United States Agency for International Development
Cooperative Agreement No. EEM-A-00-06-00024-00

Global Climate Change: Carbon Reporting Initiative

The AFOLU Carbon Calculator

USAID
FROM THE AMERICAN PEOPLE

WINROCK INTERNATIONAL
Putting Ideas to Work

AFOLU CARBON CALCULATOR

THE GRAZING MANAGEMENT TOOL: UNDERLYING DATA AND METHODS

Winrock International

December, 2014

This publication was produced for review by the United States Agency for International Development. Prepared by Winrock International under the Cooperative Agreement No. EEM-A-00-06-00024-00.

AFOLU CARBON CALCULATOR

THE GRAZING MANAGEMENT TOOL: UNDERLYING DATA AND METHODS

Cite report as:

Winrock International. 2014. AFOLU Carbon Calculator. The Grazing Tool: Underlying Data and Methods. Prepared by Winrock International under the Cooperative Agreement No. EEM-A-00-06-00024-00.

TABLE OF CONTENTS

LIST OF TABLES

1. SCOPE

This document describes the underlying data sources and calculation methods employed in the Grazing Management (GM) tool of the AFOLU Carbon Calculator (http://afolucarbon.org/). The GM tool is designed for project activities that aim at improving the management of grazing lands and grazing practices to reduce GHG emissions.

2. APPLICABILITY

The activities applicable under the GM tool through which GHG emissions could be reduced are:

- improved grassland management;
- livestock management; and
- rewetting organic soils.

3. APPROACH TO THE GRAZING TOOL

To provide an estimate of the GHG emission related to grazing management, this study employed methodologies from the IPCC (2006) Guidelines for the Agriculture, Forestry, and Other Land Uses (AFOLU)[1], by using country-specific activity data and default emission factors provided in these IPCC Guidelines. The GHG accounted for are: soil carbon from fertilizer usage, rewetting of organic soils, and methane from livestock enteric fermentation. All GHG emissions and removals are expressed in tons of CO_2e.

4. DATA SOURCES

The greenhouse gas benefit of management activities represents the sum of benefits from soil carbon sequestration, from reduced livestock enteric fermentation emissions, and from carbon accumulation in rewet organic soils. The sections below describe how the underlying data for each of the parameter used in the calculations were derived.

4.1. SOIL CARBON MANAGEMENT

Soil carbon stocks before conversion to cropland were derived from the default SOC_{REF} numbers given by the IPCC (2006), Table 2.3. These stocks were then projected on to the administrative units as follows: Major soil types from the Harmonized World Soil Database (HWSD)[2] and IPCC (2006) climate zones were re-grouped to satisfy the soil and climate regime category in Table 2.3. These datasets were combined with the grassland and cropland category from the MODIS 2009 and cover dataset and boundaries for the first level administrative units to link the climate region and soil class per

---

[1] Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html
[2] Available at: http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/

administrative unit with the reference soil organic carbon SOC_{REF} value (Table 1). Due to the different spatial resolution between the datasets, some administrative units were not covered by all of the three raster datasets (climate, soil, grassland and cropland); as a result some manual edits were performed adopting the value of neighboring administrative units. Users can override the default value with a site specific carbon stock value.

Table 1: Default reference soil organic carbon stocks (SOC_{REF}) for mineral soils (t C ha^{-1} in 0-30 cm depth) (Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

Climate region	HAC Soil[(a)]	LAC Soils[(b)]	Sandy soils[(c)]	Spodic soils[(d)]	Volcanic soils[(e)]
Boreal	68	NA	10	117	20
Cold temperate, dry	50	33	34	NA	20
Cold temperate, moist	95	85	71	115	130
Warm temperate, dry	38	24	19	NA	70
Warm temperate,	88	63	34	NA	80
Tropical, dry	38	35	31	NA	50
Tropical, moist	65	47	39	NA	70
Tropical, wet	44	60	66	NA	130
Tropical montane	88	63	34	NA	80

(a) Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols);
(b) Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols);
(c) Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments);
(d) Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols);
(e) Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols)

Soil carbon stocks after forest conversion to cropland were based on specific soil stock change factors for land use, management and inputs (f_{LU}, f_{MG}, f_I, respectively) listed in Table 6.2 of the IPCC (2006). Relevant factors are listed in Table 2. Stock change factors were selected for each land cover type and multiplied by reference soil carbon stocks. Following the IPCC (2006) Guidelines, the total difference in carbon stocks before and after activity implementation is averaged over 20 years.

Table 2: Relative stock change factors (f_{LU}, f_{MG}, and f_I) for grassland management (net effect over a period of 20 years) Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

Factor type	Level	Climate regime	Factor value	Description
Land use (*f*LU)	All	All	1.00	All permanent grassland is assigned a land-use factor of 1
Management (*f*MG)	Non-degraded grassland	All	1.00	Non-degraded and sustainably managed grassland, but without significant management improvements
Management (*f*MG)	Moderately degraded grassland	Temperate / Boreal	0.95	Overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs
		Tropical	0.97	
		Tropical montane	0.96	
Management (*f*MG)	Severely degraded	All	0.70	Lands are identified as degraded lands using the, "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities"
Management (FMG)	Improved grassland	Temperate /Boreal	1.14	Represents grassland which is sustainably managed with moderate grazing pressure and that receive at least one improvement (e.g. fertilization, species improvement, irrigation).
		Tropical	1.17	
		Tropical montane	1.16	
Input (*f*I)	Low/Medium	All	1.00	All grassland without input of fertilizers is assigned an input factor of 1
	High	All	1.11	Grasslands with direct application of fertilizers - organic or inorganic

As a default it is assumed that there are low inputs to the grasslands both with and without activity implementation and that management switches from moderately degraded grassland to improved grassland.

Users have the option to specify the grassland management both before and after activity implementation and the level of inputs to grasslands both with and without activity implementation.

4.2. LIVESTOCK MANAGMENT

Users are able to enter two types and the respective numbers of head of livestock both with and without activity implementation. The emission factors attributed to each non-cattle livestock subcategory for enteric fermentation are based on IPCC (2006) default values ascribed to developing countries (Table 3). Default IPCC emission factors for dairy and other cattle are divided by geographical region (Table 4).

Table 3: Emission factors for enteric fermentation from non-cattle livestock (kg CH_4 head^{-1} yr^{-1})

Livestock	Emission factor	
	Developed countries	Developing countries
Buffalo	55	55
Sheep	8	5
Goats	5	5
Camels	46	46
Horses	18	18
Mules and Asses	10	10
Deer	20	20
Alpacas	8	8
Swine	1.5	1.0

Table 4: Emission factors for enteric fermentation from cattle (kg CH_4 head^{-1} yr^{-1})

Region	Emission factor	
	Dairy	Other Cattle
Eastern Europe	99	58
Oceania	90	60
Latin America	72	56
Asia	68	47
Africa and Middle East	46	31
Indian Subcontinent	58	27

4.3. REWETTING ORGANIC SOILS

Changes in soil carbon stocks with organic soil rewetting were calculated based on Section 6.2.3.2 of the 2006 IPCC (2006). The assumption with rewetting is that accumulation will occur at a rate equal to the rate of loss with initial drainage (Table 5).

Table 5: Default carbon accumulation rate following rewetting of drained organic soils

Climatic temperature regime	IPCC Rate $t\ C\ ha^{-1}\ yr^{-1}$
Boreal / Cold Temperate	0.25
Warm Temperate	2.5
Tropical / Sub-tropical	5.0

5. UNCERTAINTY OF ESTIMATES

Uncertainty is a property of a parameter estimate and reflects the degree of lack of knowledge of the true parameter value because of factors such as bias, random error, quality and quantity of data, state of knowledge of the analyst, and knowledge of underlying processes. Uncertainty can be expressed as the size of the half width of a specified confidence interval as a percentage of the mean value. For example, if the area of forest land converted to grazing land (mean value) is 100 ha, with a 95% confidence interval ranging from 90 to 110 ha, we can say that the uncertainty in the area estimate is ±10% of the mean (from GOFC-GOLD 2013).

Uncertainty is an unavoidable attribute of practically any type of data including land area and estimates of carbon stocks and many other parameters used in the estimation of the AFOLU carbon benefits from activities on the land. Identification of the sources and quantification of the magnitude of uncertainty will help to better understand the contribution of each source to the overall accuracy and precision of the final estimate.

The proper manner of dealing with uncertainty is fundamental in the IPCC and UNFCCC contexts. The IPCC defines estimates that are consistent with good practice as those which contain neither over- nor underestimates so far as can be judged, and in which uncertainties are reduced as far as practicable. The first step in an uncertainty analysis is to identify the potential sources of uncertainty. Many sources are possible including measurement errors due to human errors or errors in calibration; measurement errors in the predictor variables; modelling errors due to inability of the model to fully describe the phenomenon; parameter and residual uncertainty; erroneous definitions or classifications that lead to double-counting or non-counting; unrepresentative samples; and variability resulting from the use of samples rather than censuses. In this section, the potential sources of uncertainty are identified and an assessment of their likely range of uncertainties used in the calculation of the carbon benefit in this tool is presented (Table 6). A brief primer of the steps involved in assessing total uncertainties for each carbon benefit estimate is provided with a couple of simple examples to demonstrate the process. The reader is referred to the GOFC-GOLD 2013 sourcebook for more details on all sources of uncertainty and how to reduce them. These analyses are not provided in the tools.

In addition to the uncertainties associated with each parameter, when parameters are combined as in e.g. estimating emissions from combining area grazed and emission factors for livestock, then overall error of the product will change. Uncertainties in individual parameter estimates can be combined using either (1) error propagation (IPCC Tier 1) or (2) Monte Carlo simulation (IPCC Tier 2). Tier 1 method is based on simple error propagation, and cannot therefore handle all kinds of uncertainty estimates. The key assumptions of Tier 1 method are (from GOFC-GOLD 2013):

- estimation of carbon emissions and removals is based on addition, subtraction and multiplication
- there are no correlations across parameters (or if there is, they can be aggregated in a manner that the correlations become unimportant)
- none of the parameter estimates has an uncertainty greater than about ±60%
- uncertainties are symmetric and follow normal distributions

However, even in the case that not all of the conditions are satisfied, the method can be used to obtain approximate results. In the case of asymmetric distributions, the uncertainty bound with the greater absolute value should be used in the calculation. The Tier 2 method is based on Monte Carlo simulation, which is able to deal with any kind of models, correlations and distribution. However, application of Tier 2 methods requires more resources than that of Tier 1.

The key parameters are of medium uncertainty. The other parameter used in the calculations is area grazed—it is assumed that this will be well known with an uncertainty of about 5% or less.

Table 6: Key parameters used to estimate the carbon benefits of grazing activities and an assessment of their uncertainties.

Component	Parameter	Uncertainty			Comment
		Low (<20%)	Medium (20-60%)	High (>60%)	
Soil Carbon Management	Pre-conversion soil carbon stocks		X		IPCC defaults and world soil map
	Soil carbon stock change factors		X		IPCC defaults
Livestock Management	Emission factor for cattle livestock		X		IPCC defaults
	Emission factor for non-cattle livestock		X		IPCC defaults
Rewetting Organic Soils	Carbon accumulation rate for organic soils following rewetting		X		IPCC default rates

5.1 COMBINING UNCERTAINTIES FOR MULTIPLICATION

The simple error propagation method is based on two equations: one for multiplication and one for addition and subtraction of uncertainties. The equation to be used in case of multiplication is:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2}$$

Where:

U_i = percentage uncertainty associated with each of the parameters

U_{total} = the percentage uncertainty in the product of the parameters

An example of combining uncertainties in estimating benefits from rewetting organic soil using the Tier I method is shown below:

	Mean value	Uncertainty (% of mean)
Area of organic soil to be rewet (ha)	500	5
Annual EF Drained grassland soils ($t\ C\ ha^{-1}\ yr^{-1}$)	2.5	40

Thus the benefits from rewetting organic soil are:

500 ha * 2.5 t C ha^{-1} yr^{-1} = 1,250 t C yr^{-1}

And the uncertainty = $\sqrt{5^2 + 40^2} = \pm 40\%$

5.2 COMBINING UNCERTAINTIES FOR ADDITION AND SUBTRACTION

In the case of addition and subtraction, for example when carbon emissions are summed up, the following equation will be applied:

$$U_{total} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 ...(U_n * x_n)^2}}{|x_1 + x_2 ... + x_n|}$$

Where:

U_i = percentage uncertainty associated with each of the parameters

x_i = the value of the parameter

U_{total} = the percentage uncertainty in the sum of the parameters

An example of this application is in the yearly CO_2 benefit (addition) shown below:

Component	Mean benefit (t CO^2)	Uncertainty (% of mean)
Soil carbon benefit	900	45
Livestock management benefit	200	40
Organic soil rewetting benefit	1250	40

In this example, the total benefit is 2650 t CO_2 and the uncertainty =

$$\frac{\sqrt{(45\%*900)^2+(40\%*200)^2+(40\%*1250)^2}}{|900+200+1250|} = \pm 28\%$$

Using this simple error propagation method is applicable to the calculations used in this grazing land tool. The Monte Carlo type analysis is more complicated to apply, but gives more reliable results particularly where uncertainties are large, distributions are non-normal, or correlations exist. Furthermore, Tier 2 method can be applied to models or equations, which are not based only on addition, subtraction and multiplication. (The reader is referred to Chapter 5 of IPCC GPG LULUCF for more details on how to implement the Monte Carlo analysis).

6. CALCULATION METHODS

The sections below outline individual components of the overall calculation of carbon benefits in the GM tool (Box 1).

> **Box 1: Overarching methodology for calculating carbon benefits in Grazing Management Tool**
>
> **Yearly CO_2 benefit (t CO_2/yr)** = (Soil carbon benefit) + (Livestock management benefit) + (Organic soil rewetting benefit)
>
> **Total CO_2 benefit (t CO_2)** = SUM of Yearly CO_2 benefits

Where users rely solely on the defaults in the calculator only the benefit of soil carbon accumulation is calculated. Parameters in red have default values provided, but can be changed by the user. Parameters in black are fixed within the calculations.

6.1 SOIL CARBON MANAGEMENT

The soil carbon term represents the difference in stable carbon stock between the two management approaches divided by 20 which is assumed (following the IPCC Guidelines) to be the number of years to transition from one stable stock to the other. The terms shown are in the equations below, and the default values used for each parameter are described.

Box 2: Estimating emissions from tillage management

Soil benefit = [(Soil carbon with project – Soil carbon without project) / 20] x (44/12) (Eq. 1)

Changes in soil carbon stocks were calculated based on Section 2.3.3.1 of the IPCC (2006). The equation calculates the difference in carbon stocks in the soil before and after agricultural conversion, and divides this value by an assumed time period over which the change is forecasted to occur.

Soil carbon with or without project = Area $*SOC_{REF}*F_{LU}*F_{MG}*F_I$ (Eq. 2)

Where:

SOC_{REF} = reference carbon stock (t C ha^{-1})

F_{LU} = stock change factor for land-use systems or sub-system for a particular land-use (dimensionless)

F_{MG} = stock change factor for management regime (dimensionless)

F_I = stock change factor for input of organic matter (dimensionless)

6.2 LIVESTOCK MANAGEMENT

The livestock management term represents the difference in emissions resulting from livestock populations with and without project activity implementation The terms shown are in the equations below, and the default values used for each parameter are described.

Box 3: Estimating emissions from tillage management

Livestock management benefit = [(Livestock emissions with project – Livestock emissions without project)] (Eq. 3)

Livestock emissions are calculated based on Section 10.3 of the IPCC (2006). The basic Tier 1 approach is pairing the number of livestock by type with a per head methane emission factor (Tables 3 and 4). The emission factors are converted to carbon dioxide equivalents using the global warming potential for methane.

6.3 REWETTING ORGANIC SOILS

The rewetting organic soils term is estimated by multiplying the emission factor (

Table 5) by the area that will be rewet by project activities. The terms shown are in the equations below, and the default values used for each parameter are described.

Box 4: Estimating emissions from tillage management
Rewetting organic soil benefit = Area of organic soil to be rewet * Annual EF Drained grassland soils (Eq. 4)

6.4 HYPOTHETICAL EXAMPLE

A hypothetic project activity over 500 hectares of grassland in Chad is given as an example here. First, users have to select the geographic location of the project, which in this hypothetical example will take place in Mandoul in Chad.

After entering the total area of the grazing management project activity (500 ha), the user has select improved grassland.

Thus, using equations 1 and 2, the benefits are calculated as:

Benefits (tCO_2) = {[(Area $*SOC_{REF}*F_{LU}*F_{MG,ImprovedGrassland,\ tropical}*F_{I,low}$) - (Area $*SOC_{REF}*F_{LU}*F_{MG,ModeratelyDegraded,\ tropical}*F_{I,low}$)] / 20} * (44/12)

Where:

Area = 500 ha
SOC_{REF} = 32.58 t C ha^{-1}
F_{LU} = 1
$F_{MG,ImprovedGrassland,\ tropical}$ = 1.17
$F_{MG,ModeratelyDegraded,\ tropical}$ = 0.97
$F_{i,low}$ = 1

Thus equating to:
Benefits = {[(500 *32.58*1*1.17*1) - (500 **32.58***1*0.97*1)] / 20} * (44/12)

Benefits = **597.2 tCO_2e**

In this hypothetical example, conducting only improved grassland management over these 500 ha in the Mandoul in Chad has resulted in a carbon benefit of approximately **597.2 t CO_2e** for the first year of the project.

7. OVERRIDING DEFAULT DATA

The only data required to generate a CO_2e impact result of the project activity is:

- Location of the project
- Project size, or area, associated with the grazing activity

The user is given an option to include livestock management and rewetting of organic soils as well as change default parameters by entering project-specific data. The following are the optional inputs under the grazing management calculator:

Grassland Management

- Soil carbon stocks in top 30 cm

Pre-project condition of grazing land:

- Drop down of: Unmanaged / Moderately degraded (default) / Severely degraded / Improved
- Drop down of: No inputs (default) / added fertilizer and/or manure

With-project condition of grazed land:

- Drop down of: Unmanaged / Moderately degraded / Severely degraded / Improved (default)
- Drop down of: No inputs (default) / added fertilizer and/or manure

Livestock management

Pre-project livestock

Livestock type 1

- Drop down: None (default) / dairy cows / other cattle / buffalo / sheep / goats / camels / horses / mules or asses / deer / swine or pigs
- Number of livestock

Livestock type 2

- Drop down: None (default) / dairy cows / other cattle / buffalo / sheep / goats / camels / horses / mules or asses / deer / swine or pigs
- Number of livestock

With project livestock

Livestock type 1

- Drop down: None (default) / dairy cows / other cattle / buffalo / sheep / goats / camels / horses / mules or asses / deer / swine or pigs
- Number of livestock

Livestock type 2

- Drop down: None (default) / dairy cows / other cattle / buffalo / sheep / goats / camels / horses / mules or asses / deer / swine or pigs
- Number of livestock

Rewetting organic soils:

- Area of organic soil to be rewet
- Emissions factor of drained soil

8. REFERENCES

GOFC-GOLD, 2013, A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP19-2, (GOFC-GOLD Land Cover Project Office, Wageningen University, The Netherlands).

Harmonized World Soil Database. 2012. Version 1.2. Available at: http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Volume 4 Agriculture, Forestry and Other Land Use. Paustian, K, Ravindranath, N.H. and Van Amstel, A (coordinating lead authors). Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.htm

For questions and comments:

Felipe M. Casarim Carbon Specialist, Ecosystem Services

Winrock International | 2121 Crystal Drive, Suite 500 | Arlington, VA 22202, USA | www.winrock.org

office 703.302.6538 | fax 703.302.6512 | e-mail fcasarim@winrock.org