UN-REDD
PROGRAMME

FINAL REPORT

IPCC COMPLIANT GHG REPORTING METHODOLOGY FOR FOREST LANDS IN ZAMBIA

UN-REDD READINESS PROCESS FOR ZAMBIA

UN-REDD PROGRAMME

July 2013

The UN-REDD Programme, implemented by FAO, UNDP and UNEP, has two components: (i) assisting developing countries prepare and implement national REDD strategies and mechanisms; (ii) supporting the development of normative solutions and standardized approaches based on sound science for a REDD instrument linked with the UNFCCC. The programme helps empower countries to manage their REDD processes and will facilitate access to financial and technical assistance tailored to the specific needs of the countries.

The application of UNDP, UNEP and FAO rights-based and participatory approaches will also help ensure the rights of indigenous and forest-dwelling people are protected and the active involvement of local communities and relevant stakeholders and institutions in the design and implementation of REDD plans.

The programme is implemented through the UN Joint Programmes modalities, enabling rapid initiation of programme implementation and channeling of funds for REDD efforts, building on the in-country presence of UN agencies as a crucial support structure for countries. The UN-REDD Programme encourage coordinated and collaborative UN support to countries, thus maximizing efficiencies and effectiveness of the organizations' collective input, consistent with the "One UN" approach advocated by UN members.

Disclaimer

This report on IPCC compliant GHG reporting methodology for forest lands in Zambia was prepared by Prof F.D Yamba, Centre for Energy Environment and Engineering Zambia (CEEEZ) in his capacity as National Consultant for GHG reporting for FAO Zambia, under the UN-REDD programme - UNJP/ZAM/068/UNT

The present report is designed to reflect the activities and progress related to the UN-REDD Programme. This report is not authoritative information sources – it does not reflect the official position of FAO, UNDP or UNEP and should not be used for official purposes.
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AGB	Aboveground biomass
ALU	Agriculture and Land Use
BEF	Biomass Expansion Factor
BER	Biomass Expansion Ratio
BGG	Belowground biomass
CA	Combine and Assign
CBU	Copperbelt University
CH_4	Methane
CO_2	Carbon Dioxide
DOM	Dead Organic Matter
EFDB	Emission Factor Database
EPA	Environmental Protection Agency
ESA GHG	Eastern and Southern Africa Greenhouse Gases Inventory Project
FAO	Food and Agriculture and Organization of the United Nations
FD	Forestry Department
GHG	Greenhouse Gas
GIS	Geographical Information System
GIZ	German Technical Organisation
GPG	Good Practice Guidance
GL	Guidelines
ILUA	Integrated Land Use Assessment
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
MRV	Monitoring Reporting and Verification
NFI	National Forestry Inventory
NFMS	National Forest Monitoring System
N_2O	Nitrous Oxide
NO_x	Oxides of Nitrogen
REL	Reference Emission Level
RCMRD	Regional Center for Mapping Resources for Development
REDD	Reduced Emission from Deforestation and Forest Degradation
REDD+	Reduced Emission from Deforestation and Forest Degradation plus Sustainable Forest Management, Reforestation, and Forest Conservation.
SM	Stratify and Multiply
SNC	Second National Communication
SOM	Soil Organic Matter
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations – Reduced Emissions from Deforestation and Forest Degradation
UNZA	The University of Zambia
ZARI	Zambia Agriculture Research Institute

EXECUTIVE SUMMARY

Introduction

As a part of REDD+ readiness in Zambia, several fundamental studies are required for REDD+ strategy development, including developing a methodology for an operational measurement, reporting and verification (MRV) system.

The methodology aims to be in line with decision 4/CP.15, requiring developing countries to use the Intergovernmental Panel on Climate Change (IPCC) guidance as the basis for estimating anthropogenic forested related Greenhouse Gas (GHG) emissions by sources, and removals by sinks, forest carbon stocks and forest area changes in the context of REDD+.

Objectives and outputs

The objectives and outputs of this assignment on IPCC compliant GHG reporting for forestlands were as follows:

i. Review the international and national reporting requirements for emission factors, activity data and GHG reporting under the IPCC and the REDD+ strategy for forest lands,
ii. Compile relevant data on emission factors, activity data, and GHG emissions in Zambia,
iii. Identify gaps in emission factors, activity data, GHG reporting and provide advice on how these knowledge gaps can be ameliorated,
iv. Provide advice and inputs on field measurements for generating national emission factors for Zambia,
v. Provide advice and inputs on the generation of activity data from Zambia's National Forest Monitoring System,
vi. Provide guidance and advice on the establishment of a reference emission level for Zambia, and
vii. Develop a detailed methodology for GHG reporting for forest land that can be implemented by a relevant institution.

Approach and methodology

This involved reviewing literature and analysis of guidance documents produced by the IPCC, and other relevant documentation. This methodology was used for achieving the following deliverables and outputs:

i. Review of GHG reporting requirements for forest lands under IPCC,
ii. Developing GHG detailed methodology, and
iii. Selection of reference emission level.

Output on review of GHG reporting requirements

Two methodologies were considered for GHG reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC): the 1996 IPCC guidelines (GL), and the IPCC - 2003 Good Practice Guidance (GPG). This was to make a recommendation on the most suitable methodology for estimating GHG emissions/removals in Zambia under the REDD+ strategy.

To do this, key activity data and emission factors for estimating GHG emissions/removals under the two methodologies were compared, as was the need for migrating to Tiers 2 and 3 as required under the IPCC – 2003 GPG, from Tier 1 normally recommended under the IPCC 1996 GL.

Furthermore, reporting requirements of GHG emissions/removals were compared for the purpose of recommending appropriate reporting requirements of GHG inventory under Land Use Land Use Change and Forestry (LULUCF). LULUCF is defined as “a greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities.” Land-use change can be a factor in CO_2 (carbon dioxide) atmospheric concentration, and is thus a contributor to climate change.

Following this comparison, it was determined that adoption of the IPCC 2003 - GPG approach will lead to improved GHG inventory, reduced uncertainty, full and consistent representation of all land categories, estimation of GHG emissions/removals from all land categories (resulting from land-use as well as land-use change) and consideration of all the relevant carbon pools and non-CO_2 gases (based on key source/sink category analysis).

The advantages of using the IPCC 2003 - GPG compared to the IPCC 1996 GL are that they:

i. Address most of the methodological limitations and inadequacies of the IPCC 1996 GL,
ii. Adopt key source/sink category analysis, which enables dedication of limited inventory resources to key source/sink categories,
iii. Enable estimation of carbon stock changes and non-CO_2 emissions for all the relevant geographical areas,
iv. Account for all five carbon pools and non-CO_2 gases, and
v. Reduce uncertainty in GHG estimation.

In view of the above, it is recommended that Zambia uses the IPCC 2003 - GPG for estimating GHG emissions and removals under LULUCF, including forest lands. For the purpose of REDD+ reporting requirements, it is also recommended that IPCC - 2003 GPG reporting tables be adopted.

Output on recommendations for improving activity data and emission factor migration

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:

Es,a,t= Aa,t* Fs.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”.

Under this assignment, the activity data required for migrating to Tiers 2 and 3 were identified as follows:

i. Area of remaining forest land, cropland, grasslands, settlements, wetlands and other lands, and area converted to other categories,
ii. Annual wood removed due to deforestation/degradation for land clearing for agriculture, and infrastructure and charcoal production,
iii. Traditional fuel-wood use,
iv. Area under managed organic soils,
v. Quantity of fertilizer used,
vi. Area converted annually and average area converted on a 10 year average,
vii. Area converted annually and average area converted on a 20 year average,
viii. Managed area abandoned during previous 20 years period, and
ix. Land area for savanna grassland burning.

The emission factors required for migrating to Tiers 2 and 3 were identified as follows:

i. Annual biomass growth rate – above ground for different forest types and plantations,
ii. Annual biomass growth rate – below ground for different forest types and plantations,
iii. Carbon fraction of dry matter,
iv. Biomass Expansion Ratio (BER)
v. Mortality rate in naturally and artificially generating forest,
vi. Aboveground biomass (AGB) before and after conversion – biomass density,
vii. Fraction of biomass burnt on-site,
viii. Fraction of biomass burnt off-site,
ix. Fraction of biomass oxidized on-site, and
x. Fraction of biomass left to decay,
xi. Soil carbon density in different land-use/management systems and soil types,
xii. Annual rate of loss of carbon from managed organic soils, and
xiii. Base factor, tillage factor, and input factor.

Responsible institutions were identified to generate activity data and emission factors through ongoing country activities under UNREDD and the Integrated Land Use Assessment II (ILUA II). Land use change related activity data is being developed as a joint exercise between the UN-REDD program in Zambia and the Eastern and Southern Africa Greenhouse Gas Inventory Project (ESA GHG), which is producing 1990, 2000 and 2010 land cover maps with assistance from Regional Centre for Mapping of Resources Development (RCMRD). Experts from Survey Department, National Remote Sensing Center (NRSC) and Forestry Department are also supporting this process.

For traditional fuel-wood use, a recommendation was made to enable the Department of Energy and the Department of Forestry to develop a methodology on data generation of traditional fuel-wood use including charcoal by households, industry, mining and agriculture. Similarly, emission factors are to be generated through the ILUA II project and complemented by research through the Zambia Agriculture Research Institute (ZARI), Copperbelt University (CBU) and the University of Zambia (UNZA).

Output on the detailed methodology for GHG forestlands reporting

A detailed methodology for estimating GHG emissions/removals was identified as stipulated under the IPCC – 2003 GPG using the following general steps:

i. Presentation of the IPCC – 2003 GPG land use categories and subcategories
ii. Selection of appropriate land classification system relevant to Zambia
iii. Establishment of performance status key source/sink category analysis
iv. Recommendation of appropriate tier level for the key land categories and subcategories, non- CO_2 gases and carbon pools based on the key category analysis
v. Identification of required activity data and emission factors, depending on the tier selected from regional, national and global databases
vi. Elaboration of estimation method (equations), based on tier level selected, quantifying the emissions and removals, carbon pools and non- CO_2 gases
vii. Recommendation of the estimation method for uncertainty, quality assurance/quality control (QA/QC) assessments, and documenting and archiving all information used to produce an inventory
viii. Recommendation on the IPCC reporting methodology for GHG emissions and removals using reporting tables

Presentation of the IPCC – 2003 GPG land use categories and subcategories

The IPCC – 2003 GPG adopted six land categories to ensure consistent and complete representation of land, covering all geographic areas of a country. The main land-use categories are: forest land, cropland, grassland, wetlands, settlements and other lands. The subcategories are:

i. Forest land remaining forest land and land converted to forest land,
ii. Cropland remaining cropland and land converted to cropland,
iii. Grasslands remaining grasslands and land converted to grasslands,
iv. Wetlands remaining wetlands and land converted to wetlands,
v. Settlements remaining settlements and land converted to settlements, and
vi. Other lands remaining other lands and land converted to other land.

Carbon Dioxide (CO_2) emissions and removals are estimated for all C-pools, namely: AGB, below-ground biomass (BGB), soil carbon, dead organic matter (DOM) and woody litter, and Non-CO_2 estimated gases including CH_4, N_2O, CO and $NO_{X.}$

Selection of appropriate land classification system relevant to Zambia

To conform to IPCC land classification, Zambia is part of the ESA GHG with support from RCMRD adopted specific definitions, based predominantly on criteria used in ILUA I and previous land use land cover mapping.

Zambia's land categories and subcategories, carbon pools and non-CO_2 gases, and associated disaggregated levels have been defined as follows, accounting for Zambia's national circumstances:

i. Forest land (natural forests and plantations),
ii. Cropland (annual crops and perennial crops),
iii. Grasslands (wooded grasslands and open/closed grasslands),
iv. Wetlands (dambos, pans and marshes), and

v. Settlements (built up areas)

Based on Zambia's classification and associated disaggregated levels, land cover maps for the years 1990, 2000 and 2010 are being developed from Landsat satellite imagery.

Establishment of performance status of key source/sink category analysis

Key category analysis helps a country achieve the highest possible levels of certainty while making efficient use of limited resources for the inventory process.

Since the IPCC – 2003 GPG is being used to estimate GHG emissions/removals for land use and land use change for the purpose of estimating GHG emissions under REDD+, it is recommended that key source/sink category analysis be performed using data of the GHG inventory, which is being developed as part of the ESA GHG project.

Recommendation of appropriate tier level for the key land categories and subcategories, non-CO_2 gases and carbon pools

The IPCC – 2003 GPG requires that Tiers 2 and 3 activity data and emission factors are used to estimate GHG emission/removals for LULUCF to reduce uncertainties in the estimation.

The GHG inventory for Zambia's Second National Communication (SNC) used the IPCC 1996 GL to estimate GHG emissions/removals, using a combination of Tier 1, and Tier 2 activity data and emission factor, with the latter coming from ILUA I results. However, in some cases, derivation of activity data and emission factor was not comprehensive enough. The SNC is a project that aims to strengthen the technical and institutional capacity of Zambia to ensure climate change issues are highlighted in national development priorities.

For estimating GHG emissions for LULUCF for REDD+, it is recommended that Tier 2 and Tier 3 activity data and emission factors be generated in conjunction with ILUA II and UN-REDD.

Identification of required activity data and emission factor

Activity data and emission factors, depending on Zambia's circumstances, required for estimation of GHG emissions/removal for LULUCF under REDD+ using the IPCC – 2003 GPG have been identified, and it is recommended that they be derived as part of ILUA II and UN-REDD activities.

Elaboration of method of estimations (equations)

Under this step, the summary equation, which estimates the annual emissions/removals from land remaining in each category, as well as land converted into another category, is given. Also given are the equations for:

i. Annual change in carbon stock from land remaining in each category, and land converted into another category, in tonnes C yr^{-1},
ii. Annual change in carbon stocks in living biomass (including above- and belowground biomass), in tonnes C yr^{-1},
iii. Annual change in carbon stocks in DOM (includes dead wood and litter) from land remaining in each category, as well as land converted into another category, in tonnes C yr^{-1},
iv. Annual change in carbon stocks in soils from land remaining in each category as well as land converted into another category, in tonnes C yr^{-1}, and

v. Non-CO_2 greenhouse gas emission.

A proposed methodology for generating activity data and emission factors for GHG inventory under forest lands is also further elaborated on in this report, and is based on two main approaches (stratify and multiply / combine and assign). This methodology should be followed by the Forestry Department in Zambia to generate the required activity data for GHG inventory.

Recommendation of the method for estimating uncertainty, QA/QC assessments, and documenting and archiving information

The good practice approach for inventories requires that estimates of GHG inventories be accurate and that uncertainties are reduced through undertaking QA/QC assessments and documenting and archiving all information used to produce an inventory.

To address these issues requires formalizing an institutional framework to take account of the assessments, and the development a central archive of data, preferably in the lead institution. Additionally, a GHG inventory facility should be established within the lead institution.

Output on recommendation of reference emission level estimation

A reference emission level describes the amount of GHG emissions expected from deforestation and degradation for a hypothetical 'business as usual scenario,' without REDD+ activities. This reference level can then be compared with the real reductions in the GHG emissions during the commitment period. The difference between the two determines the emission reductions performance of REDD+.

For the purpose of developing a reference emission level, it is recommended Zambia develops a historical emission level using the years 1990, 2000, and 2010 with input data of land use change determined from results of land cover mapping. The Forestry Department is developing a level for 1990, and RCMRD is developing levels for the years 2000 and 2010.

To establish a historical reference scenario, land cover maps for 1990, 1995, 2000, 2005 and 2010 also should be developed. This enables us to have sufficient points to construct historical trends for emissions and make projections into the future initially through extrapolation and later through modeling based on research.

It would be preferable to have land cover mapping for interim years (1995 and 2005) to elaborate more on land cover change trends, but this aspect is not in the current scope of the work and will need to be developed at a later stage.

Conclusions

This assignment has met the four required deliverables on

i. Review of GHG reporting requirements for LULUCF including forest lands under IPCC,
ii. Recommendations on improving activity data and emission factor migration to Tier 2 and Tier 3 under the IPCC – 2003 GPG,
iii. Elaboration of detailed methodology for GHG reporting for forest lands, and
iv. Recommendation of reference emission level estimation.

1.0 BACKGROUND

1.1 Introduction

As a part of REDD+ readiness in Zambia, several fundamental studies are required for REDD+ strategy development. REDD+ is an acronym for Reducing Emissions from Deforestation and Forest Degradation. Negotiations for REDD+ have centered on the provision of incentives to developing countries to reduce the level of their forest losses. REDD+ also aims to promote environmental, economic and social benefits while protecting the rights of forest dependent communities**.**

As a precursor to strategy development, it is necessary to understand the drivers of deforestation in Zambia, identify and map the most threatened forests and expected forest area changes, and understand other forest co-benefits (biodiversity, water, etc) and multiple benefits from REDD+ implementation.

It is also necessary to understand the economic context of REDD+, and specifically, the opportunity cost associated with REDD+ implementation in Zambia. Evidence-based alternative livelihoods for REDD+ also need to be understood.

The UN-REDD programme for Zambia intends to prepare Zambian institutions and stakeholders for effective nationwide implementation of the REDD+ strategy over a period of three years. One of the outputs of REDD+ readiness is generating an IPCC compliant GHG reporting methodology for forest lands in Zambia.

A number of actions have been identified which will result in the development of a national strategy of action for REDD+. Among those actions relevant to this assignment are:

i. Develop a national forest reference emission level and/or forest reference level (interim measure at sub national level),
ii. Develop a robust and transparent National Forest Monitoring System for the monitoring and reporting of the REDD+ activities (interim measure, sub national level),
iii. Establish a system for providing information on how safeguards on local community and forest biodiversity are being addressed and respected throughout the implementation of the REDD+ activities, while also respecting sovereignty.

As a part of developing an operational measurement, reporting and verification (MRV) system for Zambia, methodology is required to be in line with decision 4/CP.15, meaning that IPCC guidance is used by developing countries as the basis for estimating anthropogenic forest- related GHG emissions by sources and removals by sinks, forest carbon stocks and forest area changes. This is all in the context of REDD+ for estimating and reporting on GHGs for forest lands.

A central issue in the REDD+ process is the assessment of emission reductions or carbon stock changes, which is crucial to determine the performance of REDD+. Emission reductions from deforestation or degradation are considered additional if they would not have occurred in the respective area without REDD+ actions being taken (GIZ, 2011).

REDD+ activities offer the potential for a triple benefit of climate change mitigation, community development, and biodiversity conservation. In most cases, projects developed under REDD+ are encouraged to capture all three. It is also encouraged for projects developed under REDD+ to involve participation of stakeholders from the forest dependent communities. Through this process, efforts need to ensure that carbon projects provide numerous co-benefits to the local people and plants and animals that depend on healthy forest systems for survival (Nature Conservancy, 2009).

For an emission reductions programme to be effective, there must be a clear and transparent system to monitor reports and account for changes in emissions of carbon stocks. It is broadly agreed that using IPCC methodologies to estimate GHG emissions under the REDD+ process is the approach which should be adopted. IPCC methodologies provide a basis for guidance for preparing GHG inventories in the LULUCF sector.

The guidance document produced by the IPCC represents the world's most authoritative source of methods to estimate GHG inventories. The UNFCCC has recently requested to use IPCC guidance by developing countries for estimating anthropogenic forest related GHG emissions by sources and removals by sinks, forest carbon stocks and forest land changes in the context of REDD+ (UNFCCC, 2010).

1.2 Objectives and outputs

i. The general description of tasks and objectives for this assignment were as follows:
ii. Review of international and national reporting requirements for emission factors, activity data and GHG reporting under the IPCC and the REDD+ strategy for forest lands,
iii. Compile any relevant data on emission factors, activity data, and GHG emissions in Zambia,
iv. Identify gaps in emission factors, activity data and GHG reporting, and provide advice on how these knowledge gaps can be improved,
v. Provide advice and input on field measurements for generating national emission factors for Zambia,
vi. Provide advice and input on the generation of activity data from Zambia's National Forest Monitoring System,
vii. Provide guidance and advice on the establishment of a reference emission level for Zambia, and
viii. Develop a detailed methodology for GHG reporting for forest land that can be implemented by the relevant institution.

Deliverables and outputs were also elaborated as follows:

i. Review of GHG reporting requirements for forest lands under the IPCC
ii. Compile existing emission factors, activity data, and forest based GHG emissions for Zambia, identification of gaps,
iii. Provide advice and input on field measurements for generating national emission factors for Zambia,
iv. Generate activity data from Zambia's National Forest Monitoring System,
v. Establish a reference emission level for Zambia, and,
vi. Develop a detailed methodology for GHG reporting for forest land that can be implemented by the relevant institution.

1.3 Approach and methodology

Approach and Methodology involved reviewing and analyzing literature and relevant documentation to guidance documents produced by the IPCC. The same methodology was used for achieving the deliverables and outputs as follows:

i. Review of GHG reporting requirements for Forest lands under IPCC,
ii. Selection of reference emission level, and
iii. Develop GHG detailed methodology (as a elaborated in this section of the report).

1.3.1 Review of GHG reporting requirements

There are three methodologies that can be used for estimating GHG emissions/removals: the 1996 IPCC GL, the IPCC - 2003 GPG, and the 2006 IPCC GL. Listed in Table 1 are the approach, methodology, tools and outputs based on these IPCC Guidelines, to aid in the selection of appropriate GHG estimation under REDD+.

Table 1: Approach, methodology, tools and outputs - IPCC Methodologies

TASK	ACTIVITIES	METHODOLOGY	TOOLS/METHOD	OUTPUTS
1	Review the 1996 IPCC GL and identify activity data and emission factor requirements and associated challenges	Analysis	Analysis	Activity data and emission factor requirements are identified including associated challenges
2	Review the IPCC – 2003 GPG guidelines and identify activity data and emission factor requirements and associated challenges	Analysis	Analysis	Activity data and emission factor requirements are identified including associated challenges
3	Review the 2006 IPCC GL and identify activity data and emission factor requirements and associated challenges	Analysis	Analysis	Activity data and emission factor requirements are identified including associated challenges
4	Recommend through stakeholder consultation suitable methodology	Analysis and consultations with stakeholders	Analysis and consultations with stakeholders	Suitable methodology recommended for estimating GHG emissions under REDD+ mechanisms

Source: Own

1.3.2 Selection of reference emission level

The methodology used to select preferred method for determining reference level in Zambia is provided in Table 2.

Table 2: Approach, methodology, tools and outputs - reference emission level

TASK	ACTIVITIES	METHODOLOGY	TOOLS/METHOD	OUTPUTS
1	Review different methods for determining reference emission level	Analysis	Analysis	Different methods to include historical projected and/or combination of two elaborated showing strengths and weaknesses
2	Recommend and select preferred method for determining reference emission level for Zambia	Analysis and consultations with stakeholders	Analysis and consultations with stakeholders	Preferred method for determining emissions in Zambia selected and agreed upon

Source: Own

1.3.3 GHG detailed methodology: Steps for estimating GHG inventory

In Table 3 are Approach, Methodology, and Steps for estimating GHG inventory under LULUCF)

Table 3: Approach, methodology, and steps for estimating GHG inventory under LULUCF

STEPS	DESCRIPTION OF ACTIVITIES	METHODOLOGY	TOOLS/METHOD	OUTPUTS
1	Recommend all land-use categories, all carbon pool and non-CO2, gases, depending on the key source/sink category analysis	Analysis	Analysis	Land categories and subcategories, carbon pools and non-CO2 gases structure recommended
2	Review availability status of nationally adopted land-use classification system (categories and subcategories) for the inventory estimation in conformity with IPCC Land Use Categories	Analysis	Analysis	Statuses of land-use classification system determined, and if gaps exist, establish classifications in conformity with IPCC Land Use categories
3	Establish availability status of key source/sink category analysis	Analysis	Analysis	Status of key source/sink category analysis determined and if gaps exist recommend method to do further analysis
4	Recommend appropriate tier level for the key land categories and subcategories, non-CO2 gases and carbon pools based on the key category analysis	Analysis	Analysis	Appropriate tier level for the key land categories, subcategories, non-CO2 gases, and carbon pools recommended
5	Identify required activity data, depending on the tier	Analysis	Analysis	Activity data depending on tier identified, and if

	selected from regional, national and global databases			gaps exist, recommend methods for their generation and synergies with Zambia's National Forest Monitoring System
6	Identify emission/removal factors, depending on the tier selected from regional, national and global databases, forest inventories, national GHG inventory studies, field experiments and surveys, and emission factor database (EFDB)	Analysis	Analysis	Emission factors identified, and if gaps exist, recommend methods for their generation and synergies with ILUA II activities
7	Elaborate and recommend method of estimations (equations), based on the tier level selected, quantify the emissions and removals, carbon pools and non-CO2 gases.	Software	EPA software and/or 2006 IPCC software	Method of estimation selected elaborated and recommended
8	Recommend method for estimating uncertainty	Analysis	Analysis	Method for estimating uncertainty recommended
9	Recommend method for QA/QC assessment	Analysis	Analysis	Method for QA/QC assessment recommended
10	Recommend IPCC reporting methodology for GHG emissions and removals using the reporting tables	Analysis	Analysis	IPCC GHG reporting methodology for emissions reporting recommended
11	Recommended methods for documenting and archiving all information used to produce an inventory	Analysis	Analysis	Methods for documenting and archiving all information used to produce an inventory recommended

Source: Own

2.0 OUTPUT ON REVIEW OF GHG REPORTING REQUIREMENTS

2.1 Comparison of methods, activity data and emission factors

After review, the IPCC methods relevant for REDD+ activities are mainly contained in the 1996 IPCC GL for the National GHG Inventories and the IPCC – 2003 GPG for LULUCF. It should be noted the IPCC - 2003 GPG is similar to the IPCC 2006 GL as far as the land use change component is concerned, except for where the agriculture and land use components are merged.

Table 4 provides a comparison in methods for estimating GHG emissions and removals between the IPCC 1996 GL, and the IPCC- 2003 GPG for LULUCF.

Table 4: Comparison of IPCC Methodologies on methods used

IPCC- 2003 GPG	**IPCC 1996 GL**
i) Land category-based approach covering forest land, cropland, grassland, wetland, settlement and others	i) Approach based on four categories, 5A to 5D (refer to section 5 for the IPCC 1996 GL.1). All land categories not included, such as coffee, tea, coconut, etc. Lack of clarity on agroforestry
ii) These land categories are further subdivided into: Land remaining in the same use category Other land converted to this land category	ii) Forest and grassland categories defined in 5A and 5B differently
iii) Methods given for all carbon pools: AGB, BGB, DOM and soil carbon and all non-CO_2 gases	iii) Methods provided mainly for AGB and soil carbon: Assumes by default that changes in carbon stocks in DOM pools are not significant and can be assumed to be zero, i.e. inputs balance losses Similarly, BGB increment or changes are generally assumed to be zero
iv) Key source/sink category analysis provided for selecting significant: Land categories Sub-land categories C-pools CO_2 and non-CO_2 gases	iv) Key source/sink category analysis not provided
v) Three-tier structure presented for choice of methods, AD and EF	v) Three-tier structure approach presented, but its application to choice of methods, AD and EF not provided
vi) Biomass and soil carbon pools linked, particularly in Tiers 2 and 3	vi) Changes in stock of biomass and soil carbon in a given vegetation or forest type not linked

Source: CGE handbook on LULUCF, 2004

Table 5 provides a comparison of key activity data for estimating GHG emissions and removals between the IPCC 1996 GL and the IPCC - 2003 GPG.

Table 5: Comparison of key activity data

<table>
<tr><th>IPCC - 2003 GPG</th><th>IPCC 1996 GL</th></tr>
<tr><td>Forest land

i) Area of forest land remaining forest land
Disaggregation according to climatic region, vegetation type, species, management system, age, etc.
ii) Area of other land category converted to forest land
Disaggregation as mentioned above
iii) Forest area affected by disturbances
iv) Forest area undergoing transition from state (i) to (j)
v) Area of forest burnt
vi) Total afforested land derived from cropland/grassland
vii) Area of land converted to forest land through:
Natural regeneration
Establishment of plantations</td><td rowspan="2">Category 5A to 5D

i) Area of plantations/forests
ii) Area converted annually
iii) Average area converted (10-year average)
iv) Area abandoned and regenerating
20-years prior to year of inventory
20–100 years prior to the year of inventory
v) Area under different land-use/management systems and soil type
During year-t (inventory year)
20-years prior to year-t
vi) Area under managed organic soils</td></tr>
<tr><td>Cropland, grassland, wetland, etc.

Similar categorization as above and similar dataneeds</td></tr>
</table>

Source: CGE Handbook on LULUCF, 2004

Table 6 provides a comparison of emission factors for estimating GHG emissions and removals between the IPCC 1996 GL and the IPCC - 2003 GHG.

Table 6: Comparison of emission factors

IPCC – 2003 GPG	IPCC 1996 GL
Biomass expansion factor (BEF) for conversion of annual net increment (including bark) to above ground tree biomass increment	Annual biomass transfer out of deadwood
Root: shoot ratio appropriate to increment	Litter stock under different management systems
BEF for converting volumes of extracted roundwood to total AGB (including bark)	Soil organic carbon in different management systems
Annual biomass transfer into deadwood	Mass of biomass fuel present in area subjected to burning

Source: CGE Handbook on LULUCF, 2004

2.2 Reporting of GHG Inventories for LULUCF

Table 7 provides reporting table for GHG inventory for LULUCF according to the IPCC 1996 GL.

Table 7: Reporting table for GHG inventory for LULUCF according to the IPCC 1996 GL

LUCF CATEGORIES	CO2 EMISSIONS	CO2 REMOVAL/UPTAKE	CH4	N2O	CO	NOX
5A. Changes in forest and other woody biomass stocks						
5B. Forest and grassland conversion						
5C. Abandonment of croplands, pastures, plantation forests, or other managed lands						
5D. CO_2 emissions and removals from soils						
5E. Others						
TOTAL						

Source: UNFCCC's User Manual for the Guidelines on National Communication from Non-Annex 1 parties

Under this system, CO_2 emissions as well as removals are reported for all categories (5A to 5E) and trace gases are to be reported for forest land and grassland conversion subjected to open burning of biomass (5B).

Table 8 provides reporting table for GHG inventory in LULUCF according to the IPCC – 2003 GPG.

Table 8: Reporting table for GHG inventory for LULUCF according to the IPCC - 2003 GPG

GHG SOURCE AND SINK CATEGORIES FROM IPCC – 2003 GPG	IPCC 1996 GL	NET CO2 EMISSIONS / REMOVALS (1)	CH4	N2O	NOX	CO
		GIGAGRAMS (GG)				
5. TOTAL LAND-USE CATEGORIES						
5.A. FOREST LAND						
5.A.1. Forest land remaining forest land	5A					
5.A.2. Land converted to forest land	5A, 5C, 5D					
5.B. CROPLAND						
5.B.1. Cropland remaining cropland	5A, 5D					
5.B.2. Land converted to cropland	5B, 5D					
5.C. GRASSLAND						
5.C.1. Grassland remaining grassland	5A, 5D					
5.C.2. Land converted to grassland	5C, 5D					
5.D. WETLANDS (2)						
5.D.1. Wetlands remaining wetlands	5A, 5E					
5.D.2. Land converted to wetlands	5B, 5E					
5.E. SETTLEMENTS (2)						
5.E.1. Settlements remaining settlements	5A					
5.E.2. Land converted to settlements	5B, 5E					
5.F. OTHER LAND (2)						
5.F.1. Other Land remaining other land	5A					
5.F.2. Land converted to other land	5B, 5E					
5.G. OTHER (PLEASE SPECIFY) (2)						
Harvested Wood Products (2)						

Source: FCCC/CP/2003/6/Add .1

In the context of REDD+, GHG reporting is must be in line with decision 4/CP.15, requiring developing countries to use the IPCC guidance as the basis for estimating anthropogenic forest - related GHG emissions by sources and removals by sinks, forest carbon stocks, and forest area changes.

2.3 Recommendation

Adoption of the IPCC - 2003 GPG approach will lead to improved GHG inventory, reduced uncertainty, full and consistent representation of all land categories, estimation of GHG emissions/removals from all land categories (resulting from land-use as well as land-use change) and consideration of all the relevant carbon pools and non-CO2 gases (based on key source/sink category analysis).

This requires activity data and emission factors for the additional land categories, carbon pools and non-CO2 gases included. However, adoption of the IPCC – 2003 GPG approach helps use limited inventory resources more efficiently by concentrating efforts only on the identified key (or significant) land categories, carbon-pools, non-CO2 gases, and the relevant activity data and emission factors.

In view of the above advantages of the IPCC - 2003 GPG over the IPCC 1996 GL, it is recommended that Zambia use the IPCC – 2003 GPG for estimating GHG emissions and removals under LULUCF.

Since implementation of monitoring systems under REDD+ will likely demand effective measurements of emissions of forest carbon through allocation of carbon stocks related to different land use categories (forest land, cropland, grassland, settlements, wetlands and other lands), the IPCC – 2003 GPG would be the most suitable approach for estimating emissions and removals under REDD+.

For the purpose of REDD+ reporting requirements, it is recommended that the IPCC - 2003 GPG reporting tables be adopted (Table 8 from section 2.2).

3.0 OUTPUT ON RECOMMENDATIONS FOR IMPROVING ACTIVITY DATA AND EMISSION FACTOR MIGRATION TO TIER 2 AND TIER 3

3.1 Equations for estimating GHG emissions by sources and removals/sinks

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 equation:

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

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".*

The IPCC GL for estimating emissions vary between the different levels (Tiers) of methodological complexity in acquiring activity data and accessing corresponding emission factors. Usually three tiers are provided: Tier 1 is the basic method, Tier 2 intermediate and Tier 3 the most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods, and referred to as most accurate methods. Therefore, although Tier 1 offers the easiest way to calculate emissions, these calculations will also contain the highest degree of uncertainty. For Tier 1, the IPCC – 2003 GPG and the IPCC 2006 GL provide all relevant default values, assumptions and methods.

When using Tier 2, a country may combine default assumptions and methods with national data, which might lead to more realistic emission calculations, building on national measurements and monitoring activities (that is forest inventories and monitoring of deforestation).

Tier 3 is the most complex and requires detailed country specific assumptions, methods and data. The purpose of this section of the report is to review and assess availability of activity data and emission factors in the Zambian context aimed at estimating GHG emissions/removals under REDD+ strategy using higher tier activity data and emission factors. If gaps exist, recommendations are made on improvements through synergies with ILUA II and UNREDD activities. The purpose of this approach is to ensure the REDD+ strategy is effective and credible in the monitoring and accounting phase.

3.2 Recommendation

3.2.1 Activity data

Presented in Table 9 are activity data requirements, methodology/source, tier method used, actual activity data value used in the SNC, comments, recommendations to migrate to Tiers 2 and 3, and the responsible institutions who will implement the ongoing activities under UNREDD and ILUA II, so as to be able to estimate GHG emissions under the IPCC – 2003 GPG.

Table 9: Activity data for migrating to Tier 2 and Tier 3

No	Data Required	Methodology and Source	Tier	Actual Value		Comments	Recommendation for migrating to Tier 2 under IPCC - GPG 2003	Responsibility
1	Area of land remaining forest, cropland, grasslands, settlements, wetlands and other lands, and area converted to the categories above	IPCC – 2003 GPG	Tier 1 and 2 available	Not applicable		IPCC 1996 GL do not disaggregate land categories (forest land, cropland, grassland, wetlands and other lands)	Produce land cover maps for the following time series, 1990, 2000 and 2010 to establish reference emission level baseline	The ESA GHG project will produce the 2000 and 2010 land cover maps with assistance from RCMRD. Nominated experts from survey dept., NRSC and Forestry Dept. to produce 1990 land cover map with backstopping from RCMRD.
2	Annual wood removed due to deforestation/ degradation for land clearing for agriculture, infrastructure and charcoal production	IPCC 1996 GL	Tier 2 through use of satellite imagery, 2000 as the base year	Agriculture	176 kilos/hectare (Kha)	IPCC 1996 GL do not disaggregate land categories (forest land, cropland, grassland, wetlands and other lands)	That the area deforested between the time series 1990, 2000 and 2010 be distributed according to the drivers of deforestation, including agriculture, infrastructure, charcoal production, and timber harvesting	It is recommended that this analysis be a secondary activity by the Forestry Dept., done only after land use cover maps have been developed
				Infrastructure	68 Kha			
				Charcoal production	19 Kha			
				Timber harvesting	7 Kha			
				Natural causes	1 Kha			
3	Traditional fuel-wood use	IPCC 1996 GL	Tier 1 through data from DOE energy balance for year 2000	Charcoal/mining	1.401 kilotonnes (Kt)	Data based on DOE energy balance for the year 2000. Energy balance last produced in 2005, and since 2005 gaps exist.	That the Departments of Energy and Planning and Forestry reconcile the data generation of traditional fuel-wood use (including charcoal by households, industry, mining) and the agriculture development methodology for generation of data on traditional fuel – wood use (including charcoal)	Departments of Energy and Planning, and Forestry Department.
				Charcoal/industry	31.58 Kt			
				Charcoal/households	838.82 Kt			
				Firewood/mining	0.173 Kt			
				Firewood/ agriculture	275.8 Kt			
				Firewood/ industry	629.58 Kt			
				Firewood/ households	6,886.46 Kt			
4	Area under managed organic soils	IPCC 1996 GL	Tier 1. Data obtained through expert judgment	20,000 ha		Tiers 2 and 3 require country specific area under intensively managed organic soils from land use and soil maps	Studies/analysis estimate country specific area under intensively managed organic soils from land use and soil maps with higher resolution preferably (1: 250,000)	Recommend that this activity is covered under the ILUA II component focusing on soil measurement with input from ZARI and UNZA

5	Quantity of fertilizer used	Data was obtained from the Ministry of Agriculture, but it was not comprehensive enough to take account of all suppliers and end users, including use in managed forests	Tier 1	68,716 t		Study required on establishing a central archiving system for fertilizer utilization	Conduct a study to establish a central archiving system for fertilizer utilization, including for use in managed forests	ZARI and UNZA, with involvement of manufactures and end users to include the Zambia Forestry and Forest Industries Corporation
6	Area converted annually and average area converted on 10 year average	IPCC – 2003 GPG	Tier 2 through use of satellite imagery	Agriculture	1756 Kha	IPCC 1996 GL do not disaggregate land categories (forest land, cropland, grassland, wetlands and other lands	Generate average area converted on 10 year average for the purpose of determining CO2 emissions from the decay of forests, based on the land cover maps produced for the following time series, 1990, 2000 and 2010, and followed by secondary analysis	It is recommended that The Forestry Department should consider this activity only after the land-cover maps results are produced.
				Infrastructure	675 Kha			
				Charcoal production	189 Kha			
				Timber harvesting	68 Kha			
				Natural causes	1 Kha			
7	Managed area abandoned during previous 20 year period	IPCC – 2003 GPG	Tier 2 through use of satellite imagery	Agriculture	213.3 Kha	IPCC 1996 GL do not disaggregate land categories (forest land, cropland, grassland, wetlands and other lands	Generate managed area abandoned during previous 20 years period, based on land cover maps for the following time series, 1990, 2000 and 2010, and followed by secondary analysis,	The Forestry Department should consider this activity only after the land-cover maps results are produced.
				Charcoal production	454.3 Kha			
				Timber production	23.7 Kha			
				Eucalyptus	2 Kha			
				Pine	48 Kha			
				Gmelina	1 Kha			
8	Land area for savanna grassland burning	IPCC – 2003 GPG	Tier 2 through use of satellite imagery for the year 2000	Land under forest > 10% cover	1,958.122 Kha	Satellite imagery detection preferred	Analyze the estimated area of savannah burnt with higher resolution with respect to land area for grassland burning under forests, grasslands and cropland. This should be done with input from ZEMA, which is developing capacity for this purpose	The Ministry of Agriculture and the Forestry Department, UNREDD, and ZEMA
				Land under grasslands	9,161.1 Kha			
				Land under crops	4,697.6 Kha			
				Total burnt area	15,816.8 Kha			

Source: Own

3.2.2 Emission factors

Presented in Table 10 are emission factor requirements, type and methodology/source for estimating GHG emissions/removals for LULUCF using IPCC 1996 GL in the SNC, and for estimating GHG emissions for LULUCF using Tiers 2 and 3 under IPCC – 2003 GPG, and associated emission factor recommendations for achieving attainment of use of Tiers 2 and 3 emission factors, followed by recommendations on institutions involved in the ongoing ILUA II and UNREDD activities.

Table 10: Emission factors for migrating to Tier 2 and Tier 3

No	Emission factor/ removal required	Methodology and source	Type/Tier of emission factor/removal	Actual Value		Comments	Recommendation for migrating to Tiers 2 and 3 under IPCC - 2003 GPG	Responsibility
1	Annual biomass growth rate – Above ground for different forest types and plantations t/ha/yr	IPCC 1996 GL and ILUA 1	Tier 2 used in calculating GHG emissions in the SNC for LULUCF with limited control sites	Agriculture	2.1 tonnes/ hectare (t/ha)	Tiers 2 and 3 require periodic forestry inventory/ monitoring. For Zambia, country specific EF is determined under ILUA 1 on few sample plots	Improve country specific EF by increasing the sample plots to improve accuracy	The Forestry Department, through examination of biomass growth rates from increased permanent sample plot data under ILUA II (as compared to ILUA 1)
				Charcoal production	2.1 t/ha			
				Timber harvesting	2.1 t/ha			
				Infrastructure	0			
				Natural causes	2.1 t/ha			
				Pine	11.45 t/ha			
				Eucalyptus	14.5 t/ha			
				Gmelina	11.5 t/ha			
2	Annual biomass growth rate – below ground for different forest types and plantations t/ha/yr	Not applicabl e under IPCC 1996 GL	Not required under Tier 1	Not applicable		Tiers 2 and 3 require its determination but difficult to measure	IPCC – 2003 GPG recommends using ratio of BGB to a AGB for determining emission factor for below ground in relation to above ground, through both measurements and wider coverage	The Forestry Department to confirm default specific ratio of BGB to AGB for Zambia, under ILUA II and UNREDD
3	Carbon fraction of dry matter - dimensionless	IPCC 1996 GL	Tier 1 activity data was used for calculating GHG emissions in the SNC for LULUCF	Agriculture	0.47	Tiers 2 and 3 require developing emission factor using forest species – specific carbon factor obtained from laboratory estimations	Develop forest vegetation types - specific carbon fraction from laboratory estimations	The Forestry Department under ILUA II, is encouraged to improve on carbon density fraction, taking account of vegetation types since ILUA I did not cover this aspect comprehensivel y
				Infrastructure	0.47			
				Charcoal production	0.47			
				Timber harvesting	0.47			
				Natural causes	0.47			

4	BER-dimensionless	IPCC 1996 GL	Tier 1 was used to calculate GHG emissions in the SNC for LULUCF	1.3		Tiers 2 and 3 require developing country specific BER for different plantations/ forest categories	Develop country specific BER for different plantations and forest types through measurements	The Forestry Department is encouraged to synergize developing country specific BER under ILUA II and UNREDD
5	Mortality rate in naturally and artificially generating forest	IPCC 1996 GL	Tier 2 activity data was used based on measurements but coverage not comprehensive	Not applicable		Tiers 2 and 3 require measurements covering wider range of land use	Estimate mortality rate through measurements and covering a wider range of land area	Synergies with ILUA II and UNREDD
6	AGB before and after conversion – Biomass density – t/ha	IPCC 1996 GL	Tier 2 activity was used to estimate GHG under SNC but with low resolution (30 meters)	Agriculture Infrastructure Charcoal production Timber harvesting Natural causes	50 t/ha 50 t/ha 46 t/ha 46 t/ha 46 t/ha	Tiers 2 and 3 require country specific estimates of biomass stocks before and after conversion based biomass data from the forestry inventory in different land categories with higher resolution	Estimate national specific AGB for different land categories subjected to conversion using either species-specific allometric equations or Geo referenced biomass change data at finer spatial scales	The Forestry Department is encouraged to synergize ILUA II and UNREDD activities
7	Fraction of biomass burnt on-site	IPCC 1996 GL	Tier 2 activity data was used but with limited coverage of land area	Agriculture Infrastructure Charcoal production Timber harvesting Natural causes	0.85 0.85 1 0.1 0.9	Tiers 2 and 3 require country specific fraction of biomass burnt onsite and offsite from different land use categories, subjected to conversion from field measurements with wider coverage of land area	Estimate country specific fraction of biomass burnt onsite and offsite from different forest/grasslands subjected to conversion from field measurements for different sources of conversion with wider coverage of land area	The Forestry Department is encouraged to consider developing a country specific fraction of biomass burnt on site and off site under ILUA II, UNREDD, UNZA and CBU
	Fraction of biomass burnt off-site	IPCC 1996 GL	Default figure used based on Tier 1	Charcoal/mining Charcoal/industry Charcoal/households Firewood/ mining Firewood/agriculture Firewood/industry Firewood/households	0.90 0.90 0.90 0.90 0.90 0.90 0.90	Requires studies to estimate the fraction of biomass burnt off-site through experimentation	Tiers 2 and 3 require country specific fraction of biomass burnt through measurements	The Forestry Department (Forest research unit), UNZA and CBU is encouraged to conduct experiment to establish country specific emission factors
8	Fraction of biomass oxidized on-site	IPCC 1996 GL	Default figure used based on Tier 1 and expert judgment	Agriculture Infrastructure Charcoal production Timber harvesting Natural causes	0.95 0.95 0.68 0.90 0.95	Tiers 2 and 3 require estimating the fraction of biomass oxidized based on measurements/ experiments	Estimate fraction of biomass oxidized based on measurements/ experiments	The Forestry Department is encouraged to consider developing country specific fraction of biomass oxidized under ILUA II, UNZA and CBU

9	Fraction of biomass left to decay	IPCC 1996 GL	Default figure used based on Tier 1	Agriculture	0.15	Tiers 2 and 3 require estimating the fraction of biomass left to decay for different species based on measurements/ experiments	Estimate fraction of biomass left to decay for different vegetation types based on measurements/ experiments, with wider coverage of land area	The Forest department is encouraged to consider developing country specific fraction of biomass left to decay under ILUA II, UNZA and CBU
				Infrastructure	0.15			
				Charcoal production	0			
				Timber harvesting	0.9			
				Natural causes	0.1			
10	Soil carbon density in different land-use/manage ment systems and soil types t/ C/ ha	Zambia soil map and IPCC 1996 GL	Tier 2 activity data was used estimate GHG emissions under SNC from soil maps but with lower resolutions that is (1:1,000,000)	2 g/cm^3		Tiers 2 and 3 require soil carbon density from country specific sources, according to land use management and soil type based on measurements. Soil carbon data could be at disaggregated level where the land use map and soil map is over-laid to obtain sampling points	Estimate soil carbon density from country specific sources, according to land use management and soil type based on measurements with higher resolution for different land categories to include forest land, cropland, grassland, wetlands, settlements and other lands	The Forestry department under ILUA II, UNREDD with ZARI, and the Ministry of Agriculture and Livestock are currently doing soil analysis to determine soil organic carbon and mineral soils
11	Annual rate of loss of carbon from managed organic soils %	Zambia soil map and IPCC 1996 GL	Tier 2 activity data was used to estimate GHG emissions under SNC from soil maps but with lower resolutions (that is 1:1,000,000)	20 metric tonnes of carbon per hectare (Mg/C/ha)		Tiers 2 and 3 require country specific carbon loss rate according to major organic loss rate types and management systems based on measurements	Estimate country specific carbon loss rate according to major organic soil types and management systems based on measurements and consolidate description of wetlands to account for land use	The Forestry department is encouraged to identify synergies with ILUA II, UNREDD and ZARI and the Ministry of Agriculture and Livestock
12	Base factor, Tillage factor, input factor	IPCC 1996 GL	Tier 1 emission factor was used to estimate GHG emissions under SNC	0.001 Mg/C/ha		Tiers 2 and 3 recommend field measurements of soil organic density of agriculturally impacted soils	Estimate Base factor, Tillage factor, input factor in relation to soil organic density of agriculturally impacted soils	The Forestry department is encouraged to consider developing Base factor, Tillage factor, input factor in relation to soil organic density of agriculturally impacted soils under ILUA II and UNREDD, UNZA, CBU, and the Ministry of Agriculture and Livestock

Source: Own

4.0 OUTPUT ON DETAILED METHODOLOGY FOR GHG REPORTING

4.1 General steps for preparation of GHG inventory report

This section of the report reviews the status of the general steps required for detailed methodology for GHG reporting for LULUCF. It also reviews recommendations for complete preparation of GHG inventory report using the IPCC – 2003 GPG. Given in table 11 are the required general steps,

Table 11: General steps for preparation of GHG inventory report using the IPCC - 2003 GPG

1	Presentation of IPCC – 2003 GPG land use categories and subcategories
2	Selection of appropriate land classification system relevant to Zambia
3	Establishment of performance status of key source/sink category analysis
4	Recommendation of appropriate Tier level for the key land categories and subcategories, non-CO_2 gases and carbon pools based on the key category analysis
5	Identification of required activity data and emission factors, depending on the Tier selected from regional, national and global databases
6	Elaboration of estimation method (equations), based on the Tier level selected, quantifying the emissions and removals, carbon pools and non-CO_2 gases
7	Recommendation of a method for estimating uncertainty, QA/QC assessments, and documenting and archiving all information used to produce an inventory
8	Recommendation of IPCC reporting methodology for GHG emissions and removals using the reporting tables

4.2 Presentation of the IPCC – 2003 GPG land-use categories

The IPCC – 2003 GPG adopted six land categories to ensure consistent and complete representation of land, covering all the geographic area of a country. The land-use categories and subcategories, and the relevant gases and C-pools used in the IPCC – 2003 GPG are given in Table 12:

CO_2 emissions and removal are estimated for all C-pools, namely:

- *AGB, BGB, soil carbon, DOM and woody litter*

Non-CO_2 gases estimated include:

- *CH4, N2O, CO and NOX*

Table 12: Land categories and subcategories, carbon pools and non- CO2 gases

Main land categories	Subcategories (based on transformation)	Disaggregated level	C-pools	Non-CO_2 gases
Forest land	Forest land remaining forest land	- Evergreen, deciduous etc.	AGB, BGB, DOM, litter and soil carbon	CH_4, N_2O
	Land converted to forest land	- Eucalyptus, secondary forest		
Cropland	Cropland remaining cropland	- Irrigated, unirrigated		
	Land converted to cropland	- Paddy, irrigated, rain-fed - Coconut, coffee, tea, etc.		
Grassland	Grassland remaining grassland	- Climatic regions		
	Land converted to grassland			
Wetland	Wetland remaining wetland	- Peat land		
	Land converted to wetland	- Flooded land		
Settlements	Settlement remaining settlement			
	Land converted to settlements			

Sources of non-CO_2 gases: N_2O and CH_4 from forest fire, N_2O from managed (fertilized) forests, N_2O from drainage of forest soils, N_2O and CH_4 from managed wetland, and soil emissions of N_2O following land-use conversion.

4.3 Status and recommendation: Selection of land classification system relevant to Zambia

Status

The IPCC – 2003 GPG provides general non-prescriptive definitions for the six main land use categories: Forest land, Cropland, Grassland, Wetlands, Settlements and Other Land. To reflect national circumstances, Zambia as part of the ESA GHG with support from the RCMRD, adopted specific definitions, based predominantly on criteria used in the land use land cover mapping and/or surveys in the country. Provided in Table 13 are the land categories and subcategories, carbon pools and non-CO2 gases and associated disaggregated levels, taking account of Zambia's circumstances.

Table 13: Land categories and subcategories, carbon pools and non-CO2 gases and associated disaggregated levels

MAIN LAND CATEGORIES	SUBCATEGORIES (BASED ON TRANSFORMATION)	DISAGGREGATED LEVEL	C-POOLS	NON-CO_2 GASES
FOREST LAND	Forest land remaining forest land Land converted to forest land	Natural forest Dry Deciduous forests Dry Evergreen forests Moist Evergreen forests Woodlands Plantations Broadleaved forest plantations Coniferous forest plantations	AGB, BGB, DOM, litter and soil carbon	CH_4, N_2O
CROPLAND	Cropland remaining cropland Land converted to cropland	Annual crops (Maize, Cotton, Groundnuts, wheat, tobacco) Perennial crops (Sugarcane, Jatropha, coffee, Banana, tea, palm oil, citrus)		
GRASSLAND	Grassland remaining grassland Land converted to grassland	Wooded grasslands (Shrubland/scrub) Grasslands (Open and closed grasslands)		
WETLAND	Wetland remaining wetland Land converted to wetland	Dambos Marshlands/Swamps Pans		
SETTLEMENTS	Settlement remaining settlement	Built-up areas Other populated areas/schools and facilities Villages Open pit mine areas Landing facilities		
	Land converted to settlements			

Source: The Forestry Department

Based on Zambia's classification and associated disaggregated levels, land cover maps for the years 2000 and 2010 are being developed from Landsat satellite imagery in conjunction with RCMRD and the National Forest Monitoring System (NFMS), and including the following institutions: the Survey department, the National Remote Sensing Centre and the Forestry Department.

Recommendation

To enable Zambia to develop historical time series land cover maps, from which reference emission levels will be developed, requires land cover maps for the year 1990, which is being undertaken by Forestry Department. It is recommended that capacity which has been developed while working with RCMRD now be used to develop land cover maps for 1995 and 2005.

4.4 Status and recommendation: Establish performance status of key source/sink category analysis

The IPCC – 2003 GPG defined a key source/sink category as "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of absolute level of emissions (removals), the trends in emissions (or removals), or both."

In this section, the term 'key category' is used to represent both the sources and sinks. Key category analysis helps a country achieve the highest possible levels of certainty while making efficient use of the limited resources for the inventory process. Deciding which tier to use and where to allocate resources for inventory improvement should take into account the key category analysis. Key category analysis is required to identify the following:

i. Which land-use categories are critical
ii. Which land subcategory is significant
iii. Which carbon pools are significant
iv. Which non non-CO_2 gases are significant

A land use system, a carbon pool, or a non-CO_2 gas is significant if its contribution to the GHG emissions/removals accounts for between either 25% or 30% of overall national inventory, or LUCF sector inventory. The key source/sink category analysis given in the IPCC – 2003 GPG (which is land use category based) is not directly applicable to the categories used (5A to 5D) in the IPCC 1996 GL.

The key category analysis should be performed at the level of IPCC source or sink category (i.e. the level at which the IPCC methods are described). The analysis should be performed using CO_2-equivalent emissions calculated using global warming potentials.

The *key source category* evaluation should be performed for each of the gases separately because the methods, emission factors and related uncertainties differ for each gas. For each *key source category*, the inventory agency should determine if certain sub-source categories are particularly significant (i.e. represent a significant share of the emissions). In the case of CO_2 emissions/removals, a certain land category (say, land converted to forest land) and further a certain carbon pool (e.g., AGB) may contribute to a dominant share of net CO_2 emissions/removals.

Status

Zambia has undertaken a preliminary key source/sink category analysis using data from the SNC GHG inventory using the IPCC 1996 GL.

Recommendation

Since the IPCC – 2003 GPG is being used to estimate GHG emissions/levels for land use and land use change for the purpose of estimating GHG emissions under REDD+, it is recommended that key source/sink category analysis be performed using data of the GHG inventory being developed as part of the ESA GHG project.

4.5 Status and recommendation: Appropriate key land category and subcategory tier levels,

The IPCC – 2003 GPG requires that the methodological choice (Tiers 2 and 3) activity data and emission factors use GHG emission/removals estimation for LULUCF, to reduce uncertainties in the estimation.

Status

The GHG inventory from the SNC used the IPCC 1996 GL to estimate GHG emissions/removals, using a combination of Tier 1 and Tier 2 activity data and emission factor, with the latter coming from ILUA I results. However, in some cases, derivation of activity data and emission factor was not comprehensive enough.

Recommendations

For estimating GHG emissions for LULUCF for REDD+, it is recommended that Tier 2 and Tier 3 activity data and emission factors be developed as indicated in Tables 9 and 10, in conjunction with ILUA II activities under REDD+.

4.6 Status and recommendation: Identification of required activity data and emission factors

Status/recommendation

Activity data and emission factors required for estimation of GHG emissions/removals for LULUCF under REDD+ using the IPCC – 2003 GPG have already been identified in section 3.2, and it is recommended that they be derived as part of ILUA II and NFMS activities.

4.7 Elaboration of estimation methods (equations)

4.7.1 Detailed equations for estimating GHG emissions by source and removals

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".

Emissions and removals from land use change

Plant biomass constitutes a significant carbon stock in many ecosystems. Biomass is present in both aboveground and belowground 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 either annually or every few years, and is therefore negligible.

Thus, the emission and removal 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. The status of carbon pools is summarized below, and currently 5 carbon pools have to be reported under the UNFCCC.

Above ground
Below ground } **Biomass**

Dead wood
Litter } **DOM**

Soil Organic Matter (SOM) } **Mineral Soils** / **Organic Soils**

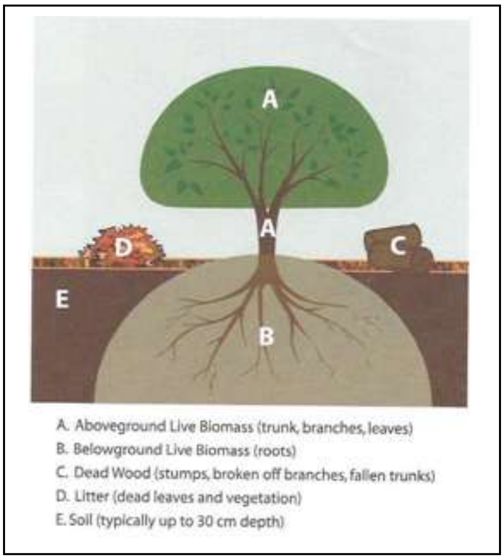

Figure 1: Five Carbon Pools

Either CO_2 emissions and removals or the carbon stock change are typically the dominant sources of GHG in the LULUCF sector. Carbon stock change is the sum of changes in stocks of all the carbon pools in a given area over a period of time, which could be averaged to annual stock changes. Annual carbon stock change for a land use category is the sum of changes in all carbon pools, and a generic equation for estimating the changes in carbon stock for a given land use category is given below:

$$\Delta C_{LUi} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SC}$$

Where:

$\Delta C_{LUi\ is}$ carbon stock change for a land-use category, AB = aboveground biomass, BB = below ground biomass, DW= deadwood, LI= litter and SC = soil carbon

The equation requires the stock change to be estimated for each of the pools. The changes in the carbon pool could be estimated using the two IPCC guideline-based approaches (IPCC 2003 and IPCC 2006)

Carbon 'Gain – Loss': Annual carbon stock change in a given pool is a function of gains and losses ('Gain – Loss' Method):

$$\Delta C = \Delta C_G + \Delta C_L$$

Where:

ΔC is annual carbon stock change in the pool, ΔC_G is the annual gain of carbon and ΔC_L is the annual loss of carbon.

Carbon 'Stock – Change' or 'Stock – Difference': Carbon stock change in a pool is the annual average difference between estimates at two points in time (the Stock – Difference method):

$$\Delta C = (C2 - C1) / (t2 - t1)$$

Where:

ΔC is the annual carbon stock change in the pool, C1 = carbon stock in the pool at time t1, in tonnes C, C2 = carbon stock in the pool at time t2, in tonnes C, C_{t1} the carbon stock in the pool at time t_1 and C_{t2} the carbon stock in the same pool at time $t_{2..}$

For Zambia, under the ILUA II / UNREDD+ process of activity data collection, four out of the five carbon pools are being considered: AGB, DOM, litter and soil carbon. The fifth carbon pool, BGB (roots), is not being considered due to difficulties associated with measurements.

It is recommended that Zambia's GHG inventory of the LULUCF sector under the REDD+ strategy adopt the Stock – Difference method to estimate C stock changes. The rationale for this is that Zambia has established a NFMS and undertaken two National Forest Inventories (ILUA I and II). Also, there is an on-going capacity building programme (ESA GHG) to undertake a GHG inventory in LULUCF using the Agriculture and Land Use software, which is compatible with both methodologies.

The detailed methodology for estimating C stock changes using the Stock – Difference method is in appendix 1.

4.7.2 Proposed methodology for generating activity data and emission factors for GHG inventory

Generally, there are two main methodological approaches that need to be followed by the Forestry Department in Zambia to generate the required activity data for GHG inventory. It is known very well that GHG inventory is a function of reliable forest inventory data (tree, litter, grass, crop residue and soil biomass) combined with spatial data (land use and land cover data) assigned and multiplied by the emission factors.

In a similar manner, setting the reference emission level (REL) for the country requires that accurate historical deforestation rates are determined; and that some modeling approach projects or indicates the expected deforestation rates in future consistently.

For instance, below is a record of the carbon pool activity data that needs to be collected:

CARBON POOLS		METHOD USED FOR CARBON STOCK ESTIMATION
BIOMASS	Above ground	Methods applied as described in Table 3 of chapter 4.1.6 in this report. Estimates should be done for all land use categories, however, estimates correspond to the IPCC 2006 GL Tier level 2 or 3. The Carbon fraction of biomass is equal to 0.47.
	Below ground	Using look-up tables and correlations with above biomass applied as provided in the IPCC 2006 GL for Tier level 1 estimations. BGB/AGB fraction = 0.28 for tropical dry forest with AGB > 20tonnes/ha. Calculated for all land use categories carbon fraction of biomass equal to 0.47.
DOM	Dead wood	Estimated in similar manner as for AGB, and is calculated for all land use categories. The Carbon fraction for dead wood estimates is assumed to be equal to that of living biomass (0.47). However, studies suggest a carbon fraction of deadwood to be closer to 0.34 (Pearson & Brown 2005).
	Litter (grasses, twigs, leaves, debris)	Using look-up tables as provided in the IPCC 2006 guidelines for Tier level 1 estimates. Evergreen = 5.2 tons carbon/ha, deciduous and other natural forest = 2.1 tons of carbon/ha. For semi-evergreen forest (miombo), the Frost (1996) litter estimate has been applied (5.48 tons of biomass/ha) converted to carbon using 0.47 as carbon fraction. Carbon in the litter pool has only been calculated for forest land use categories.
SOIL CARBON	Soil profile	Using IPCC look-up tables for Tier level 1 estimations. All areas are assumed to contain mineral soils (31 tons of carbon/ha). Soil carbon has only been calculated for the land use categories of forest and other wooded land where it is assumed (following the Tier 1 approach) that no change in soil carbon occurs with change of management.

Source: NFMA Plan for Zambia

The information on the carbon pools indicates the contribution of forest and other land to the carbon cycle. International processes that monitor greenhouse gases and climate change use this information, and in Zambia the following steps are used to collect this data:

Step 1: Stratify & Multiply (SM) - This step requires that comprehensive national forestry inventory (NFI) data (which includes tree and soil data) is collected from permanent sample plots where the growing stock, biomass stock and carbon stock can be calculated. The field data becomes the training dataset used for extrapolation over the entire area of interest. The ILUA II project has designed an NFI framework collecting this data country-wide. This approach defines the measurement, reporting and verification (MRV) method that has since been adopted by all the districts in Zambia.

Step 2: Combine & Assign (CA) - This step is an extension of SM above. However, land use and land cover maps are generated from remote sensing platforms so that the values of the biomass stocks generated in the SM approach can be calculated by assigning the estimates per hectare according to land cover classes. Therefore, the land cover changes for a bare minimum of three time slices is computed to account for historical deforestation, and account for possible committed emissions from land use and land cover loss. The Forestry Department through the UNREDD project has since provided the GIS facilities to enhance this process in all the provinces of Zambia.

Figure 2 below explains the two steps above in detail.

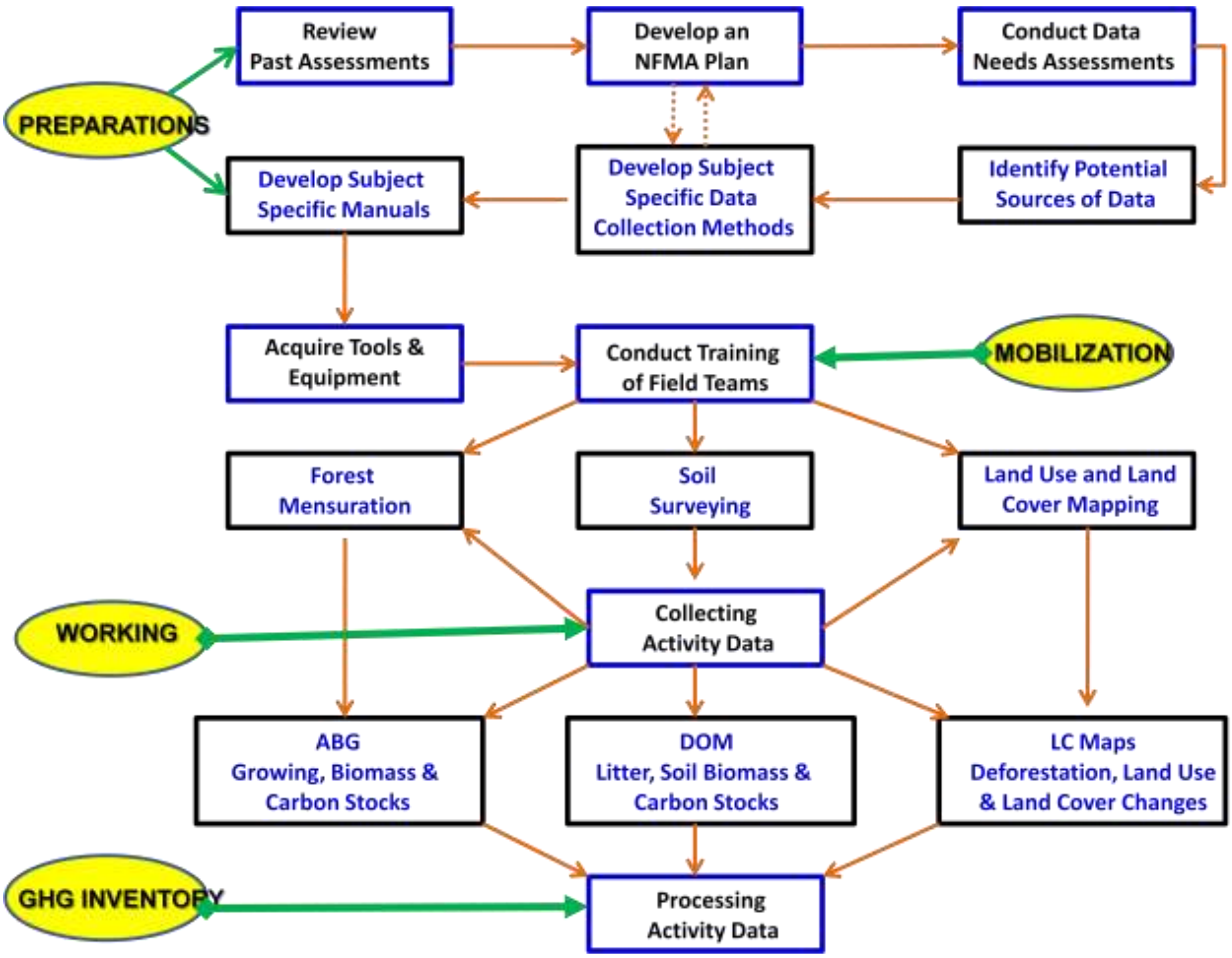

Figure 2: Stratify and Multiply / Combine and Assign Approaches

Status and recommendations

The calculation of GHG emissions requires using equations elaborated in section 4.7 with inputs of activity data and emission factors from the various land categories and subcategories.

Since estimation of GHG emissions/removals require complex computations, UNFCCC and other organizations have developed tools such as the UNFCCC software based on the IPCC 2006 GL, and the Agriculture and Land Use software (ALU) developed by University of Colorado, USA in conjunction with the United States Environmental Protection Agency (US EPA).

As part of the ESA GHG project, capacity is being developed for the preparation of activity data and emission factors, which will serve as input data into the ALU software. Additionally, the Centre for Energy, Environment and Engineering in Zambia is working closely with the IPCC Task Force for GHG inventories in Japan to develop capacity using the UNFCCC software. It is recommended that Zambia takes advantage of these tools for estimating GHG emissions under REDD+.

4.8 Status and recommendation: Method for estimating GHG inventory uncertainty, QA/QC assessment and archive system development

Uncertainty assessment

The good practice approach for inventories requires accurate estimates of GHG inventories, and that uncertainties are reduced. The causes of uncertainty could include: unidentified sources and sinks, lack of data, quality of data, lack of transparency, etc.

Uncertainty analysis involves:

i. Identifying the types of uncertainties (measurement error, lack of data, sampling error, missing data, model limitations, etc.)
ii. Identifying methods for reducing uncertainties (improving representativeness, using precise measurement methods, correct statistical sampling method, etc.)
iii. Quantifying uncertainties (sources of data and information, techniques for quantifying uncertainty), and
iv. Identifying methods to combine uncertainties (simple propagation of errors and Monte Carlo analysis)

The estimates of carbon stock changes, emissions and removals arising from LUCF activities have uncertainties associated with:

i. Area and other activity data,
ii. Biomass growth rates,
iii. Expansion factors, biomass loss or consumption, and
iv. Soil carbon density, etc.

The IPCC – 2003 GPG describes two methods for the estimation of combined uncertainties: Tier 1 (simple propagation of errors) and Tier 2 Monte Carlo analysis. Use of either provides insight into how individual categories and GHGs contribute to uncertainty in total emissions in a given year. It is important to note that Tier 1 and Tier 2 methods of assessment of uncertainty are different from the Tiers' methods for inventory estimation, which are mutually compatible (where the Tier 1 uncertainty assessment could be used by parties adopting any of the three Tiers or methods of inventory estimation).

Tier 1 uncertainty assessment methods

The uncertainty associated with Tier 1 methods is generally high, as the suitability of the available default parameters to a country's circumstances is not known. The application of default data in a country or region that has different characteristics from those of the source of the data can lead to large systematic errors. Ranges of uncertainty estimates for the emission factors are given in Chapter 3 of the IPCC – 2003 GPG. A few examples include:

i. Average annual biomass growth rate: about 50% uncertainty
ii. Commercial fellings: uncertainty <30%, and
iii. Activity data on area: uncertainty 1%–15% (in European countries), uncertainty of remote sensing methods 10%–15%.

Tier 1 is spreadsheet-based and easy to apply. Thus, all countries can undertake uncertainty analysis according to Tier 1 of uncertainty estimation, irrespective of which method or Tier is used in the inventory process.

Tier 2 uncertainty assessment methods – Estimating Uncertainties by Category Using Monte Carlo Analysis

The Monte Carlo analysis is suitable for detailed category-by-category Tier 2 assessment of uncertainty. In this method, country-specific data is used. These data are often only broadly defined, presumably with very little stratification according to climate/management/soil/land use. It is possible to assess the uncertainties involved due to the national circumstances, based on a few national-level studies or direct measurements, and statistical packages are readily available for adopting the Monte Carlo algorithm.

Quality assurance and quality control

The IPCC – 2000 GPG and IPCC – 2003 GPG provide definitions and guidelines for QA and QC, keeping in mind the need to enhance the transparency and accuracy GHG inventory estimates.

QC is a system of routine technical activities to measure and control the quality of the inventory as it is being developed, and is designed to:

i. Provide routine and consistent checks to ensure data integrity, correctness and completeness,
ii. Identify and address errors and omissions, and
iii. Document and archive inventory material and record all QC activities.

QA is a planned system of review procedures, conducted by personnel not directly involved in the inventory compilation/development process.

Tier 1 - General QC procedures

It is good practice to implement the generic Tier 1 QC checks as outlined in Table 5.5.1 of the IPCC – 2003 GPG. The general methods focus on the processing, handling, documenting, archiving and reporting procedures. A few examples of QC activity and procedure involves the following:

i. Check the integrity of database files,
ii. Confirm the appropriate data processing steps are correctly represented in the database,
iii. Confirm the data relationships are correctly represented in the database,
iv. Ensure data fields are properly labeled and have the correct design specifications, and

v. Ensure adequate documentation of database and model structure

Tier 2 - Source/sink category-specific QC procedures

Tier 2 relates to source/sink category-specific procedures for key categories, whereas Tier 1 QC checks relate to data processing, handling and reporting. Tier 2 QC procedures are directed at specific types of data used in the methods and require knowledge of:

i. Source/sink category,
ii. Type of data available, and
iii. Parameters associated with emissions/removals.

Tier 2 QC procedures should focus on the following types of checks (these are only examples, refer to Chapter 5 of the IPCC – 2003 GPG for details):

Check that land areas are properly classified and no double counting or omission of land area has occurred,

i. Ensure completeness of source/sink categories,
ii. Check consistency of time series activity data, and
iii. Check sampling and extrapolation protocols adopted.

Tier 1 and Tier 2 QA review procedures

This requires an expert review to assess the quality of the inventory and to identify areas where improvements are necessary.

Tier 1 QA procedure involves basic expert peer review by inventory agencies, applying the review process to all source/sink categories, particularly the key categories.

Tier 2 QA procedure also involves expert peer review, including:

i. Review of calculations or assumptions,
ii. Identify if the major models used have undergone peer review, and
iii. Assess documentation of models, input data and other assumptions.

Archiving system

A critical component of the inventory development process is the appropriate and systematic archiving and compiling of all documents. The Archive System is important for sustaining the National Inventory System, because the national inventory must be transparent and easy to use. The Archive System is the foundation for development of subsequent inventories by future inventory staff or source leads (i.e. individuals responsible for developing estimates within a particular sector such as energy or waste).

All information used to create the inventory should be archived in a single location through electronic and/or paper storage. Any new inventory manager should be able to reference any relevant files to respond to public and/or expert inquiry, and to answer questions about methodologies. Furthermore, each new year the inventory will benefit from effective data and document management from the previous year.

Archived information should include all disaggregated emission factors, activity data, and documentation of how these factors and data have been generated and aggregated for the preparation of the inventory. This should also include internal documentation on QA/QC procedures, external and internal reviews, documentation of annual key sources and key source identification, and planned inventory improvements.

If possible a copy of all archive documents should be kept in another location to reduce the risk of losing all records due to theft or disaster (e.g., fire, earthquake, or flooding).

Status and recommendations

Uncertainty and QA/QC assessments were not performed during preparation of the GHG inventory in the SNC. These two issues are under consideration as part of ESA GHG project; however their implementation requires formulation of a national institutional arrangement.

In the institutional arrangement, 'lead institution' implies that the agency has the overall responsibility for the inventory covering such activities as:

i. Coordination/compilation of national inventory,
ii. Documentation of selection process for national activity data, emission factors, and other conversion factors,
iii. Documentation of methods and assumptions used,
iv. Validation of conversion units and other data,
v. Verification of inventory estimates, Management of the inventory database and archiving of relevant national data,
vi. Periodic updating of the inventory, and
vii. Reporting to international bodies.

Institutional arrangements will be built upon the actions of the UN REDD national strategy.

The ESA GHG project, together with the Low Emission Capacity Development project under the Ministry of Lands, Natural Resources and Environmental Protection, have proposed an institutional arrangement for sustainable management of GHG inventories, and one that provides for a central archiving function. This institutional framework can be of relevance to the REDD+ activities concerning GHG estimation under forest lands, once formalized and implemented.

4.9 Recommendation of IPCC reporting methodology for GHG emissions and removals

The IPCC – 2003 GPG requires that GHG emissions/removals reporting be done using standard IPCC/ UNFCCC reporting tables elaborated in section 4.6. Accordingly it is recommended that GHG reporting for Zambia use these standard tables.

5.0 OUTPUT ON RECOMMENDATION OF REFERENCE EMISSION LEVEL ESTIMATION

5.1 Reference emission level characteristics

For emission reductions to be effective in combating climate change, and for countries to benefit from incentive based payments, they must be real, quantifiable and reliable. A reference emissions level (RL) is therefore key to the success of emission reductions within a REDD+ mechanism.

However, an agreement as a country is needed as to whether this should be a historical, current, or projected baseline, and how it should be measured. An RL describes the amount of GHG emissions expected from deforestation and degradation for a hypothetical 'Business as Usual scenario', without REDD+ activities.

This RL can then be compared with the real reductions in GHG in the commitment period. The difference between the two will determine the emission reductions performance of REDD+. The setting of the RL crucially influences the amount of financial benefits gained from a REDD+ mechanism.

This section of the report will assess and analyze an RL either based on historical trends with extrapolation into future projections, or based on modeling, or a mixture of both. This section will also make recommendations on a suitable approach for use under REDD+ strategy in Zambia.

Historical RLs use information on changes in forest cover from a past reference period (e.g. from satellite and/or inventory data). While Annex 1 countries use a base year against which to measure their GHG emission reductions, the high annual fluctuations of deforestation rates require the use of a longer reference period for REDD+. From this data, linear trends of deforestation emissions are extrapolated for a future commitment period. While such an RL technique is comparatively easy to implement, it has several shortcomings. The most crucial aspects are potential over-estimation or under-estimation of real emissions in the commitment period due to often non-linear behavior of deforestation drivers. (Kerr et al 1999; Rudel et al 2005)

Because of the potential environmental and financial inefficiency historical RLs incur, and their inability to account for non-linear forest area change and specific country circumstances, some scholars advocate the use of modeling to determine RLs. Models of deforestation trends primarily use general equilibrium approaches, agent-based modeling, spatially-explicit land use models, simple regressions, or a mixture of these methods. In all cases, such models are based on land use driver projections, often in combination with historic deforestation trend data. Although model-based RLs can help avoid the risks associated with purely historical RLs, they are also open to abuse if artificial driver assumptions are made in the model, thus inflating the reference emission projections. It is therefore important to use conservative and transparent RLs to avoid most of these misconceptions (Papua New Guinea, 2009)

5.2 Status and recommendations

Zambia has not yet defined which approach to use for developing the RL and projections. However, work being undertaken through the National Forest Monitoring System can be used as input in developing the RL to estimate historical emissions, and will require land use change for at least three time points. This work is also being done in conjunction with the ESA GHG project through the RCMRD, which is developing land-cover maps for 1990, 2000 and 2010.

To achieve this will require using land cover maps for 1990 as a base year for 2000 and 2010. From this analysis, land use change will be determined between 1990 to 2000 (as the first point), and 2000 to 2010 (as the second point).

At each point GHG emissions will be determined using the Stock – Difference method under the IPCC 2003 GPG. Calculations for estimating CO_2 emissions will be based on carbon stock change in living biomass, net carbon change in dead organic matter, and net carbon change in soils. Direct N_2O emissions from fertilization if any will be estimated from the amount of fertilizer applied and corresponding emission factor. N_2O from drainage of soils if any will be estimated on area of drained soils and corresponding emission factor. N_2O emissions from disturbances associated with land use conversion to cropland will be estimated based on land area converted and corresponding emission factor. Further CH_4 emissions from biomass burning under forests will be estimated as carbon released with the corresponding emission factor.

GHG net emissions need to take account of uptake through natural forest re-growth after forest clearing, or abandonment of managed cultivated lands and reforestation plantations. In this case carbon uptake will be estimated based on annual biomass increment and corresponding emission factor.

It should be emphasized that to establish a historical reference scenario, there is need to develop land cover maps for 1990, 1995, 2000, 2005 and 2010. This is to enable us to have sufficient points to construct historical trends for emissions and make projections into the future initially through extrapolation and later through modeling based on research. It would be preferable to have land cover mapping for interim years (1995 and 2005) to elaborate more on land cover change trends, but this aspect is not in the current scope of the work and will need to be developed at a later stage.

6.0 CONCLUSIONS

This assignment has met the four required deliverables on

i. Review of GHG reporting requirements for LULUCF including forest lands under IPCC,
ii. Recommendations on improving activity data and emission factor migration to Tier 2 and Tier 3 under IPCC – 2003 GPG,
iii. Elaboration of detailed methodology for GHG reporting for forest lands, and
iv. Recommendation of reference emission level estimation.

For the purpose of REDD+, it is recommended that the IPCC - 2003 Good Practice Guidance be adopted for estimating GHG emissions/removals under REDD+ strategy and the need for activity data and emission factors migrating to Tiers 2 and 3. For the comparison of reporting requirements, it is recommended that UNFCCC reporting applied to Annex 1 Parties be adopted for the purpose of reporting under REDD+.

Responsible institutions have also been identified to generate activity data and emission factors through ongoing country activities under ILUA II and UNREDD. Land use change related activity data was to be developed under the ESA GHG project which is in the process of producing the 1990, 2000 and 2010 land cover maps with assistance from RCMRD in conjunction with experts from Survey Department, NRSC and the Forestry Department.

As regards traditional fuel-wood use, a recommendation was made to enable the Department of Energy and Department of Forestry to develop a methodology on data generation of traditional fuel-wood use including charcoal by households, industry, mining and agriculture. Similarly, emission factors are to be generated through the ILUA II project and UNREDD activities process and complemented by research through ZARI, CBU and UNZA.

To conform to IPCC land classification, as part of the ESA GHG project / RCMRD arrangement, Zambia's main categories and sub categories have been defined as: Forest land (natural forests (defined by density) and plantations), cropland (annual crops and perennial crops), grasslands (wooded grasslands and open/closed grasslands), wetlands (dambos, pans and marshes) and settlements (built up areas).

It is recommended that key source/sink category analysis be performed using data from the GHG inventory being developed as part of the ESA GHG project. For estimating GHG emissions for LULUCF for REDD+, it is recommended that Tiers 2 and 3 activity data and emission factors be generated in conjunction with ILUA II under REDD+.

Activity data and emission factors have been identified and it is recommended that they be derived as part of ILUA II and UNREDD activities. These are required for GHG emissions/removal estimation for LULUCF under REDD+ using the IPCC – 2003 GPG, and are customized to Zambia's national circumstances.

To address issues related to uncertainty, QA/QC assessments as well as documentation and archiving, require formalizing an institutional framework to take account of the assessments and to create a central archive. This would preferably be located in the lead institution, in addition to a GHG inventory facility.

Estimating historical emissions will require land use change for three time points. To achieve this will require developing land cover maps for 1990 as a base year, 2000 and 2010. From this analysis, land use change will be determined. It would be preferable to have land cover mapping for interim years (1995 and 2005) to elaborate more on land cover change trends, but this aspect is not in the current scope of the work and will need to be developed at a later stage.

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8.0 APPENDIX I: DETAILED METHODOLOGY FOR ESTIMATING CARBON STOCK CHANGES BASED ON THE IPCC – 2003 GOOD PRACTICE GUIDANCE

Estimating C stock changes using the Stock-Difference Method

The Stock-Difference Method can be used where carbon stocks in relevant pools are measured at two points in time to assess carbon stock changes.

$$\Delta C = (C2 - C1) / (t2 - t1)$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr-1

C1 = carbon stock in the pool at time t1, tonnes C

C2 = carbon stock in the pool at time t2, tonnes C

t1 = the carbon stock in the pool at time t1

t2 = the carbon stock in the same pool at time t2

Non-CO2 emissions

The Non-CO2 emissions rate is generally determined by an emission factor for a specific gas (e.g., CH4, N2O) and source category and an area (e.g., for soil or area burnt) that defines the emission.

$$\textbf{Emission} = \textbf{A} \bullet \textbf{EF}$$

Where:

Emission = non-CO2 emissions, tonnes of the non-CO2 gas

A = activity data relating to the emission source (can be area, or mass unit, depending on the source type)

EF = emission factor for a specific gas and source category, tonnes per unit of a source

Biomass: Land remaining in a land-use category

Carbon stock change in biomass in forest land is likely to be an important sub-category due to substantial fluxes arising from management and harvest, natural disturbances, natural mortality and forest regrowth. Changes in C stocks in the biomass pool can be estimated using either the Stock-Change or the Gain-Loss method.

The Gain-Loss Method requires the biomass carbon loss to be subtracted from the biomass carbon gain. This method is the basis of the Tier 1 method, where default values for the calculation of increment and losses are provided in the IPCC Guidelines.

Stock-Change Method

$$\textbf{C= Σ i jCAi j Vi j BCEFS Ri j CFi j)}$$

Where:

C = total carbon in biomass for time t1 to t2 [*i* = ecological zone i (*i* = 1 to *n*)

j = climate domain j (*j* = 1 to *m)*]

A = area of land remaining in the same land-use category, ha (see note below)

V = merchantable growing stock volume, m3 ha-1

R = ratio of BGB to AGB, tonne d.m. (BGB (tonne d.m. AGB)-1

CF = carbon fraction of dry matter, tonnes C (tonnes d.m.)-1

BCEFS = biomass conversion and expansion factor

Initial change in biomass carbon stocks in, and converted to, other land-use category

$$\Delta CCONVERSION = \Sigma i(BAFTER - BBEFORE) \bullet \Delta ATO\ OTHERS\ i \bullet CF$$

Where:

ΔCCONVERSION = initial change in biomass carbon stocks on land converted to another land category, tonnes C yr-1

BAFTER*i* = biomass stocks on land type *i* immediately after conversion, t d.m.ha-1

BEFORE*i* = biomass stocks on land type *i* before conversion, t d.m. ha-1

ΔATO_OTHERS*i* = area of land use *i* converted to another land-use category in a certain year, ha yr-1

CF = carbon fraction of dry matter, tonne C (t d.m.)-1

i = type of land use converted to another land-use category

Change in C stocks in DOM: land remaining in the same land-use category

The Tier 1 assumption for both dead wood and litter pools for all land-use categories is their stocks do not change over time if the land remains within the same land-use category. Tier 2 methods for estimation of carbon stock changes in DOM pools calculate the changes in dead wood and litter carbon pools by either *the Gain-Loss Method or the Stock-Difference Method* (*GPG LULUCF* provides guidance on DOM only for FL). These estimates require either detailed inventories that include repeated measurements of dead wood and litter pools, or models that simulate dead wood and litter dynamics.

The Stock-Difference Method

$$\Delta CDOM = [A \bullet (DOMt2 - DOMt1)/T] \bullet CF$$

Where:

ΔCDOM =

A = area of managed land, ha

DOMt1 = DW/litter stocks at time t1 for managed land, t d.m/ha

DOMt2 = DW/litter stocks at time t2 for managed land, t d.m/ha

T= (t2-t1) = time period between the two estimates of DOM, yrs.

CF = carbon fraction of dry matter, t C/ (t d.m.)

Change in C stocks in DOM: land converted to other land-use categories

The Tier 1 assumption is that DOM pools in non-forest land categories after the conversion are zero, i.e., they contain no carbon. The Tier 1 assumption for land converted from forest to another land-use category is that all DOM carbon losses occur in the year of land-use conversion.

For land converted to forest land litter and dead wood, carbon pools start from zero in those pools. DOM carbon gains on land converted to forest occur linearly, starting from zero, over a transition period (the default assumption is 20 years).

Changes in soil C stocks

$$\Delta CSoils = \Delta CMineral - LOrganic + \Delta CInorganic$$

Where:

ΔCSoils = annual change in carbon stocks in soils, t C yr-1

ΔCMineral = annual change in organic carbon stocks in mineral soils, t C yr-1

LOrganic = annual loss of carbon from drained organic soils, t C yr-1

ΔCInorganic = annual change in inorganic carbon stocks from soils, t C yr-1 (assumed to be 0 unless using a Tier 3 approach)

Mineral soils

Soil organic matter in soils is in a state of dynamic balance between inputs (litterfall and its decay/incorporation into the soil) and outputs (organic matter decay through respiration) of organic C. Human actions and other disturbances alter the carbon dynamics. IPCC default method assumes:

– Over time, soil organic C reaches a spatially averaged, stable value specific to the soil, climate, land-use and management practices

– Soil organic C stock changes during the transition to a new equilibrium SOC occur in a linear fashion

– The change is computed based on C stock after the management change relative to the carbon stock in a reference condition (i.e. native vegetation that is not degraded or improved)

Mineral soils (2)

$$\Delta CFF\ Mineral = (SOC0 - SOC(0\text{-}T))/D \text{ (or T)}$$

$$SOC = \sum (SOCREF \bullet FND/LU \bullet FMG \bullet FI \bullet A)$$

Where:

ΔCFF Mineral =

SOC0 =

SOC(0-T)/D =

T = number of years between inventories (inventory time period), years (to be substituted

for D if T > D; not done in GPG-LULUCF)

D = time dependence of stock change factors (default = 20), years

SOC =

SOCREF = reference C stock for a climate-soil combination, tC/ha

FND/LU, FMG, FI = stock change factors for natural disturbance (or land use if it is not forest), management and organic matter input (GPG-LULUCF had an adjustment factor for the forest type and none for the input regime), dimensionless

A = area of the stratum of forest/land use (with a common climate and soil type), ha.

Organic soils

Organic soils have organic matter accumulated over time under anaerobic conditions.

C dynamics of organic soils are closely linked to hydrologic conditions and C stored in organic soils readily decomposes in aerobic conditions following soil drainage. Loss rates of organic C vary according to climate type, drainage depth, type of organic substrate and temperature.

Organic soils (2)

$$\Delta CFFOrganic = ADrained \bullet EFDrainage$$

Where:

ΔCFFOrganic = CO_2 emissions from drained organic soils, t C/yr

A drained = area of drained organic soils, ha

EFDrainage =EF for CO_2 from drained organic soils, t C/ha/yr

Non-CO2 emissions from biomass burning

Emissions from fire include not only CO_2, but also other GHGs, or precursors, due to incomplete combustion of the fuel, including carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds (NMVOC) and nitrogen (e.g., N_2O, NOx.) species. Non-CO_2 greenhouse gas emissions are estimated for all land use categories.

Non-CO2 emissions from biomass burning (2)

$$Lfire = A \bullet MB \bullet Cf \bullet Gef \bullet 10{-}3$$

Where:

Lfire = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.

A = area burnt, ha

MB = mass of fuel available for combustion, tonnes ha-1 (including biomass, ground litter and dead wood; litter and dead wood pools assumed zero, when there is no land-use change.)

Cf = combustion factor, dimensionless

Gef = emission factor, g (kg dry matter burnt)-1

Non-CO2 greenhouse gas emission

The most direct N_2O emissions from managed forests were calculated the equation below.

N2O direct-NFF = (N2O direct-Nfertiliser + N2O direct-Ndrainage)

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 fertilization 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 were estimated using the below equations.

CH4 emissions = (carbon released) • (emission ratio) • 16/12 ....

CO emissions = (carbon released) • (emission ratio) • 28/12 ....

N2O emissions = (carbon released) • (N/C ratio)• (emission ratio) • 44/28 ....

NOx emissions = (carbon released) • (N/C ratio)• (emission ratio) • 46/14