Grow Asia Counter
Methodology

Contents

Glossary

Carbon dioxide equivalent/CO_2e – a term used to present the emissions of different greenhouse gases in a common unit. CO_2e is calculated for any given greenhouse gas based on its global warming potential.

CH_4 – methane, a greenhouse gas.

CO_2 – carbon dioxide, a greenhouse gas.

Emission factor – Net emissions or removals of greenhouse gases per unit of that activity, for example per liter of petroleum used.

Global warming potential/GWP – a measure of how much energy the emissions of 1 unit (e.g., 1 tonne) of gas will absorb over a given period of time (usually 100 years) in comparison to the emissions of the same quantity (1 tonne) of carbon dioxide[1].

IPCC guidelines –2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use

N_2O – Nitrous oxide, a greenhouse gas

Scenario 1 – Agricultural management scenario prior to any intervention/changes in practices

Scenario 2 - Agricultural management scenario after any intervention/changes in practices

Tier – Refers to the level of specificity and complexity of the IPCC Guideline data methodologies used. Tier 1 usually refers to simple methods and international default data used; Tier 2 refers to country-specific data generally more complex than Tier 1; and Tier 3 refers to highly complex, country-specific methods and data used, frequently through models developed.

Tonnes (t) – metric ton; equal to 1 kilogram

[1] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Introduction

This document articulates the methods and data inputs used to estimate emissions in the Grow Asia Counter. The methods are broken down by the following categories:

1) Tillage and Soil Management
2) Nutrient Management
3) Liming
4) Agrochemical Use
5) Fossil Fuel Use
6) Agroforestry Practices
7) Rice Irrigation

1. Tillage and Soil Management

Emissions from soil management reflect the different stable carbon stocks in soils before and after changes in management practices (Scenarios 1 and 2), calculated according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use[2] (hereafter referred to as IPCC guidelines). To derive estimates for Scenario 1 practices, methodologies in the Counter assume soil management practices have been constant for 10-20 years and therefore have stable soil carbon stocks (i.e., no fluxes in emissions). IPCC guidelines assume that it takes 20 years to transition from one stable stock to the other, and thus to derive annual emissions from changes in management practices in Scenario 2, the change in carbon stocks are divided by 20. Values correspond to appropriate values from Table 1. below (Adapted from IPCC guidelines). Calculation methods are only applicable for cultivation on mineral soils.

Emissions from soil management estimated as:

$$E_{SM_1} = 0$$

and

$$E_{SM_2} = \frac{(Area * CroplandSOC_{ref} * F_{LU} * F_{MG_1} * F_{IN_1}) - (Area * CroplandSOC_{ref} * F_{LU} * F_{MG_2} * F_{IN_2})}{20} * \frac{44}{12}$$

Where:

E_{SM_1} = Emissions from soil management in Scenario 1, t CO_2e yr^{-1}

E_{SM_2} = Emissions from soil management in Scenario 2, t CO_2e yr^{-1}

$\frac{44}{12}$ = the conversion factor from carbon to carbon dioxide (CO_2). It is the ratio of the molecular weight of carbon dioxide to the molecular weight of carbon.

$CroplandSOC_{ref}$ = values for soil organic carbon, t C ha^{-1}. Default values from the Harmonized World Soil Database[3] based on geographic location selected are given in Annex 1.

F_{LU} = Land Use Factor, based on IPCC guidelines. Table 1 shows which values correspond to which climate zones. For corn, potatoes, vegetables/horticulture, and upland rice, Annex 1 lists appropriate values for each geography based on climate zone in the column “FLU Long-term cultivated.” For coffee, tea, and cacao, the value will always be 1. For paddy rice, the value will always be 1.10.

[2] http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html
[3] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/

F_{MG} = Management Factor Type for scenarios 1 and 2 (F_{MG_1} and F_{MG_2}), based on IPCC guidelines. Table 1 shows what values correspond to climate zones and Annex 1 lists appropriate values for each geography based on climate zone. The option selected for tillage will correspond to which F_{MG} value is used:

- No Tillage = F_{MG} No tillage
- Minimal/shallow tillage = F_{MG} Reduced tillage
- Full tillage = F_{MG} Full tillage

For coffee, tea, and cacao, F_{MG} will always be 1, as there is no tillage on for perennial plants.

F_{IN} = Input Factor Type for scenarios 1 and 2 (F_{IN_1} and F_{IN_2}) based on IPCC Guidelines. Table 1 shows what values correspond to climate zones and Annex 1 lists appropriate values for each geography based on climate zone.

For **corn, potatoes, vegetables/horticulture, and upland rice**, the final F_{IN} values depend on the user's inputs on their application of synthetic fertilizer management, animal manure and/or additional crop management based on the following criteria:

- $\boldsymbol{F_{IN}}$ **low** when there is burning of residues, no synthetic fertilizer application, no manure application, and no additional crop management practices (no cover crop, green manure, no improved fallow, no nitrogen fixing crops, nor crop rotation).

- $\boldsymbol{F_{IN}}$ **medium** when

  - *Synthetic fertilizers and/or nitrogen fixing crops are applied, animal manure is not applied, when crop residues are burned, and there are no additional crop management practices (no cover crop, green manure, no improved fallow, no nitrogen fixing crops, nor crop rotation), or*

  - *Synthetic fertilizers and/or nitrogen fixing crops may or may not be applied, crop residues are not burned, animal manure is not applied, there are no additional crop management practices (no cover crop, no green manure, no improved fallow, nor crop rotation), or*

  - *Synthetic fertilizers and/or nitrogen fixing crops may or may not be applied, crop residues are burned, animal manure is not applied, there are no additional crop management practices (no cover crop, no green manure, no improved fallow, nor crop rotation), or*

  - *When neither synthetic fertilizers nor nitrogen fixing crops are applied, crop residues are not burned, animal manure is not applied, and at least* *one of the additional crop management practices are applied (cover crop, green manure, improved fallow, or crop rotation).*

- F_{IN} **high without manure** when either synthetic fertilizer and/or nitrogen fixing crops are applied, crop residues are not burned, animal manure is not applied, and at least one of the additional crop management practices are applied (cover crop, green manure, improved fallow, or crop rotation).

- F_{IN} **high with manure** when animal manure is applied.

For **coffee, tea, cacao**, **and paddy rice**, the F_{IN} criteria are different since the only relevant variable will be synthetic fertilizer and animal manure inputs.

- F_{IN} **low –** not applicable

- F_{IN} **medium** when neither synthetic fertilizer nor animal fertilizer is applied.

- F_{IN} **high without manure** when synthetic fertilizer is applied, and animal fertilizer is not applied.

- F_{IN} **high with manure** when animal manure is applied, and synthetic fertilizer may or may not be applied.

Table 1 Soil carbon 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})	Paddy rice	All	Dry and Moist/ Wet	1.10	Long-term (> 20 year) annual cropping of wetlands (paddy rice). Can include double-cropping with nonflooded crops. For paddy rice, tillage and input factors are not used.
Land use (f_{LU})	Perennial /Tree Crop	All	Dry and Moist/ Wet	1	Long-term perennial tree crops such as fruit and nut trees, coffee and cacao.
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 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.

2. Nutrient Management

Synthetic and/or Animal Manure Fertilizer

Fertilizer management impacts are estimated as the difference in emissions between the two management approaches (Scenarios 1 and 2). They are estimated using an IPCC Tier 1 approach based on Section 11.2 of the IPCC Guidelines. Emissions include direct emissions from application[4], indirect emissions from application, emissions from atmospheric deposition of volatilized N, and emissions from initial fertilizer production. While the equation is the same, emissions from synthetic fertilizer and animal manure use are presented separately.

Emissions from fertilizer management are estimated as:

$$E_{SF} = \frac{A \times Fert \times \%N \times (EF_{app} + EF_{prod})}{1000}$$

And

$$E_{AM} = \frac{A \times Fert \times \%N \times (EF_{app} + EF_{prod})}{1000}$$

Where:

E_{SF} = Emissions from synthetic fertilizer use, t CO_2e yr^{-1}

E_{AM} = Emissions from animal manure use, t CO_2e yr^{-1}

A = Area, hectares, ha

Fert = Amount of fertilizer applied, kg ha^{-1} yr^{-1}. Values use from Table 2.

%N = the percentage of the fertilizer type made up of nitrogen, %. Values can be found in Table 2.

EF_{app} = emission factor for the application of the fertilizer type, kg CO_2e / kg N. Values can be found in Table 2.

EF_{prod} = emission factor for the production of the fertilizer type, kg CO_2e / kg N. Values can be found in Table 2.

[4] CO_2 emissions from fossil fuel use associated with machinery are covered separately under 'Fossil Fuel Use' section

Table 2 %$N_{fertilizer\ type}$ and EF_{prod} CO_2 (Derived from The Agronomy Guide 2015-2016. Penn State College of Agricultural Sciences[5] and Echochem Solutions[6] for manure and poultry litter) and EF_{app} CO_2 (calculated based on IPCC Tier 1 Approach – see Box 1)

Fertilizer	%$N_{fertilizer\ type}$	EF_{prod} (kg CO_2-e/kg N)	EF_{app} (kg CO_2-e/kg N)
Urea	46	1.54	6.205
Ammonia	82	1.35	6.205
Ammonium sulphate	21	0.35	6.205
Mono-ammonium phosphate (MAP)	11	0.18	6.205
Di-ammonium phosphate (DAP)	18	0.3	6.205
Ammonium nitrate	33.5	0.55	6.205
Calcium ammonium nitrate	27	0.43	6.205
Manure, dry (treated)	0.0195	0	6.673
Manure, wet (fresh)	0.7	0	6.673
Poultry litter, dry (treated)	4.5	0	6.673
Poultry litter, wet (fresh)	0.9	0	6.673

5 http://extension.psu.edu/agronomy-guide/cm/sec2/sec28
6 http://www.ecochem.com/t_manure_fert.html

Box 1 Fertilizer application emissions were estimated using an IPCC Tier 1 approach based on Section 11.2 of the 2006 Guidelines on Agriculture, Forestry and Other Land Use (AFOLU)

*Direct emissions (t CO_2e) = 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 for <u>synthetic fertilizer</u> = annual application kg N yr^{-1} 0.1 * 0.01*1.5714 * 298*

Volatilization and deposition emissions for <u>organic fertilizer</u> = annual application kg N yr^{-1} 0.2 * 0.01*1.5714 * 298*

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
- 0.0075 is the emission factor for leaching/runoff[1]
- 0.3 is the fraction of N losses by leaching/runoff for regions where runoff exceeds the soil water holding capacity
- 0.1 is the default fraction of synthetic fertilizer that volatilizes[1] and 0.2 is the default fraction of organic fertilizer that volatizes[1]

Results from the equations above were combined to derive a fertilizer application emission factor for both synthetic and organic fertilizer.

Crop Residue Decomposition and Burning

The emission impact of changes in crop residue decomposition and crop residue and rice straw burning are estimated as the difference between crop residue amount in Scenarios 1 and 2 (before and after changes in agricultural practices). Estimates combine factors from the IPCC guidelines, Table 11.2 and emission factors published by Satyendra et al. (2013)[7] with the amount of crop residue and rice straw per crop, for which default values are given. For coffee, cacao, and tea, these categories are excluded as the crops are perennial and, therefore, a relatively minimal amount of their residue is burned or decomposes annually.

[7] http://www.isca.in/EARTH_SCI/Archive/v1/i1/4.ISCA-IRJES-2013-005.pdf

Emissions from crop residue decomposition are estimated as:

If Crop Residue Burning is selected, then emissions from crop residue decomposition = **0**.

If Crop Residue Burning is not selected, then:

$$E_{RD} = \frac{(A \times Resid \times N_{AG} + Resid \times R_{BG} \times N_{BG}) \times 5.736}{1000}$$

Where:

E_{RD} = Emissions from crop residue decomposition, t CO_2e yr^{-1}

A = Area, ha

$Resid$ = Amount of crop residue, kg ha^{-1} yr^{-1}

N_{AG} = Nitrogen content of aboveground residues, kg N (kg d.m.)$^{-1}$. Values can be found in Table 5.

R_{BG} = Ratio of belowground residue to aboveground biomass. Values can be found in Table 5.

N_{BG} = Nitrogen content of belowground residues, kg N (kg d.m.)$^{-1}$. Values can be found in Table 5.

Note that crop residues produce nitrous oxide emissions through direct emissions and leaching/run off but not through volatilization[8] (cf IPCC 2006).

Emissions from crop residue burning and rice straw burning are estimated as:

$$E_{RB} = A \times Resid \times EF_{burn}$$

Where:

E_{RB} = Emissions from crop residue burning, t CO_2e yr^{-1}

A = Area, ha

$Resid$ = Amount of crop residue, kg ha^{-1} yr^{-1}

EF_{burn} = Emission factor for burning crop residue, kg/kg dry matter burned. For rice straw, EF_{burn} is 1.5. For all other crop residue, EF_{burn} is 1.6. See Box 2 for more details on how these value were derived.

[8] 5.736 = (Direct + Leaching) = (0.01 * 1.5714 *298) + (0.3 * 0.0075 * 1.5714 * 298)

Box 2 Development of Emission Factors for Crops based on Satyendra et al. (2013)

Table 4 Values reported in Satyendra et al. (2013)

GHG	Emission Factor for Open Burning of Crop Residue (kg/kg d.m. burned)	Emission Factor for Open Burning of Rice Straw (kg/kg d.m. burned)
CO_2	1.515	1.46
CH_4	0.0027	0.0012
N_2O	0.00007	0.00007

d.m. = dry matter

Global warming potential (GWP) values for the three GHGs (for the 100-year time horizon) were applied to convert the Satyendra et al. (2013) EFs into a single emission factor (kg CO_2-e/kg d.m. burned)

Table 3 Final EFs for Crop Residue Burning

GHG	GWP (100 yr)	Emission Factor for Open Burning of Crop Residue (kg/kg d.m. burned) as CO_2e	Final Emission Factor for Open Burning of Crop Residue (kg CO_2e/kg d.m. burned)	Emission Factor for Open Burning of Rice Straw (kg/kg d.m. burned) as CO_2e	Final Emission Factor for Open Burning of Rice Straw (kg CO_2e/kg d.m. burned)
CO_2	1	1.515	1.6	1.46	1.5
CH_4	25	0.0675		0.03	
N_2O	298	0.02086		0.021	

Table 5 Default data for Crop Residue Amount (based on Koopmans and Koppejan 1998 and N Content values adapted from Table 11.2 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories)[9]

Crop	Residue amount (kg/ha)	Residue-to-product ratio (RPR)	Moisture content	Final Default Crop Residue Amount (kg/ha)	N_{AG} N content of above ground residues	R_{BG} Ratio of below ground residues to above ground biomass	N_{BG} N content of BG residues
Corn		2	15%	**=Yield (kg/ha)** *RPR*%(1-moisture content)	**0.006**	**0.22**	**0.007**
Potatoes		0.3[10]	15 %	**=Yield (kg/ha)** *RPR*%(1-moisture content)	**0.019**	**0.20**	**0.014**
Vegetables/ horticulture		1.53[11]	15%	**=Yield (kg/ha)** *RPR*%(1-moisture content)	**0.008[#]**	**0.19[#]**	**0.008[#]**
Rice		1.757	12.7%	**=Yield (kg/ha)** *RPR*%(1-moisture content)	**0.007**	**0.16**	**-**

[9] Koopmans, A. and Koppejan J. (1998) AGRICULTURAL AND FOREST RESIDUES - GENERATION, UTILIZATION AND AVAILABILITY. FAO. Paper presented at the Regional Consultation on Modern Applications of Biomass Energy, 6-10 January 1997, Kuala Lumpur, Malaysia. http://www.fao.org/docrep/006/AD576E/ad576e00.pdf

[10] No value available for potato, so average RPR for cassava applied

[11] Number reflects Koopmans, A. and Koppejan J. (1998) average values contained in Annex 1 for cassava stalks, groundnut husks/shells, groundnut straw, soyabean straw, sugarcane bagasse, sugar cane tops/leaves, jute stalk, cotton stock, pigeon pea, and cow pea

Urea Hydrolysis

If the user selects urea as the fertilizer applied, then an additional emission must be calculated.

<u>Emissions from urea hydrolysis are estimated as:</u>

$$E_{UH} = \frac{A \times UApp \times EF_{UH} \times \frac{44}{12}}{1000}$$

Where:

E_{UH} = Emissions from urea hydrolysis, t CO_2e yr^{-1}

A = Area, ha

$UApp$ = Amount of urea applied, kg ha^{-1} yr^{-1}

EF_{UH} = Emission factor from urea hydrolysis, kg ha^{-1} yr^{-1}. The emission factor is 0.20 and comes from the IPCC guidelines, Section 11.4.

$\frac{44}{12}$ = the conversion factor from carbon to carbon dioxide (CO_2). It is the ratio of the molecular weight of carbon dioxide to the molecular weight of carbon.

3. Liming

The emissions from liming depend on whether lime or dolomite are applied.

Emissions from liming are estimated as:

$$E_L = \frac{A \times LApp \times EF_{liming} \times \frac{44}{12}}{1000}$$

Where:

E_L = Emissions from liming, t CO_2e yr^{-1}

A = Area, ha

$LApp$ = Amount of lime or dolomite applied, kg ha^{-1} yr^{-1}.

EF_{liming}= The emission factor for liming, t C. For lime, this value is 0.12. For dolomite, this value is 0.13. These values are derived from the IPCC guidelines, Section 11.3.

$\frac{44}{12}$ = the conversion factor from carbon to carbon dioxide (CO_2). It is the ratio of the molecular weight of carbon dioxide to the molecular weight of carbon.

4. Pesticide and Herbicide Use

The emissions impact from changing the application of pesticides and herbicides reflect the difference in the amount applied in Scenarios 1 and 2. Emissions from the use of pesticides and herbicides are based on the Bellarby et al. (2008)[12] publication that estimated that the application of agrochemicals, including pesticides and herbicides, results in GHG emissions from fossil fuel and energy use in farm operations and production of chemicals for agriculture to range of 180-3700 kg CO_2-eq km^2. The mean value for this range (1,940 kg CO_2e km^2) is used. This is equivalent to an emissions value for pesticide and herbicide use of 19.4 kg CO_2/ha.

Emissions from agrochemical use are estimated as:

$$E_{PH} = \frac{A \times PH_{App} \times EF_{PH}}{1000}$$

Where:

E_{PH} = Emissions from pesticide and herbicide use, t CO_2e yr^{-1}

A = Area, ha

PH_{App} = Amount of pesticides and herbicides applied, kg ha^{-1} yr^{-1}.

EF_{PH} = Emission factor associated with pesticide and herbicide use according to Bellarby et al. (2008)[13], kg CO_2 ha^{-1}. This value is 19.4.

[12] Bellarby, J., Foereid, B., Hastings, A., and Smith, P. (2008). Cool Farming: Climate impacts of agriculture and mitigation potential. Greenpeace. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&sqi=2&ved=0ahUKEwjPnOHS2YLOAhUI_IMKHXZcB1MQFggcMAA&url=https%3A%2F%2Fwww.organicconsumers.org%2Fsites%2Fdefault%2Ffiles%2Fcool-farming-full-report.pdf&usg=AFQjCNHFVVfb02FtSeGG97uMTjOVNND6Rw&sig2=Pfw6tb4RTI6NyHQ3OU0cpQ&bvm=bv.127521224,d.amc

[13] Ibid.

5. Fossil Fuel Use

The emissions impact from changes in fossil fuel use are estimated as the difference between emissions before and after the intervention (Scenarios 1 and 2). There are three categories for which fossil fuel emissions occur (transportation, irrigation, and other) that users may enter information on volume used before/and after intervention. The total emissions from fossil fuel use represent the summation of all three activities.

<u>Emissions from fossil fuel use, per activity (transportation, irrigation, and other) are estimated as:</u>

$$E_{FF} = \frac{Vol_{FF} \times EF_{FF}}{1000}$$

Where:

E_{FF} = Emissions from fossil fuel use, t CO_2 yr^{-1}

Vol_{FF} = Volume of fossil fuel use, liter yr^{-1} or gallons yr^{-1}

EF_{FF} = Emission factors for fossil fuel use, kg CO_2 $liter^{-1}$ or kg CO_2 yr^{-1}. Values given in Table 6.

Table 6 Emission Factors for Fuel Use (US Energy Information Administration[14])

Fuel	EF_{fuel} kg CO_2/gallon	EF_{Fuel} kg CO_2/liter
Diesel[15]	10.15	2.68
Motor Gasoline[16]	8.91	2.35

14 http://www.eia.gov/oiaf/1605/coefficients.html#tbl2
15 Same value given for this type of fuel for transportation fuels and stationary combustion
16 Stationary combustion value not given for motor gasoline, so transportation fuel value used.

6. Agroforestry Practices

The greenhouse gas impact from the introduction of agroforestry practices represents the amount of CO_2 sequestered in the agroforestry system each year after the intervention is introduced. This category is not relevant for paddy rice.

The carbon sequestered in agroforestry systems is estimated as:

$$R_{AF} = A \times RF_{AF} \times \frac{44}{12}$$

Where:

R_{AF} = Removals due to the introduction of agroforestry system, t CO_2 yr^{-1}

RF_{AF} = Removal factor for agroforestry systems, t C ha^{-1} yr^{-1}. Values for different crops given in Table 7.

$\frac{44}{12}$ = the conversion factor from carbon to carbon dioxide (CO_2). It is the ratio of the molecular weight of carbon dioxide to the molecular weight of carbon.

Table 7 Carbon sequestered annually in agroforestry systems for key crops from various sources

Crop	$C_{crop\ type}$ Agroforestry t C ha^{-1} yr^{-1} (scenario 2)
Cocoa	'Plant Biomass Production' rates of 6 t C ha^{-1} yr^{-1} for 'complex agroforestry' (Beer et al. 1990, Jensen 1993a, Jensen 1993b)[17]
Coffee	'Plant Biomass Production' rates of 6 t C ha^{-1} yr^{-1} for 'complex agroforestry' (Beer et al. 1990, Jensen 1993a, Jensen 1993b)[18]
Tea	IPCC biomass accumulation rate of 2.6 t C ha^{-1} yr^{-1} for perennial species in tropical moist climates (table 5.1 from 2006 IPCC Guidelines)
Corn	IPCC biomass accumulation rate of 2.6 t C ha^{-1} yr^{-1} for perennial species in tropical moist climates (table 5.1 from 2006 IPCC Guidelines)
Potatoes	IPCC biomass accumulation rate of 2.6 t C ha^{-1} yr^{-1} for perennial species in tropical moist climates (table 5.1 from 2006 IPCC Guidelines)
Vegetables/horticulture	IPCC biomass accumulation rate of 2.6 t C ha^{-1} yr^{-1} for perennial species in tropical moist climates (table 5.1 from 2006 IPCC Guidelines)

[17] Rainforest Alliance (2011). Climate Change Mitigation and Adaptation: Opportunities for Climate-Friendly Perennial Crop Farming Practices in East and West Africa and Southeast Asia.
[18] Rainforest Alliance (2011). Climate Change Mitigation and Adaptation: Opportunities for Climate-Friendly Perennial Crop Farming Practices in East and West Africa and Southeast Asia.

7. Rice Irrigation (only applicable to paddy rice)

Changes in emissions from altering rice management in paddy systems is estimated using a Tier 1 approach based on Section 5.5 of the IPCC Guidelines and represent the difference in emissions (t CO_2e) between rice emissions before and after intervention (Scenarios 1 and 2). The emissions represent methane, but are converted to t CO_2e by applying a Global Warming Potential (GWP) factor of 25.

<u>Emissions from rice irrigation are estimated as:</u>

$$E_{RI} = (EF_{RI} \times Days \times Cycle \times A \times 10^{-6}) \times 25$$

Where:

E_{RI} = Emissions from rice irrigation, t CO_2e yr^{-1}

EF_{RI} = Daily emission factor for rice (specific to water regime and organic amendment), kg CH_4 ha^{-1} day^{-1}. Calculation of EF_{RI} given below.

$Days$ = Number of cultivation days per cycle

$Cycle$ = Number of annual cultivation cycles

A – Area, ha

EF_{RI} is estimated as:

$$EF_{RI} = EF_C \times SF_W \times SF_P \times SF_O$$

Where:

EF_{RI} = Daily emission factor for rice (specific to water regime and organic amendment), kg CH_4 ha^{-1} day^{-1}.

EF_C = Baseline emission factor for continuously flooded fields without organic amendments, kg CH_4 ha^{-1} day^{-1}. Value is always 1.30.

SF_W = Scaling factor to account for the differences in water regime during the cultivation period. Values given in Table 8.

SF_P = Scaling factor to account for the differences in water regime in the pre-season before the cultivation period. Values given in Table 9.

SF_O = Scaling factor to account for the type and amount of organic amendment applied. Values given in Table 10. When there are no organic amendments applied, this is equal to 1.

Table 8 Rice Water Regime Scaling Factors for calculation of emissions adapted from rice management from IPCC Guidelines Table 5.12.

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

Table 9 Rice Water Regime Scaling Factors for Pre-Cultivation Flooding Amendment for calculation of emissions adapted from rice management from IPCC Guidelines Table 5.13.

Flooding prior to cultivation	**Scaling Factor**
Not flooded more than 6 months before cultivation	0.68
Not flooded less than 6 months before cultivation	1
Flooded for more than 30 days before cultivation	1.9

Table 10 Scaling Factor for Organic Amendment for calculation of emissions adapted from rice management from IPCC Guidelines Table 5.14

Organic amendment	**Conversion factor**	**Application Rate (t/ha fresh weight)**	**Scaling Factor Calculation** [19]
Straw <30 days before cultivation	1	*User provided*	= (1+Application Rate*0.873* Conversion Factor) ^0.59
Straw >30 days after cultivation	0.29	*User provided*	= (1+Application Rate*0.873* Conversion Factor) ^0.59
Compost	0.05	*User provided*	= (1+Application Rate*Conversion Factor) ^0.59

[19] For straw, application rate is converted to dry weight, assuming as moisture content of 12.7%. For others, the fresh weight is applied. Moisture content based on Koopmans, A. and Koppejan J. (1998) AGRICULTURAL AND FOREST RESIDUES - GENERATION, UTILIZATION AND AVAILABILITY. FAO. Paper presented at the Regional Consultation on Modern Applications of Biomass Energy, 6-10 January 1997, Kuala Lumpur, Malaysia. http://www.fao.org/docrep/006/AD576E/ad576e00.pdf

Farm yard manure	0.14	*User provided*	= (1+Application Rate*Conversion Factor) ^0.59
Green manure	0.5	*User provided*	= (1+Application Rate*Conversion Factor) ^0.59

Final Calculations

Final calculations will be presented in terms of total emissions (tonnes CO_2e) and emissions per unit of yield (tonnes CO_2e per tonne).

Total emissions

To calculate total emissions for the baseline scenario and after-intervention scenario for **corn, potatoes, vegetable/horticulture, and upland rice systems**, the following equation is used.

$$E_{T_{CPVU}} = E_{SM} + E_{SF} + E_{AM} + E_{UH} + E_L + E_{PH} + E_{RB} + E_{RD} + E_{FF} - R_{AF}$$

Where:

$E_{T_{CPVU}}$= Total emissions, t CO_2e yr^{-1}

E_{SM} = Emissions from soil management, t CO_2e yr^{-1}

E_{SF} = Emissions from synthetic fertilizer application, t CO_2e yr^{-1}

E_{AM} = Emissions from animal manure application, t CO_2e yr^{-1}

E_{RB} = Emissions from crop residue burning, t CO_2e yr^{-1}

E_{RD} = Emissions from crop residue decomposition, t CO_2e yr^{-1}

E_{UH} = Emissions from urea hydrolysis, t CO_2e

E_L = Emissions from liming, t CO_2e

E_{PH} = Emissions from pesticide and herbicide application, t CO_2e

E_{FF} = Emissions from fossil fuels, t CO_2e

R_{AF} = Emissions from agroforestry removals, t CO_2e

To calculate total emissions for the baseline scenario and after-intervention scenario for **coffee, cacao, and tea**, the same equation is used but excluding E_{RB} and E_{RD}.

$$E_{T_{CCT}} = E_{SM} + E_{SF} + E_{AM} + E_{UH} + E_L + E_{PH} + E_{FF} - R_{AF}$$

Where:

$E_{T_{CCT}}$= Total emissions, t CO_2e yr^{-1}

E_{SM} = Emissions from soil management, t CO_2e yr^{-1}

E_{SF} = Emissions from synthetic fertilizer application, t CO_2e yr^{-1}

E_{AM} = Emissions from animal manure application, t CO_2e yr^{-1}

E_{UH} = Emissions from urea hydrolysis, t CO_2e yr^{-1}

E_L = Emissions from liming, t CO_2e yr^{-1}

E_{PH} = Emissions from pesticide and herbicide application, t CO_2e

E_{FF} = Emissions from fossil fuels, t CO_2e yr^{-1}

R_{AF} = Emissions from agroforestry removals, t CO_2e yr^{-1}

To calculate total emissions for the baseline scenario and after-intervention scenario *for* **paddy rice**, the following equation is used.

$$E_{T_{PR}} = E_{SF} + E_{UH} + E_L + E_{PH} + E_{RB} + E_{FF} + E_I$$

Where:

$E_{T_{PR}}$ = Total emissions for rice, t CO_2e yr^{-1}

E_{SF} = Emissions from synthetic fertilizer application, t CO_2e yr^{-1}

E_M = Emissions from manure application, t CO_2e yr^{-1}

E_{UH} = Emissions from urea hydrolysis, t CO_2e yr^{-1}

E_L = Emissions from liming, t CO_2e yr^{-1}

E_{PH} = Emissions from pesticide and herbicide application, t CO_2e

E_{SB} = Emissions from crop residue burning, t CO_2e yr^{-1}

E_{FF} = Emissions from fossil fuels, t CO_2e yr^{-1}

E_I = Emissions from rice irrigation, t CO_2e yr^{-1}

Emissions per unit of yield

$$E_Y = \frac{E_T}{y * A}$$

Where:

E_Y = Emissions per unit of yield, t CO_2e per tonne of product

E_T = Total emissions, t CO_2e yr^{-1}

y = Yield, tonnes ha^{-1} yr^{-1}

A = Area, hectares

Annex 1: Variables determined by Geographic Location: Soil Carbon and F_{LU}, F_{MG}, and F_{IN}

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Indonesia	Aceh	54.08	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Bali	143.90	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Bangka-Belitung	196.15	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Bengkulu	131.30	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Banten	45.73	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Gorontalo	46.04	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Irian Jaya Barat	86.38	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Jambi	234.63	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Jawa Timur	67.07	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Jakarta Raya	47.24	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Jawa Barat	67.76	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Jawa Tengah	67.67	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Kalimantan Barat	214.68	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Kalimantan Timur	92.48	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Kepulauan Riau	79.08	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Kalimantan Selatan	194.33	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Indonesia	Kalimantan Tengah	101.53	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Lampung	83.32	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Maluku	62.96	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Maluku Utara	53.49	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Nusa Tenggara Barat	74.88	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Nusa Tenggara Timur	99.58	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Papua	594.36	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Riau	452.19	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sumatera Barat	259.76	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sulawesi Selatan	44.78	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sulawesi Tenggara	47.18	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sumatera Selatan	240.03	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sulawesi Barat	51.28	0.64	1.10	1	1.00	1.09	1.16	0.94	1	1.08	1.41
Indonesia	Sulawesi Tengah	50.70	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Sumatera Utara	136.92	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Indonesia	Sulawesi Utara	57.07	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Indonesia	Yogyakarta	52.15	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Batdâmbâng	40.41	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Krong Preah Sihanouk	43.79	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kep	40.34	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kâmpóng Chhnang	33.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Krâchéh	37.68	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kaôh Kong	44.66	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kâmpóng Cham	41.17	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kândal	39.49	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kâmpôt	34.06	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kâmpóng Spœ	33.67	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Kâmpóng Thum	38.30	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Môndól Kiri	34.22	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Otdar Mean Chey	36.98	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Bântéay Méanchey	33.85	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Preah Vihéar	34.42	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Krong Pailin	45.36	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Cambodia	Pouthisat	37.14	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Phnom Penh	39.38	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Prey Vêng	42.48	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Rôtânôkiri	49.59	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Siemréab	33.97	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Svay Rieng	64.69	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Stœng Trêng	38.87	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Cambodia	Takêv	35.22	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Ayeyarwady	41.26	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Bago	43.33	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Chin	81.53	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Kachin	106.15	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Kayah	42.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Kayin	42.58	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Mandalay	55.64	0.58	1.10	1	1.00	1.09	1.17	0.95	1	1.04	1.37
Myanmar	Magway	66.63	0.58	1.10	1	1.00	1.09	1.17	0.95	1	1.04	1.37
Myanmar	Mon	43.21	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Rakhine	52.23	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Sagaing	61.78	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Shan	46.32	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Tanintharyi	42.82	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Myanmar	Yangon	42.37	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Abra	41.21	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Philippines	Aklan	41.89	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Albay	73.08	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Agusan del Norte	40.99	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Apayao	41.42	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Antique	41.63	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Agusan del Sur	38.90	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Aurora	40.93	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Bataan	60.28	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Benguet	41.63	0.69	1.10	1	1.00	1.15	1.15	0.92	1	1.11	1.44
Philippines	Biliran	41.18	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Bukidnon	68.90	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Batanes	159.81	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Bohol	37.81	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Basilan	58.98	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Batangas	184.87	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Bulacan	33.57	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Cebu	36.83	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Cagayan	41.12	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Compostela Valley	40.89	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Camiguin	291.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Camarines Norte	42.18	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Philippines	Capiz	40.17	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Camarines Sur	80.12	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Catanduanes	41.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Cavite	75.43	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Dinagat Islands	41.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Davao Oriental	40.75	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Davao del Sur	63.17	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Davao del Norte	40.45	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Eastern Samar	37.16	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Guimaras	20.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Isabela	41.73	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Ifugao	41.50	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Iloilo	41.17	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Ilocos Norte	41.05	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Ilocos Sur	41.62	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Kalinga	41.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Leyte	41.83	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Laguna	93.71	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Lanao del Norte	42.19	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Lanao del Sur	72.61	0.64	1.10	1	1.00	1.09	1.16	0.94	1	1.08	1.41

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Philippines	La Union	41.47	0.69	1.10	1	1.00	1.15	1.15	0.92	1	1.11	1.44
Philippines	Masbate	38.57	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Occidental Mindoro	41.11	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Misamis Occidental	59.55	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Maguindanao	37.30	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Metropolitan Manila	42.33	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Misamis Oriental	68.02	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Marinduque	39.80	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Oriental Mindoro	52.81	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Mountain Province	41.02	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	North Cotabato	41.28	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Negros Occidental	55.87	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Nueva Ecija	40.29	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Negros Oriental	92.14	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Northern Samar	36.28	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Nueva Vizcaya	41.57	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Philippines	Palawan	39.04	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Pampanga	32.10	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Pangasinan	37.84	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Quirino	41.21	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Quezon	57.84	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Rizal	56.57	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Romblon	54.98	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	South Cotabato	113.59	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Shariff Kabunsuan	51.09	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Sarangani	50.68	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Sultan Kudarat	40.53	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Southern Leyte	40.71	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Samar	39.76	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Surigao del Norte	40.54	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Siquijor	34.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Sorsogon	42.60	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Surigao del Sur	40.16	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Sulu	41.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Tarlac	39.47	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Tawi-Tawi	41.02	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

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Philippines	Zambales	41.32	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Zamboanga del Norte	42.83	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Zamboanga del Sur	43.07	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Philippines	Zamboanga Sibugay	40.57	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	An Giang	57.23	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Binh Dinh	46.46	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Bac Giang	36.60	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Binh Duong	38.27	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Bac Kan|Bac Can	42.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Bac Lieu	60.37	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Bac Ninh	42.40	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Binh Phuoc	39.69	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ben Tre	44.97	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Binh Thuan	34.74	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ba Ria - VTau|Ba Ria-Vung Tau	39.40	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Cao Bang	49.41	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ca Mau	294.53	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Can Tho	63.38	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

Country	State	Cropland SOCref (t C ha^{-1})	F_{LU} Long-term cultivated	F_{LU} Paddy rice	F_{LU} Perennial/Tree Crop	F_{MG} Full	F_{MG} Reduced	F_{MG} No-till	F_{IN} Low	F_{IN} Medium	F_{IN} High without manure	F_{IN} High with manure
Vietnam	Da Nang City|Da Nang	36.90	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Dien Bien	41.94	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Dak Lak|Dac Lac	35.78	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Dong Nai	40.92	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Dac Nong	39.37	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Dong Thap	65.37	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Gia Lai	38.51	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ha Tay	42.85	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ho Chi Minh City|Ho Chi Minh	64.80	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Hai Duong	46.83	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ha Giang	44.00	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ha Nam	41.60	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ha Noi City|Hanoi	39.54	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Hoa Binh	41.66	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Hai Phong City|Haiphong	56.55	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ha Tinh	51.62	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Hau Giang	73.11	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Hung Yen	41.68	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Kien Giang	200.20	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

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Vietnam	Khanh Hoa	37.54	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Kon Tum	34.37	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Long An	71.96	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Lam Dong	39.62	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Lai Chau	49.39	0.69	1.10	1	1.00	1.15	1.15	0.92	1	1.11	1.44
Vietnam	Lao Cai	42.96	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Lang Son	48.92	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Nghe An	41.30	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ninh Binh	46.88	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Nam Dinh	39.89	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Ninh Thuan	40.01	0.58	1.10	1	1.00	1.09	1.17	0.95	1	1.04	1.37
Vietnam	Phu Tho	32.69	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Phu Yen	42.90	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Quang Binh	42.49	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Quang Ngai	43.25	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Quang Nam	43.80	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Quang Ninh	42.94	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Quang Tri	42.91	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Son La	40.87	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Soc Trang	64.80	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Thai Binh	40.24	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Tien Giang	63.05	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Thanh Hoa	43.32	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44

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Vietnam	Tay Ninh	40.11	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Tuyen Quang	38.15	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Thua Thien - Hue	45.33	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Tra Vinh	46.07	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Thai Nguyen	35.33	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Vinh Phuc	33.59	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Vinh Long	59.70	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44
Vietnam	Yen Bai	39.58	0.48	1.10	1	1.00	1.15	1.22	0.92	1	1.11	1.44