



T-VER-P-TOOL-01-12

Calculation for change in soil organic carbon stocks in agriculture project activities

Version 01

1. Introduction

This tool is used for calculating changes in soil organic carbon stocks of agricultural project activities. This can be used to calculate the quarantine volume both for the base case and for operations.

2. Relevant Definitions

Details as per Annex 1

3. Characteristics of relevant activities and conditions

This tool is suitable for calculating changes in soil organic carbon sequestration in the base case and in the case of agricultural project implementation.

4. Assumptions

The instrument has the following assumptions to assess changes in soil organic carbon sequestration:

- 1) Project implementation increases the amount of organic carbon in the soil. Compared with the amount of organic carbon in the soil before the project until the amount of organic carbon in the soil was stable (steady-state).
- 2) The increase in organic carbon in the soil in the case of the project is constant for 20 years from the year of planting.

5. Calculation of changes in soil organic carbon sequestration

Stratification of project areas can be carried out as follow:

- 1) Climate zone and soil type (Annex 2 Table 1)
- 2) Area management before the project for agricultural land (Annex 2 Table 2)

Changes in soil organic carbon accumulation from project implementation There are methods for evaluating as follows:

Step 1 Calculation of organic carbon sequestration in the soil prior to project activities. It can be calculated as the following equation:

Option 1 Soil organic carbon content of the samples collected from the sampling plots
Soil organic carbon accumulation It is the collection of soil samples and analyzing the amount of organic carbon in the soil. and soil bulk density directly from the project area Details on the calculation is shown in the following equation.

$$SOC_{i,0} = \sum (SOC_{sample,i,0} \times BD_{sample,i,0} \times Dep_{sample,i,0} \times 0.16) / N_i$$

Where:

$SOC_{i,0}$ = The amount of carbon deposited in the soil before the project started in the sample unit i of the project area (tonnes carbon per rai)

$SOC_{sample,i,0}$ = Soil organic carbon content of the samples taken from sample unit i before the start of the project (Lab values in units, grams of carbon for soil particles < 2 mm in size) (grams of carbon per 100 grams of soil)

$BD_{sample,i,0}$ = Bulk density of soil with particle size <2 mm from sample unit i before project implementation. (Value from the laboratory in units grams per cubic centimeter)

$Dep_{sample,i,0}$ = Soil depth collected from sample unit i before project commencement (centimeter) (not less than 30 centimeter)

i = Sample unit 1, 2, 3, ...

0.16 = Unit conversion value (1 gram = 10⁻⁶ tons and 1 rai = 1.6 × 10⁷ square centimeter)

N_i = The number of sample plots that store data in the i-th sample unit.

Option 2 Carbon sequestration in the soil from a reference value

$$SOC_{i,0} = SOC_{REF,i} \times F_{LU,i,0} \times F_{MG,i,0} \times F_{I,i,0}$$

Where:

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- $SOC_{i,0}$ = The amount of carbon deposited in the soil before the project started in the sample unit i of the project area. (tonnes carbon per rai)
- $SOC_{REF,i}$ = Carbon stocks in natural reference soils (e.g., non-improved areas). does not deteriorate and native vegetation cover) according to climatic zones and soil types in sample unit i of the area (tonnes carbon per rai).
- $F_{LU,i,0}$ = The coefficient of changes in organic carbon accumulation in the soil by land use type before project commencement in sample unit i .
- $F_{MG,i,0}$ = Coefficient of change in soil organic carbon accumulation according to soil management methods before project start date of sample unit i
- $F_{I,i,0}$ = Coefficient of change in soil organic carbon accumulation according to the level of organic matter returned to the soil before project start date of sample unit i
- i = Sample unit 1, 2, 3, ...

Step 2 Calculation of organic carbon accumulation in soil in case of project implementation It can be calculated as the following equation.

Option 1 Soil organic carbon content of the samples collected from the sampling plots

The amount of carbon stored in the soil It is a soil sampling and analysis of soil organic carbon content and soil bulk density directly from the project area. Details of the calculation is shown in the following equation:

$$SOC_{i,t} = \sum (SOC_{sample,i,t} \times BD_{sample,i,t} \times Dep_{sample,i,t} \times 0.16) / N_i$$

Where:

- $SOC_{i,t}$ = The amount of carbon accumulated in the soil in the project area from sample unit i at time t (tonnes carbon per rai)
- $SOC_{sample,i,t}$ = Soil organic carbon content of samples collected from sample unit i at time t (laboratory value in units, grams of carbon for <2 mm soil particles) (grams carbon per 100 grams of soil)
- $BD_{sample,i,t}$ = Bulk density of soil with particle size <2 mm from unit sample i at time t (laboratory value in gram/cm³).

$Dep_{sample,i,t}$	=	Soil depth collected from sample unit i at time t (centimeter) (not less than 30 centimeter)
N_i	=	The number of sample plots that store data in the i -th sample unit.
i	=	Sample unit 1, 2, 3, ...
t	=	1, 2, 3, ... years since the project start date
0.16	=	Unit conversion value (1 gram = 10^{-6} tons and 1 rai = 1.6×10^7 square centimeter)

Option 2 Carbon sequestration in the soil from a reference value

$$SOC_{i,t} = SOC_{REF,i} \times f_{LU,i,t} \times f_{MG,i,t} \times f_{I,i,t}$$

Where:

$SOC_{t,i}$	=	The amount of carbon deposited in the soil when implementing the project in the sample unit i of the project site. (tonnes carbon per rai)
$SOC_{REF,i}$	=	Carbon stocks in natural reference soils (e.g., non-improved areas). does not deteriorate and native vegetation cover) according to climatic zones and soil types in sample unit i of the area (tonnes carbon per rai).
$F_{LU,i,t}$	=	Coefficient of changes in soil organic carbon accumulation by land use type When executing a project in sample unit i
$F_{MG,i,t}$	=	Coefficient of change in soil organic carbon accumulation according to soil management methods When executing a project in sample unit i
$F_{I,i,t}$	=	Coefficient of change in soil organic carbon accumulation according to the level of organic matter returned to the soil. When executing a project in sample unit i
i	=	Sample unit 1, 2, 3, ...
t	=	1, 2, 3, ... year since the project start date

Step 3 Calculation of change rate of organic carbon deposition in soil in case of project implementation It is the rate of change in the case of project implementation until the amount of organic carbon in the soil remains constant. Details of the assessment are shown below.

$$dSOC_{i,t} = \frac{(SOC_{i,t} - SOC_{i,0})}{20 \text{ years}}$$

Where:

- $dSOC_{i,t}$ = Change rate of soil organic carbon sequestration in sample unit i of the project area in year t (tonnes carbon per rai per year)
- $SOC_{i,t}$ = The amount of carbon stored in the soil When executing a project in the i instance unit of the project area (tonnes carbon per rai)
- $SOC_{i,0}$ = The amount of carbon deposited in the soil before the start of the project in the sample unit i of the project site. (tonnes carbon per rai)
- i = Sample unit 1, 2, 3, ...
- t = 1, 2, 3, ... year since the project start date

When considering the uncertainty, the uncertainty and inherent limits for the accuracy of the coefficient estimates used in this tool require that the rate of change in soil organic carbon sequestration is not greater than 0.8 tonnes carbon per hectare per year, or 0.128 tons of carbon per rai per year.

Therefore, if estimated $dSOC_{t,i} > 0.128$ ton carbon per rai a year, it is determined that $dSOC_{t,i} = 0.128$ ton carbon per rai a year.

Step 4 The change in soil organic carbon accumulation of the project area in year t was assessed as follows:

$$\Delta SOC_t = \sum_i^n A_i \times dSOC_{i,t} \times \frac{44}{12} \times 1 \text{ year}$$

Where:

- ΔSOC_t = Changes in soil organic carbon sequestration for all strata of the project area in year t (tCO₂e per year)
- A_i = Project area in sample unit i (rai)
- $dSOC_{i,t}$ = Change rate of soil organic carbon accumulation in sample unit i of the project area in year t (tonnes carbon per rai per year)
- i = Sample unit 1, 2, 3, ...
- 44/12 = Molar mass ratio of carbon dioxide to carbon

6. Parameterที่เกี่ยวข้อง

6.1 Parameter not required monitoring

Parameter	$SOC_{REF,i}$
Unit	tons of carbon per rai
Definition	The amount of carbon accumulated in the reference soil.
Source of information	Option 1 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use (ภาคผนวกที่ 2) Option 2 The values obtained from research are published in recognized academic papers and can be identified as appropriate for the project area. Option 3 Collecting samples from the project area to develop values as determined by the TGO
Remark	-

Parameter	$SOC_{sample,i,0}$
Unit	Grams of carbon per 100 g of soil (<2 mm soil particles)
Definition	The organic carbon content of soil samples collected from sample unit i and reported in units g carbon per 100 g of soil.
Source of information	Collect samples from the project area to analyze the amount of organic carbon in the soil in the laboratory to determine the amount of organic carbon deposition in the soil before starting the project ($SOC_{i,0}$)
Remark	-

Parameter	$BD_{sample,i,0}$
Unit	Grams per cubic centimeter
Definition	Bulk density of soil with <2 mm particle size per unit volume. Collected from sample unit i and assigned to report values by dry weight.
Source of information	Collect samples from the project area to analyze the bulk density of the soil in the laboratory to determine the amount

	of organic carbon deposition in the soil before starting the project ($SOC_{i,0}$)
Remark	-

Parameter	$Dep_{sample,i,0}$
Unit	centimeter
Definition	Soil depth collected from sample unit i
Source of information	Collect data from the project area to determine the amount of organic carbon deposition in the soil before starting the project ($SOC_{i,0}$)
Remark	-

Parameter	F_{LU}
Unit	-
Definition	Coefficient of change in soil organic carbon accumulation according to soil management methods
Source of information	Option 1 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use (ภาคผนวกที่ 2) Option 2 The values obtained from research are published in recognized academic papers and can be identified as appropriate for the project area. Option 3 Collecting samples from the project area to develop values as determined by the TGO
Remark	-

Parameter	F_{MG}
Unit	-
Definition	Coefficient of change in soil organic carbon accumulation according to soil management methods
Source of information	Option 1 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use (ภาคผนวกที่ 2)

	<p>Option 2 The values obtained from research are published in recognized academic papers and can be identified as appropriate for the project area.</p> <p>Option 3 Collecting samples from the project area to develop values as determined by the TGO</p>
Remark	-

Parameter	F_I
Unit	-
Definition	Coefficient of change in soil organic carbon accumulation according to the level of organic matter returned to the soil
Source of information	<p>Option 1 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use (ภาคผนวกที่ 2)</p> <p>Option 2 The values obtained from research are published in recognized academic papers and can be identified as appropriate for the project area.</p> <p>Option 3 Collecting samples from the project area to develop values as determined by the TGO</p>
Remark	-

Parameter	44/12
Unit	-
Details	Molar mass of carbon dioxide per carbon To convert units from tons of carbon dioxide to tons of carbon dioxide.
Source of information	IPCC Guidelines
Remark	-

6.2 Parameter required monitoring

Parameter	A_i
Unit	rai
Definition	Project area in model unit i
Source of information	<ul style="list-style-type: none"> - area exploration - use satellite/air photographs

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Frequency of monitoring	Follow-up assessment cycle for accreditation
Remark	-

Parameter	$SOC_{sample,i,t}$
Unit	gram of carbon per 100 g of soil (<2 mm soil particles)
Definition	The organic carbon content of soil samples collected from sample unit i and reported in units of grams of carbon per 100 grams of soil.
Source of information	Collect samples from the project area to analyze the amount of organic carbon in the soil in the laboratory and to determine the amount of organic carbon accumulation in the soil in the case of the project ($SOC_{i,t}$)
Frequency of monitoring	Follow-up assessment cycle for accreditation
Remark	-

Parameter	$BD_{sample,i,t}$
Unit	grams per cubic centimeter
Definition	Bulk density of soil with <2 mm particle size per unit volume. Collected from sample unit i and assigned to report values by dry weight.
Source of information	Collect samples from the project area to analyze soil bulk density in the laboratory. To determine the amount of organic carbon in the soil in the case of a project ($SOC_{i,t}$).
Frequency of monitoring	Follow-up assessment cycle for accreditation
Remark	-

Parameter	$Dep_{sample,i,t}$
Unit	centimeter
Definition	Soil depth collected from sample unit i
Source of information	Collect data from the project area To determine the amount of organic carbon in the soil in the case of a project ($SOC_{i,t}$)



Frequency of monitoring	Follow-up assessment cycle for accreditation
Remark	-

7. Reference

1. Clean Development Mechanism (CDM)
Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities (Version 01.1.0)
2. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use
3. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use

Annex

Annex 1 Relevant definitions

Soil disturbance	Human activities that result in the release of carbon stored in soil organic form into the atmosphere, such as tillage, digging, harrowing, trenching, and drainage
Soil carbon	Decomposition of organic matter accumulated in the soil in the form of organic carbon
Soil	<p>The natural celestial bodies that thinly cover the Earth's surface are formed as a result of the metamorphism or weathering of rocks and minerals. and organic matter mixed together with the following components:</p> <ul style="list-style-type: none"> - Mineral matter is the part of minerals within a rock that have weathered down into tiny pieces. by physical, chemical and biological methods - Organic matter is the part that is caused by decomposition or decomposition of the accumulated remains of plants and animals. - Water is water in solution. which are found in the channels between soil grains (aggregate) or soil particles (particles). - Air is a gas in the space between soil or soil particles. The most common gases found in soil are nitrogen, oxygen and carbon dioxide.
Organic soils	<p>Organic soil is soil that has various characteristics as specified by the FAO, which must have the characteristics in items 1 and 2 or items 1 and 3 as follows:</p> <p>(1) Have a thickness of 10 centimeters or more Soil thickness <20 cm. must contain organic carbon of 12% or more when soil mixing reaches a depth of 20 cm.</p> <p>(2) In case the soil has never been saturated with water for more than 2-3 days and has >20% by weight organic carbon (approximately 35% organic matter in the soil).</p> <p>(3) If the soil is saturated with water and</p> <ul style="list-style-type: none"> (i) have at least 12% by weight of soil organic carbon (contains soil organic matter, about 20%) if there is no clay or (ii) have at least 18% by weight of soil organic carbon (contains soil organic matter, about 30%) if it contains more than 60% clay minerals, or (iii) moderate soil organic carbon for clay minerals at moderate level.

	<p>Area data should be classified according to climatic zones i.e., temperate and humid tropics, and classified by soil fertility for temperate forest areas organic soil area information which may be compiled from the country's official statistical data or the organic soil area of each country reported by the FAO (http://faostat.fao.org/).</p> <p>Source: 2006 IPCC Guidelines (Volume 4 Chapter 3)</p>
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Annex 2 Land Management

Table 1 SOC classified based on climatic zones and soil types

TABLE 2.3 (UPDATED) DEFAULT REFERENCE CONDITION SOIL ORGANIC CARBON STOCKS (SOC _{REF}) FOR MINERAL SOILS (TONNES C HA ⁻¹ IN 0-30 CM DEPTH) ^{1,2}			
IPCC Climate Zone ⁵	IPCC soil class ⁶		
	High activity clay soils (HAC) ⁷	Low activity clay soils (LAC) ⁸	Sandy soils (SAN) ⁹
Polar Moist/Dry (Px - undiff) ¹³	59 ± 41% (24)	NA	27 ± 67% (18)
Boreal Moist/Dry (Bx - undiff) ¹³	63 ± 18% (35)	NA	10 ± 90% ⁴
Cool temperate dry (C2)	43 ± 8% (177)	33 ± 90% ³	13 ± 33% (10)
Cool temperate moist (C1)	81 ± 5% (334)	76 ± 51% (6)	51 ± 13% (126)
Warm temperate dry (W2)	24 ± 5% (781)	19 ± 16% (41)	10 ± 5% (338)
Warm temperate moist (W1)	64 ± 5% (489)	55 ± 8% (183)	36 ± 23% (39)
Tropical dry (T4)	21 ± 5% (554)	19 ± 10% (135)	9 ± 9% (164)
Tropical moist (T3)	40 ± 7% (226)	38 ± 5% (326)	27 ± 12% (76)
Tropical wet (T2)	60 ± 8% (137)	52 ± 6% (271)	46 ± 20% (43)
Tropical montane (T1)	51 ± 10% (114)	44 ± 11% (84)	52 ± 34% (11)
	Spodic soils (POD) ¹⁰	Volcanic soils (VOL) ¹¹	Wetland soils (WET) ¹²
Polar Moist/Dry (Px - undiff) ¹³	NO	NA	NA
Boreal Moist/Dry (Bx - undiff) ¹³	117 ± 90% ³	20 ± 90% ⁴	116 ± 65% (6)
Cool temperate dry (C2)	NO	20 ± 90% ⁴	87 ± 90% ³
Cool temperate moist (C1)	128 ± 14% (45)	136 ± 14% (28)	128 ± 13% (42)
Warm temperate dry (W2)	NO	84 ± 65% (10)	74 ± 17% (49)
Warm temperate moist (W1)	143 ± 30% (9)	138 ± 12% (42)	135 ± 28% (28)
Tropical dry (T4)	NA	50 ± 90% ⁴	22 ± 17% (32)
Tropical moist (T3)	NA	70 ± 90% ⁴	68 ± 17% (55)
Tropical wet (T2)	NA	77 ± 27% (14)	49 ± 19% (33)
Tropical montane (T1)	NA	96 ± 31% (10)	82 ± 50% (12)

Source 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories

Table 2 Agricultural area management

TABLE 5.5 (UPDATED)						
RELATIVE CARBON STOCK CHANGE FACTORS (FLU, FMG, AND FI) (OVER 20 YEARS) FOR MANAGEMENT ACTIVITIES ON CROPLAND						
Factor value type	Level	Temperature regime	Moisture regime ¹	IPCC defaults	Error ^{2,3}	Description
Land use ⁵ (F _{LU})	Long-term cultivated	Cool Temperate/ Boreal	Dry	0.77	±14%	Represents area that has been converted from native conditions and continuously managed for predominantly annual crops over 50 yrs. Land-use factor has been estimated under a baseline condition of full tillage and nominal ("medium") carbon input levels. Input and tillage factors are also applied to estimate carbon stock changes, which includes changes from full tillage and medium input.
			Moist	0.70	±12%	
		Warm Temperate	Dry	0.76	±12%	
			Moist	0.69	±16%	
		Tropical	Dry	0.92	±13%	
			Moist/Wet	0.83	±11%	
Land use ⁶ (F _{LU})	Paddy rice	All	Dry and Moist/Wet	1.35	±4%	Long-term (> 20 year) annual cropping of wetlands (paddy rice). Can include double-cropping with non-flooded crops. For paddy rice, tillage and input factors are not used.
Land use ⁵ (F _{LU})	Perennial/ Tree Crop	Temperate/ Boreal	Dry and Moist	0.72	±22%	Long-term perennial tree crops such as fruit and nut trees, coffee and cacao.
		Tropical	Dry and Moist/Wet	1.01	±25%	
Land use (F _{LU})	Set aside (< 20 yrs)	Temperate/ Boreal and Tropical	Dry	0.93	±11%	Represents temporary set aside of annually cropland (e.g., conservation reserves) or other idle cropland that has been revegetated with perennial grasses.
			Moist/Wet	0.82	±17%	
		Tropical montane ⁴⁴	n/a	0.88	±50%	
Tillage (F _{MO})	Full	All	Dry and Moist/Wet	1.00	n/a	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.
Tillage ⁷ (F _{MO})	Re-duced	Cool Temperate/ Boreal	Dry	0.98	±5%	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	1.04	±4%	
		Warm Temperate	Dry	0.99	±3%	
			Moist	1.05	±4%	
		Tropical	Dry	0.99	±7%	
			Moist/Wet	1.04	±7%	
Tillage ⁷ (F _{MO})	No-till	Cool Temperate/ Boreal	Dry	1.03	±4%	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.
			Moist	1.09	±4%	
		Warm Temperate	Dry	1.04	±3%	
			Moist	1.10	±4%	
		Tropical	Dry	1.04	±7%	
			Moist/Wet	1.10	±5%	

Table 2 Agricultural area management (continue)

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TABLE 5.5 (UPDATED) (CONTINUED)						
RELATIVE CARBON STOCK CHANGE FACTORS (F_{LU} , F_{MG} , AND F_I) (OVER 20 YEARS) FOR MANAGEMENT ACTIVITIES ON CROPLAND						
Factor value type	Level	Temperature regime	Moisture regime ¹	IPCC defaults	Error ^{2,3}	Description
Input (F_I)	Low	Tem-perate/ Boreal	Dry	0.95	±13%	Low residue return occurs when there is removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g., vegetables, tobacco, cotton), no mineral fertilization or N-fixing crops.
			Moist	0.92	±14%	
		Tropical	Dry	0.95	±13%	
			Moist/ Wet	0.92	±14%	
		Tropical montane ⁴	n/a	0.94	±50%	
Input (F_I)	Medium	All	Dry and Moist/ Wet	1.00	n/a	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 mineral fertilization or N-fixing crop in rotation.
Input (F_I)	High without manure	Tem-perate/ Boreal and Tropical	Dry	1.04	±13%	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	±10%	
		Tropical montane ⁴	n/a	1.08	±50%	
Input (F_I)	High – with manure	Tem-perate/ Boreal and Tropical	Dry	1.37	±12%	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	±13%	
		Tropical montane ⁴	n/a	1.41	±50%	

Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 5: Cropland



Document information

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01	--	1 March 2023	-