T-VER-P-TOOL-01-04

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

Version 01

องค์การบริหารจัดการก๊าซเรือนกระจก (องค์การมหาชน) (อบก.)

Thailand Greenhouse Gas Management Organization (Public Organization) (TGO)

1. Introduction

This document is a tool for estimating changes in soil organic carbon stock in forest project activities, which can be used to estimate carbon stock in both baseline and project scenarios.

2. Relevant Definitions

Details appear in Annex 1

3. Characteristics of Relevant Activities and Conditions

This tool is suitable for estimating changes in soil organic carbon stock in the baseline and project scenarios in the areas of land with the following characteristics:

Areas of land where this tool can be used are:

(1) those are not wetlands; or
(2) those are not organic soils as defined in 2006 IPCC Guidelines (Vol. 4 Chapter 3).
(3) they must not be areas with land management and organic materials loading listed in Annex 2, Tables 1 and 2, especially activities with high organic carbon accumulation in soils such as tilling and/or adding organic material.

1) Forest project activities must meet the following conditions:
(1) The litter must be left in the area and not removed in the project activities; and
(2) soil disturbances in accordance with project activities (if any)
a. Consistent with activities that can appropriately conserve soil, such as land contour
b. Limit soil disturbances from pre-planting site preparation and must not disturb the soil repeatedly at least 20 years

4. Hypothesis

This tool provides hypotheses to estimate changes in soil organic carbon stocks as follows:

1) Area reparation and tree planting are carried out within 1 year.
2) Project operations increase the soil organic carbon stock in the area, compared with soil organic carbon stocks before the project until the soil organic carbon stock was stable (steady-state).

3) Increase in soil organic carbon stock when the project has been maintained at constant rate over a period of 20 years from the year of planting.

5. Calculation of carbon stock in soil

Project areas are classified by landscape (stratification) as per following conditions :

1) Climatic zones and soil types (Appendix 2, Table 3)
2) Land undergone land management for agriculture prior to project initiation as mentioned in Annex 2, Table 4.
3) Land undergone area preparation for grassland prior to project initiation as mentioned in Annex 2, Table 4.

Changes in soil organic carbon stock collected from project implementation can be estimated through the following estimation methods:

Step 1 Estimation of soil organic carbon stock **prior to project activities It can be estimated as the following equation.**

Option 1 Soil organic carbon stocks of samples collected from the sample plots

Soil organic carbon stocks collected from sampling collection and analysis of carbon stock in soil and soil density from project area . The estimation details are shown in the following equation.

$$SOC_{0,sp,i} = SOC_{sample,sp,i} \; x \; BD_{sample,sp,i} \; x \; Dep_{sample,sp,i} \; x \; 0.16$$

Where:

$SOC_{0,sp,i}$	=	Soil organic carbon stock prior to the project start in the stratum i of sample plot sp in the project site (ton of carbon per rai)
$SOC_{sample,sp,i}$	=	Soil organic carbon stock of samples collected from sample plots sp in the stratum i (unit lab values for soil particles < 2 mm) (g carbon per 100 g soil)
$BD_{sample,sp,i}$	=	Soil density with particle size < 2 mm in sp sample plots in the stratum I (Laboratory value in Unit grams per cubic centimeter)
$Dep_{sample,sp,i}$	=	Depth of soil collected from sample plot sp in the stratum I (cm) (not less than 30 cm)
sp	=	Sample plot 1, 2, 3, ...P_i in the stratum i
i	=	Stratum1, 2, 3, ...

0.16 = Unit conversion cost (1 gram = 10^{-6} tons and 1 Rai = 1.6 x 107 square centimeters)

$$SOC_{0,i} = \frac{\sum_{sp=1}^{Pi} (SOC_{0,sp,i})}{P_i}$$

Where:

$SOC_{0,i}$ = Soil organic carbon stock prior to the start of the project in stratum i of the project site (Tons of carbon per rai)

$SOC_{0,sp,i}$ = Soil organic carbon stock prior to the project start in the stratum i in sample plot sp of the project site (ton of carbon per Rai).

P_i = Number of sample plots in the stratum i

sp = Sample plot 1, 2, 3, ...P_i in the stratum i

i = Stratum 1, 2, 3, ...

Option 2 The amount of carbon stored in the reference soil

$$SOC_{0,i} = SOC_{REF,0,i} \; x \; f_{LU,0,i} \; x \; f_{MG,0,i} \; x \; f_{I,0,i}$$

Where:

$SOC_{0,i}$ = Soil organic carbon stock prior to the start of the project in the stratum i of the project site (Tons of carbon per ฬai)

$SOC_{REF,i}$ = Soil organic carbon stock in the reference soil that is natural (e.g. unimproved not deteriorating and cover with indigenous flora) by climatic zone and soil type in landscape i (tons of carbon per rai)

$f_{LU,0,i}$ = Change coefficients for soil organic carbon stock by land use type before starting the project in stratum i

$f_{MG,0,i}$ = Change coefficient of soil organic carbon stock according to soil management method before starting the project in landscape i

$f_{I,0,i}$ = Change coefficient of soil organic carbon stock by level of organic matter returning to the soil before starting the project in stratum i

i = Stratum 1, 2, 3, ...

Step 2 Estimation of loss of soil organic carbon stock from soil disturbance in the project site in larger area than baseline value (if any) or more than 10% of the stratum, such carbon loss from soil disturbance can be calculated as follow:

$$SOC_{LOSS,i} = SOC_{0,i}\ x\ 0.1$$

Other stratum with soil disturbances not more than 10% of the stratum can be determined as no loss of soil organic carbon stock or $SOC_{LOSS,i} = 0$

Where:

$SOC_{LOSS,i}$	=	Loss of soil organic carbon stock from soil disturbance resulting from project activities in the i tier of the project site. (Tons of carbon per rai)
0.1	=	The approximate proportion of SOC lost by soil disturbance
i	=	Stratum 1, 2, 3, ...

Step 3 Estimation of soil organic carbon stock during project operation can be estimated as the following equation.

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

Where:

$SOC_{t,i}$	=	Soil organic carbon stock when implementing the project in the stratum i of the project site (ton carbon per rai)
$SOC_{REF,i}$	=	Soil organic carbon stock in the reference soil that is natural (e.g. unimproved not deteriorating and cover with indigenous flora) by climatic zone and soil type in the terrain layer i (tons of carbon per rai)
$f_{LU,t,i}$	=	Change coefficients for soil organic carbon stock by land use type when executing the project in stratum i (value determined is 1) referred to *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories: Volume 4*
$f_{MG,t,i}$	=	Change coefficients for soil organic carbon stock according to soil management method when executing the project in stratum i (value determined is 1) referred to *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories: Volume 4*

$f_{I,t,i}$ = Change coefficients for soil organic carbon stock according to the level of reclaimed organic matter. when executing the project in stratum i (value determined is 1) referred to *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories: Volume 4*

i = Stratum 1, 2, 3, ...

Step 4 Estimation of the rate of change in soil organic carbon stock during project operation uses the change rate during project operation until the soil organic carbon stock is stable. Details of the estimation are shown as follows.

Soil was prepared and disturbed in previous years ($t < t_{PREP}$)

$$dSOC_{t,i} = 0 \text{ for } t < t_{PREP,i}$$

Year in which the soil in project site is prepared and disturbed ($t = t_{PREP}$)

$$dSOC_{t,i} = -\frac{SOC_{LOSS,i}}{1\ year} \text{ for } t = t_{PREP,i}$$

At least for the period 20 years after project operations taking place with no soil disturbance or preparation ($t_{PREP} < t \leq t_{PREP}+20$)

$$dSOC_{t,i} = \frac{SOC_{t,i} - (SOC_{0,i} - SOC_{LOSS,i})}{20\ years} \text{ for } t_{PREP,i} < t \leq t_{PREP,i} + 20$$

When:

$dSOC_{t,i}$ = Rate of change in soil organic carbon stock in the stratum of the project site in year t (tons of carbon per rai per year).

$t_{PREP,i}$ = Year of the first soil disturbance in the stratum i of the project site.

$SOC_{LOSS,i}$ = Soil organic carbon loss from soil disturbance resulting from project activities in stratum i of the project site (Tons of carbon per rai)

$SOC_{t,i}$ = Soil organic carbon stock when the project is carried out in the i layer of the project area (tons of carbon per Rai) or equal to $SOC_{REF,i}$ for forestry activities

$SOC_{0,i}$ = Soil organic carbon stock before the start of the project in the i landscape of the project site (tons of carbon per rai)

$SOC_{REF,i}$ = Soil organic carbon stock in natural reference soils (e.g. unimproved areas not deteriorating and cover with indigenous flora) in climatic zone and soil type in the i landscape (tons of carbon per rai)

i = Stratum 1, 2, 3, ...

t = 1, 2, 3, ... year from the project initiation

Considering the uncertainty and inherent limitation of the coefficient estimation accuracy used in this tool, they determine the rate of change in soil carbon stock which is valued less than 0.8 tons of carbon per rai or 0.128 tons of carbon per rai per year.

So, if estimated $dSOC_{t,i}$ >0.128 tons of carbon per rai in a yar, the project must use $dSOC_{t,i}$ =0.128 tons of carbon per rai per year.

Step 5 Change in soil organic carbon stock for all stratum of the project in year t can be estimated as follows:

$$\Delta SOC_{AL,t} = \sum_i^n A_i \, x \, dSOC_{t,i} \, x \, \frac{44}{12} \, x \, 1 \, year$$

Where:

$\Delta SOC_{AL,t}$ = Changes in soil organic carbon stock for all stratum of the project site in year t (tons of carbon dioxide equivalent per year).

A_i = Project area in stratum i (rai)

$dSOC_{t,i}$ = Rate of change in soil organic carbon stock in the stratum i of the project site in year t (tons of carbon per rai per year).

i = Stratum 1, 2, 3, ...

44/12 = Carbon dioxide to carbon molecular mass ratio

6. Relevant Parameters

6.1 Parameter not required monitoring

Parameter	$SOC_{REF,i}$
Unit	tons of carbon per rai

Definition	Soil organic carbon stock 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 Option 2 as specified by the TAO in the reference manual for the development of the Voluntary Greenhouse Gas Reduction Project according to the standards of Thailand Forestry and Agriculture Option 3 Values derived from research published in academic papers that are recognized and identifiable as appropriate for the project area.
Remark	-

Parameter	F_{LU}
Unit	-
Definition	Coefficient of soil organic carbon stock according to land use
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 (except for coefficients for activities with high soil carbon accumulation) Option 2 Values derived from research published in academic papers that are recognized and identifiable as appropriate for the project area. Option 3 Collect samples from the project area to develop the values as specified by the TGO.
Remark	-

Parameter	F_{MG}
Unit	-
Definition	Coefficient of change soil organic carbon stock according to soil management method
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 (except for coefficients for activities with high soil carbon accumulation)

	Option 2 Values derived from research published in academic papers that are recognized and identifiable as appropriate for the project area. Option 3 Collect samples from the project area to develop the values as specified by the TGO
Remark	-

Parameter	F_I
Unit	-
Definition	Coefficient of change soil organic carbon stock according to the level of reclaimed organic matter
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 (excluding coefficients for activities with high soil carbon accumulation) Option 2 Values derived from research published in academic papers that are recognized and identifiable as appropriate for the project area. Option 3 Collect samples from the project area to develop the values as specified by the TGO
Remark	-

Parameter	44/12
Unit	-
รายละเอียด	molecular mass of carbon dioxide to carbon to convert unit from tons of carbon to tons of carbon dioxide
Source of Information	IPCC Guideline
Remark	-

6.2 Parameter required monitoring

Parameter	A
Unit	Rai
Definition	All project areas

Source of Information	- Land exploration - Use satellite/aerial imagery.
Frequency of monitoring	Following a cycle of follow-up assessments for certification
Remark	-

Parameter	$SOC_{sample,sp,i}$
Unit	gram carbon per 100-gram soil (soil particles < 2 mm)
Definition	Samples of soil organic carbon stock collected and reported in gram unit of carbon per 100 g of soil
Source of Information	Samples were collected from the project area and analyzed for soil carbon content in the laboratory to determine the soil organic carbon stock prior to project initiation ($SOC_{0,i}$)
Frequency of monitoring	Following a cycle of follow-up assessments for certification
Remark	-

Parameter	$BD_{sample,sp,i}$
Unit	grams per cubic centimeter
Definition	Soil density with particle size < 2 mm per unit volume. and required to report the values by dry weight
Source of Information	Samples were collected from the project site and analyzed for soil density in the laboratory to determine the amount of soil carbon deposition prior to the start of the project (SOC0,i)
Frequency of monitoring	Following a cycle of follow-up assessments for certification
Remark	-

Parameter	$Dep_{sample,sp,i}$
Unit	centimeter
Definition	Depth of soil
Source of Information	Collect data from the project area to determine the soil organic carbon stock prior to the start of the project (SOC0,i)

Frequency of monitoring	Following a cycle of follow-up assessments for certification
Remark	-

7. References

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

Annex

Annex 1 Relevant Definitions

Soil disturbance	Human activities that result in the release of soil organic carbon stock to the atmosphere, such as tilling, digging, raking, trenching, drainage, etc.
Soil carbon	Decomposition of organic matter that accumulates in soil to form organic carbon.
Soil	Natural objects that cover the earth's surface are thin, formed as a result of the transformation or decay of rocks and minerals and organic matter mixed together with the following components Inorganic matter (mineral matter) is the portion of minerals within a rock that has been eroded into tiny pieces. by physical, chemical and biological methods Organic matter is the decaying, decaying or decomposing part of plant and animal remains that are deposited together. Water is water in solution which is found in the gap between the soil or soil particles Air is a gas that lies in the space between soil grains or soil particles. The most common gases found in soil are nitrogen, oxygen, and carbon dioxide.
Organic soils	Organic soil is Soil with various characteristics as specified by FAO, which must have the characteristics in items 1 and 2 or items 1 and 3 as follows: (1) having a thickness of 10 cm or more The soil layer is <20 cm thick and must contain at least 12% organic carbon in the soil when the soil is mixed to a depth of 20 cm. (2) In case the soil has not been saturated with water for more than 2-3 days and has soil organic carbon >20% by weight (approximately 35% soil organic matter). (3) In case the soil is saturated with water and (i) at least 12% by weight of soil organic carbon (containing soil organic matter about 20%) if there is no clay ore, or (ii) at least 18% by weight of soil organic carbon (containing soil organic matter about 30%), if it contains 60% or more of clay minerals, or (iii) Carbon containment in soil at median level and at median level for clay minerals Area data should be classified by climatic zone, namely temperate and tropical. and classified according to soil fertility for temperate forest areas. Organic land area

	data may be compiled from official country statistics. or the organic land area of each country as reported by the FAO (http://faostat.fao.org/) Source: 2006 IPCC Guidelines (Vol. 4 Chapter 3)
Wetlands	The Ramsar Convention or the Convention on Wetlands (Article 1.1 and Article 2.1) has defined "Wetlands" as lowlands, lowlands, wet areas, swamps, bodies of water, both natural and man-made. Either with waterlogging or Floods are permanent and temporary. both as a source of still and running water Both freshwater, brackish and saltwater, including the coast and inland areas where when the tide is the lowest with a depth of not more than 6 m.

Annex 2 Land Management

Table 1 Land management area

Table 1: Baseline cropland management practices under which the tool is not applicable

Temperature / Moisture Regime	Land use	Management	Inputs
Boreal	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure High with manure
Temperate, cold, dry	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	Medium High without manure
Temperate, cold, moist	Long-term cultivated cropland	Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure High with manure
Temperate, warm, dry	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	Medium High without manure
Temperate, warm, moist	Long-term cultivated cropland	Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure High with manure
Tropical, dry	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	Medium High without manure High with manure
		No-till	All cases
Tropical, moist	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure High with manure

Table 1 Land Management Area (cont.)

Temperature / Moisture Regime	Land use	Management	Inputs
		No-till	High without manure High with manure
Tropical, montane	Long-term cultivated cropland	No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure High with manure
		No-till	Medium High without manure High with manure
Tropical, wet	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure High with manure
		No-till	High without manure High with manure

Table 2 Land containing the following organic materials

Table 2: Baseline grassland management practices under which the tool is not applicable

Temperature / Moisture Regime	Management	Inputs
Boreal	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, dry	Improved	All
	Non-degraded	All
Tropical, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, montane	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, wet	Improved	All
	Non-degraded	High
	Moderately degraded	High

Table 3_ SOC classified by climate zone and soil type

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 4 Agricultural Land Management

TABLE 5.5 (UPDATED)
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
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_{MG})	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_{MG})	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_{MG})	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 4 Agricultural Land Management (cont.)

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)	Mediu m	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: Clopland

Document information

Version	Amendment	Entry into force	Description
01	--	1 March 2023	-