NATIONAL GREENHOUSE GAS INVENTORY SYSTEM OF MALAWI

LAND COVER CHANGE EMISSIONS CALCULATOR

Standard Operating Procedures

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March 2019

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ACRONYMS AND ABBREVIATIONS

AD	Activity Data
EF	Emission Factor
GHG-IS	Greenhouse Gas Inventory System
QA/QC	Quality Assurance/Quality Control
SOP	Standard Operating Procedure
IPCC	Intergovernmental Panel on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
EAD	Environmental Affairs Department
PERFORM	Protecting Ecosystems and Restoring Forests in Malawi
USAID	United States Agency for International Development
LCC	Land Cover Change

1.0　INTRODUCTION

The Government of Malawi with USAID's Protecting Ecosystems and Restoring Forests in Malawi (PERFORM) has developed the Greenhouse Gas Inventory System (GHG-IS) to support Malawi's Low Emissions Development Strategy. The GHG-IS uses a series of Microsoft Excel emissions calculators that combine methods and data from Intergovernmental Panel on Climate Change (IPCC) Guidelines (2006) with Malawi-specific data to produce estimates of emissions from each sector (see box). These emission calculators are accompanied by Standard Operating Procedures (SOPs) which provide comprehensive guidance on using the calculators.

The Land Use and Land Use Change Emissions Calculator produces estimates for reporting part of the annual emissions from the Agriculture, Forestry, and Other Land Use (AFOLU) Sector in Malawi. To derive the total estimated annual emissions from the AFOLU sector in Malawi, outputs from the separate Fuelwood Emissions Calculator, Livestock Calculators (Enteric Fermentation and Manure Management Systems), and Managed Agricultural Soil Calculator are also needed.

This SOP provides comprehensive guidance on the Land Use and Land Use Change Emissions Calculator and serves to: (1) provide an overview of steps required to operate the Land Use and Land Use Change Emissions Calculator; (2) direct analysts through the collection and entry of activity data; and (3) guide the interpretation and reporting of resulting emission estimates.

Under the GHG-IS, emissions from the land use sector in Malawi are accounted following the Intergovernmental Panel on Climate Change (IPCC) Tier 1 approach and accounts for emissions resulting from land use change and forest degradation. The greenhouse gases (GHGs) emitted from these sources only include CO_2. To calculate forest degradation emissions, we refer the user to the Fuelwood Emissions Calculator.

The main Government entity responsible for the GHG-IS Land Use and Land Use Change Emissions Calculator is the Environmental Affairs Department (EAD). Personnel responsible for collecting, entering, and analyzing data for the GHG-IS will need to be assigned in accordance with the guidance set forth in the *GHG-IS Master Document* and will need to work with relevant government agencies to collect appropriate data for evaluating emissions from land cover change.

Sectors accounted for in Malawi's GHG-IS

Energy: Emissions resulting from production and use of fuels for energy.

Industrial Processes and Product Use: Emissions from producing cement, lime, and ceramics.

Agriculture, Forestry, and other Land Use: Emissions from livestock and agricultural soil management (i.e., fertilizer application), forests remaining forests (degradation from unsustainable fuelwood harvest), and land use change.

Waste: Emissions from wastewater treatment and discharge, incineration and open burning of waste, and solid waste disposal.

2.0 OVERVIEW OF THE LAND COVER CHANGE EMISSIONS CALCULATOR

The Land COVER Change Emissions Calculator is currently built to accommodate data entry and estimate emissions from 2010 to 2040. It includes the following tabs (i.e., Excel Worksheets):

Table 1 LAND COVER CHANGE EMISSIONS CALCULATOR TABS

TAB NAME	PURPOSE
Workbook Overview	Provides an overview of the calculator and basic instructions on how to utilize the workbook
Change Log	List of all changes made to the calculator, and documents if they have been QA/QC'ed. The change log must be updated every time the calculator is updated or modified.
Activity Data Tracker	Displays all the AD that needs to be entered in the calculator, per year of inventory. Clicking on the name of the AD shows the tab where the AD must be entered. Staff responsible for updating the calculator with new data must update the table in this tab to indicate whether the AD on a given year was complete, assumed to be 0, partially entered, missing, or entered but still requiring validation and QA/QC - these options appear in the dropdown menu in each cell of the table.
Land Use Change Emissions	Reports total annual emissions in CO_2e due to land use change, based on the AD entered and the EF used. Results are reported by transition of land use cover, and a bottom table summarizes net, gross, and total emissions.
AD - Land Cover Change	Activity Data: Hectares of land converted to another land use every year in Malawi. Land uses are forest land, cropland non-flooded, cropland flooded rice, grassland, wetland, settlement, or other land. This tab should be updated as new AD becomes available every year.
AD – Forest Plantations	Activity Data: Hectares of new plantations planted each year in Malawi in customary lands and tobacco estates. This data is compiled by the Department of Forests from individual plantation managers.
Coefficients	Carbon stock and land use management default factors (from the IPCC Guidelines). Forest land uses carbon stock biomass from Malawi's National Forest Inventory; the rest of the defaults can be replaced by collected data in the country, when available.
Soil stock change	Intermediary emission factor for changes on soil carbon stock with land use transitions, in $t\ C\ ha^{-1}\ yr^{-1}$ and $t\ C\ y^{-1}$.
CH4_rice	This tab compiles AD, EF, and emissions (in CO_2e and CH_4) for rice cultivation, both flooded (irrigated) or upland (rain-fed).

EF land cover change	Emission factors (EF) for each land use transition.
	Emission factors should only be updated if improved information is made available on emissions from land use change.
EF enhancements	Removal factors (RF) for each of the tree main tree species planted in Malawi in forest plantations (i.e. eucalyptus species, pine species, and other conifer species excluding pine).
	Removal factors should only be updated if improved information is made available on emissions from land use change.

The tabs and tables are color-coded to indicate their function following this key:

Table 2 COLOR KEY FOR TAB AND TABLE FUNCTIONS

TABLE COLOR	FUNCTION
Orange	Total estimated yearly emissions estimates, either by sector or aggregated.
Yellow	Quality Control checks for specific data-entry tasks that are likely to have errors, and Activity Data Tracker.
Green	Activity data
Blue	Default coefficient factors that contribute to emission factors. Should be periodically reviewed by sectoral experts and updated as new information are developed.
Purple	Coefficients developed in the reporting format and units that other inventory calculators (i.e. agricultural soil management calculator) require as inputs.
Grey	Products of equations that represent intermediary steps between activity data and final emissions estimates. For review only, should not need update unless the formula has been corrupted. To recover the formula, the calculator manager should visit the reference listed on the table heading (usually an equation from the IPCC Guidelines).

The tables within each tab of the Land Cover Change Emissions Calculator include a heading that describes:

- The IPCC-defined coefficient name (i.e., activity data, IPCC coefficient, etc.)
- A plain-language definition of the coefficient name
- Units of measurement
- Reference to where the coefficient is referred to in the IPCC 2006 Guidelines
- Frequency of review
- Notes where additional context is needed. Where deviations from IPCC 2006 Guidelines or assumptions have been made (see section 3.5) these will be noted here.

3.0 GHG ACCOUNTING USING THE LAND COVER CHANGE EMISSIONS CALCULATOR

Malawi's GHG-IS is designed to allow for clear and consistent accounting for emissions by limiting data entry in the emissions calculators to activity data (AD)[1]. The process for collecting, entering, and reviewing those data are described below.

3.1 ACTIVITY DATA PRODUCTION

To account for emissions from land cover change, data for land use change and forest degradation are needed. Specific activity data needs are given in Table 3 below.

The full list of activity data needs and activity data sources are detailed in Annex III of this SOP and on the *GHG-IS Master Document*.

Table 3 ACTIVITY DATA NEEDS FOR ESTIMATING EMISSIONS FROM LAND COVER CHANGE

LAND COVER CHANGE CATEGORIES		UNITS
Forest land →	Cropland	*Hectares per year (ha y^{-1})*
Forest land →	Grassland	*Hectares per year (ha y^{-1})*
Forest land →	Wetland	*Hectares per year (ha y^{-1})*
Forest land →	Settlement	*Hectares per year (ha y^{-1})*
Forest land →	Other land	*Hectares per year (ha y^{-1})*
Cropland →	Wetland	*Hectares per year (ha y^{-1})*
Cropland →	Settlement	*Hectares per year (ha y^{-1})*
Cropland →	Other land	*Hectares per year (ha y^{-1})*
Cropland →	Forest land	*Hectares per year (ha y^{-1})*
Cropland →	Grassland	*Hectares per year (ha y^{-1})*
Grassland →	Forest land	*Hectares per year (ha y^{-1})*
Grassland →	Cropland	*Hectares per year (ha y^{-1})*
Grassland →	Wetland	*Hectares per year (ha y^{-1})*
Grassland →	Settlement	*Hectares per year (ha y^{-1})*
Grassland →	Other land	*Hectares per year (ha y^{-1})*
Wetland →	Forest land	*Hectares per year (ha y^{-1})*
Wetland →	Cropland	*Hectares per year (ha y^{-1})*
Wetland →	Grassland	*Hectares per year (ha y^{-1})*

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[1] The magnitude of human activity resulting in emissions or removals taking place during a given period of time
https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/definitions

Wetland →	**Settlement**	*Hectares per year (ha y^{-1})*
Wetland →	**Other land**	*Hectares per year (ha y^{-1})*
Settlement →	**Forest land**	*Hectares per year (ha y^{-1})*
Settlement →	**Cropland**	*Hectares per year (ha y^{-1})*
Settlement →	**Grassland**	*Hectares per year (ha y^{-1})*
Settlement →	**Wetland**	*Hectares per year (ha y^{-1})*
Settlement →	**Other land**	*Hectares per year (ha y^{-1})*
Other land →	**Forest land**	*Hectares per year (ha y^{-1})*
Other land →	**Cropland**	*Hectares per year (ha y^{-1})*
Other land →	**Grassland**	*Hectares per year (ha y^{-1})*
Other land →	**Wetland**	*Hectares per year (ha y^{-1})*
Other land →	**Settlement**	*Hectares per year (ha y^{-1})*

Note that this tool calculates emissions from land cover change <u>only</u>, which includes forest plantations and deforestation. To assess emissions from forest degradation of forest land remaining forest land from fuelwood collection please refer to the **Fuelwood Emissions Calculator**, and for emissions from agricultural land refer to the **Livestock and Managed Agricultural Soils Calculators** of this GHG-IS.

These data are produced by the <u>Department of Forests</u>. The specific sectoral focal points to contact for these data are listed in Annex I of this SOP and in the *GHG-IS Master Document.*

These data are produced <u>every year</u>. In accordance with the timelines and guidance set forth in the established master GHG-IS Calendar, data should be entered into the Land Cover Emissions Calculator during <u>the second trimester of the year,</u> <u>every year</u>.

3.2   ACTIVITY DATA ENTRY

Once EAD personnel have collected the activity data for the necessary period, they must be entered in the green **AD - Land Cover Change** tab and **AD – Forest Plantations** tab in the Land Use and Land Use Change Emissions Calculator. Values in the blue and grey tabs will populate automatically, according to the equations and assumptions indicated in their table headings.

Once AD are entered, the total emissions are automatically calculated multiplying AD by corresponding EFs. The **LCC Emissions** tab compiles the results generated on emissions from land use change from in tons of CO_2e for each year. A graph that visually describes the results is also produced and automatically updated.

When the calculator has been updated and/or the AD has been entered, rename the file to be saved file with today's date. **Do not overwrite existing versions**. For example, "Land Cover Change Emissions Calculator – July_17_2018".

3.3   QA/QC & APPROVAL OF EMISSION ESTIMATES

It is imperative that quality assurance/quality control measures are undertaken to ensure data are
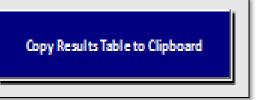
correctly entered. The following steps must be followed by the individual responsible for QA/QC every time AD are entered into the Land Cover Change Emissions Calculator.

1. Whenever the data entry analyst makes a change or a series of changes, review the new version of the workbook by reading the **Change Log** tab.

2. If there are new changes that have not been reviewed yet, do so considering the following:
   - Ensure data appear correct and plausible. If there is a large discrepancy in values since the previous reporting period, make sure the reason for this difference has been identified and documented in the **Change Log** notes.
   - Confirm that the emission factors (blue) are appropriately converting AD to tons of CO_2e.

3. In the **LCC Emissions** tab (orange) confirm that all emissions estimates for the current year are within a reasonable range (± 20%) from previous year. If a change over this threshold is observed, the reason must have been identified and documented in the **Change Log** by the person responsible of entering the data. Note in the **Change Log** tab any comments related to changes that have been QA/QC'd. If any errors were resolved, note the change and set the status to **'OK'd'**.

4. If any errors could not be resolved immediately, change the status to 'needs resolution' while a solution is determined. Seek out the expertise of teammates to resolve unexplained errors. Once resolved, update the change log again for this entry and change status to 'OK'd'.

5. Update the status of the AD entered on the **AD_Tracker** tab.

3.4   REPORTING EMISSIONS FROM LAND COVER CHANGE

Once reviewed, appropriate EAD personnel should enter the emissions estimated using the Land Cover Change Emissions Calculator into the **Emissions Aggregator Calculator**, which compiles all sectoral emissions for UNFCCC reporting purposes. The total emissions calculated will also need to be included in Malawi's GHG Inventory Annual Report, both as total tons of CO_2e and per GHG (i.e., CO_2, CH_4, and N_2O), if applicable.

To facilitate the entry of the sectoral emission results into the IPCC reporting tables, the Land Cover Change Emissions Calculator includes a 'Button' that automatically selects and copies the results that are needed as inputs in the sectoral reporting table of the **Emissions Aggregator Calculator**. The Emissions Aggregator Calculator and its SOPs instruct the calculator manager to simply paste these values in the indicated cells of the Emissions Aggregator Calculator; the Emissions Aggregator Calculator will automatically create uncertainty estimates and emissions graphs and tables for reporting purposes once values from the Land Cover Change Emissions Calculator are pasted in the Emissions Aggregator Calculator.

Copy Results Table to Clipboard

This button is located in the LCC Emissions tab of the Land Cover Change Emissions Calculator.

3.5 ASSUMPTIONS MADE IN ACTIVITY DATA, COEFFICIENTS, & EMISSION FACTORS

Each coefficient, activity data, or emission factor table in the calculator has a heading describing its name, source, units, and additional relevant information. While the IPCC 2006 Guidelines were followed when choosing equations and default factors, it was necessary to make some additional assumptions for Malawi. To ensure consistent adherence to the methodology, these additional key assumptions are indicated on the 'Notes' cell in these headings and are elaborated below in Table 4.

Table 4 ASSUMPTIONS OF THE LAND COVER CHANGE EMISSIONS CALCULATOR

COEFFICIENT	ASSUMPTION
Carbon stocks	IPCC carbon fraction default from Ch.4, table 4.3, of 0.47 is used across land uses to convert biomass dry mass to carbon.
	Cropland non-flooded (includes upland rice) uses IPCC biomass defaults from Ch.5, table 5.1, and IPCC soil stock defaults from 5.9; cropland flooded rice uses IPCC biomass defaults from Ch.5, table 5.1, and IPCC soil stock defaults from IPCC table 5.9.
	Grassland uses IPCC default from Ch. 6, table 6.2 and table 6.4. Forest land assumes temporarily a biomass stock for tropical moist deciduous forest in Africa (table 4.7), until the NFI provides a Tier 2 value.
	Wetlands assumes grassland biomass; settlements and other land assumes 0 biomass and C stock.
	Soil C stocks from Henry et al. 2009 (www.biogeosciences-discuss.net/bgd-2008-0194/) and Bessah et al. 2016 (available in: cogentoa.com/article/10.1080/23312041.2016.1140319.pdf).
Management coefficients	Management factors for cropland non-flooded assumes long-term, tropical moist, full tillage, and average of low and medium input from table 5.5 and 5.9; cropland flooded rice assumes long-term rice paddy, full tillage, and low input from table 5.9; grassland assumes moderately degraded management from table 6.2.
	The product of these factors is calculated following IPCC eq. 2.25 in Ch.2.
AD – Land Cover Change	Annual data for 2010 to 2016 currently assumes a constant land use change rate from malawi's 2006-2016 Forest Reference Level Report of forest land converted to grassland. This data must be reassessed as new annual AD becomes available.
AD – Forest plantations	These data are collected annually by Malawi's Department of Forest from individual plantation managers in customary lands and tobacco estates. Data entered here each year is the total amount of new hectares planted every year under each of these three commonly planted species.
AD rice	Assumes upland rice is rain-fed rice; flooded rice is irrigated rice.
EF rice	EF (kg CH_4/ha/d) = Efc x SFw x SPp (IPCC equation 5.2). Assumes Sfo and SFsr are not applicable in Malawi at the moment.
	Default values from IPCC tables 5.11, 5.12, and 5.13.
EF enhancements	Every year the removal factor assumes that the entire committed sequestration for the planted tree until it is felled is achieved. This is possible thanks to the annual plantation survival rate being accounted for in the AD entered (hectares of newly established plantations).
	Removal factors from the Global CO2 Removals Database (https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-018-0110-8).

4.0   UPDATING DEFAULTS AND EMISSION FACTORS

It is not expected that the GHG-IS operators will be responsible for refining or updating default emission factors, except for the aboveground and belowground biomass carbon stock each time a new National Forest Inventory (NFI) is completed (tentatively, every 2 to 5 years). In addition, due to newly available research, there may come a time where existing coefficients no longer appropriately represent national circumstances. The process through which default factors are be updated could be a combination of expert review, literate review, original research, and comparison to neighboring countries. Guidelines for updating these factors are not provided here. However, in the event that any factors require updating, the following steps should be followed:

1. Decide if the update should apply to all or only select years. Applying to all years (including past) will result in past years being recalculated. Changes due to new research may be appropriate to apply to past years. Changes related to new economic developments in Malawi should only be applied to years that these developments are believed to significant (including future years if appropriate).

2. Directly change the values in the corresponding emission factor table for the appropriate years.

3. For additions or removal of strata (i.e., land uses):
    a. Change to one table must be made to all tables that express that stratification.
    b. An appropriate value for each coefficient relevant to that strata must be developed or adopted.
    c. Add a row by inserting a new row across the entire workbook intersecting with the table.
    d. Ensure all formulas are coped into new row for that table.
    e. Check final results (orange tab) to ensure that change is having anticipated result.

4. Document any changes in the **Change Log** tab.

5. Update the status of the AD entered on the **AD_Tracker** tab.

6. Deliver any documentation, studies, references etc. that support why the particular change was made to EAD, including a summary of the rationale for the change.

5.0   EXTERNAL RESOURCES

2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry, and Other Land Use (AFOLU), available at https://www.ipcc.ch/meetings/session25/doc4a4b/vol4.pdf.

National Greenhouse Gas Inventory System Of Malawi. Master Document. October 2018.

Malawi's National Forest Reference Level report. February 2019.

Malawi's National Forest Inventory Report February 2019.

ANNEX I. SECTORAL FOCAL POINTS

The sectoral focal points as presented below reflect institutional arrangements implemented for the 2017 Annual Greenhouse Gas Inventory. Future cycles may necessitate adjustments to the table to accurately reflect personnel changes.

GHG-IS Calculator name	Primary EAD Focal Point	Secondary EAD Focal Point	Sectoral focal point Institution	Primary Sectoral Focal Point	Secondary Sectoral Focal Point
Land Use Change Calculator	Mphatso Kalemba	Chimwemwe Yonasi	Department of Forestry	Henry Utila	Henry Kadzuwa

ANNEX II. SAMPLE DATA REQUEST LETTER

[EAD letterhead]

[name of primary sectoral FP]
[position]

[name of secondary sectoral FP]
[position]

Department of Forests

[date]

Dear [name of forestry EAD primary FP] and [name of forestry EAD secondary FP],

Through this letter, the agriculture EAD focal point formally requests that you share sectoral data produced by the Land Use and Land Use Change GHG-IS Calculator, necessary to estimate annual greenhouse gas emissions from the forestry sector. As you know, Malawi has now formalized its annual greenhouse gas accounting and reporting, managed by the Environmental Affairs Department, and we reach out to all sectors every year seeking their collaboration to complete the annual multisectoral greenhouse gas emission estimates.

We request that you kindly share with us the information on annual land use change transitions (hectares per year) and annual new hectares under forest plantations compiled by planted tree species and accounting for survival rate (%) for [year].

Please share this data in an excel format, indicating in the column headings the units of the data.

Do not hesitate to reach out to us if this request raises any questions or concerns. We appreciate your collaboration and thank you in advance for your prompt reply to this request.

Regards,

[signature]

[name]
[position]
Environmental Affairs Department

ANNEX III. ACTIVITY DATA NEEDS & SOURCES USED IN 2010-2017

Activity Data (AD) needed	GHG-IS Calculator Name	AD subcategories	Required AD input units	AD relevant in Malawi (2010 - 2017)	Source (2010-2017)
Land coverchange	Land Cover Change Calculator	Transitions from and to forest land, cropland non-flooded, cropland flooded rice, grassland, wetland, settlements, and other lands	hectares	all	Visual assessment of digital imagery in Google Earth
Enhancements from forest plantations	Land Cover Change Calculator	Plantations in customary lands and tobacco estates of eucalyptus, pine, and conifer species.	hectares	all	Tabular data from plantation managers in customary lands and tobacco estates.