Nitrogen oxides (NOx), Ammonia (NH3), non-methane organic volatile compounds. (NMVOC) and Carbon monoxide (CO) (precursors for the formation of GHG in the atmosphere)

5.0 PRACTICAL EXERCISE FOR LAND USE CHANGE AND FORESTY EMISSION/REMOVALS ESTIMATIONS FOR ZAMBIA FOR THE YEAR 2000

Table 5.1 Calculations for CO2 emissions based on activity data and emission factors-2000-Onsite burning

	Land Use Change and Forstry		carbon releas	by On-site burning					
Source	Area converted annually kha	Biomass before conversion t/ha	Biomass after conversion t/ha	Net change in biomass t/ha	Annual loss of biomass kt	Fraction of biomass burned on-site	Fraction of biomass oxidised on-site	Carbon content	Carbon dioxide released Gg
Agriculture	176	117	67	50	8800	0.85	0.95	0.47	12257.14
Infrastructure	68	117	67	50	3400	0.85	0.95	0.47	4735.713
Charcoal production	19	117	71	46	874	1	0.68	0.47	1025.143
Timber harvesting	7	117	71	46	322	0.1	0.9	0.47	49.9876
Natural Causes	1	117	71	46	46	0.9	0.95	0.47	67.84032
Total									**18135.82**

Calculations for CO2 emissions based on activity data and emission factors-2000-Offsite burning

	Land Use Change and Forst	(carbon released by off-site burning)				
Source	Fraction of biomass burned off-site kt	Quantity of biomass burned off-site kt	Fraction of biomass oxidised off-site kt	Carbon content	Quantity of carbon released from off-site kt	Total Carbon dioxide released from off-site Gg
Charcoal/mining	0.9	1.401	0.98	0.88	1.08740016	3.990758587
Charcoal/industry	0.9	31.58	0.98	0.88	24.5111328	89.95585738
Charcoal/households	0.9	838.82	0.98	0.88	651.0585312	2389.38481
Firewood/mining	0.9	0.173	0.98	0.47	0.07171542	0.263195591
Firewood/agriculture	0.9	275.8	0.98	0.47	114.330132	419.5915844
Firewood /industry	0.9	629.58	0.98	0.47	260.9860932	957.818962
Firewood households	0.9	6,886.46	0.98	0.47	2854.713128	10476.79718
Total						**14337.80235**

Table 5.3 Calculations for CO2 emissions based on activity data and emission factors-2000-Decay of biomass

	Land Use Change and Forstry		carbon released by decay of biomass						
Source	Area converted 10 year average kha	Biomass before conversion t/ha	Biomass after coversion t/ha	Net change in biomass density kt/ha	Average annual of loss of biomass kt	Fraction left to decay	Quantity of biomass left to decay kt	Carbon fraction in above ground biomass	Carbon dioxide released from decay of above ground biomass
Agriculture	1756	117	67	50	87800	0.15	13170	0.47	22716.93
Infrastructure	675	117	67	50	33750	0.15	5062.5	0.47	8732.306
Charcoal production	189	117	71	46	8694	0	0	0.47	0
Timber harvesting	68	117	71	46	3128	0.9	2815.2	0.47	4855.938
Natural causes	1	117	71	46	46	0.1	4.6	0.47	7.93454
Total							**21052.3**		**36305.18**

Table 5.4: Calculations of trace gases based on activity data and emission factors-2000

	Trace gas emissions from burning of cleared forest						
Quantity of carbon released kt	Nitrogen/carbon ratio	Total nitrogen released	Gas symbol	Emissions factors	Emissions	Conversion ratios	Trace gases Gg
4941.6403	0.002	9.8832806	CH4	0.012	59.2996836	1.33	**289.447686**
4941.6403			CO	0.06	296.498418	2.33	**2535.38762**
		9.8832806	N2O	0.007	0.06918296	1.57	**0.39862532**
		9.8832806	NOX	0.121	1.19587695	3.29	**14.4393771**

Table 5.5 Calculations of carbon emissions from managed organic soils for the year 2000

Use of organic soils	Land area ha	Annual loss rate MgC/ha	Net carbon loss from organic soils MgC/year
Upland crops	20,000	20	400,000
Pasture/forest			0

Source	Worksheet value	Unit conversion factor	Total carbon dioxide emissions Gg
Total net change in soil carbon in mineral soils			
Total net carbon from organic soils	400000	0.001	1468
Carbon emissions from liming			0
Total			1468

Table 5.6: Calculations of carbon emissions from lime for the year 2000

Type of lime	Total amount of annual lime Mg	Carbon conversion	Carbon emissions from liming MgC	CO2 emissions
limestone	41000	0.12	4920	18.0564
Dolomite			0	

5.7 Calculations of Carbon uptake based on activity data and emission factors-2000

	Land use change carbon uptake				
Category	**Area of forest abandoned over 20 year period kha**	**Annual growth rate t/ha**	**Annual biomass increament kt**	**Carbon fractionn of above ground biomass**	**Annual carbon uptake Gg**
Agriculture	213.3	2.1	447.93	0.47	772.634457
Charcoal production	454.3	2.1	954.03	0.47	1645.60635
Timber production	23.7	2.1	49.77	0.47	85.848273
Infrastructure	0	0	0	0.47	0
Natural Causes	0	2.1	0	0.47	0
Pine	0.8	11.45	9.16	0.47	15.800084
Eucalyptus	2	14.5	29	0.47	50.0221
Gmelina	0	11.5	0	0.47	0
Total			**1489.89**		**2569.91126**
Plantations					
Eucalyptus	2	14.5	29	0.45	47.8935
Pine	48	11.5	552	0.45	911.628
Gmelina	1	11.5	11.5	0.45	18.99225
Total					**978.51375**
Grand Total					**3548.425**

Table 5.8 GHG emissions and removals from land use change and forestry for 2000

	Annual Emissions CO_2Gg	Annual Uptake (Removal) CO2 Gg	Balance Gg
SOURCES	2000	2000	2000
On site burning	18,135.82		
On site decay	3630.52		
Off site burning	14,337.80		
Liming of soil	18.06		
Change in soil carbon in mineral soil	1468.00		
Total Sources	37,590.20		
SINKS			
Carbon uptake by plantations		959.52	
Carbon uptake in abandoned areas		2504.09	
Total Sources		3463.61	
Balance			34,126.6

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7.0 GLOSSARY

Activity
A practice or ensemble of practices that take place on a delineated area over a given period of time.

Activity data
Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arisings are examples of activity data.

Biological treatment of waste
Composting and anaerobic digestion of organic wastes, such as food waste, garden/park waste and sludge, to reduce volume in the waste material, stabilisation of waste, and destruction of pathogens in the waste material. This includes mechanical-biological treatment.

Biomass
(1) The total mass of living organisms in a given area or of a given species usually expressed as dry weight. (2) Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material.

Blowing agent (for foam production)
A gas, volatile liquid, or chemical that generates gas during the foaming process. The gas creates bubbles or cells in the plastic structure of a foam.

Bootstrap technique
Bootstrap technique is a type of computationally intensive statistical methods which typically uses repeated re-sampling from a set of data to assess variability of parameter estimates.

Calcium carbide
Calcium carbide is used in the production of acetylene, in the manufacture of cyanamide (a minor historical use), and as a reductant in electric arc steel furnaces. It is made from calcium carbonate (limestone) and carbon containing reductant (e.g., petroleum coke).

Carbon dioxide equivalent
A measure used to compare different greenhouse gases based on their contribution to radiative forcing. The UNFCCC currently (2005) uses global warming potentials (GWPs) as factors to calculate carbon dioxide equivalent

Category
Categories are subdivisions of the four main sectors Energy; Industrial Processes and Product Agriculture, Forestry and Other Land Use (AFOLU); and waste. Categories may be further divided into subcategories.

Chlorofluorocarbons (CFCs)
Halocarbons containing only chlorine, fluorine, and carbon atoms. CFCs are both ozone-depleting substances (ODSs) and greenhouse gases.

Country-specific data
Data for either activities or emissions that are based on research carried out on sites either in that country or otherwise representative of that country.

CSO-Central Statistical Office (Zambia)

ECZ-Environmental Council of Zambia

Emission factor
A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Emissions
The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Energy recovery
A form of resource recovery in which the organic fraction of waste is converted to some form of usable energy. Recovery may be achieved through the combustion of processed or raw refuse to produce steam through the pyrolysis of refuse to produce oil or gas; and through the anaerobic digestion of organic wastes to produce methane gas.

Enhanced coal bed methane (recovery)
Increased CH4 recovery produced by the injection of CO2 into coal seams.

Estimation
The process of calculating emissions and/or removals.

Evaporative emissions
Evaporative emissions fall within the class of fugitive emissions and are released from area (rather than point) sources. These are often emissions of Non-Methane Volatile Organic Compounds (NMVOCs), and are produced when the product is exposed to the air – for example in the use of paints or solvents.

Expert judgement
A carefully considered, well-documented qualitative or quantitative judgement made in the absence of unequivocal observational evidence by a person or persons who have a demonstrable expertise in the given field.

Feedstock
Fossil fuels used as raw materials in chemical conversion processes to produce primarily organic chemicals and, to a lesser extent, inorganic chemicals.

Flaring
Deliberate burning of natural gas and waste gas/vapour streams, without energy recovery.

Fluorocarbons
Halocarbons containing fluorine atoms, including chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

Flux
(1) Raw materials, such as limestone, dolomite, lime, and silica sand, which are used to reduce the heat or other energy requirements of thermal processing of minerals (such as the smelting of metals). Fluxes also may serve a dual function as a slagging agent.
(2) The rate of flow of any liquid or gas, across a given area; the amount of this crossing a given area in a given time. E.g., "Flux of CO2 absorbed by forests".

Fossil carbon
Carbon derived from fossil fuel or other fossil source.

Fuel
Any substance burned as a source of energy such as heat or electricity. See also *Primary Fuels* and *Secondary Fuels*.

Fuel combustion
Within the Guidelines fuel combustion is the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.

Fuel wood
Wood used directly as fuel.

Fugitive Emissions
Emissions that are not emitted through an intentional release through stack or vent. This can include leaks from industrial plant and pipelines.

GHG-Greenhouse Gases

Global warming potential
Global Warming Potentials (GWP) are calculated as the ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO2 over a period of time (e.g., 100 years).

Good Practice

Good Practice is a set of procedures intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as possible. *Good Practice* covers choice of estimation methods appropriate to national circumstances, quality assurance and quality control at the national level, quantification of uncertainties and data archiving and reporting to promote transparency.

Hydrocarbon

Strictly defined as molecules containing only hydrogen and carbon. The term is often used more broadly to include any molecules in petroleum which also contains molecules with S, N, or O An unsaturated hydrocarbon is any hydrocarbon containing olefinic or aromatic structures.

Hydrochlorofluorocarbons (HCFCs)

Halocarbons containing only hydrogen, chlorine, fluorine and carbon atoms. Because HCFCs contain chlorine, they contribute to ozone depletion. They are also greenhouse gases.

Hydrofluorocarbons (HFCs)

Halocarbons containing only hydrogen, fluorine and carbon atoms. Because HFCs contain no chlorine, bromine, or iodine, they do not deplete the ozone layer. Like other halocarbons, they are potent greenhouse gases.

Hydrofluoroethers (HFEs)

Chemicals composed of hydrogen, fluorine and carbon atoms, with ether structure. Because HFES contain no chlorine, bromine, or iodine, they do not deplete the ozone layer. Like other halocarbons, they are potent greenhouse gases.

IE-Estimated Else where

IPCC-Intergovernmental Panel on Climate Change

Key category

A key category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions or removals. Whenever the term key category is used, it includes both source and sink categories.

Land cover

The type of vegetation , rock, water etc. covering the earth’s surface.

Landfill gas

Municipal solid waste contains significant portions of organic materials that produce a variety of gaseous products when deposited, compacted, and covered in landfills. Anaerobic bacteria thrive in the oxygen-free environment, resulting in the decomposition of the organic materials and the production of primarily carbon dioxide and methane. Carbon dioxide is likely to leach out of the landfill because it is soluble in water. Methane, on the other hand, which is less soluble in water and lighter than air, is likely to migrate directly to the atmosphere.

Lubricants
Lubricants are hydrocarbons produced from distillate or residue, and they are mainly used to reduce friction between bearing surfaces. This category includes all finished grades of lubricating oil, from spindle oil to cylinder oil, and those used in greases, including motor oils and all grades of lubricating oil base stocks.

LULUCF-Land Use, Land Use Change and Forestry

Manure
Waste materials produced by domestic livestock which can be managed for agricultural purposes. When manure is managed in a way that involves anaerobic decomposition, significant emissions of methane can result.

Climate change mitigation- are measures or actions to decrease the intensity of radiative forcing in order to reduce global warming. Mitigation is distinguished from adaptation, which involves acting to minimize the effects of global warming. Most often, mitigations involve reductions in the concentrations of greenhouse gases, either by reducing their sources or by increasing their sinks

NE-Not Estimated

Non-energy products
Primary or secondary fossil fuels which are used directly for their physical or diluent properties. Examples are: lubricants, paraffin waxes, bitumen, and white spirits and mineral turpentine (as solvent).

Non-energy use
Within the *Guidelines* this term refers to the use of fossil fuels as *Feedstock*, *Reductant* or *Non-energy products.* However, the use of this term differs between countries and sources of energy statistics. In most energy statistics, e.g., of the International Energy Agency (IEA), fuel inputs of *reductants* to blast furnaces are not included but accounted for as inputs to a fuel conversion activity transforming coke and other inputs to blast furnace gas.

Non-Methane Volatile Organic Compounds (NMVOCs)
A class of emissions which includes a wide range of specific organic chemical substances. Non-Methane Volatile Organic Compounds (NMVOCs) play a major role in the formation of ozone in the troposphere (lower atmosphere). Ozone in the troposphere is a greenhouse gas. It is also a major local and regional air pollutant, causing significant health and environmental damage. Because they contribute to ozone formation, NMVOCs are considered "precursor" greenhouse gases. NMVOCs, once oxidized in the atmosphere, produce carbon dioxide.

NO-Not Occurring

Open burning of waste
The combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, and other debris in the open or at an open dump site, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion.

Oxidation
Chemically transform of a substance by combining it with oxygen.

Ozone-depleting substances (ODS)
A compound that contributes to stratospheric ozone depletion. Ozone-depleting substances (ODS) include CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride, and methyl chloroform. ODS are generally very stable in the troposphere and only degrade under intense ultraviolet light in the stratosphere. When they break down, they release chlorine or bromine atoms, which then deplete ozone.

Perfluorocarbons (PFCs)
Synthetically produced halocarbons containing only carbon and fluorine atoms. They are characterized by extreme stability, non-flammability, low toxicity, zero ozone depleting potential, and high global warming potential.

Primary fuels
Fuels which are extracted directly from natural resources. Examples are: crude oil, natural gas, coals, etc.

Process emissions
Emissions from industrial processes involving chemical transformations other than combustion.

Quality Assurance
Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process to verify that data quality objectives were met, ensure that the inventory represents the best possible estimate of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the quality control (QC) programme.

Quality Control
Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to: (i) Provide routine and consistent checks to ensure data integrity, correctness, and completeness; (ii) Identify and address errors and omissions; (iii) Document and archive inventory material and record all QC activities. QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. More detailed QC activities include technical reviews of source categories, activity and emission factor data, and methods.

Removals
Removal of greenhouse gases and/or their precursors from the atmosphere by a sink.

Reporting
The process of providing results of the inventory

Secondary fuels
Fuels manufactured from primary fuels. Examples are: cokes, motor gasoline and coke oven gas, blast furnace gas.

Sequestration- The process of storing carbon in a carbon pool.

Sink- Any process, activity or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere.

Source- Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere.

Temperate, cold-Areas where mean annual temperature (MAT) is between 0 – 10 ^{o}C.

Temperate, warm-Areas where mean annual temperature (MAT) is between 10 – 20 ^{o}C.

Tropical-Areas where mean annual temperature (MAT) is more than 20 ^{o}C.

Uncertainty-Lack of knowledge of the true value of a variable that can be described as a probability density function characterizing the range and likelihood of possible values. Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.

UNFCCC- United Nations Framework Convention on Climate Change

Baseline Scenario-In the context of Mitigation, a baseline scenario is a description of existing conditions as they relate to the sectors and systems to be targeted by a mitigation project, with an assessment of how these conditions might evolve in the future in the absence of the proposed adaptation interventions

APPENDIX ACTIVITY DATA FOR LAND USE CHANGE AND FORESTRY

VEGETATION CHANGE DETECTION BASED ON REMOTE SENSED DATA - ZAMBIA

Province	Area (ha)	1974 WA (ha)	%
Central	9,439,438	6,513,554	69
Copperbelt	3,132,839	2,385,193	76
Eastern	6,910,582	5,395,732	78
Luapula	5,056,908	3,267,485	65
Lusaka	2,189,568	1,568,776	72
Northern	14,782,565	11,003,576	74
Northwestern	12,582,637	10,201,069	81
Southern	8,528,283	6,942,339	81
Western	12,638,580	9,584,150	76
Total	**75,261,400**	**56,861,875**	**76**

1974 - 1984	Total change	3,777,032	10 Ys
		377,703	Annum
	GS (m3)	5,191,489,182	91.3/ha
	W/BCEF	144	

Province	Area (ha)	1984 WA (ha)	%
Central	9,439,438	6,410,254	68
Copperbelt	3,132,839	2,244,398	72
Eastern	6,910,582	5,380,433	78
Luapula	5,056,908	3,370,391	67
Lusaka	2,189,568	1,462,356	67
Northern	14,782,565	8,973,541	61
Northwestern	12,582,637	9,679,159	77
Southern	8,528,283	6,972,099	82
Western	12,638,580	8,592,212	68
Total	**75,261,400**	**53,084,843**	**71**

54,973,359

1984 - 1990	Total Change	1,700,405	6 Ys
		283,401	Annum
	GS (m3)	3,938,895,380	74.2/ha
	W/BCEF	117	

Province	Area (ha)	1990 WA (ha)	%
Central	9,439,438	6,213,999	66
Copperbelt	3,132,839	2,118,888	68
Eastern	6,910,582	5,334,941	77
Luapula	5,056,908	3,314,598	66
Lusaka	2,189,568	1,405,363	64
Northern	14,782,565	7,900,920	53
Northwestern	12,582,637	9,599,120	76
Southern	8,528,283	6,961,224	82
Western	12,638,580	8,535,384	68
Total	**75,261,400**	**51,384,438**	**68**

1990 - 1994	Total Change	1,592,491	4 Ys
		398,123	Annum
	GS (m3)	3,812,725,300	74.2/ha
	W/BCEF	117	

Province	Area (ha)
Central	9,439,438
Copperbelt	3,132,839
Eastern	6,910,582
Luapula	5,056,908
Lusaka	2,189,568
Northern	14,782,565
Northwestern	12,582,637
Southern	8,528,283
Western	12,638,580
Total	**75,261,400**

1994 - 2000	Total Change
	GS (m3)
	W/BCEF

Source: Siampale A. M. (2000) "Vegetation Monitoring Using Landsat Image 1974, 1984, 1990, 1994 an

1974

ID	Province	% of WA	Rank
1	Luapula	65	9
2	Central	69	8
3	Lusaka	72	7
4	Northern	74	6
5	Western	76	5
6	Copperbelt	76	4
7	Eastern	78	3
8	Northwestern	81	2
9	Southern	81	1

1984

ID	Province	% of WA	Rank
1	Northern	61	9
2	Luapula	67	8
3	Lusaka	67	7
4	Central	68	6
5	Western	68	5
6	Copperbelt	72	4
7	Northwestern	77	3
8	Eastern	78	2
9	Southern	82	1

1990

ID	Province	% of WA	Rank
1	Northern	53	9
2	Central	66	8
3	Lusaka	64	7
4	Luapula	66	6
5	Western	68	5
6	Copperbelt	68	4
7	Northwestern	76	3
8	Eastern	77	2
9	Southern	82	1

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ID	Province
1	Northern
2	Central
3	Luapula
4	Lusaka
5	Copperbelt
6	Western
7	Southern
8	Northwestern
9	Eastern

1974 - 1994 UPTAKE FROM NET PRIMARY PRODUCTIVITY (NNP)

Land categories	LUC/FC	Total land use change (kha)	Area of forest abandoned over 20 year period (kha)	Annual growth rate (m3/ha)	Growing Stock Increment (kt)
	Agriculture	4,595	229.8	2.1	482.5
	Infrastructure	1,767	0.0	0.0	0.0
	Charcoal production	495	386.0	2.1	810.6
	Timber harvesting	177	23.0	2.1	48.3
7,069,928	Natural causes	35	0.0	2.1	0.0
Forest plantation	Pine	456	0.5	11.5	5.2
	Eucalyptus	120	0.1	14.5	1.7
	Gmelina	24	0.0	11.5	0.0
	Total	7,670	639.3	-	1,348.4

1980 - 2000 UPTAKE FROM NET PRIMARY PRODUCTIVITY (NNP)

Land categories	LUC/FC	Total land use change (kha)	Area of forest abandoned over 20 year period (kha)	Annual growth rate (t/ha)	Growing Stock Increment (kt)
	Agriculture	4,739	213.3	2.1	447.9
	Infrastructure	1,823	0.0	0.0	0.0
	Charcoal production	510	454.3	2.1	953.9
	Timber harvesting	182	23.7	2.1	49.8
7,291,397	Natural causes	36	0.0	2.1	0.0
Forest plantation	Pine	760	0.8	11.5	8.7
	Eucalyptus	200	0.2	14.5	2.9
	Gmelina	40	0.0	11.5	0.0
	Total	8,291	692.2	-	1,463.2

CONSIDERED UPTAKE FROM NET PRIMARY PRODUCTIVITY (NNP)

Land categories	LUC/FC	Total land use change (kha)	Area of forest abandoned over 20 year period (kha)	Annual growth rate (t/ha)	Growing Stock Increment (kt)
	Agriculture	9,335	443.0	2.1	930.4
	Infrastructure	3,590	0.0	0.0	0.0
	Charcoal production	1,005	840.3	2.1	1,764.6
	Timber harvesting	359	46.7	2.1	98.0
14,361,325	Natural causes	72	0.0	2.1	0.0
Forest plantation	Pine	456	1.2	11.5	14.0
	Eucalyptus	320	0.3	14.5	4.6
	Gmelina	64	0.0	11.5	0.0
	Total	15,201	1,331.5	-	2,811.6

MONITORED ANNUAL CHANGE OVER THE YEARS			
ID	Time Period	No. of Years	Annual Change (Ha)
1	1974 - 1984	10	377,703
2	1984 - 1990	6	283,401
3	1990 - 1994	4	398,123
4	1994 - 2000	6	351,664
5	1974 - 2000	26	207,803
Average over 26 years is 207,803ha/a			

ON SITE LUC/FC AVERAGE ESTIMATES			
ID	Drivers	Area in Ha	% Share
1	Agriculture	135	65
2	Infrastructure	52	25
3	Charcoal production	15	7
4	Timber harvesting	5	2.5
5	Natural effects	1	0.5
Total Land Converted		208	100

AREA CONVERTED IN 10 YEARS ON AVERAGE			
ID	Time Period	Change (Ha)	Annual Change (Ha)
1	1984 - 1994	3,292,896	329,290
2	1990 - 2000	3,702,476	370,248
3	1984 - 2000	5,402,882	270,144
4	1994	-	-
5	2000	-	-

1994 AND 2000 BASE YEARS			
ID	Drivers	Area in kha	Biomass BC
1	Agriculture	176	65
2	Infrastructure	68	25
3	Charcoal production	19	7
4	Timber harvesting	7	2.5
5	Natural causes	1	0.5
Total Land Converted		270	100

AREA CONVERTED IN 10 YEARS ON AVERAGE					ON SITE BIOMASS ESTIMATES		
ID	Drivers	Area in kha	Biomass BC t/ha		Biomass AC t/ha	%Burnt onsite	% Decay onsite
1	Agriculture	1,756	117		67	0.85	0.15
2	Infrastructure	675	117		67	0.85	0.15
3	Charcoal production	189	117		71	1.00	0.00
4	Timber harvesting	68	117	174 AND 141	71	0.10	0.90
5	Natural causes	14	117		71	0.90	0.10
OP 1	Weighted BCEF	1974 - 1984	91.3m3/ha		144	WD	0.56
OP 2	1.575	1984 - 2005	74.2m3/ha	BBC t/ha	117	BEF	3.4

ANNUAL COMMERCIAL HARVEST - PLANTATIONS			
ID	Species	1994 (M3)	2000 (M3)
1	Pine	136,800	228,000
2	Eucalyptus	36,000	60,000
3	Gmelina	7,200	12,000
TOTAL		180,000	300,000

WASTE ESTIMATIONS / CALCULATIONS		
Species	% Waste In-situ	% Waste S/M
Pine	10	45
Eucalyptus	30	25
Gmelina	10	45

ID	Species	1994 (M3)	Waste burnt (M3)	Waste decay (M3)	Bush Waste	Sawmill Waste
1	Pine	136,800	26,334	48,906	13,680	61,560
2	Eucalyptus	36,000	6,930	12,870	10,800	9,000
3	Gmelina	7,200	1,386	2,574	720	3,240
TOTAL		180,000	34,650	64,350	25,200	73,800

ID	Species	2000 (M3)	Waste burnt (M3)	Waste decay (M3)	Bush Waste	Sawmill Waste
1	Pine	228,000	43,890	81,510	22,800	102,600
2	Eucalyptus	60,000	11,550	21,450	18,000	15,000
3	Gmelina	12,000	2,310	4,290	1,200	5,400
TOTAL		300,000	57,750	107,250	42,000	123,000

SOURCE: MODIS_Terra_Acqua_500m_Satellite_Monitored_Every_2_Days (Apr to Nov)						
ID	Land categories	1994 Actual Land Area (Ha)	Area Burnt by Early fires (Ha)	Area Burnt by Late fires (Ha)	Actual Land Area Burnt (Ha)	% Burnt
1	Land under Forests >10% CC (Ha)	49,791,947	363,904	926,300	1,290,204	2.6
2	Land under Grasslands (Ha)	10,668,248	1,925,510	4,901,297	6,826,806	67.6
3	Land under crops (Ha)	4,917,064	1,243,632	3,165,608	4,409,240	89.7
4	**Total Burnt Area**	**64,807,217**	**3,533,045**	**8,993,205**	**12,526,250**	**19.3**
ID	Land categories	2000 Actual Land Area (Ha)	Area Burnt by Early fires (Ha)	Area Burnt by Late fires (Ha)	Actual Land Area Burnt (Ha)	% Burnt
1	Land under Forests >10% CC (Ha)	47,681,962	739,594	1,218,528	1,958,122	4.1
2	Land under Grasslands (Ha)	10,098,208	2,214,355	6,946,746	9,161,101	96.1
3	Land under crops (Ha)	5,487,104	1,474,760	3,222,835	4,697,595	85.6
4	**Total Burnt Area**	**62,697,232**	**4,428,709**	**11,388,109**	**15,816,818**	**25.2**