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The AFOLU Carbon Calculator

AFOLU CARBON CALCULATOR

THE CROPLAND MANAGEMENT TOOL: UNDERLYING DATA AND METHODS

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1. SCOPE

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

2. APPLICABILITY

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

- Tillage management
- Fertilizer management
- Rice management

3. APPROACH TO THE CROPLAND TOOL

To provide an estimate of the GHG emission related to cropland management, this tool 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 guidelines. The GHG sources covered here are: methane from rice management, nitrous oxide from fertilizer use and carbon emissions from soils. In Level A only soil carbon emissions from tillage management is considered, with nitrous oxide from fertilizer and methane from rice management considered under Level B.

4. DATA SOURCES

The greenhouse gas benefit of cropland activities represents the sum of benefits from tillage, fertilizer, and rice management. The sections below describe how the underlying data 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 1). These stocks were then projected on to the administrative units as follows: Major soil types from the Harmonized World Soil Database (HWSD, 2011)[2] and IPCC (2006) climate zones were re-grouped to apply to the soil and climate regime category in Table 2.3 of the IPCC AFOLU Guidelines. These datasets were combined with the grassland and cropland category from the

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

MODIS 2009 land cover dataset and boundaries for the first level administrative units to link the climate region and soil class per administrative unit with the SOC_{REF} value. 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.

Table 1: Default reference SOC 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 5.5 of the IPCC (2006). Relevant factors are listed in Table 2. Stock change factors were selected for each land cover type (before and after activity implementation) and multiplied by reference soil carbon stocks. Following the IPCC (2006) Guidelines, the total difference in carbon stocks before and after conversion was annualized to give the total emissions over 20 years.

Table 2: Relative stock change factors for different management activities on cropland (net effect over a period of 20 years) (Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
Land use (f_{LU})	Long-term cultivated	Temperate/ Boreal	Dry	0.80	Area has been continuously managed for crops for more than 20 years
			Moist	0.69	
		Tropical	Dry	0.58	
			Moist/Wet	0.48	
		Tropical montane	n/a	0.64	
Land use (f_{LU})	Short-term cultivated (< 20 yrs) or set aside (< 5 years)	Temperate/ Boreal and Tropical	Dry	0.93	Area has been managed for crops for less than 20 years and/or the area is cropland that has been in a fallow state for less than five years at any point during the last 20 years
			Moist/Wet	0.82	
		Tropical montane	n/a	0.88	
Manage-ment (f_{MG})	Full tillage	All	Dry and Moist/Wet	1.00	Substantial soil disturbance with full inversion and/or frequent (within-year) tillage operations. At planting time, little (e.g. <30%) of the surface is covered by residues
Manage-ment (f_{MG})	Reduced tillage	Temperate/ Boreal	Dry	1.02	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30% coverage by residues at planting
			Moist	1.08	
		Tropical	Dry	1.09	
			Moist/ Wet	1.15	
		Tropical montane	n/a	1.09	
Manage-ment (f_{MG})	No tillage	Temperate/ Boreal	Dry	1.10	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.
			Moist	1.15	
		Tropical	Dry	1.17	
			Moist/ Wet	1.22	
		Tropical montane	n/a	1.16	
Inputs (f_{IN})	Low	Temperate/ Boreal	Dry	0.95	Removal of residues (collection or burning), frequent bare fallowing, production of crops with low residues (e.g. vegetables, tobacco, cotton), no mineral fertilization or nitrogen fixing species
			Moist	0.92	
		Tropical	Dry	0.95	
			Moist/ Wet	0.92	
		Tropical montane	n/a	0.94	
Inputs (f_{IN})	Medium	All	All	1.00	Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g., manure) is added. Also requires

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
					mineral fertilization or N-fixing crop in rotation.
Inputs (f_{IN})	High without manure	Temperate / Boreal / Tropical	Dry	1.04	Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see row below).
			Moist/Wet	1.11	
		Tropical montane	n/a	1.08	
Inputs (f_{IN})	High with manure	Temperate / Boreal / Tropical	Dry	1.37	Represents significantly higher C input over medium C input cropping systems due to an additional practice of regular addition of animal manure.
			Moist/Wet	1.44	
		Tropical montane	n/a	1.41	

4.2. FERTILIZER MANAGMENT

Emissions from fertilizer are derived from direct emissions from application, indirect emissions from runoff/leaching, emissions from atmospheric deposition of volatilized N and emissions from initial fertilizer production. They will vary depending on which fertilizer is applied. The approach is from IPCC (2006) Tier 1. In the calculator, fertilizer production emission factors are derived from CDM methodology III.A[3] (Table 3). The default values for direct emissions, runoff and volatilization emissions are given in Section 5.2.

Table 3: Fertilizer types and associated emission factors derived from CDM methodology III.A.

Fertilizer Type	EF (t CO_2) per ton of fertilizer
Urea	1.54
Ammonia	1.35
Ammonium sulphate	0.35
Monammonium sulphate (MAP)	0.18
Diammonium suphate (DAP)	0.30
Ammonium nitrate	0.55
Calcium ammonium nitrate	0.43

[3] http://cdm.unfccc.int/methodologies/DB/4OC3QS857382TW21LYYOJLTX3HHQKK

4.3 RICE MANAGEMENT

Rice emissions under the IPCC approach are calculated from the area multiplied by the number of days of cultivation multiplied by an emission factor. The emission factor has a default value of 1.30 t CO_2 which is adjusted by scaling factors for differences in water regime during the cultivation period (Table 4), differences in water regime in the pre-season before cultivation, for type and amount of organic amendment, for soil type and for rice cultivar.

Table 3: Fertilizer types and associated emission factors derived from CDM methodology III.A.

Water regime		Water Regime Scaling Factor
Upland		0
Irrigation	Continuous flooding	1.0
	Intermittent flooding with sing aeration	0.6
	Intermittent flooding with multiple aeration	0.52
Rainfed	Regular	0.28
	Drought-prone	0.25
	Deep water potential	0.31

5. CALCULATION METHODS

The greenhouse gas benefit of cropland activities represents the sum of benefits from tillage management, fertilizer management and rice management. The sections below outline individual components of the overall calculation (Box 1), and describe how default values for each parameter within an equation were derived.

Box 1: Overarching methodology for calculating carbon benefits in Cropland Calculator

Yearly CO_2 benefit (t CO_2 y^{-1}) = (Soil carbon benefit) + (Fertilizer management benefit) + (Rice management benefit)

Total CO_2 benefit (t CO_2) = SUM of Yearly CO_2 benefits

Parameters in blue must be specified by the user under Level A. Parameters in red have default values under Level B, but can be changed by the user. Parameters in black are fixed within the calculations.

5.1 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) Guidelines. The equation calculates the difference in carbon stocks in the soil before and after agricultural conversion, and divides this value by the assumed time period over which the change is forecasted to occur (20 years). However, in this tool we assume the all the soil emissions associated with agricultural conversion occur in the first year.

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

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

5.2 FERTILIZER MANAGEMENT

Fertilizer management benefits are calculated through the difference in emissions with and without the emission reduction activity (eq. 3). The emissions are calculated using an IPCC Tier 1 approach based on Section 11.2 of the 2006 Guidelines on Agriculture, Forestry and Other Land Use with fertilizer production emission factors derived from CDM methodology III.A. Emissions are derived from direct emissions from application, indirect emissions from application, emissions from atmospheric deposition of volatilized N and emissions from initial fertilizer production.

Box 3: Estimating benefit of fertilizer management

Fertilizer management benefit = fertilizer emissions without project – fertilizer emissions with-project (eq. 3)

Fertilizer emissions with or without project = Fertilizer Area * Fertilizer Applied *(6.205 + EF_{CO2}) (eq. 4)

Post-fertilizer application emissions under Tier 1 are calculated from the quantity of fertilizer applied multiplied by default constants as described below

- Direct emissions = annual application kg N yr^{-1} *0.01 * 1.5714 * 298
- Leaching/runoff emissions = annual application kg N yr^{-1} * 0.3 * 0.0075 * 1.5714 * 298
- Volatilization and deposition emissions = annual application kg N yr^{-1}* 0.1 * 0.01 *1.5714 * 298
- Production emissions = annual application kg N yr^{-1}x EF_{CO2}

Where:

- 0.01 is the default for the emission factor for direct emissions and for emission from atmospheric deposition of N on soils and water surfaces
- 1.5714 is the ratio for conversion of N_2O-N to N_2O
- 298 is the global warming potential of nitrous oxide (for conversion of N_2O emissions to CO_2-equivalent emissions
- 0.1 is the default fraction of synthetic fertilizer that volatilizes

These equations can be summed using the defaults to 6.205 multiplied by the emission factor for fertilizer production EF_{CO2} which varies by fertilizer type applied (Table 3).

5.3 RICE MANAGEMENT

Rice management benefits are calculated through the difference in emissions with and without the emission reduction activity (eq. 5). The emissions are calculated using an IPCC Tier 1 approach based on Section 5.5 of the IPCC (2006) (Box 4 and eq. 6). We assumed that:

- Soil exposure by default was non-flooded soil for more than 180 days before planting
- No inputs were applied
- There are no specific differences by soil type or rice cultivar
- Cultivation is for 120 days

Box 4: Estimating benefit of rice management

Rice management = rice emissions without project – rice emissions with-project (eq. 5)

Rice emissions with or without project = Rice Area * Rice Water Regime *2.652 (eq. 6)

Rice emissions under the IPCC approach are calculated from the area multiplied by the number of days of cultivation multiplied by an emission factor. The emission factor has a default value of 1.30 kg CH_4 ha^{-1} day^{-1} which is adjusted by scaling factors for differences in water regime during the cultivation period, differences in water regime in the pre-season before cultivation, for type and amount of organic amendment, for soil type and for rice cultivar.

Here the equation is simplified with the assumptions above allowing the calculation of emissions with just the entered rice area and a drop-down decision on the water regime during cultivation.

So that the default emission factor (eq. 7) is multiplied by 0.68 for flooding regime before cultivation and by 120 cultivation days and by the global warming potential of methane to convert from tons of methane to tons of CO_2 equivalent (25 from AR4 2007). This number is multiplied by 0.001 to convert from grams to tons.

$$\text{Default rice emission factor} = 1.30 * 0.68 * 120 * 25 * 0.001 = 2.652 \qquad \text{eq. 7}$$

5.4 HYPOTHETICAL LEVEL A EXAMPLE

A hypothetic project activity over 500 hectares of cropland in Mozambique 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 Inhambane, Mozambique.

After entering the total area of the cropland management project activity (500 ha), the user has select the tillage practice used before the project from a drop down menu (full, reduced or no till) and the level of inputs before the intervention (e.g. low, medium, high with manure or high without manure). In this example, the cropland management practices will improve practices from full tillage and high inputs with no manure, to no-tillage and low inputs. Given the same options, users must then select the appropriate actions for the after intervention scenario.

Thus, benefits are calculated as:

$$\text{Benefits } (tCO_2) = \{[(\text{Area} * SOCref * f_{LU} * f_{MG,no\text{-}till} * f_{I,low}) - (\text{Area} * SOCref * f_{LU} * f_{MG,full\text{-}till} * f_{I,high\text{-}without\ manure})] / 20\} * (44/12)$$

Where:

Area	= 500 ha
SOC_{REF}	= 24 t C ha^{-1}
f_{LU}	= 0.58
$f_{MG,no\text{-}till}$	= 1.17
$f_{I,low}$	= 0.95
$f_{MG,full\text{-}till}$	= 1.0
$f_{I,high\text{-}without\ manure}$	= 1.04

Thus equating to:
Benefits = {[(500*24*0.58*1.17*0.95)-(500*24*0.58*1*1.04)]/20}*(44/12)
Benefits = **93 tCO_2e**

In this hypothetical example, improvement of management of 500 ha of cropland in Inhambane, Mozambique has resulted in a carbon benefit of approximately **93 t CO_2e** each per year.

6. OVERRIDING LEVEL A DATA

As with the other AFOLU Carbon Calculator's tools, the Cropland Tool functions on two levels: A and B.

Under Level A, 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 cropland activity
- Previous tillage:
  - Full
  - Reduced
  - No
- With-project tillage:
  - Full
  - Reduced
  - No
- Previous soil inputs:
  - Low
  - Medium
  - High without manure
  - High with manure
- With-project soil inputs:
  - Low
  - Medium
  - High without manure
  - High with manure

Under Level B, the user is given an option to also consider fertilizer management and rice management. The following are the optional inputs for Level B under the grazing management calculator:

- Soil carbon stock for cropland area
- Area of fertilizer management
- Area of rice management

- Fertilizer:
  - Previous management amount of fertilizer applied per hectare
  - Previous management type of fertilizer
    - Urea
    - Ammonia
    - Ammonium sulphate
    - Monammonium sulphate (MAP)
    - Diammonium sulphate (DAP)
    - Ammonium nitrate
    - Calcium ammonium nitrate
  - With project amount of fertilizer applied per hectare
  - With project type of fertilizer
    - Urea
    - Ammonia
    - Ammonium sulphate
    - Monammonium sulphate (MAP)
    - Diammonium sulphate (DAP)
    - Ammonium nitrate
    - Calcium ammonium nitrate

- Rice Management:
  - Previous rice management system
    - Upland
    - Irrigation
      - Continuous flooding
      - Intermittent flooding with single aeration
      - Intermittent flooding with multiple aerations
    - Rainfed
      - Regular
      - Drought-prone
      - Deep water potential
  - With project rice management system:
    - Upland
    - Irrigation
      - Continuous flooding
      - Intermittent flooding with single aeration
      - Intermittent flooding with multiple aerations
    - Rainfed
      - Regular
      - Drought-prone
      - Deep water potential

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