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of the United Nations

Ex-Ante Carbon-balance Tool | EX-ACT

GUIDELINES

Second edition – Tool version 9

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Acronyms and abbreviations

AFOLU	agriculture, forestry and other land use
AGB	above-ground biomass
BGB	below-ground biomass
CH_4	methane
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
DIC	dissolved inorganic carbon
d.m.	dry matter
DOC	dissolved organic carbon
EX-ACT	EX-Ante Carbon-balance Tool
FAO	Food and Agriculture Organization of the United Nations
FUI	fuel use intensity
GHG	greenhouse gas
GWP	Global Warming Potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HWP	harvested wood product
IPCC	Intergovernmental Panel on Climate Change
N	nitrogen
N_2O	nitrous oxide
POC	particulate organic carbon
SDGs	Sustainable Development Goals
SOC	soil organic carbon
USDA	United States Department of Agriculture
WRB	World Reference Base

Introduction

These methodological guidelines document the structure of the EX-Ante Carbon Balance Tool version 9 (EX-ACT) and underlying concepts.

EX-ACT is a land use based accounting system developed by the Food and Agriculture Organization of the United Nations (FAO) to evaluate the effects of the interventions in agriculture[1] on greenhouse gas (GHG) emissions and carbon stock changes expressed as carbon-balance. The carbon-balance comprises of changes in GHG emissions and carbon stock changes in the five quantifiable carbon pools: above ground biomass, below ground biomass, litter, deadwood and soil.

Applying the tool does not require specific scientific knowledge; the analysis can be conducted by any user interested in impacts on GHG emissions of land use related interventions in agriculture. EX-ACT has been designed to complement the standard economic analysis of the interventions and can easily fit into to the time constraints of the intervention design and evaluation processes.

EX-ACT can be applied to calculate the mitigation potential of any type of land use based intervention, either public or private. It can be used to evaluate projects, policies as well as national level programmes. The results allow the decision makers to ensure that all the interventions contribute to meeting climate change mitigation goals, such as those expressed in the Nationally Determined Contributions, while continuing progress towards other environmental and socioeconomic objectives, either at regional, national or international levels, for example climate change adaptation goals expressed in National Adaptation Plans or Sustainable Development Goals. Although the EX-ACT appraisals were initially designed for *ex ante* analysis, the tool can be successfully applied during the project implementation as well as *ex post* for comprehensive monitoring and evaluation, both at a project and at a country levels.

The current version of EX-ACT is primarily based on the Intergovernmental Panel on Climate Change *(IPCC) 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories* (IPCC, 2019) and *IPCC 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (IPCC, 2014), complemented by another scientific research. GHG fluxes from farm operations, inputs, transport and irrigation systems implementation are based on Lal (2004). Emission Factors for electricity use are based on United Nations Framework Convention on Climate Change (UNFCCC, 2021). Emission factors for the fishery sector are derived from Parker and Tyedmers (2015), Winther *et al.* (2009) and Irribaren *et al.* (2010 and 2011). Soil carbon stock in mangroves is complemented by the review from Atwood *et al.* (2017).

This document presents the methodology used to build the tool. It describes in detail the main logic behind the tool, the tool structure, and the underlying equations and parameters used to calculate the carbon balance. This document is not intended as a user manual.

[1] Agriculture includes the agriculture, forestry and other land use (AFOLU) sector, fisheries and aquaculture, agricultural inputs and infrastructure.

PART 1. Basic methodological framework

1.1 The scope

EX-ACT is a land use based accounting system, measuring emissions and carbon stock changes per unit of land (in hectare), expressed in tonne of carbon dioxide equivalent (tCO_2-e) per ha and per year (tCO_2-e/ha/yr). It covers the whole agricultural sector including the agriculture, forestry and other land use (AFOLU) sector, fisheries and aquaculture, agricultural inputs and infrastructure. The AFOLU activities included cover land use changes (deforestation, afforestation/reforestation and other land use change) and land management (annual crops, perennial crops, flooded rice, grasslands and livestock breeding), as well as inland and coastal wetlands. Agricultural inputs covered in the tool include fertilizers, pesticides, use of machinery, use of irrigation and alike, while infrastructure includes construction of irrigation systems, on-farm buildings and feeder roads.

1.2 The tool

EX-ACT consists of a set of linked Microsoft Excel sheets into which the user inserts basic data on agricultural activities and practices.

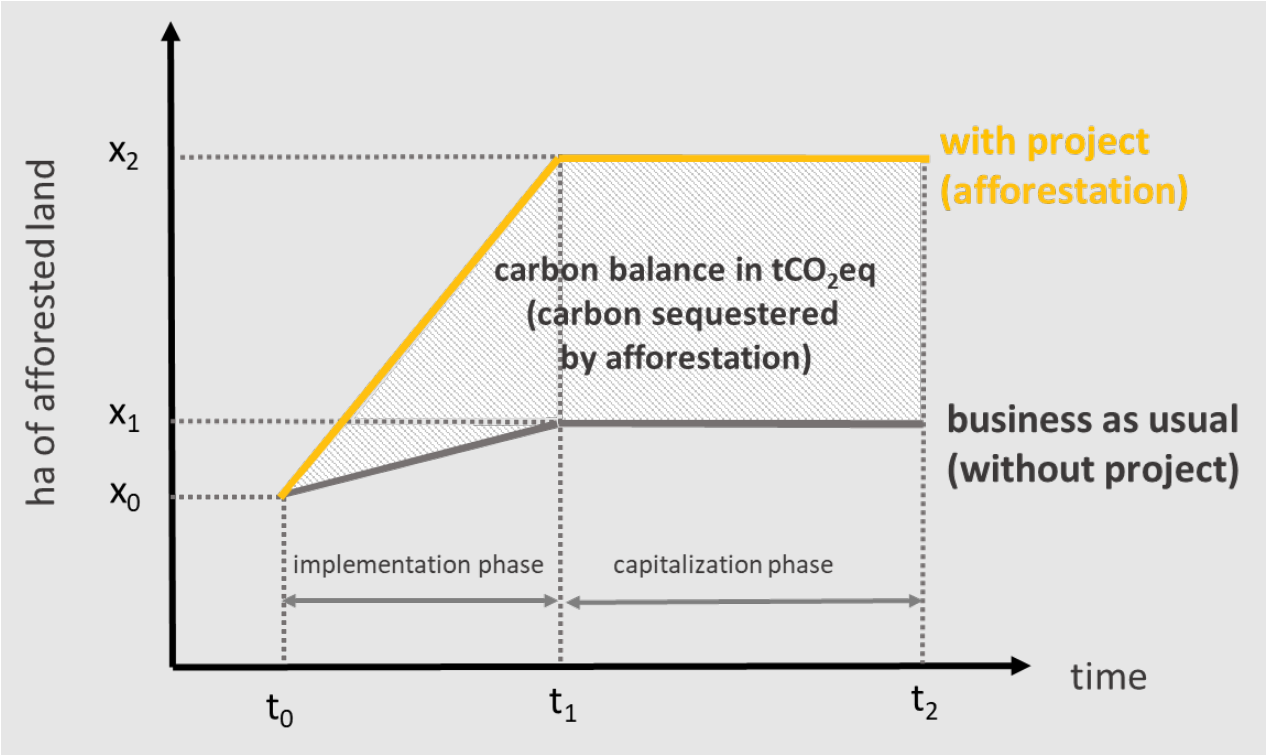
1.2.1 The underlying concepts

The analysis is conducted by comparing two scenarios: a situation when an intervention, for example a project, is implemented and a baseline situation that would prevail in the absence of the project (also referred to as "reference scenario"). The comparison between the GHG emissions and carbon stock changes resulting from the implemented project and those that would occur in the baseline (without the project) gives the final carbon-balance reported in EX-ACT.

The tool distinguishes two periods of time related to the project: the implementation phase (i.e. the active phase of the project when activities are being implemented) and the capitalization phase (i.e. a period where emissions and carbon stock changes continue to occur as a result of the implemented activities).

Figure 1 presents a simplified example of how the carbon balance is calculated in EX-ACT using an afforestation project. In a reference scenario, without project, only a small portion of land will be afforested (grey line). The project activities foresee afforestation at a larger scale (yellow line). Afforestation activities will occur in the period from t_0 to t_1 (implementation phase), yet the carbon will continue to be sequestered until t_2 is reached (the capitalization phase). The overall benefits of afforestation project can be calculated as the difference between with project and reference scenario, represented on the figure by the shaded area.

Figure 1. Calculating carbon balance in EX-ACT

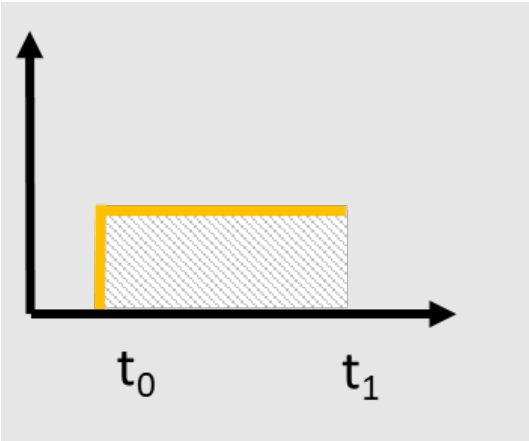


Source: Authors' own elaboration.

1.2.2 Dynamics of change

The tool allows users to take into account different dynamics of change. Default dynamics of change adopted by the tool are "Linear", but users have the possibility to change the dynamic type either to "Immediate" or "Exponential"[2] (see **Figures 2**, **3** and **4**).

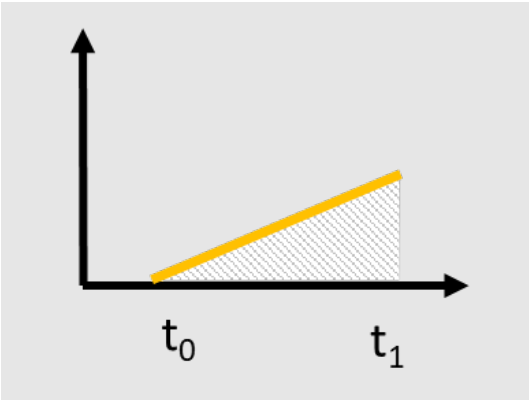
Figure 2. Schematic representation of the immediate dynamic in the implementation phase



Source: Authors' own elaboration based on Bernoux, M., Schiettecatte, L.-S., Tinlot, M., Bockel, L., Branca, G., Gentien, A. & Colomb, V. 2017. *Ex-Ante Carbon-balance tool (EX-ACT) Technical guidelines for version 7.* Rome, FAO.

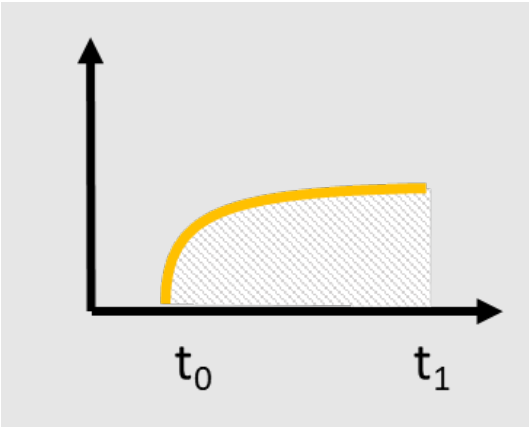
[2] Exponential refers to exponential decay, increasing form.

Figure 3. Schematic representation of the linear dynamic in the implementation phase



Source: Authors' own elaboration based on Bernoux, M., Schiettecatte, L.-S., Tinlot, M., Bockel, L., Branca, G., Gentien, A. & Colomb, V. 2017. *Ex-Ante Carbon-balance tool (EX-ACT) Technical guidelines for version 7.* Rome, FAO.

Figure 4. Schematic representation of the exponential dynamic in the implementation phase



Source: Authors' own elaboration based on Bernoux, M., Schiettecatte, L.-S., Tinlot, M., Bockel, L., Branca, G., Gentien, A. & Colomb, V. 2017. *Ex-Ante Carbon-balance tool (EX-ACT) Technical guidelines for version 7.* Rome, FAO.

The "Immediate" dynamics (**Figure 2**) consider an abrupt change of level when considered activity has an immediate effect on the carbon balance. For example, a farmer may have ten cows at a start and due to a project, he will immediately add an additional cow to his herd. As the effect on carbon balance will be immediate, the user should use the "immediate" dynamics of change in the calculations. Under the "Linear" dynamics (**Figure 3**), the change is gradual; for example, when a farmer progressively increases the surface of crops to which he applies fertilisers. The "Exponential" dynamics of change (see **Figure 4**) would be preferred in situations when the rate of change is faster at the beginning of the project and slower at the end of implementation phase of the project. The dynamics of change can also be used to represent the adoption rate of the farmers.

The immediate dynamics correspond to the maximum change in the carbon balance possible for a given activity (100 percent of the maximum level), the linear dynamics correspond to 50 percent of the maximum level, while the exponential decay corresponds to about 78 percent of the maximum level.

In practice, the dynamics of change may also follow an S-shaped curve. The total amount of GHG releases associated with S-curve shaped dynamics of change are similar to a situation with linear dynamics of change, which can be used instead.

Box 1 summarises the calculation of a carbon balance in EX-ACT.

Box 1. How does EX-ACT calculate a carbon balance?

The EX-ACT tool calculates carbon balances for individual activities by taking the difference between carbon fluxes generated "with project" and those linked to the situation "without project":

$$C_{Balance} = GHG_{with} - GHG_{without}$$

The gross fluxes for each situation ("with" or "without" project) are computed by taking into considerations both the time of implementation and the time of capitalization. Fluxes generated during the implementation time are computed following the selected dynamic of change: the tool computes the emissions according to a specific mathematical formula linked to the dynamic of change chosen by the user.

Fluxes generated during the capitalization time are instead always assumed to follow a constant trend. The tool will automatically compute carbon balances considering that the activities introduced in the tool have fully been performed:

$$GHG_{situation} = (EF_{activity} * Coefficient_{change} * Imp_{years} * + EF_{activity} * Cap_{years}) * Unit_{situation}$$

or, in case of an activity concerning changes in biomass levels

$$GHG_{situation} = (Biomass_{activity} * Coefficient_{change} * Imp_{years} + Biomass_{activity} * Cap_{years}) * Unit_{situation}$$

where:

$GHG_{situation}$ = gross fluxes linked to the specific project situation analyzed (without/with project);

$EF_{activity}$ = emission factor of the considered activity;

$Coefficient_{change}$ = coefficient associated with the selected dynamic of change for implementation of the activity (i.e. linear, exponential, immediate);

Imp_{years} = years of implementation of the project;

Cap_{years} = years of capitalization of the project;

$Unit_{situation}$ = number of units of the activity (i.e. hectares for land activities, heads for livestock-based activities, tonnes of catch for fishery-based activities);

$Biomass_{activity}$ = biomass growth rates for the activity.

After the end of the project capitalization phase, the tool automatically assumes that all GHG fluxes will cease being generated. It is the user that defines the duration of implementation and capitalization phases. It is key to ensure that the data entered in the tool and the total duration of the activity chosen is in line with the specific recommendations for GHG accounting such as those of IPCC, as applicable.

1.2.3 Categories and representation of land use areas

The tool is based on the six broad categories and sub-categories proposed by IPCC for reporting GHG inventory, yet it focuses mainly on four of them: Forest Land, Cropland, Grassland and Wetlands. Other two categories (Settlement and Other Lands) are only considered in the land use conversions.

There are three approaches to represent land use according to the level of information available (see Chapter 3 of IPCC [2019] for details). The tool retains an approach, which considers information on conversion between land use categories without spatially explicit location data. Tracking land use conversions requires information on the initial and final land use categories for all conversion types, as well as of total area of unchanged land by category. The final results of this approach can be represented as a land use change matrix between categories (see **Figure 5**). The matrices are reported in the "Results" tab of the tool.

Figure 5. Matrices of land uses and land use changes for with and without project situations

WITHOUT PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest	0	0	0	0	0	0	0	**0**
Annual cropland	0	0	0	0	0	0	0	**0**
Agroforestry	0	0	0	0	0	0	0	**0**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	0	0	0	**0**
Degraded land	0	0	0	0	0	0	0	**0**
Other land	0	0	0	0	0	0	0	**0**
Total area without project (ha)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

WITH PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest	0	0	0	0	0	0	0	**0**
Annual cropland	0	0	0	0	0	0	0	**0**
Agroforestry	0	0	0	0	0	0	0	**0**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	0	0	0	**0**
Degraded land	0	0	0	0	0	0	0	**0**
Other land	0	0	0	0	0	0	0	**0**
Total area with project (ha)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

This approach embeds several elements of uncertainty; the reader may refer to Section 3.5 of IPCC (2019) for more details.

Additionally, to change in land use categories, EX-ACT also considers the GHG emissions associated with management practices, or the change in practices, for each category of land use, when applicable (for example, tillage intensity for croplands, use of inputs, etc.).

1.2.4 Structure of the tool

EX-ACT adopts a modular approach, with the first module allowing for setting the basic parameters, the last module summarising the results and the modules in-between representing a specific group of activities (see **Figure 6**). The start worksheet (**Figure 7**) shows the version of the tool being used, as well as the terms of use for EX-ACT. The logic of the tool has been developed around the following steps:

a. gathering the basic information about the project and intervention area (geographic location, climate and soil characteristics, and duration of the project);

b. the identification of agricultural activities, for example changes in land use and practices, foreseen by the project and in the baseline scenario using specific modules; and

c. the computation of carbon-balance with and without the project using IPCC default values (Tier 1) or Tier 2 whenever provided by users.

EX-ACT contains ten frontend worksheets that users interact with (see **Table 1**), while the bulk of calculations is done by the backend worksheets unavailable to the users to ensure they cannot modify the contents by accident, which could lead to incorrect results. This also ensures the user-friendliness of the tool by preventing users from accessing the detailed computations and, instead, offering them clear, clean and tidy data entry forms.

Figure 6. Structure of the tool

EX-ACT v.9

Step 1. Description module

The first module requires providing information on:

- Location of the intervention: region, country, climate, moisture and soil type;
- Duration of the analysis: implementation phase and capitalization phase.

These variables trigger the default parameters applied in the tool.

Step 2. Activities

EX-ACT covers all agricultural activities including: deforestation, re/afforestation, other land use changes, annual crops, perennial crops, flooded rice, grasslands, livestock, forest management, inland and coastal wetlands, fisheries and aquaculture, agricultural inputs and infrastructure. These are organized in topical modules and sub-modules.

Step 3. Results

The final module summarizes all the results from the topical modules. Key indicators include:

- Carbon balance in tonne of carbon dioxide (tCO_2e) total and by activity;
- Annual carbon balance;
- Average annual and per hectare carbon balance;
- Disaggregation by type of GHG (CO_2, CH_4, N_2O);
- GHG fluxes for with and without intervention scenarios.

Source: Authors' own elaboration.

Table 1. Description of the modules and respective components on EX-ACT

Worksheet	Module	Sub-module	Section
1. Description	Description	Project description	
		Project site and duration	
		Global warming potential	
		Reference soil organic carbon stock	
2. Land use change (LUC)	Land use change	Deforestation	
		Afforestation and reforestation	
		Non forest land use changes	
3. Cropland	Cropland management	Annual cropping systems	From deforestation or converted to forest land
			From other land use (LU) or converted to other LU
			Annual system remaining annual systems
		Perennial cropping systems	From deforestation or converted to forest land
			From other land use (LU) or converted to other LU
			Perennial system remaining perennial systems
		Flooded rice systems	From deforestation or converted to forest land
			From other land use (LU) or converted to other LU
			Flooded rice system remaining flooded rice systems
4. Grassland	Grassland and livestock	Grassland management	From deforestation or converted to forest land
			From other land use (LU) or converted to other LU
			Grassland system remaining grassland systems
		Livestock and manure management	-
5. Management	Forest management	Forest degradation and management	-
6. Inland wetlands	Inland wetlands	Land use change on organic soil	Organic soil management practices associated with deforestation
			Organic soil management practices associated with afforestation/reforestation
			Organic soil management practices associated with other land use changes

Worksheet	Module	Sub-module	Section
		Land management on organic soil	Forest management
			Other land use management
		Land managed for peat extraction	-
		Inland waterbodies	-
7. Coastal wetlands	Coastal wetlands	Management of coastal wetlands	Extraction and excavation
			Drainage
			Rewetting and revegetation
		Coastal waterbodies	
8. Fisheries and aquaculture	Fisheries and aquaculture	Small scale fisheries	-
		Large scale fisheries	-
		Inland and coastal aquaculture	-
9. Inputs	Inputs and investments	Inputs	Fertilizers
			Pesticides
			Animal feed
		Energy consumption	Electricity
			Liquid or gaseous fuels
			Solid fuels
		Irrigation	Implementation of new irrigation systems
			Operational phase of groundwater irrigated systems
		Buildings and roads	
10. Results			

Source: Authors' own elaboration based on FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Figure 7. Start module of EX-ACT

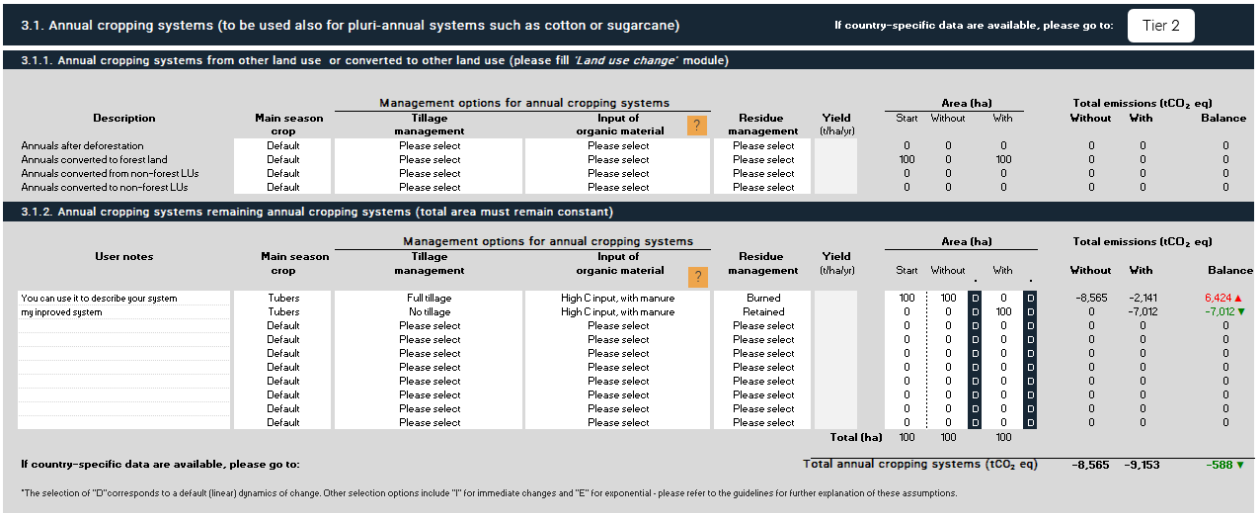
Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

1.2.5 User interface

The user interface applies a repeating colour code in all the modules. All cells that users can modify and enter data are in white (see **Figure 8**). Grey cells cannot be modified and report variable names, units and results of the calculations. Orange boxes with question marks allow users to jump into definitions tab or help tab to cross check the type of information that is required. Each module and sub-module have a "Tier 2" button, which directs users to another interface (on the right-hand side from the main interface) where they can insert location-specific values of parameters to be used instead of the default Tier 1 parameters in the calculations (see **Figure 9**).

Figure 8. Main user interface in EX-ACT



3.1. Annual cropping systems (to be used also for pluri-annual systems such as cotton or sugarcane) — If country-specific data are available, please go to: Tier 2

3.1.1. Annual cropping systems from other land use or converted to other land use (please fill *'Land use change'* module)

Description	Main season crop	Management options for annual cropping systems: Tillage management	Input of organic material	Residue management	Yield (t/ha/yr)	Area (ha): Start	Without	With	Total emissions (tCO_2 eq): Without	With	Balance
Annuals after deforestation	Default	Please select	Please select	Please select		0	0	0	0	0	0
Annuals converted to forest land	Default	Please select	Please select	Please select		100	0	100	0	0	0
Annuals converted from non-forest LUs	Default	Please select	Please select	Please select		0	0	0	0	0	0
Annuals converted to non-forest LUs	Default	Please select	Please select	Please select		0	0	0	0	0	0

3.1.2. Annual cropping systems remaining annual cropping systems (total area must remain constant)

User notes	Main season crop	Management options for annual cropping systems: Tillage management	Input of organic material	Residue management	Yield (t/ha/yr)	Area (ha): Start	Without	With	Total emissions (tCO_2 eq): Without	With	Balance
You can use it to describe your system	Tubers	Full tillage	High C input, with manure	Burned		100	100	0	-8,565	-2,141	6,424 ▲
my inproved system	Tubers	No tillage	High C input, with manure	Retained		0	0	100	0	-7,012	-7,012 ▼
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
	Default	Please select	Please select	Please select		0	0	0	0	0	0
					Total (ha)	100	100	100			
					Total annual cropping systems (tCO_2 eq)				-8,565	-9,153	-588 ▼

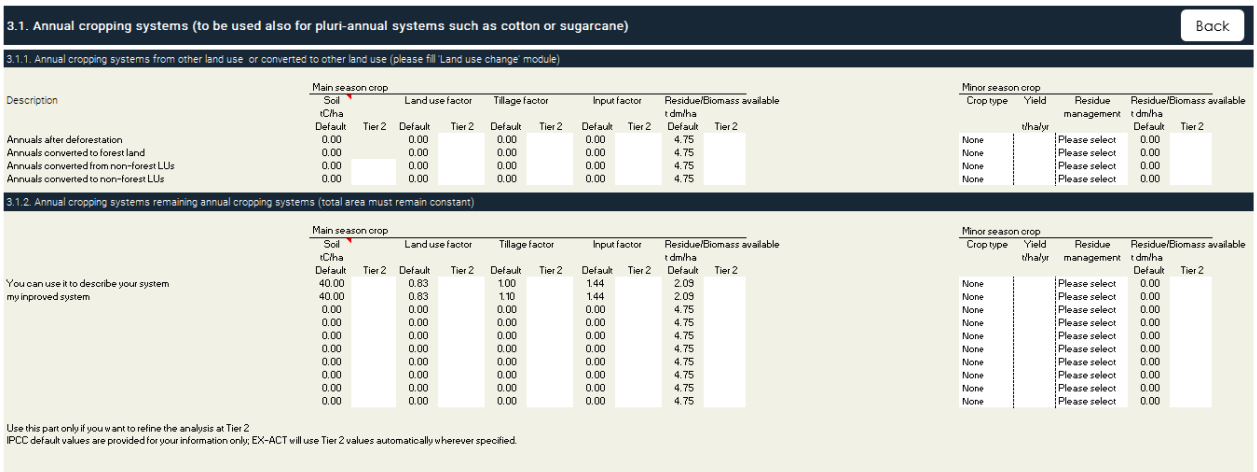
If country-specific data are available, please go to:

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Figure 9. Tier 2 user interface



3.1. Annual cropping systems (to be used also for pluri-annual systems such as cotton or sugarcane) — Back

3.1.1. Annual cropping systems from other land use or converted to other land use (please fill 'Land use change' module)

Description	Main season crop: Soil tC/ha Default	Tier 2	Land use factor Default	Tier 2	Tillage factor Default	Tier 2	Input factor Default	Tier 2	Residue/Biomass available t dm/ha Default	Tier 2	Minor season crop: Crop type	Yield t/ha/yr	Residue management	Residue/Biomass available t dm/ha Default	Tier 2
Annuals after deforestation	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
Annuals converted to forest land	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
Annuals converted from non-forest LUs	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
Annuals converted to non-forest LUs	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	

3.1.2. Annual cropping systems remaining annual cropping systems (total area must remain constant)

	Main season crop: Soil tC/ha Default	Tier 2	Land use factor Default	Tier 2	Tillage factor Default	Tier 2	Input factor Default	Tier 2	Residue/Biomass available t dm/ha Default	Tier 2	Minor season crop: Crop type	Yield t/ha/yr	Residue management	Residue/Biomass available t dm/ha Default	Tier 2
You can use it to describe your system	40.00		0.83		1.00		1.44		2.09		None		Please select	0.00	
my inproved system	40.00		0.83		1.10		1.44		2.09		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	
	0.00		0.00		0.00		0.00		4.75		None		Please select	0.00	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

1.3 General methodology applied in EX-ACT

EX-ACT has been developed using primarily the volume 4 of the *2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories* (IPCC, 2019) and the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: Wetlands (IPCC, 2014). GHG fluxes from farm operations, inputs, transport and irrigation systems implementation are based on Lal (2004). Emission Factors for electricity use are based on United Nation Framework Convention on Climate Change (UNFCCC, 2021), and those for on-farm infrastructure are from *Agence De l'Environnement et de la Maitrise de l'Energie* (ADEME, 2021). Emission factors for the fishery sector are derived from Parker and Tyedmers (2015), Winther *et al.* (2009) and Irribaren *et al.* (2010 and 2011). Soil carbon stock in mangroves is complemented by the review from Atwood *et al.* (2017).

1.3.1 Methodology for evaluating changes in CO_2 emissions

Following IPCC (2019), the changes in CO_2 emissions can be evaluated using either standard methods applicable to any type of land use or land use change, or methods that only apply to a specific land use or land use change.

Chapter 2 in Volume 4 of IPCC (2019) outlines the standard methodology to evaluate changes in CO_2 emissions. This methodology allows to account for changes in CO_2 coming from five carbon pools, namely above-ground biomass, below-ground biomass, soil, deadwood and litter, and which are associated with conversion of land from one category to another, for example from forest to annual crop. Most of the calculations involve calculating the CO_2 emissions resulting from changes in carbon stocks in the five pools, referred to as a stock-difference method. Unless specified otherwise through Tier 2 section of the tool, the calculations are done using Tier 1 parameters provided by IPCC (2019) that represent average values differentiated by region, climate, moisture level and soil type, drawing from the most recent scientific literature. The users have the possibility to input location-specific parameters (Tier 2) if data are available (see **Box 1**).

Box 2. Definitions of Tiers

A Tier represents a level of methodological complexity to estimate GHG emissions following the definition in IPCC (2006). EX-ACT can accommodate two of these precision levels, Tier 1 and Tier 2.

Tier 1 methods are designed to be the simplest to use, for which equations and default parameter values (i.e. emission and stock change factors) are provided in IPCC (2019), IPCC (2014) and IPCC (2006) or other scientific sources for modules not sourced from IPCC (fisheries and aquaculture, for example). While users need to furnish project specific activity data, the default parameters are mostly applicable globally or at regional level. Tier 1 values provided in EX-ACT are duly documented throughout the present guidelines.

Tier 2 can use the same methodological approach as Tier 1, but applies emission and stock change factors that are based on country- or location-specific data. Country-defined emission factors are usually more specific to the climatic conditions, land use systems and livestock categories in that country. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land use or livestock categories.

Tier 3 refers instead to the use of more complex methodologies, including GHG modelling techniques. They are tailored to address very specific local circumstances and are driven by high-resolution activity data and are disaggregated at sub-national level. The strong data requirements make their estimation time and resource intensive. As a result, these are more difficult to obtain.

The default Tier 1 values are proposed for each pool by category and type of vegetation, as follows:

a. **Above-ground biomass:** Default values are estimates expressed in tonnes of dry matter per hectare (t d.m./ha), (IPCC, 2019). The corresponding carbon stock, in tonnes of carbon per hectare (tC/ha) is calculated using the specific carbon content indicated: i.e. 0.47 for above-ground forest biomass (see Table 3 of IPCC [2019]) and 0.451 for above-ground mangrove forest biomass (see Table 4.2 of IPCC [2014]). The values of these carbon stocks are displayed in each module and sub-module as appropriate.

b. **Below-ground biomass:** In most cases, the below-ground biomass is estimated using a ratio R of below-ground biomass to above-ground biomass expressed in tonne of root d.m per tonne of shoot d.m. EX-ACT uses the default values provided in Table 4.4 of IPCC (2019) and for mangrove Table 4.4 of IPCC (2014). The values of these factors are displayed in each module and sub-module as appropriate.

c. **Litter and deadwood:** It is assumed that litter and deadwood pools are zero in all non-forest categories (excluding tree crops and perennial systems). Thus transitions between non-forest categories involve no changes in the carbon stock changes of these two pools. Other transition values are displayed in each and sub-module as appropriate. Default values are provided in Table 2.2 of IPCC (2019). For mangroves, litter and dead-wood carbon stocks are equal to 0.7 and 10.7 tC/ha, respectively (see Table 4.7 of IPCC [2014]).

d. **Soil carbon (mineral soil):** For the soil carbon estimates, the default values are based on references for soil organic carbon (SOCref) stocks for mineral soils to a depth of 30 cm (see Table 2.3 of IPCC [2019]). When SOC changes over time (following a land use change or land management change), it requires a finite period of time to reach a new equilibrium; the required period of time is assumed equal to 20 years. Accordingly, for mineral soils, the default method is based on changes in soil carbon stocks over the assumed period of time (20 years). Further, IPCC (2019) assumes that:

    i. The change is computed based on carbon stock after the management change relative to the carbon stock in a reference condition (i.e. native vegetation that is not degraded or improved), see Equation 1.

    ii. Over time, SOC reaches a spatially averaged stable value specific to the soil, climate, land use and management practices.

    iii. SOC stock changes during the transition to a new equilibrium SOC occurs in a linear fashion.

Assumption (ii) is widely accepted, however, soil carbon changes in response to management changes may often be best described by non-linear function. Yet, given that the analysis is conducted over a multiyear period, assumption (iii) allows for a reasonable approximation, while greatly simplifying the calculations. As a result, the new organic carbon stock in mineral soils can be calculated as:

$$SOC_{mineral} = \sum (SOC_{ref} * F_{Lu} * F_{MG} * F_I * A)$$

(Eq. 1)[3]

Where:

$SOC_{mineral}$ = total mineral SOC at a defined time, in tC;

SOC_{ref} = SOC in the reference condition, in tC/ha;

F_{Lu} = stock change factor for mineral SOC land use system or sub-systems, dimensionless;

F_{MG} = stock change factor for mineral SOC for management regime, dimensionless;

F_I = stock change factor for mineral SOC for the inputs of organic amendments; dimensionless and

A = land area under the different management, in ha.

[3] Equation based on Chapter 2in Volume 4 of IPCC (2019).

Over the duration of the analysis and according to the dynamics of change, EX-ACT estimates the increase/decrease in SOC_{ref} following changes in management practices on a given land and area, and following a land use changes and associated management practices, if any, on the converted area.

Default values are provided using the IPCC simplified soil classification (see **Table 2**).

Table 2. Default carbon stocks for mineral soils to a depth of 30 cm, in tC/ha

IPCC climate zones	High activity clay soils	Low activity clay soils	Sandy soils	Spodic soils	Volcanic soils	Wetland soils
Boreal moist/dry	63	N/A	10	117	20	116
Cool temperate dry	43	33	13	No	20	87
Cool temperate moist	81	76	51	128	136	128
Warm temperate dry	24	19	10	N/A	84	74
Warm temperate moist	64	55	36	143	138	135
Tropical dry	21	19	9	N/A	50	22
Tropical moist	40	38	27	N/A	70	68
Tropical wet	60	52	46	N/A	77	49
Tropical montane	51	44	52	N/A	96	82

Notes: N/A denotes that the soil category may occur in a climate zone, but no data was available. No denotes that the soil type does not normally occur within a climate zone.

Source: Authors' own elaboration based on Table 2.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

1.3.2 Methodology for evaluating changes in non-CO_2 emissions

For nitrous oxide (N_2O) and methane (CH_4) emissions, the generic approach considers multiplying an emission factor for a specific gas or source category with activity data related to the emission source (area, animal numbers or unit of weight). Emissions of N_2O and CH_4 are either associated with a specific land use category or subcategory (i.e. CH_4 emission from rice) or are estimated at aggregated level (i.e. CH_4 emissions from livestock and N_2O emissions from manure management, fertilizers and aquaculture).

Non-CO_2 emissions to the atmosphere are derived as:

$$\text{Emissions} = \text{AD} * \text{EF}$$

(Eq. 2) [4]

Where:

AD = activity data;

EF = emission factor.

Emissions from biomass burning for all kinds of biomass are calculated based on the generic methods proposed in Section 2.4 (see pages 2.52-2.60 of IPCC [2019]) and principally the Equation 2.27 of IPCC (2019). The emission of individual GHG (N_2O or CH_4) from fire is obtained as follows:

$$GHG_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$$

(Eq. 3) [5]

[4] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

[5] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

Where:

GHG_{fire} = amount of GHG emissions from fire, in tonne of each GHG (CH_4, N_2O, CO);

A = area burnt, in ha;

M_B = mass of fuel available for combustion, in tonne/ha;

C_f = combustion factor, dimensionless;

G_{ef} = emission factor, in g/kg d.m. burnt.

MB includes biomass, ground litter and deadwood, but litter and deadwood pools are assumed to be zero, except where there is a land use change. For the combustion and emissions factors, EX-ACT uses the default values from Table 2.5 (G_{ef}) and Table 2.6 (C_f) of IPCC (2019). For example, C_f is 0.36 for all tropical forests, 0.8 for rice residues and 0.72 for shrublands. These factors are displayed in each module as appropriate when the default parameters are set in the description module (see Part 2).

1.3.3 Global warming potential

By default, EX-ACT converts CH_4 and N_2O emissions using their global warming potential (GWP) over 100 years horizon: 34 and 298 years, respectively, following the *IPCC's 5th Assessment Report* (IPCC, 2013). However, users may choose to use other values as necessary, by changing the default settings of EX-ACT (see Part 2, Section 2.3 for more details).

1.4 Before starting the analysis

1.4.1 Boundaries of the project

It is important to fix the project boundaries to limit the risk of accounting for activities that are out of the project's limits.

The project boundaries may include:

a. land use change or land management change following the implementation of the project, for example, improved cultivation of rice targeting a given number of farmers;

b. avoided land use change due to project activities, for example, intensification of rice production that limits agricultural land expansion that would otherwise occur at a cost of forest land.

Both related areas should be reported in the tool.

Good practice: prepare a list of those project activities that may result in change of GHG emissions (or carbon stocks) and match them with the modules in EX-ACT before entering data into the tool.

1.4.2 Building the with-project scenario

The with-project scenario reflects the activities of the project. The related information may be found in project formulation, appraisal and evaluation documents or obtained by contacting experts involved in the project. When information is missing, users may need to make assumptions to conduct the analysis. The assumption should be always justified and duly documented.

1.4.3 Building the baseline scenario

Building the baseline scenario (without project) consists in projecting what would happen if project activities were not implemented over the duration of the implementation phase. There is no standard, one-size-fits-all methodology to build the baseline scenario. Yet, a few key criteria should always be followed:

a. The project boundaries should always be respected to compare always like with like, for example in terms of number of hectares of land;

b. Baseline scenario should represent the most plausible evolution of the situation including the most credible options of land use, possible land use changes and main management practices that could have occurred on the land within the project boundary (UNFCCC, 2020);

c. The baseline scenario should be designed in a way that the final carbon balance represents well the net effect of the project (the additionality of the project);

d. The underlying assumptions must draw on quality data and information sources, be well documented and easily verifiable.

1.4.4 Transparency of the carbon appraisal

EX-ACT is based on the IPCC methodology, complemented when necessary with other sound scientific information, ensuring quality and robust appraisals. The present document allows for checking the underlying references: methodology sources and values of the default parameters used in the calculations. The robustness of the results depends also on the quality of the information used to derive the scenarios. To ensure full transparency, it is key to document all assumptions and sources of data. EX-ACT includes a dedicated worksheet for user calculations and notes; it is strongly suggested to include in this worksheet all the data used in the analysis together with references to sources of information.

1.4.5 Use of Tier 2 in EX-ACT to reduce the uncertainty of GHG appraisal

Uncertainty derives from the lack of knowledge of the true value of a variable and is associated with a probability density function characterizing the range and likelihood of possible values. To reduce the uncertainty of the GHGs estimations it is key to reflect all the important differences in climate, ecology, species, forest types, land uses. The Tier 2 method employs at least some location-specific values, which will improve the accuracy of estimates because they represent better the conditions prevailing in the analysed area. Tier 2 values can include C stocks in the considered carbon pools, emission factors related to a specific activity in the analysed area or land use and land-management related factors and parameters. Local or country/region specific values will lead to higher degree of precision and accuracy in the analysis and reduce uncertainty on the GHG appraisal, provided they come from a reliable source.

PART 2. Description module

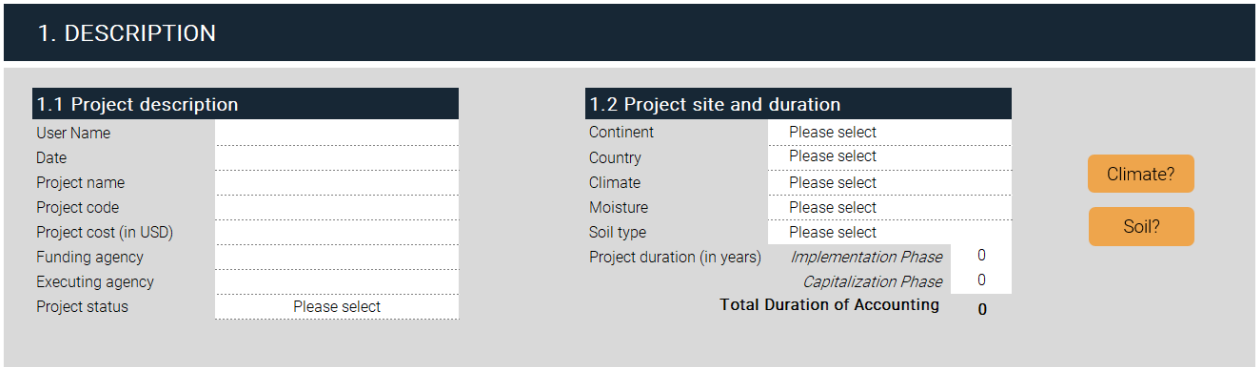
In this module, users set up the basic parameters that trigger the available options and default values in the subsequent modules.

2.1 Description of the project

In the Section "Project description" users can record some basic information about the analysis done in the file including the username, date of the analysis, project name and code, the overall cost, the funding and executive agencies, and the project status. While filling in this information is not mandatory, it is helpful for subsequent reviews of the analysis.

The section "Project site and duration" is mandatory, and users are required to provide the following type of information (see **Figure 10**).

Figure 10. Description module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

a. **Location:** from the dropdown lists, users should select the continent and country in which the project takes place (see Table A1 in Annex 1 for the detailed list of continents and countries adopted in EX-ACT).

b. **Climate:** as default values and ecosystems can change drastically accordingly to climate, it is important to define it as precisely as possible. Users should indicate the mean climate of the project location from the following options available in the dropdown list: boreal, cool temperate, warm temperate, tropical or tropical montane.

c. **Moisture regime:** dry, wet or moist.

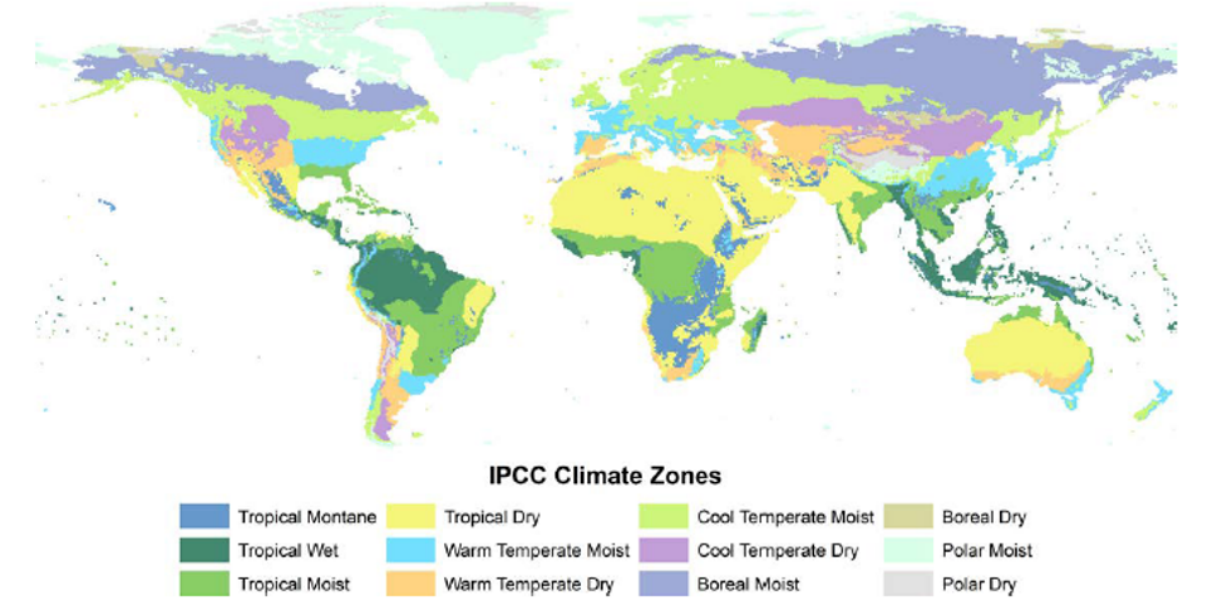
d. **Soil type:** the main dominant soil type using the simplified IPCC classification with six soil categories including sandy soils, spodic soils, volcanic soils, wetland soils, high activity clay or low activity clay.

e. **Project duration:** users should define the **implementation phase** of the project (i.e. the active phase of the project) and **capitalization phase** (i.e. a period where the benefits of the implemented activities are still occurring). The total duration of the project is the sum of these two phases and is typically assumed equal to 20 years following the IPCC recommendations (IPCC, 2006). Yet, EX-ACT allows also for shorter or longer time span of the analysis if required by the user.

Box 3. How to select the right parameters?

EX-ACT offers a help tab to support users in finding the right information for the description module. The help is provided in the form of maps, tables and links to find additional information. For climate, the help includes a visual representation of the IPCC climate zones (see **Figure 11**) and proposes a climate identifier that helps match the closest climate type available in EX-ACT to the data on mean annual temperature (MAT) in °C, mean annual precipitation (MAP) in mm, potential evapotranspiration (PET) in mm and elevation above sea level in m (see **Figure 12**) that may be found in other sources of data, for example Earth Map (see Section 2.3).

Figure 11. Representation of the IPCC climate zones



Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Figure 12. Climate identifier in EX-ACT

CLIMATE IDENTIFIER		
MAT	Mean Annual Temperature in C	20.0
MAP	Mean Annual Precipitation in mm	2 400
PET	Potential Evapotranspiration in mm	1 000
Elevation	Elevation above sea level	900
Climate	***Tropical***	
Moisture	***Wet***	

Climate and moisture regime to be specified in the "Description" module

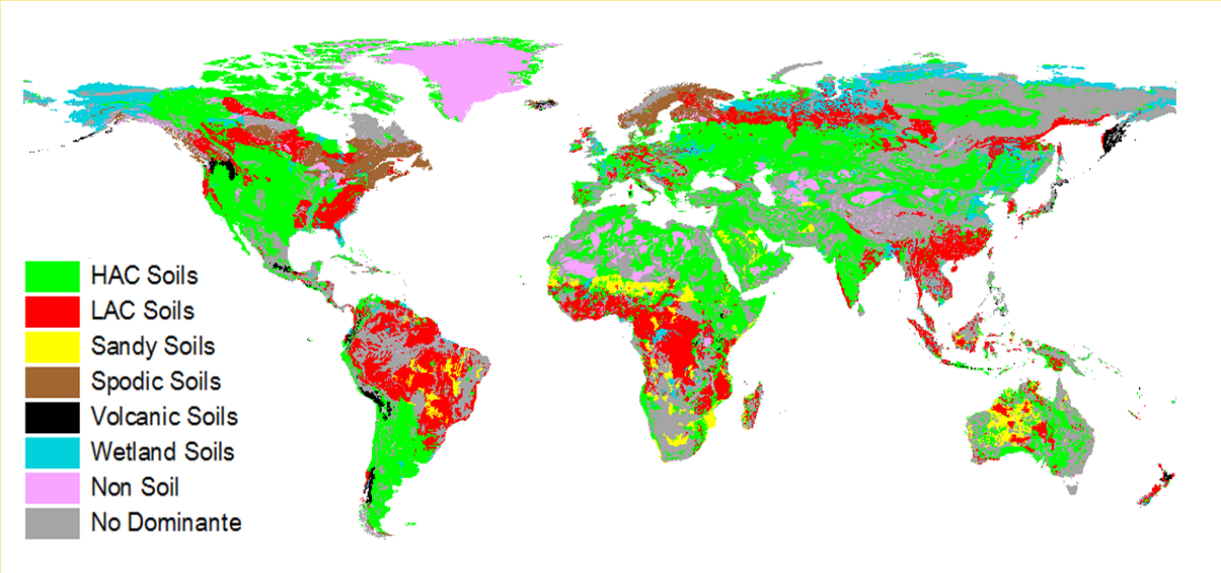
Climate	Elevation in m	MAP and PET in mm	Climate & Moisture regime
MAT > 18	< 1000	MAP ≥ 2000	Tropical Wet
MAT > 18	< 1000	1000 ≤ MAP < 2000	Tropical Moist
MAT > 18	< 1000	MAP < 1000	Tropical Dry
MAT > 18	≥ 1000	MAP ≥ 1000	Tropical Montane
MAT > 18	≥ 1000	MAP < 1000	Tropical Montane
10 < MAT ≤ 18	< 1000	MAP > PET	Warm Temperate Moist
10 < MAT ≤ 18	< 1000	MAP < PET	Warm Temperate Dry
0 < MAT ≤ 10	< 1000	MAP > PET	Cool Temperate Moist
0 < MAT ≤ 10	< 1000	MAP < PET	Cool Temperate Dry
-10 < MAT ≤ 0	< 1000	MAP > PET	Boreal Moist
-10 < MAT ≤ 0	< 1000	MAP < PET	Boreal Dry
MAT ≤ -10	< 1000	MAP > PET	Polar Moist
MAT ≤ -10	< 1000	MAP < PET	Polar Dry

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

The help tab also facilitates the selection of the most appropriate type of soil. It includes a soil map using IPCC classification of soils (see **Figure 13**). The map was constructed by matching detailed soil types from World Reference Base classification to the six IPCC soil classes using the decision tree proposed in IPCC (2019, see **Figure 14**). A reproduction of the dominant World Reference Base for Soil Resources (WRB) reference soil groups is also available at www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en

Figure 13. Map of the distribution of the dominant soil type using IPCC classification



Source: Bernoux, M., Schiettecatte, L.-S., Tinlot, M., Bockel, L., Branca, G., Gentien, A. & Colomb, V. 2017. *Ex-Ante Carbon-balance tool (EX-ACT) Technical guidelines for version 7.* Rome, FAO.

Figure 14. Classification scheme for mineral soil types based on World Reference Base for soil resources

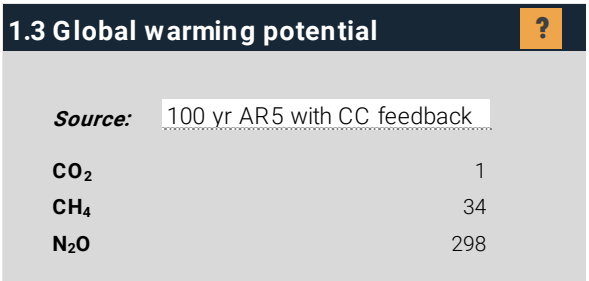
Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

2.2 Other basic parameters

EX-ACT allows users also to set the GWP for the analysis (see **Figure 15**). The options include:

- **100 yr SAR:** Global warming potential over 100 years from the Second Assessment Report (SAR), *Climate Change 1995 - The Science of Climate Change* (IPCC, 1996).
- **100 yr AR4:** Global warming potential over 100 years from the Fourth Assessment Report (AR4), *Climate Change 2007 - The Physical Science Basis* (IPCC, 2007).
- **100 yr AR5 with CC feedback (default):** Global warming potential over 100 years from the Fifth Assessment Report (AR5) with climate carbon feedback, *Climate Change 2013 - The Physical Science Basis* (IPCC, 2013).
- **100 yr AR5 w/out CC feedback:** Global warming potential over 100 years from the Fifth Assessment Report (AR5) without climate carbon feedback, *Climate Change 2013 - The Physical Science Basis* (IPCC, 2013).

Figure 15. Default global warming potential

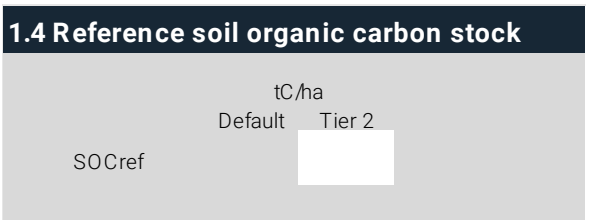


Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

More advanced users also have a possibility to set the reference soil organic carbon stock (SOC_{ref}) (**Figure 16**) for the entire analysis. The default value is triggered by filling in the mandatory information on project site and duration (see Section 2.1) and displayed in sub-module 1.4 of the Description module under "Default". Filling in "Tier 2" cell will assign a general user-defined value for all subsequent calculations where SOC_{ref} is used. The general user defined SOC_{ref} value can be further refined as necessary using Tier 2 interface in the other modules and sub-modules of the tool, as necessary. If "Tier 2" is left blank, the standard default value will be used by the tool. Again, it is possible to refine the default value in other modules and sub-modules of the tool, as necessary.

Figure 16. Reference soil organic carbon stock in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 3. Land use change module

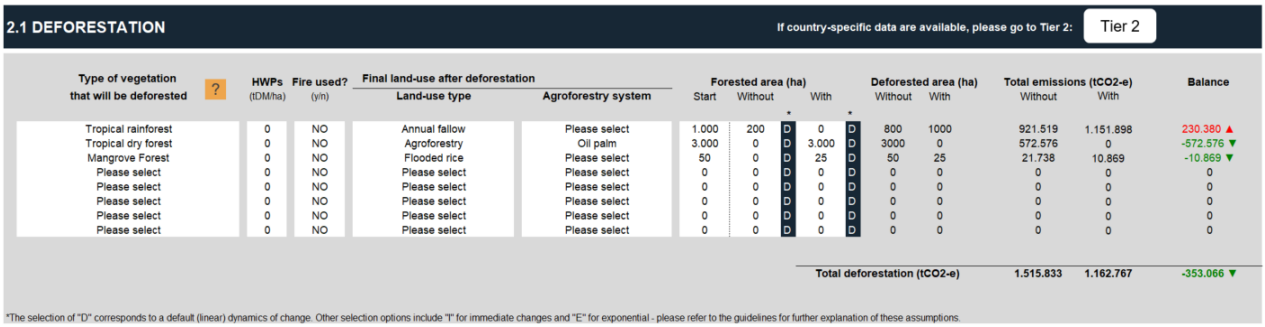
The land use change module consists of three sub-modules: deforestation, afforestation/reforestation and other land use changes. The user interacts with this module when project activities or baseline scenario lead to a change in the use of land.

3.1 Deforestation

3.1.1 Methodology

This sub-module draws on Volume 4 (AFOLU) of IPCC (2019) Chapter 4 "Forest Land" and Chapter 2 "Generic Methodology Applicable to Multiple Land use Categories". It is built on four types of information: (i) the definition of the vegetation that will be deforested, (ii) deforestation process including the quantity of harvested wood products (HWP) and the use of fire, (iii) the final land use after deforestation, and (iv) the surface of the area that will be deforested (see **Figure 17**).

Figure 17. Deforestation sub-module in EX-ACT



2.1 DEFORESTATION — If country-specific data are available, please go to Tier 2: Tier 2

Type of vegetation that will be deforested	HWPs (tDM/ha)	Fire used? (y/n)	Final land-use after deforestation: Land-use type	Final land-use after deforestation: Agroforestry system	Forested area (ha) Start	Forested area (ha) Without	*	Forested area (ha) With	*	Deforested area (ha) Without	Deforested area (ha) With	Total emissions (tCO2-e) Without	Total emissions (tCO2-e) With	Balance
Tropical rainforest	0	NO	Annual fallow	Please select	1.000	200	D	0	D	800	1000	921.519	1.151.898	230.380 ▲
Tropical dry forest	0	NO	Agroforestry	Oil palm	3.000	0	D	3.000	D	3000	0	572.576	0	-572.576 ▼
Mangrove Forest	0	NO	Flooded rice	Please select	50	0	D	25	D	50	25	21.738	10.869	-10.869 ▼
Please select	0	NO	Please select	Please select	0	0	D	0	D	0	0	0	0	0
Please select	0	NO	Please select	Please select	0	0	D	0	D	0	0	0	0	0
Please select	0	NO	Please select	Please select	0	0	D	0	D	0	0	0	0	0
Please select	0	NO	Please select	Please select	0	0	D	0	D	0	0	0	0	0
Please select	0	NO	Please select	Please select	0	0	D	0	D	0	0	0	0	0
											Total deforestation (tCO2-e)	1.515.833	1.162.767	-353.066 ▼

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

3.1.2 Definition of the vegetation

The user needs first to identify the type of vegetation that will be deforested selecting the most appropriate one from a dropdown list provided in the sub-module. The choice of vegetation available to select from varies according to the climate zone selected in the "Description" module. EX-ACT distinguishes between natural vegetation and planted vegetation. **Table 3** summarises the vegetation types per climate zone available in EX-ACT.

Table 3. Vegetation types (natural or plantation) per climate zone available in EX-ACT

Tropical	Warm temperate	Cool temperate	Boreal	Tropical montane
Tropical rainforest	Subtropical humid forest	Temperate oceanic forest	Boreal coniferous forest	Tropical mountain systems
Tropical moist deciduous forest	Subtropical dry forest	Temperate continental forest	Boreal tundra woodland	Planted tropical mountain systems
Tropical dry forest	Subtropical steppe	Temperate mountain systems	Boreal mountain systems	
Tropical shrubland	Subtropical mountain systems	Temperate desert	Planted boreal coniferous forest	

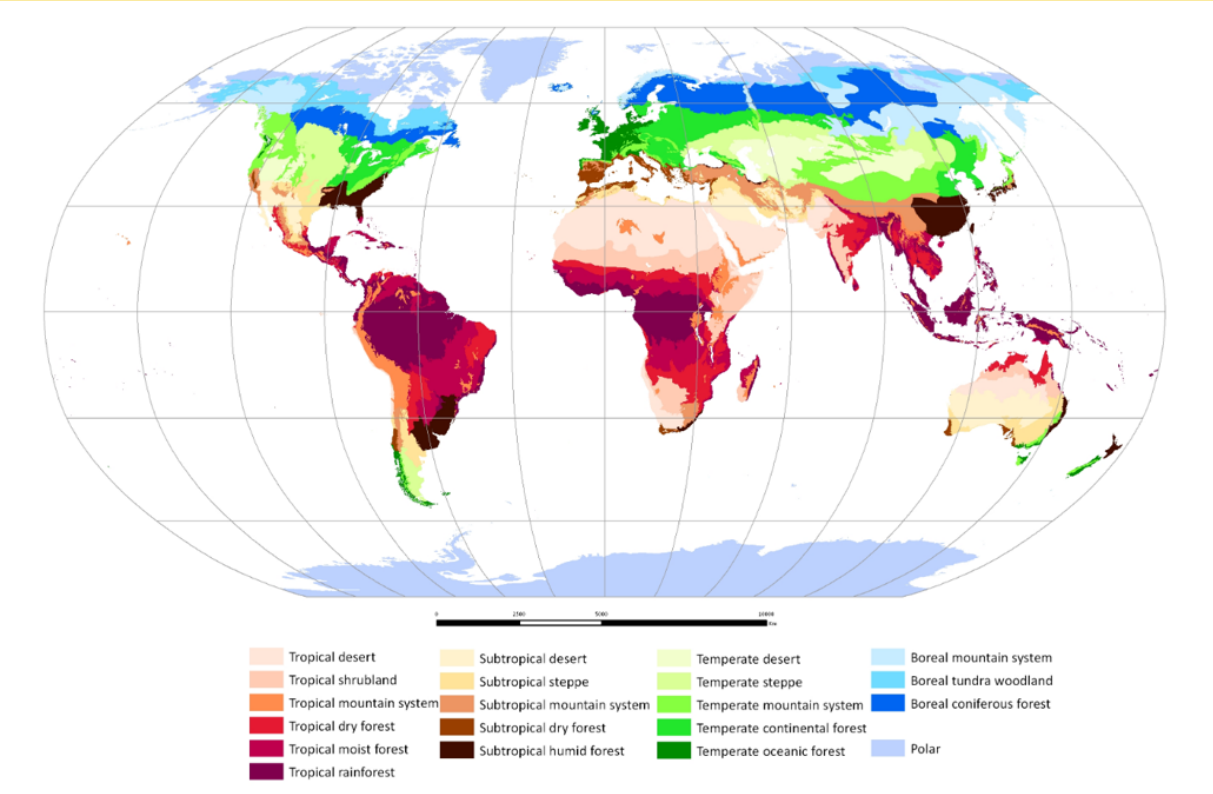
Tropical	Warm temperate	Cool temperate	Boreal	Tropical montane
Planted tropical rainforest	Planted subtropical humid forest	Temperate steppe	Planted boreal tundra woodland	
Planted tropical moist deciduous forest	Planted subtropical dry forest	Planted temperate oceanic forest	Planted boreal mountain systems	
Planted tropical dry forest	Planted subtropical steppe	Planted temperate continental forest		
Planted tropical shrubland	Planted subtropical mountain systems	Planted temperate mountain systems		

Source: Authors' own elaboration based on Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Box 4. Selecting the right type of vegetation

The "Help" tab provides a map of global ecological zones to help users select the most adequate vegetation type in their project location (see **Figure 18**).

Figure 18. Global ecological zones based on observed climate and vegetation patterns



Source: FAO. 2012. *Global ecological zones for FAO forest reporting: 2010 update*. Forest Resources Assessment Working Paper 179. Rome.

The distinction between "Forest" and "Planted forest" allows to distinguish between intensively (i.e. plantation forestry) and extensively (naturally re-growing stands with reduced or minimum human intervention) managed forests. Management regime has a strong influence on forests' characteristics, such as the growth rate of trees, which are key from the point of view of estimating GHG emissions associated with deforestation.

The five carbon pools for the selected vegetation type are quantified according to the general methodology described in Section 1.3 using forest-related parameters:

- **Above-ground biomass** is derived from Table 4.12 of IPCC (2019) for natural forest and is reported from **Figure 4** to **Figure 8**. EX-ACT retains either the value proposed by IPCC directly or the central value when a range of possible values is proposed. Values vary according to the continent and the ecological zone (see Table 4 to Table 8 of IPCC [2019]). When no specific numbers were available, the default value for a determined continent is proposed, which corresponds to the default used for a full Tier 1 approach (see Table 4.12 of IPCC [2006]). The default values in t d.m./ha are converted into tC/ha using the carbon fraction of above-ground biomass of 0.47 t C/t d.m. (see Table 4.3 of IPCC [2006]). For mangroves, EX-ACT retains default values from Table 4.3 of IPCC (2014), i.e. 92 tonne of dry matter per hectare (t d.m./ha) for tropical dry climate, 192 t d.m./ha for tropical moist and wet climate, and 75 t d.m./ha for warm temperate climate. Values are converted in tonne of carbon per hectare (tC/ha) using the carbon fraction of above-ground biomass of 0.451 tC/t d.m. (see Table 4.2 of IPCC [2014]).

Table 4. Above ground biomass, in tonne of dry matter per hectare, for tropical climate

Geographical regions	Tropical rainforest	Tropical moist deciduous forest	Tropical dry forest	Tropical shrubland	Planted tropical rainforest	Planted tropical moist deciduous forest	Planted tropical dry forest	Planted tropical shrubland
Africa	404	237	70	48	250	302	127	20
Asia	413	68	185	38	281	177	67	147
Europe	**300**	**180**	**130**	**70**	**150**	**120**	**60**	**30**
Oceania	**300**	**180**	**130**	**70**	**150**	**120**	**60**	**30**
The Americas and the Caribbean	307	187	128	72	225	166	80	45

Notes: Values for plantations are calculated as the average of a given range.

Sources: Values in bold are taken from Table 4.12 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 5. Above-ground biomass, in tonne of dry matter per hectare, for warm temperate climate

Geographical regions	Subtropical humid forest	Subtropical dry forest	Subtropical steppe	Subtropical mountain systems	Planted subtropical humid forest	Planted subtropical dry forest	Planted subtropical steppe	Planted subtropical mountain
Africa	54	65	51	35	**140**	65	18	90
Asia	323	71	42	250	140	111	50	**90**
Europe	**220**	**130**	**70**	**140**	**140**	**60**	**30**	**90**
Oceania	**220**	**130**	**70**	**140**	**140**	**60**	**30**	**90**
The Americas and the Caribbean	85	116	44	75	141	85	45	98

Notes: Values for plantations are calculated as the average of a given range.

Sources: Values in bold are taken from Table 4.12 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 6. Above-ground biomass, in tonne of dry matter per hectare, for temperate climate

Geographical regions	Temperate oceanic forest	Temperate continental forest	Temperate mountain systems	Temperate desert	Temperate steppe	Planted temperate oceanic forest	Planted temperate continental forest	Planted temperate mountain systems	Planted temperate desert	Planted temperate steppe
Africa	**180**	**120**	**100**	**44**	**119**	**160**	**100**	100	44	44
Asia	290	**120**	**100**	**44**	**119**	175	93	100	44	44
Europe	126	332	301	**44**	**119**	175	**100**	100	44	44
Oceania	353	**120**	**100**	**44**	**119**	**160**	**100**	100	44	44
The Americas and the Caribbean	**180**	**120**	**100**	**44**	**119**	104	59	59	44	44

Notes: Values for plantations are calculated as the average of a given range.

Sources: Values in bold are taken from Table 4.12 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 7. Above-ground biomass, in tonne of dry matter per hectare, for boreal climate

Geographical regions	Boreal coniferous forest	Boreal tundra woodland	Boreal mountain systems	Planted boreal coniferous forest	Planted boreal tundra woodland	Planted boreal mountain systems
Africa	**50**	**15**	**30**	**40**	**15**	**30**
Asia	63	**15**	**30**	45	25	45
Europe	63	**15**	**30**	45	25	45
Oceania	**50**	**15**	**30**	**40**	**15**	**30**
North America	63	**15**	**30**	45	25	45
South and Central America and the Caribbean	**50**	**15**	**30**	**40**	**15**	**30**

Notes: Values for plantations are calculated as the average of a given range.

Sources: Values in bold are taken from Table 4.12 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 8. Above-ground biomass, in tonne of dry matter per hectare, for tropical mountain climate

Geographical regions	Tropical mountain systems	Planted tropical mountain systems
Africa	190	90
Asia	434	88
Europe	**140**	**90**
Oceania	**140**	**90**
The Americas and the Caribbean	195	100

Notes: Values for plantations are calculated as the average of a given range.

Sources: Values in bold are taken from Table 4.12 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

- **Below-ground biomass** is estimated using a ratio of below-ground biomass to above-ground biomass, R, expressed in t root d.m. per t shoot d.m. The values used in EX-ACT represent the default R values from Table 4.4 (IPCC, 2019) and are reported in **Tables 9** to **14**. For all ecosystem in boreal climate, when AGB (above-ground biomass) has ≤ 125 t d.m./ha, a default ratio of below-ground biomass to above-ground biomass of 0.390 is used, and 0.240 for when AGB has > 75 t d.m./ha. For tropical mountain system (forest and plantation), a default value of 0.27 is used for all regions. For mangrove, IPCC (2014) recommends considering a specific R ratio of below-ground to above-ground biomass according to climate zone, i.e. 0.49 for tropical wet climate, 0.29 for tropical dry climate and 0.91 for warm temperate climate, (IPCC, 2014). Below-ground values are then converted in tC/ha using the same carbon fractions as for the above-ground biomass.
- **Litter and deadwood:** Proposed values are based on default values from Table 2.2 (IPCC, 2019) by climate zone and reported in **Table 15**. The litter in mangrove is 0.7tC/ha, and the deadwood carbon stock is 10.7 tC/ha from Table 4.7 (IPCC, 2014).

- **Soil:** the estimates are based on default references for SOC stocks for mineral soils to a depth of 30 cm (see Section 1.3 and **Table 1**). For mangroves, in the absence of a related methodology, EX-ACT assumes the related SOC stocks are equivalent to the inland wetland soil (wetland soil) default values for SOC stocks to a depth of 30 cm.

Table 9. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass ≤ 125 t d.m./ha in tropical climate

Geographical regions	Tropical rainforest	Tropical moist deciduous forest	Tropical dry forest	Tropical shrubland	Planted tropical rainforest	Planted tropical moist deciduous	Planted tropical dry forest	Planted tropical shrubland
Africa	0.825	0.232	0.332	**0.400**	**0.370**	**0.200**	**0.560**	**0.400**
Asia	0.207	0.323	0.381	0.322	0.325	**0.200**	**0.560**	**0.400**
Europe	**0.370**	**0.200**	**0.560**	**0.400**	**0.370**	**0.200**	**0.560**	**0.400**
Oceania	**0.370**	**0.200**	**0.560**	**0.400**	**0.370**	**0.200**	**0.560**	**0.400**
The Americas and the Caribbean	0.221	0.284	0.334	0.348	0.170	**0.200**	**0.560**	2.158

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 10. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass ≤ 125 t d.m./ha in warm temperate climate

Geographical regions	Subtropical humid forest	Subtropical dry forest	Subtropical steppe	Subtropical mountain systems	Planted subtropical humid forest	Planted subtropical dry forest	Planted subtropical steppe	Planted subtropical mountain
Africa	0.232	**0.560**	**0.320**	0.270	0.200	0.560	**0.320**	**0.270**
Asia	0.230	0.440	**0.320**	0.270	0.200	0.560	2.158	**0.270**
Europe	**0.200**	**0.560**	**0.320**	0.270	0.200	0.560	**0.320**	**0.270**
Oceania	**0.200**	**0.560**	**0.320**	0.270	0.200	0.560	**0.320**	**0.270**
The Americas and the Caribbean	0.175	0.336	1.338	0.270	0.200	0.560	**0.320**	**0.270**

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 11. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass ≤ 125 t d.m./ha in temperate climate

Geographical regions	Temperate oceanic forest	Temperate continental forest	Temperate mountain systems	Temperate desert	Temperate steppe	Planted temperate oceanic forest	Planted temperate continental forest	Planted temperate mountain systems	Planted temperate desert	Planted temperate steppe
Africa	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**
Asia	*0.267*	*0.243*	*0.323*	**0.440**	**0.440**	0.307	*0.305*	*0.254*	**0.440**	**0.440**
Europe	*0.276*	**0.440**	1.155	**0.440**	**0.440**	*0.880*	0.340	**0.440**	**0.440**	**0.440**
Oceania	*0.339*	**0.440**	0.145	**0.440**	**0.440**	*0.513*	**0.440**	0.293	**0.440**	**0.440**
The Americas and the Caribbean	*0.402*	0.481	*0.301*	**0.440**	**0.440**	**0.440**	0.237	0.302	**0.440**	**0.440**

Notes: Values in italic are the average of a given range including conifers.

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 12. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass >125 t d.m./ha in tropical climate

Geographical regions	Tropical rainforest	Tropical moist deciduous forest	Tropical dry forest	Tropical shrubland	Planted tropical rainforest	Planted tropical moist deciduous forest	Planted tropical dry forest	Planted tropical shrubland
Africa	0.532	0.232	0.379	**0.400**	**0.370**	**0.240**	**0.280**	**0.400**
Asia	0.212	0.246	0.379	0.345	**0.370**	**0.240**	**0.280**	**0.400**
Europe	**0.370**	**0.240**	**0.280**	**0.400**	**0.370**	**0.240**	**0.280**	**0.400**
Oceania	**0.370**	**0.240**	**0.280**	**0.400**	**0.370**	**0.240**	**0.280**	**0.400**
The Americas and the Caribbean	0.221	0.284	0.379	0.283	0.170	**0.240**	**0.280**	**0.400**

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 13. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass ≤ 125 t d.m./ha in warm temperate climate

Geographical regions	Subtropical humid forest	Subtropical dry forest	Subtropical steppe	Subtropical mountain systems	Planted subtropical humid forest	Planted Subtropical dry forest	Planted Subtropical steppe	Planted subtropical mountain systems
Africa	0.232	**0.280**	**0.320**	**0.270**	**0.240**	**0.280**	**0.320**	**0.270**
Asia	0.246	0.440	1.338	**0.270**	**0.240**	**0.280**	**0.320**	**0.270**
Europe	**0.240**	**0.280**	**0.320**	**0.270**	**0.240**	**0.280**	**0.320**	**0.270**
Oceania	**0.240**	**0.280**	**0.320**	**0.270**	**0.240**	**0.280**	**0.320**	**0.270**
The Americas and the Caribbean	0.284	0.352	**0.320**	**0.270**	**0.240**	**0.280**	**0.320**	**0.270**

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 14. Ratio of below-ground biomass to above-ground biomass (R) in t root d.m./t shoot d.m., for above-ground biomass >125 t d.m./ha in temperate climate

Geographical regions	Temperate oceanic forest	Temperate continental forest	Temperate mountain systems	Temperate desert	Temperate steppe	Planted temperate oceanic forest	Planted temperate continental forest	Planted temperate mountain systems	Planted temperate desert	Planted temperate steppe
Africa	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**	**0.220**
Asia	0.229	*0.288*	*0.265*	**0.220**	**0.220**	*0.240*	*0.234*	*0.233*	**0.220**	**0.220**
Europe	0.172	0.477	0.394	**0.220**	**0.220**	*0.283*	**0.220**	**0.220**	**0.220**	**0.220**
Oceania	*0.253*	**0.220**	0.302	**0.220**	**0.220**	*0.242*	**0.220**	0.201	**0.220**	**0.220**
The Americas and the Caribbean	*0.264*	0.277	*0.231*	**0.220**	**0.220**	0.203	**0.220**	**0.220**	**0.220**	**0.220**

Notes: Values in italic are the average of a given range including conifers.

Sources: Values in bold are taken from Table 4.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl; other values are taken from Table 4.4 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 15. Default litter and dead wood carbon stocks, in tC/ha

Forest type stratified by climate	Litter carbon stocks	Dead wood carbon stocks
Tropical rainforest	4.8	14.8
Tropical moist deciduous forest	5.9	8.0
Tropical dry forest	2.4	9.0
Tropical shrubland	0	0
Mangrove Forest	0.7	10.7
Subtropical humid forest	8.7	13.2
Subtropical dry forest	0	64.4
Subtropical steppe	0	6.8
Subtropical mountain systems	0	11.8
Temperate oceanic forest	2.9	36.8
Temperate continental forest	47.8	23
Temperate mountain systems	3.7	37.6
Temperate desert	0	10.5
Temperate steppe	28.7	21.7
Boreal coniferous forest	31.4	19.7
Boreal tundra woodland	49.5	3.1
Boreal mountain systems	0	0
Tropical mountain systems	0	3.3
Planted tropical rainforest	4.8	14.8
Planted tropical moist deciduous forest	5.9	8.0
Planted tropical dry forest	2.4	9.0
Planted tropical shrubland	0	0
Planted subtropical humid forest	8.7	13.2
Planted subtropical dry forest	0	64.4
Planted subtropical steppe	0	6.8
Planted subtropical mountain systems	0	11.8
Planted temperate oceanic forest	2.9	36.8
Planted temperate continental forest	47.8	23
Planted temperate mountain systems	3.7	37.6
Planted temperate desert	0	10.5
Planted temperate steppe	28.7	21.7
Planted boreal coniferous forest	31.4	19.7
Planted boreal tundra woodland	49.5	3.1
Planted boreal mountain systems	0	0
Planted tropical mountain systems	0	3.3

Source: Authors' own elaboration based on Table 2.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

3.1.3 Deforestation process

After selecting the type of vegetation, the user needs to provide information related to the process of deforestation including:

- The amount of **harvested wood product (HWP)** during the land conversion process and expressed in t d.m./ha. The amount of carbon exported is then calculated by the tool using the default carbon content of 0.47, and 0.451 for mangrove. HWP can be used as (i) raw material; (ii) fuel; and (iii) disposed solid waste. As the end-use of HWP can be different, the amount of carbon stored in HWP is not included in the final carbon-balance in EX-ACT. However, if HWP is used as a source of energy (fuel), users can include GHG emissions from this source using the "Inputs and Investments" module (see Section 9).

Fire use to account for emissions from burning. The emissions are calculated for individual GHG (N_2O and CH_4) as follows:

$$GHG_{fire} = M_B \times C_F \times G_{ef}$$

(Eq. 4)[6]

Where:

GHG_{fire} = amount of GHG from fire, kg of each, N_2O and CH_4;

M_B = mass of fuel available for combustion, tonnes;

C_F = combustion factor, dimensionless;

G_{ef} = emission factor, g/kg d.m. burnt.

The values of the factors C_F and G_{ef} applied are detailed in **Table 16**. The M_B parameter corresponds to above-ground biomass available for burning (total above-ground biomass less HWP). In the tool, if the fire is set to "yes", the corresponding default emission factor associated with the vegetation type is used, and applied to M_B. The amount of CH_4 and N_2O are calculated in kg per gas, and the sum expressed in tCO_2-e is determined using the GWP indicated in the "Description" module.

Table 16. Combustion factor (CF), dimensionless, and emission factor (Gef), in g per kg of dry matter burnt, used for fire used during deforestation

Forest types stratified by IPCC climate	CF	Gef CH_4	Gef N_2O
Tropical rainforest	0.32	6.8	0.2
Tropical moist deciduous forest	0.36	6.8	0.2
Tropical dry forest	0.36	6.8	0.2
Tropical shrubland	0.72	6.8	0.2
Mangrove forest	0.32	6.8	0.2
Planted tropical rainforest	0.32	6.8	0.2
Planted tropical moist deciduous forest	0.36	6.8	0.2
Planted tropical dry forest	0.36	6.8	0.2
Planted tropical shrubland	0.72	6.8	0.2
Subtropical humid forest	0.36	4.7	0.26
Subtropical dry forest	0.36	4.7	0.26
Subtropical steppe	0.74	4.7	0.26

[6] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

Forest types stratified by IPCC climate	CF	Gef CH_4	Gef N_2O
Subtropical mountain systems	0.36	4.7	0.26
Planted subtropical humid forest	0.36	4.7	0.26
Planted subtropical dry forest	0.36	4.7	0.26
Planted subtropical steppe	0.74	4.7	0.26
Planted subtropical mountain systems	0.36	4.7	0.26
Temperate oceanic forest	0.45	4.7	0.26
Temperate continental forest	0.45	4.7	0.26
Temperate mountain systems	0.45	4.7	0.26
Temperate desert	0.45	4.7	0.26
Temperate steppe	0.45	4.7	0.26
Planted temperate oceanic forest	0.45	4.7	0.26
Planted temperate continental forest	0.45	4.7	0.26
Planted temperate mountain systems	0.45	4.7	0.26
Planted temperate desert	0.45	4.7	0.26
Planted temperate steppe	0.45	4.7	0.26
Boreal coniferous forest	0.34	4.7	0.26
Boreal tundra woodland	0.34	4.7	0.26
Boreal mountain systems	0.34	4.7	0.26
Planted boreal coniferous forest	0.34	4.7	0.26
Planted boreal tundra woodland	0.34	4.7	0.26
Planted boreal mountain systems	0.34	4.7	0.26
Tropical mountain systems	0.36	6.8	0.2
Planted tropical mountain systems	0.36	6.8	0.2

Source: Authors' own elaboration based on Table 2.5 and Table 2.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

3.1.4 Final land use after deforestation

The user must determine the **final use of land after conversion** to determine the default carbon stocks the year following the deforestation in terms of biomass and SOC. The options available in the tool include annual cropland, annual fallow, flooded rice, grassland, other (non-vegetated) land, degraded land and agroforestry. Agroforestry is further disaggregated, and the choice depends on the project location defined in the "Description" module. Overall, the available agroforestry systems include alley cropping, perennial fallow, hedgerow, multi-strata, parkland, shaded perennial, silvoarable, silvopasture, olive, orchard, short rotation coppice, tea, vine, oil palm and rubber.

The proposed default biomass carbon stocks, in tC/ha, in the year following the conversion are detailed from **Table 17** to **25**. Values for annual crops correspond to the proposed value for default biomass carbon stocks present on land converted to cropland in the year following conversion (see Table 6.4 of IPCC [2019]). Flooded rice is assumed to have the same values as annual crops. Values for grassland are derived from Table 6.4 of IPCC (2006) using the default carbon content of 0.47 (IPCC, 2006). Other land (non-vegetated) is set to zero, and can thus be used for constructions, roads, parking lots or any kind of land use where no vegetation will be present. Values for agroforestry systems are derived from Tables 5.2 and Table 5.3 of IPCC (2019).

Table 17. Default biomass carbon stock, in tC/ha, for system implanted after deforestation for all region

IPCC climate zones	Annual cropland	Annual fallow	Paddy rice	Grassland	Other land (non-vegetated)	Degraded land
Boreal	4.7	4.7	4.7	**4.00**	**0**	1
Cool temperate dry	4.7	4.7	4.7	**3.06**	**0**	1
Cool temperate moist	4.7	4.7	4.7	**6.39**	**0**	1
Warm temperate dry	4.7	4.7	4.7	**2.87**	**0**	1
Warm temperate moist	4.7	4.7	4.7	**6.35**	**0**	1
Tropical montane and tropical dry	4.7	4.7	4.7	**4.09**	**0**	1
Tropical moist and tropical wet	4.7	4.7	4.7	**7.57**	**0**	1

Notes: Bold values are from IPCC (2006). The value for paddy rice is assumed the same as for annual crop.

Source: Authors' own elaboration based on Table 5.9 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl and in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and Table 6.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

Table 18. Default biomass carbon stock, in tC/ha, for monoculture agroforestry system implanted after deforestation according to the climate characteristics

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Temperate (all) and boreal (all)	0.46	0.43	0.28	3.2	0	0	0.7
Tropical (all)	0	0	0	0	2.4	3.0	0.7
All	0	0	0	0	0	0	0.7

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 19. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for cool temperate dry and cool temperate moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded Perennial	Silvoarable	Silvopasture
Africa	1.6	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.3
Asia	2.4	0.0	0.0	1.1	0.0	0.0	0.0	3.7	2.3
Europe	1.7	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.7
Oceania	1.6	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.3
North America		0.0	0.0	1.1	0.0	0.0	0.0	0.7	1.1
South and Central America, and the Caribbean	1.4	0.0	0.0	1.1	0.0	0.0	0.0	1.4	1.7

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 20. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for warm temperate moist and warm temperate dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded Perennial	Silvoarable	Silvopasture
Africa	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Asia	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Europe	2.0	0.0	0.0	1.1	0.0	0.0	0.0	0.7	4.1
Oceania	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
The Americas and the Caribbean	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 21. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for boreal dry and boreal moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Asia	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Europe	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Oceania	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
The Americas and the Caribbean	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 22. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for tropical dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded Perennial	Silvoarable	Silvopasture
Africa	3.6	2.3	8.2	0.6	2.1	0.8	3.0	7.9	3.9
Asia	3.5	3.5	6.1	0.6	2.1	0.8	3.0	7.9	3.9
Europe	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9
Oceania	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9
The Americas and the Caribbean	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 23. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for tropical moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded Perennial	Silvoarable	Silvopasture
Africa	3.4	3.3	6.6	0.6	3.7	0.8	2.3	6.3	3.7
Asia	2.9	3.2	6.6	0.6	3.8	0.8	2.6	1.9	3.7
Europe	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
Oceania	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
North America	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
South America	3.2	3.2	6.6	0.6	3.8	0.8	3.8	3.3	3.7
Central America	3.1	2.8	6.6	0.6	3.8	0.8	3.0	3.3	3.7
Caribbean	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 24. Total biomass various agroforestry systems, in tC/ha, of land uses following deforestation for tropical montane climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded Perennial	Silvoarable	Silvopasture
Africa	2.7	2.9	4.2	0.8	4.1	0.8	3.0	2.8	3.4
Asia	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
Europe	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
Oceania	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
The Americas and the Caribbean	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 25. Total biomass for various agroforestry systems, in tC/ha, of land uses following deforestation for tropical wet climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.9	2.3	7.7	0.5	3.6	0.8	3.9	4.5	0.1
Asia	2.4	2.3	2.5	0.5	6.0	0.8	2.2	4.5	0.1
Europe	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
Oceania	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
North America	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
South America	2.6	2.3	5.9	0.5	3.3	0.8	3.7	4.5	0.1
Central America	2.6	2.3	5.7	0.5	4.0	0.8	2.8	4.5	0.1
Caribbean	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

For soils, the estimation method is based on changes in SOC stocks over a finite period following changes in management that impact the $SOC_{ref,}$ as described in Section 1.3. According to the information provided by the user, EX-ACT estimates the carbon stocks variation relative to the carbon stock before conversion from the land use change stock change factor, FL_u, (see **Table 26**). FL_u is based on the relative factors for cropland systems provided by IPCC in Table 5.5 and Table 6.2 of IPCC (2019). These factors were fixed to their nominal values (i.e. the value given for a system that is non-degraded and sustainably managed without significant management improvements). Specific management options that impact the SOC stocks in the new system after deforestation are treated separately and at a later step of the analysis in the corresponding sub-modules. For example, if a grassland system is set after deforestation, the SOC remains unchanged (nominal value is set to 1), while further in the "Grassland" module users have the possibility to determine the management practices, as may be required, which will adjust the subsequent calculations by changing the SOC away from the nominal value of 1. This allows for isolating the land management effect from the land use change effect. The specific factors applied in each sub-module for each land use after deforestation are detailed in their respective sections.

The change in SOC stock (over the reference period of 20 years) is computed using the default soil organic carbon content corresponding to the deforested vegetation (see **Table 1**):

$$\Delta C = (SOC_{ref} - SOC_{ref} * FL_u)$$

(Eq. 5)

Table 26. Relative stock change factor for land use (FL_u) dimensionless

IPCC climate zones	Annual cropland	Annual fallow	Flooded rice	Grassland	Other land (non-vegetated)	Agroforestry	Degraded land
Boreal dry	0.77	0.93	1.35	1.0	1.0	0.72	0.39
Boreal moist	0.7	0.82	1.35	1.0	1.0	0.72	0.35
Cool temperate dry	0.77	0.93	1.35	1.0	1.0	0.72	0.39
Cool temperate moist	0.7	0.82	1.35	1.0	1.0	0.72	0.35
Tropical dry	0.92	0.93	1.35	1.0	1.0	1.01	0.46
Tropical moist	0.83	0.82	1.35	1.0	1.0	1.01	0.42
Tropical wet	0.83	0.82	1.35	1.0	1.0	1.01	0.42
Tropical montane	0.64	0.88	1.35	1.0	1.0	1.00	0.32
Warm temperate dry	0.76	0.93	1.35	1.0	1.0	0.72	0.38
Warm temperate moist	0.69	0.82	1.35	1.0	1.0	0.72	0.35

Notes: FLu between the various agroforestry systems, including monoculture, are the same than for the general system "Agroforestry". FLu for conversion to "Degraded land" is 50 percent of "Annual cropland".

Source: Authors' own elaboration based on Table 5.5 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

3.1.5 N_2O emissions associated with loss of soil organic carbon stocks in mineral soils through land use change

Together with changes and oxidation of SOC storage, land use management is also accompanied by mineralization of nitrogen (N), which is an additional source of N_2O emissions. Where soil carbon losses occur, the release of N_20 by mineralization of N is estimated as:

$$F_{SOM} = \sum((\Delta C_{mineral} \times 1/R) \times 1000)$$

(Eq. 6) [7]

Where:

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, in kg N;

$\Delta C_{mineral}$ = average annual loss of soil carbon for each land use type, in tonnes C;

R = ratio of the soil organic matter.

For R, a default value of 15 is given for land use changes from Forest to Cropland (annual and perennial), and Forest to degraded land. Default values are provided in Chapter 11 in Volume 4 of IPCC (2019).

[7] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

3.1.6 Surface and GHG emissions

To trigger the calculations, users must provide data on the amount of land concerned by deforestation expressed in hectares: the surface of forest at the start, with project and without project scenario. Using this information, EX-ACT derives the deforested areas for each scenario and each system defined by the user. Based on the surface, vegetation characteristics and deforestation process details, the GHG emissions are calculated for each scenario as well as the carbon balance in tCO_2-e.

The dynamics of change are set by default to linear ("D" in the dark blue cell) and used in the calculations. The user can change the default setting, which will automatically adjust the calculations. See Section 1.2.2 on dynamics of change for more details.

The area of land reported under deforestation sub-module is later used in the land use change matrix ("Results" module and also feed the subsequent sub-modules (in "Cropland" and "Grassland" modules as applicable), which allows users to determine the corresponding land management practices as may be required (see Section 3.1.4).

3.1.7 Tier 2 options

Users have the possibility to enter location-specific parameters that will be used instead of the default ones. The Tier 2 section of the "Deforestation" sub-module allows for changing the carbon content of the five different carbon pools: above-ground and below-ground biomass, litter, dead wood and soil carbon (see **Figure 19**).

Figure 19. Default values and Tier 2 approach for "Deforestation"

2.1 DEFORESTATION — Back

All units are in tC/ha

Type of vegetation that will be deforested	Above-ground Default	Above-ground Tier 2	Below-ground Default	Below-ground Tier 2	Litter Default	Litter Tier 2	Dead wood Default	Dead wood Tier 2	Soil carbon Default	Soil carbon Tier 2
Tropical rainforest	190,0		101,1		4,8		14,8		52,0	
Tropical dry forest	32,7		10,9		2,4		9,0		52,0	
Mangrove Forest	86,6		42,4		0,7		10,7		49,0	
Please select	0,0		0,0		0,0		0,0		0,0	
Please select	0,0		0,0		0,0		0,0		0,0	
Please select	0,0		0,0		0,0		0,0		0,0	
Please select	0,0		0,0		0,0		0,0		0,0	
Please select	0,0		0,0		0,0		0,0		0,0	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Annual balance

Start year of implementation	
1	4
1	2
1	
1	
1	
1	
1	
1	

Use this part only if you want to refine yearly GHG fluxes

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

3.2 Afforestation and reforestation

3.2.1 Methodology

This sub-module draws on Volume 4 (AFOLU) of IPCC (2019) Chapter 4 entitled "Forest Land" and Chapter 2 "Generic Methodology Applicable to Multiple Land use Categories". It is built on four types of information: (i) definition of the vegetation that will be afforested/reforested; (ii) afforestation/reforestation process; (iii) land use before afforestation/reforestation; and (iv) surface of the area that will be afforested/reforested (see **Figure 20**).

Figure 20. Afforestation and Reforestation sub-module in EX-ACT

2.2 AFFORESTATION & REFORESTATION — If country-specific data are available, please go to Tier 2: Tier 2

Final land-use	Fire used? (y/n)	Initial land-use	Initial agroforestry systems	Reforested area (ha) Without	*	Reforested area (ha) With	*	Total emissions (tCO2-e) Without	Total emissions (tCO2-e) With	Balance
Tropical dry forest	NO	Annual cropland	Please select	100	D	0	D	-20.959	0	20.959 ▲
Tropical shrubland	NO	Flooded rice	Please select	500	D	200	D	32.483	12.993	-19.490 ▼
Planted Tropical moist deciduous forest	NO	Grassland	Please select	0	D	300	D	0	-104.679	-104.679 ▼
Please select	NO	Agroforestry	Multistrata	100	D	0	D	0	0	0
Please select	NO	Please select	Please select	0	D	0	D	0	0	0
Please select	NO	Please select	Please select	0	D	0	D	0	0	0
Please select	NO	Please select	Please select	0	D	0	D	0	0	0
Please select	NO	Please select	Please select	0	D	0	D	0	0	0
						Total af/re forestation (tCO2-e)		11.524	-91.686	-103.210 ▼

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

3.2.2 Definition of the vegetation

The user needs first to identify the type of vegetation that will be planted or restored selecting the most appropriate one from a dropdown list provided in the sub-module. The choice of vegetation available to select from varies according to the climate zone selected in the "Description" module. EX-ACT distinguishes between natural vegetation and planted vegetation. **Table 3** summarises the vegetation types per climate zone available in EX-ACT.

The distinction between "Forest" and "Planted forest" allows to distinguish between intensively (i.e. plantation forestry) and extensively (naturally re-growing stands with reduced or minimum human intervention) managed forests. Management regime has a strong influence on forests' characteristics, such as the growth rate of trees, which are key from the point of view of estimating GHG emissions associated with deforestation.

The five carbon pools for the selected vegetation type are quantified according to the general methodology described in Section 1.3 using forest-related parameters. IPCC (2019) highlights that in deriving estimates of biomass accumulation rates it is key to recognize that biomass growth rates will occur primarily during the first 20 years following changes in management, after which time the rates will tend towards a new steady-state level with little or no change unless further changes in management conditions occur. As a result, the accumulation rates applied must make a distinction between systems that are 20 years old and younger and systems that are older than 20 years.

- **Above-ground biomass growth rates** are derived from Table 4.12 of IPCC (2019). EX-ACT uses directly the values proposed by IPCC or the central value of a range of possible values when only a range is proposed. The possible values vary according to the continent and the ecological zone and are detailed in **Tables 27** to **35**. As these data weigh heavily on the final GHG estimates, it is highly recommended that the user seeks location-specific data to be used instead (in the Tier 2 section and if such data exist) to improve the quality of the analysis. For planted vegetation, Table 4.10 of IPCC (2019) provides information of above-ground biomass growth rate in forest plantation by ecological zone and continent for a range of the principal subcategories of plantation such as pinus sp., eucalyptus sp., tectona grandis and other broadleaf.
- **Below-ground biomass** is estimated using a ratio of below-ground biomass to above-ground biomass, R, expressed in t root d.m. per t shoot d.m. The default values are taken from Table 4.4 of IPCC (2019) and are the same as those used in "Deforestation" sub-module (see **Tables 9** to **14**). The default carbon content used for above and below-ground biomass is 0.47.
- **Litter, deadwood and soil carbon** are treated in this sub-module exactly in the same way as in the "Deforestation" sub-module (see Section 3.1.2).

3.2.3 Afforestation/reforestation process

After selecting the type of vegetation, the user needs to provide information related to the process of afforestation/reforestation including:

- **Previous land use,** selecting from the list of proposed systems. Available options include agroforestry, annual cropland, annual fallow, degraded land, flooded rice and grassland. Agroforestry is further disaggregated into different systems according to the climate and geographical characteristics defined in the "Description" module. The possible options include alley cropping, perennial fallow, hedgerow, multistrata, parkland, shaded perennial, silvoarable, silvopasture, olive, orchard, short rotation coppice, tea, vine, oil palm and rubber. According to the choice, the corresponding default biomass carbon stock is proposed, as shown in **Tables 36** to **38**. Values for annual crops correspond to the proposed value for default biomass carbon stocks present on land converted to cropland in the year following conversion from Table 5.9 of IPCC (2019). Flooded rice is assumed to have the same values of biomass carbon stocks as annual crops. Values for grassland are derived from Table 6.4 of IPCC (2019) using the default carbon content of 0.47. Values for agroforestry systems are derived from Table 5.2 and Table 5.3 of IPCC (2019). Value for degraded land is set to 1, and can thus be used for areas where very little vegetation is present.

Table 27. Above-ground net biomass growth in natural forests in tropical climate, in tonne d.m./ha/yr

Geographical regions	Tropical rainforest		Tropical moist deciduous forest		Tropical dry forest		Tropical shrubland	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	3.5	7.6	0.9	2.9	1.6	3.9	0.9	*0.5*
Asia	2.7	3.4	0.9	2.4	1.6	3.9	*1.2*	*3.5*
Europe	**7.0**	**7.0**	**5.0**	**5.0**	**2.4**	**2.4**	**1.0**	**1.0**
Oceania	**7.0**	**7.0**	**5.0**	**5.0**	**2.4**	**2.4**	**1.0**	**1.0**
The Americas and the Caribbean	2.3	5.9	2.7	5.2	1.6	3.9	1.0	4.0

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 28. Above-ground net biomass growth in plantations forests in tropical climate, in tonne d.m./ha/yr

Geographical regions	Tropical rainforest		Tropical moist deciduous forest		Tropical dry forest		Tropical shrubland	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	**15.0**	*6.5*	**10.0**	*9.0*	*9.5*	*12.0*	*8.3*	*5.0*
Asia	*5.0*	*5.0*	8.0	8.0	*13.5*	*13.5*	*6.5*	*6.5*
Europe	**15.0**	**15.0**	**10.0**	**10.0**	**8.0**	**8.0**	**5.0**	**5.0**
Oceania	**15.0**	**15.0**	**10.0**	**10.0**	**8.0**	**8.0**	**5.0**	**5.0**
The Americas and the Caribbean	*22.5*	*22.5*	*12.0*	*12.0*	*17.0*	*17.0*	*12.5*	*12.5*

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 29. Above-ground net biomass growth in natural forests in warm temperate climate, in tonne d.m./ha/yr

Geographical regions	Subtropical humid forest		Subtropical dry forest		Subtropical steppe		Subtropical mountain systems	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	1.0	2.5	1.8	2.4	0.9	1.2	0.5	2.5
Asia	1.0	2.5	*1.8*	6.5	*1.15*	*3.5*	0.5	*2.5*
Europe	**5.0**	**5.0**	**2.4**	**2.4**	**1.0**	**1.0**	**1.0**	**1.0**
Oceania	**5.0**	**5.0**	**2.4**	**2.4**	**1.0**	**1.0**	**1.0**	**1.0**
The Americas and the Caribbean	1.0	2.5	1.0	4.0	1.0	4.0	0.5	2.5

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 30. Above-ground net biomass growth in plantations forests in warm temperate climate, in tonne d.m./ha/yr

Geographical regions	Subtropical humid forest		Subtropical dry forest		Subtropical steppe		Subtropical mountain systems	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	**10.0**	**10.0**	8.0	*12.0*	*8.3*	*7.8*	10.0	10.0
Asia	8.0	8.0	*13.5*	*13.5*	*6.5*	*6.5*	*6.5*	*6.5*
Europe	**10.0**	**10.0**	**8.0**	**8.0**	**5.0**	**5.0**	**5.0**	**5.0**
Oceania	**10.0**	**10.0**	**8.0**	**8.0**	**5.0**	**5.0**	**5.0**	**5.0**
The Americas and the Caribbean	*17.5*	*17.5*	*16.5*	*16.5*	*12.5*	*12.5*	*10.0*	*10.0*

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 31. Above-ground net biomass growth in natural forests in temperate climate, in tonne d.m./ha/yr

Geographical regions	Temperate oceanic forest		Temperate continental forest		Temperate mountain systems		Temperate desert		Temperate steppe	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	**4.4**	**4.4**	**4.0**	**4.0**	**3.0**	**3.0**	**0.6**	**0.5**	**3.5**	**2.3**
Asia	**4.4**	**4.4**	**4.0**	**4.0**	**3.0**	**3.0**	**0.6**	**0.5**	**3.5**	**2.3**
Europe	2.3	2.3	**4.0**	**4.0**	**3.0**	**3.0**	**0.6**	**0.5**	**3.5**	**2.3**
Oceania	2.1	3.1	**4.0**	**4.0**	**3.0**	**3.0**	**0.6**	**0.5**	**3.5**	**2.3**
The Americas and the Caribbean	*9.1*	*6.3*	*3.6*	*3.3*	*4.4*	*3.1*	0.6	0.5	3.5	2.3

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 32. Above-ground net biomass growth in plantations forests in temperate climate, in tonne d.m./ha/yr

Geographical regions	Temperate oceanic forest		Temperate continental forest		Temperate mountain systems		Temperate desert		Temperate steppe	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	**4.4**	**4.4**	**4.0**	**4.0**	**3.0**	**3.0**	0	0	11.0	4.0
Asia	4.4	4.4	4.0	4.0	3.0	3.0	0	0	11.0	4.0
Europe	4.4	4.4	4.0	4.0	3.0	3.0	0	0	11.0	4.0
Oceania	4.4	4.4	**4.0**	**4.0**	**3.0**	**3.0**	0	0	11.0	4.0
The Americas and the Caribbean	*10.0*	*6.0*	*4.0*	*5.0*	*9.0*	*10.0*	0	0	11.0	4.0

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 33. Above-ground net biomass growth in natural forests in boreal climate, in tonne d.m./ha/yr

Geographical regions	Boreal coniferous forest		Boreal tundra woodland		Boreal mountain systems	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	0	0	0	0	0	0
Asia	*1.15*	*1.2*	0.4	0.4	*1.3*	*1.05*
Europe	*1.15*	*1.2*	0.4	0.4	*1.3*	*1.05*
Oceania	*1.15*	*1.2*	0.4	0.4	*1.3*	*1.05*
The Americas and the Caribbean	*1.15*	*1.2*	0.4	0.4	*1.3*	*1.05*

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 34. Above-ground net biomass growth in plantations forests in boreal climate, in tonne d.m./ha/yr

Geographical regions	Boreal coniferous forest		Boreal tundra woodland		Boreal mountain systems	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	1.0	1.0	0.4	0.4	1.0	1.0
Asia	1.0	1.0	0.4	0.4	1.0	1.0
Europe	1.0	1.0	0.4	0.4	1.0	1.0
Oceania	1.0	1.0	0.4	0.4	1.0	1.0
The Americas and the Caribbean	1.0	1.0	0.4	0.4	1.0	1.0

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 35. Above-ground net biomass growth in natural forests and plantations forests in tropical mountain climate, in tonne d.m./ha/yr

Geographical regions	Forest tropical mountain systems		Planted tropical mountains systems	
	AGB > 20 yrs	AGB ≤ 20 yrs	AGB > 20 yrs	AGB ≤ 20 yrs
Africa	1.8	5.5	10.0	10.0
Asia	1.1	2.9	*5.5*	*5.5*
Europe	**1.0**	**1.0**	**5.0**	**5.0**
Oceania	**1.0**	**1.0**	**5.0**	**5.0**
The Americas and the Caribbean	1.8	4.4	*13.0*	*13.0*

Notes: Values in bold are from IPCC (2006). Values in italic are the average of a given range.

Source: Authors' own elaboration based on Table 4.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 36. Default biomass carbon stock, in tC/ha, for system prior afforestation/reforestation for all region

IPCC climate zones	Annual cropland	Annual fallow	Paddy rice	Grassland	Other land (non-vegetated)	Degraded land
Boreal	4.7	4.7	4.7	**4.0**	**0**	1.0
Cool temperate dry	4.7	4.7	4.7	**3.1**	**0**	1.0
Cool temperate moist	4.7	4.7	4.7	**6.4**	**0**	1.0
Warm temperate dry	4.7	4.7	4.7	**2.9**	**0**	1.0
Warm temperate moist	4.7	4.7	4.7	**6.4**	**0**	1.0
Tropical montane and tropical dry	4.7	4.7	4.7	**4.1**	**0**	1.0
Tropical moist and tropical wet	4.7	4.7	4.7	**7.6**	**0**	1.0

Notes: Bold values are from IPCC (2006). The value for paddy rice is assumed the same as for annual crop.

Sources: Authors' own elaboration based on Table 5.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and Table 6.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

Table 37. Default biomass carbon stock for various agroforestry systems, in tC/ha, prior afforestation/reforestation according to the climate characteristics

IPCC climate zones	Fallow	Hedgerow	Alley cropping	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Temperate (all) and boreal (all)	0	13.1	0	0	0	0	13.7	35.0
Tropical (all)	11.1	4.7	23.7	32.5	5.9	24.0	36.1	29.1

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 38. Default biomass carbon stock, in tC/ha, for monoculture agroforestry system implanted prior afforestation/reforestation according to the climate characteristics

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Temperate (all) and boreal (all)	6.9	6.4	2.8	6.4	0	0	18.3
Tropical (all)	0	0	0	0	30.0	40.1	18.3

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Fire use generates emissions from burning. These emissions are calculated for individual GHG (N_2O and CH_4) as follows:

$$GHG_{fire} = M_B \times C_F \times G_{ef}$$

(Eq. 7)[8]

Where:

GHG_{fire} = amount of GHG from fire, kg of each, N_2O and CH_4;

M_B = mass of fuel available for combustion, tonnes;

C_F = combustion factor, dimensionless;

G_{ef} = emission factor, g/kg d.m. burnt.

The values of the factors C_F and G_{ef} applied are detailed in **Table 39**. The M_B parameter corresponds to above-ground biomass available for burning. In the tool, if the fire is set to "yes", the corresponding default emission factor associated with the vegetation type is used, and applied to M_B. The amount of CH_4 and N_2O are calculated in kg per gas, and the sum expressed in tCO_2-e is determined using the GWP indicated in the "Description" module.

Table 39. Combustion factor (C_F), dimensionless, and emission factor (G_{ef}), in g per kg of dry matter burnt, used for fire used prior afforestation/reforestation

Non-forestry land use	Cf	Gef for CO_2	Gef for CH_4	Gef for N_2O
Annual cropland	0.4	1515	2.7	0.07
Agroforestry	0.8	1613	2.3	0.21
Annual fallow	0.4	1515	2.7	0.07
Degraded land	0.8	1613	2.3	0.21
Other land (non-vegetated)	0	0	0	0
Flooded rice	0.4	1515	2.7	0.07
Grassland	0.8	1613	2.3	0.21
Alley cropping	0.8	1613	2.3	0.21
Perennial fallow	0.8	1613	2.3	0.21
Hedgerow	0.8	1613	2.3	0.21
Multi-strata	0.8	1613	2.3	0.21
Parkland	0.8	1613	2.3	0.21
Shaded perennial	0.8	1613	2.3	0.21
Silvoarable	0.8	1613	2.3	0.21
Silvopasture	0.8	1613	2.3	0.21
Degraded land	0.8	1613	2.3	0.21
Olive	0.8	1613	2.3	0.21
Orchard	0.8	1613	2.3	0.21
Short rotation coppice	0.8	1613	2.3	0.21
Tea	0.8	1613	2.3	0.21
Vine	0.8	1613	2.3	0.21
Oil palm	0.8	1613	2.3	0.21
Rubber	0.8	1613	2.3	0.21

Source: Authors' own elaboration based on Tables 2.5 and 2.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

[8] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

3.2.4 Changes in soil organic carbon content

For soils, the estimation method is based on changes in SOC stocks over a finite period following changes in management that impact the SOC_{ref}, as described in Section 1.3. According to the information provided by the user, EX-ACT estimates the carbon stocks variation relative to the carbon stock before conversion from the land use change stock change factor, FL_u, (see **Table 40**). FL_u is based on the relative factors for cropland systems provided by IPCC in Table 5.5 and Table 6.2 of IPCC (2019). These factors were fixed to their nominal values, i.e. the value given for a system that is non-degraded and sustainably managed without significant management improvements. Specific management options that impact the SOC stocks are treated separately and at a later step of the analysis in the corresponding sub-modules. For example, if a grassland system is set before afforestation, the SOC remains unchanged (nominal value is set to 1), while further in the "Grassland" module, users have the possibility to determine the management practices, as may be required, which will adjust the subsequent calculations by changing the SOC away from the nominal value of 1. This allows for isolating the land management effect from the land use change effect. The specific factors applied in each sub-module for each land use before afforestation/reforestation are detailed in their respective sections.

The change in SOC stock (over the reference period of 20 years) is computed using the default soil organic carbon content corresponding to the deforested vegetation (see **Table 1**):

$$\Delta C = (SOC_{ref} - SOC_{ref} * FL_u)$$

(Eq. 8)

Table 40. Relative stock change factor for land use (FL_u) dimensionless

IPCC climate zones	Annual cropland	Annual fallow	Flooded rice	Grassland	Other land (non-vegetated)	Agroforestry	Degraded land
Boreal dry	0.77	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Boreal moist	0.70	0.82	1.35	1.0	**1.0**	0.72	**0.33**
Cool temperate dry	0.77	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Cool temperate moist	0.70	0.82	1.35	1.0	**1.0**	0.72	**0.33**
Tropical dry	0.92	0.93	1.35	1.0	**1.0**	1.01	**0.33**
Tropical moist	0.83	0.82	1.35	1.0	**1.0**	1.01	**0.33**
Tropical wet	0.83	0.82	1.35	1.0	**1.0**	1.01	**0.33**
Tropical montane	0.64	0.88	1.35	1.0	**1.0**	1.00	**0.33**
Warm temperate dry	0.76	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Warm temperate moist	0.69	0.82	1.35	1.0	**1.0**	0.72	**0.33**

Note: Values in bold are from IPCC (2006).

Source: Authors' own elaboration based on Tables 5.5 and 6.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

3.2.5 Surface and GHG emissions

To trigger the calculations, users must provide data on the amount of land concerned by afforestation/reforestation expressed in hectares: the surface at the start, with project and without project scenario. Using this information, EX-ACT derives the deforested areas for each scenario and each system defined by the user. Based on the surface, vegetation characteristics and afforestation/

reforestation process details, the GHG emissions are calculated for each scenario as well as the carbon balance in tCO_2-e.

The dynamics of change are set by default to linear ("D" in the dark blue cell) and used in the calculations. The user can change the default setting, which will automatically adjust the calculations. See Section 1.2.2 on dynamics of change for more details.

The area of land reported under deforestation module is later used in the land use change matrix ("Results" tab) and also feed the subsequent sub-modules (in "Cropland" and "Grassland" as applicable), which allows users to determine the corresponding land management practices as may be required (see Section 3.2.4)

3.2.6 Tier 2 options

Users have the possibility to enter location-specific parameters that will be used instead of the default ones. The Tier 2 section of the "Afforestation/reforestation" sub-module allows for changing the carbon content of the five different carbon pools: above-ground and below-ground biomass (both, below 20 years old and older than 20 years), litter, dead wood and soil carbon (see **Figure 21**).

Figure 21. Tier 2 approach for the afforestation/reforestation sub-module in EX-ACT

2.2 Afforestation and Reforestation — Back

Final land uses after affo/reforestation	Above-ground biomass growth (≤ 20 years) tC/ha/yr Default	Above-ground biomass growth (≤ 20 years) tC/ha/yr Tier 2	Above-ground biomass growth (> 20 years) tC/ha/yr Default	Above-ground biomass growth (> 20 years) tC/ha/yr Tier 2	Below-ground biomass growth (≤ 20 years) tC/ha/yr Default	Below-ground biomass growth (≤ 20 years) tC/ha/yr Tier 2	Below-ground biomass growth (> 20 years) tC/ha/yr Default	Below-ground biomass growth (> 20 years) tC/ha/yr Tier 2	Max biomass level AGB+BGB tC/ha Default	Max biomass level AGB+BGB tC/ha Tier 2	Litter tC/ha Default	Litter tC/ha Tier 2	Dead wood tC/ha Default	Dead wood tC/ha Tier 2	Soil tC/ha Default	Soil tC/ha Tier 2
Tropical dry forest	1,83		0,75		0,61		0,25		43,57		2,40		9,00		52,0	
Tropical shrubland	0,21		0,42		0,08		0,17		31,85		0,00		0,00		52,0	
Planted Tropical moist deciduous forest	4,23		4,70		0,85		0,94		170,05		5,90		8,00		52,0	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,0	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,0	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,0	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,0	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,0	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Annual balance

Start year of implementation
1
1
1
1
1
1
1
1

Use this part only if you want to refine yearly GHG fluxes

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

3.3 Other land use changes

3.3.1 Methodology

This sub-module draws on Volume 4 (AFOLU) of IPCC (2019) Chapter 2 "Generic Methodology Applicable to Multiple Land use Categories". It is built on four types of information: (i) land use before conversion, (ii) land use after conversion, (iii) the conversion process and (iv) the surface of the area that will be converted and concerns all non-forest land use changes (see **Figure 22**).

Figure 22. Non-forest land use changes sub-module in EX-ACT

2.3 OTHER LAND-USE CHANGES — If country-specific data are available, please go to Tier 2: Tier 2

User notes	Fire used? (y/n)	Initial land-use	Final land-use	Area of land-use change (ha) Without	*	With	*	Total emissions (tCO2-e) Without	Total emissions (tCO2-e) With	Balance
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
	NO	Please select	Please select	0	D	0	D	0	0	0
				Total non forest land-use change (tCO2-e)				0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

3.3.2 Definition of land use before and after conversion

The first part of the module is dedicated to defining the land use before and after the land use change. Depending on the information provided in the "Description" module, the user has several options to choose from, including, annual cropland, annual fallow, degraded land, flooded rice, grassland, other land (non-vegetated), agroforestry (default), alley cropping, hedgerow, multistrata, oil palm, parkland, perennial fallow, rubber, shaded perennial, silvoarable, silvopasture and tea. In total, 306 different combinations can be built.

3.3.3 CO_2 emissions associated with land use change

The changes in the CO_2 emissions associated with other land use change come from two sources: changes in biomass carbon stocks and changes in soil organic carbon stocks.

To calculate the biomass carbon stock changes, the user needs to provide information on:

- **Initial land use.** The default biomass carbon stocks in tC/ha are detailed in **Tables 41** to **43**. Values for annual crops correspond to the default biomass carbon stocks of cropland in the year following land conversion (see Table 5.9, IPCC [2019]). Flooded rice is treated as annual crop. Values for grassland are derived from Table 6.4 of IPCC (2006) using the default carbon content of 0.47. Values for agroforestry systems are derived from Table 5.2 and Table 5.3 of IPCC (2019). Other land (non-vegetated) is set to zero and should be used where no vegetation is present, e.g. constructions, roads or parking lots. Biomass carbon stock of degraded land is set to 1 and should be used for areas with very little vegetation.

Table 41. Default biomass carbon stock, in tC/ha, for systems prior to non-forest-land use change

IPCC climate zones	Annual cropland	Annual fallow	Paddy Rice	Grassland	Other land (non-vegetated)	Degraded land
Boreal	4.7	4.7	4.7	**4.0**	**0**	1.0
Cool temperate dry	4.7	4.7	4.7	**3.1**	**0**	1.0
Cool temperate moist	4.7	4.7	4.7	**6.4**	**0**	1.0
Warm temperate dry	4.7	4.7	4.7	**2.9**	**0**	1.0
Warm temperate moist	4.7	4.7	4.7	**6.4**	**0**	1.0
Tropical montane and tropical dry	4.7	4.7	4.7	**4.1**	**0**	1.0
Tropical moist and tropical wet	4.7	4.7	4.7	**7.6**	**0**	1.0

Notes: Bold values are from IPCC (2006). The value for paddy rice is assumed the same as for annual crop.

Sources: Authors' own elaboration based on Table 5.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and Table 6.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

Table 42. Default biomass carbon stock for various agroforestry systems, in tC/ha, prior to non-forest land use change according to the climate characteristics

IPCC climate zones	Fallow	Hedgerow	Alley cropping	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Temperate (all) and boreal (all)	0	13.1	0	0	0	0	13.7	35.0
Tropical (all)	11.1	4.7	23.7	32.5	5.9	24.0	36.1	29.1

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 43. Default biomass carbon stock, in tC/ha, for monoculture agroforestry system prior to non-forest land use change according to the climate characteristics

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Temperate (all) and boreal (all)	6.9	6.4	2.8	6.4	0	0	18.3
Tropical (all)	0	0	0	0	30.0	40.1	18.3

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

- **Final land use.** The default biomass carbon stocks in tC/ha are detailed in **Tables 44** to **52**. Values for annual crops correspond to the default biomass carbon stocks of cropland in the year following land conversion (Table 6.4, of IPCC [2006]). Flooded rice is treated as annual crop. Values for grassland are derived from Table 6.4 of IPCC (2006) using the default carbon content of 0.47. Values for agroforestry systems are derived from Tables 5.2 and 5.3 in Chapter 5 in Volume 4 of IPCC (2019). Values for Other land (non-vegetated) is set to zero, this land use should be selected where no vegetation is present: i.e. constructions, roads or parking lots. Biomass carbon stock of degraded land is set to 1 and should be used for areas with very little vegetation.

The variation between initial and final biomass is computed in tCO_2.

Table 44. Default biomass carbon stock, in tC/ha, for system implanted after other land use change

IPCC climate zones	Annual cropland	Annual fallow	Paddy Rice	Grassland	Other land (non-vegetated)	Degraded land
Boreal	4.7	4.7	4.7	**4.00**	**0**	1
Cool temperate dry	4.7	4.7	4.7	**3.06**	**0**	1
Cool temperate moist	4.7	4.7	4.7	**6.39**	**0**	1
Warm temperate dry	4.7	4.7	4.7	**2.87**	**0**	1
Warm temperate moist	4.7	4.7	4.7	**6.35**	**0**	1
Tropical montane and tropical dry	4.7	4.7	4.7	**4.09**	**0**	1
Tropical moist and tropical wet	4.7	4.7	4.7	**7.57**	**0**	1

Notes: Bold values are from IPCC (2006). The value for paddy rice is assumed the same as for annual crop.

Sources: Authors' own elaboration based on Table 5.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and Table 6.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

Table 45. Default biomass carbon stock, in tC/ha, for monoculture agroforestry system implanted after other land use change according to the climate characteristics

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Temperate (all) and boreal (all)	0.46	0.43	0.28	3.2	0	0	0.7
Tropical (all)	0	0	0	0	2.4	3.0	0.7
All	0	0	0	0	0	0	0.7

Note: Temperate default values are used as proxy for boreal climate.

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 46. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for cool temperate dry and cool temperate moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.6	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.3
Asia	2.4	0.0	0.0	1.1	0.0	0.0	0.0	3.7	2.3
Europe	1.7	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.7
Oceania	1.6	0.0	0.0	1.1	0.0	0.0	0.0	1.4	2.3
North America	1.0	0.0	0.0	1.1	0.0	0.0	0.0	0.7	1.1
South and Central America, and the Caribbean	1.4	0.0	0.0	1.1	0.0	0.0	0.0	1.4	1.7

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 47. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for warm temperate moist and warm temperate dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Asia	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Europe	2.0	0.0	0.0	1.1	0.0	0.0	0.0	0.7	4.1
Oceania	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
The Americas and the Caribbean	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 48. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for boreal dry and boreal moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Asia	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Europe	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
Oceania	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0
The Americas and the Caribbean	1.8	0.0	0.0	1.1	0.0	0.0	0.0	1.1	3.0

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 49. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for tropical dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	3.6	2.3	8.2	0.6	2.1	0.8	3.0	7.9	3.9
Asia	3.5	3.5	6.1	0.6	2.1	0.8	3.0	7.9	3.9
Europe	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9
Oceania	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9
The Americas and the Caribbean	3.6	2.8	7.6	0.6	2.1	0.8	3.0	7.9	3.9

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 50. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for tropical moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	3.4	3.3	6.6	0.6	3.7	0.8	2.3	6.3	3.7
Asia	2.9	3.2	6.6	0.6	3.8	0.8	2.6	1.9	3.7
Europe	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
Oceania	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
North America	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7
South America	3.2	3.2	6.6	0.6	3.8	0.8	3.8	3.3	3.7
Central America	3.1	2.8	6.6	0.6	3.8	0.8	3.0	3.3	3.7
Caribbean	3.1	3.2	6.6	0.6	3.8	0.8	3.0	3.3	3.7

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 51. Total biomass various agroforestry systems, in tC/ha, of land uses following other land use change for tropical montane climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.7	2.9	4.2	0.8	4.1	0.8	3.0	2.8	3.4
Asia	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
Europe	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
Oceania	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4
The Americas and the Caribbean	3.0	2.9	5.9	0.8	4.1	0.8	3.0	2.8	3.4

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 52. Total biomass for various agroforestry systems, in tC/ha, of land uses following other land use change for Tropical wet climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.9	2.3	7.7	0.5	3.6	0.8	3.9	4.5	0.1
Asia	2.4	2.3	2.5	0.5	6.0	0.8	2.2	4.5	0.1
Europe	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
Oceania	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
North America	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1
South America	2.6	2.3	5.9	0.5	3.3	0.8	3.7	4.5	0.1
Central America	2.6	2.3	5.7	0.5	4.0	0.8	2.8	4.5	0.1
Caribbean	2.6	2.3	5.7	0.5	4.2	0.8	2.9	4.5	0.1

Note: Default values for agroforestry systems are the average of default values from other perennial systems.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

The **soil organic carbon stock variations** are estimated based on maximum changes in SOC stocks under initial and final vegetation. Maximum SOC stocks are calculated by multiplying a relative factor depending on the vegetation with the nominal SOC stocks which depends on soil type and climate. For the nominal SOC estimates, the default values are based on default references for SOC stocks for mineral soils to a depth of 30 cm (see **Table 1**). The relative stock change factors, FLu, (see **Table 53**), are based on the relative factors for croplands systems provided in Table 5.5 and Table 6.2 for grassland (IPCC, 2019). These factors were fixed to the nominal values, i.e. the value given for a system nominally managed, i.e. non-degraded and sustainably managed but without significant management improvements. Specific option of management and inputs that impact the soil carbon stocks in the newly implanted systems are treated in the ad hoc corresponding module. These changes, therefore, have additional mitigation options that are retained in other modules. See stock changes factors are detailed in their respective sections.

Table 53. Relative stock change factor for land use (Flu) dimensionless

IPCC climate zones	Annual cropland	Annual fallow	Flooded rice	Grassland	Other land (non-vegetated)	Agroforestry	Degraded land
Boreal dry	0.77	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Boreal moist	0.70	0.82	1.35	1.0	**1.0**	0.72	**0.33**
Cool temperate dry	0.77	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Cool temperate moist	0.70	0.82	1.35	1.0	**1.0**	0.72	**0.33**
Warm temperate dry	0.76	0.93	1.35	1.0	**1.0**	0.72	**0.33**
Warm temperate moist	0.69	0.82	1.35	1.0	**1.0**	0.72	**0.33**
Tropical dry	0.92	0.93	1.35	1.0	**1.0**	1.01	**0.33**
Tropical moist	0.83	0.82	1.35	1.0	**1.0**	1.01	**0.33**
Tropical wet	0.83	0.82	1.35	1.0	**1.0**	1.01	**0.33**
Tropical montane	**0.64**	0.88	1.35	1.0	**1.0**	1.00	**0.33**

Note: Values in bold are from IPCC (2006).

Source: Authors' own elaboration based on Table 5.5 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

3.3.4 Non-CO_2 emissions associated with non-forest land use changes

The non-CO_2 emissions come from the N mineralization induced by soil organic carbon stock losses following the land use change or management practices and from residue burning.

Mineralization of N accompanies land use management processes and leads to N_2O releases to the atmosphere. Where soil carbon losses occur, the release of N_2O by mineralization is estimated as:

$$F_{SOM} = \sum((\Delta C_{mineral} \times 1/R) \times 1000)$$

(Eq. 9) [9]

Where:

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, in kg of N;

$\Delta C_{mineral}$ = average annual loss of soil carbon for each land use type, in tonnes of C;

R = C to N ratio of the soil organic matter.

The default value of R is set to 15 for conversions of grassland to cropland (annual and perennial) and degraded land, while for cropland conversions to other types of cropland[10] or degraded land the value is set to 10 (Chapter 11 of IPCC [2019]).

To calculate the emissions from residue burning, EX-ACT assumes that the residues represent 40 percent of the default biomass of the initial land use. Emissions from burning are calculated following the generic methodology described in Part 1. Combustion factor is set to 0.4 for annual fallow, annual crops and irrigated rice, and 0.8 for all other land uses. Greenhouse gas emissions factors are respectively 0.07 g of N_2O and 2.7 g of CH_4 per kg of dry matter burnt (see **Table 39**). The amount of CH_4

[9] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

[10] Annual crops to perennial crops or vice versa.

and N_2O are calculated in kg per GHG, and the sum expressed in tCO_2-e is determined using the GWP selected in the Description module, described in Part 2.

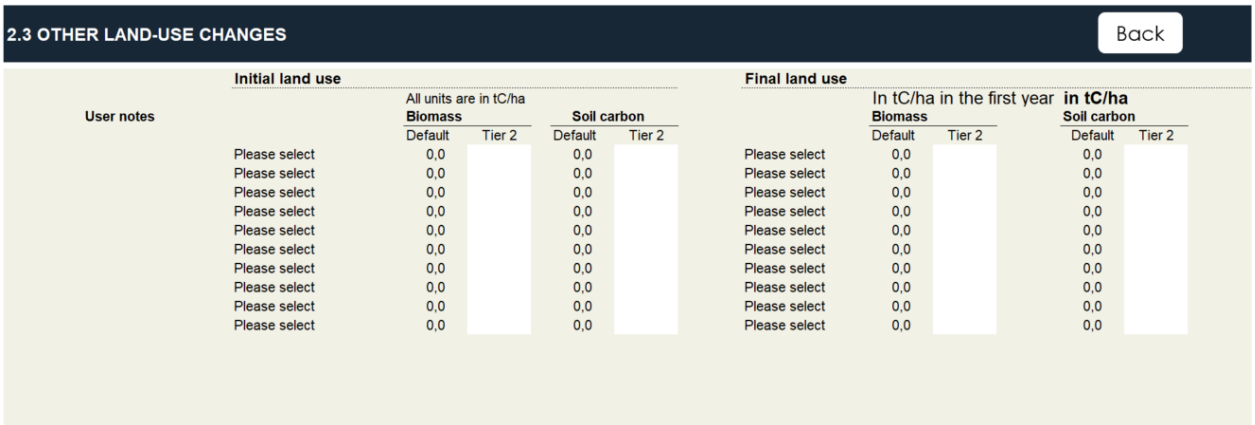
3.3.5 Surface and GHG emissions

Users must inform the changes in surface with each successive system described above (see **Figure 22**). The dynamics are set by default to linear. Based on the selected vegetation, information on residue burning and provided surface of activities, the tool calculates the carbon balance in tCO_2-e.

3.3.6 Tier 2 options

Users have the possibility to enter location-specific parameters that will be used instead of the default ones. The Tier 2 section of the "Non-forest land use changes" sub-module allows for changing the default value of carbon stock in the biomass and in the soil for the initial land use and for the final land use (see **Figure 23**).

Figure 23. Tier 2 approach of the "Non-forest land use changes" sub-module in EX-ACT



2.3 OTHER LAND-USE CHANGES

Back

User notes	Initial land use	All units are in tC/ha Biomass Default	Biomass Tier 2	Soil carbon Default	Soil carbon Tier 2	Final land use	In tC/ha in the first year in tC/ha Biomass Default	Biomass Tier 2	Soil carbon Default	Soil carbon Tier 2
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	
	Please select	0,0		0,0		Please select	0,0		0,0	

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 4. Cropland management module

Cropland represents land that is used for growing annual and perennial crops, including rice and agro-forestry systems. The cropland management module is composed of three sub-modules: annual systems, perennial systems and flooded rice systems.

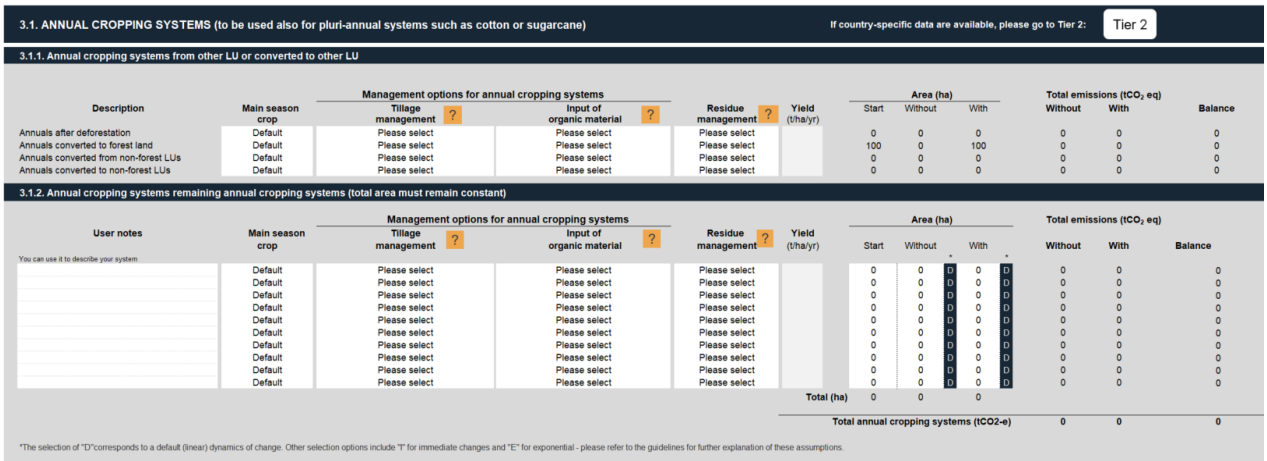
4.1 Annual systems

4.1.1 Methodology

Material used to develop this module can be found in Chapter 2 ("Generic Methodology Applicable to Multiple Land use Categories), Chapter 5 ("Cropland") and Chapter 11 ("N_2O emissions from managed soils, and CO_2 emissions from lime and urea application") of IPCC (2019).

The Annual Cropping Systems module is made up of 2 components, (i) annual systems from other land use or converted to other land use and (ii) annual systems remaining annual systems. These two sections require defining the annual system(s) considered, associated management practices and surface of the concerned area to calculate the corresponding GHG emissions (see **Figure 24**).

Figure 24. Annual systems sub-module in EX-ACT



3.1. ANNUAL CROPPING SYSTEMS (to be used also for pluri-annual systems such as cotton or sugarcane) — If country-specific data are available, please go to Tier 2: Tier 2

3.1.1. Annual cropping systems from other LU or converted to other LU

Description	Main season crop	Management options for annual cropping systems: Tillage management	Input of organic material	Residue management	Yield (t/ha/yr)	Area (ha): Start	Area (ha): Without	Area (ha): With	Total emissions (tCO_2 eq): Without	With	Balance
Annuals after deforestation	Default	Please select	Please select	Please select		0	0	0	0	0	0
Annuals converted to forest land	Default	Please select	Please select	Please select		100	0	100	0	0	0
Annuals converted from non-forest LUs	Default	Please select	Please select	Please select		0	0	0	0	0	0
Annuals converted to non-forest LUs	Default	Please select	Please select	Please select		0	0	0	0	0	0

3.1.2. Annual cropping systems remaining annual cropping systems (total area must remain constant)

User notes	Main season crop	Management options for annual cropping systems: Tillage management	Input of organic material	Residue management	Yield (t/ha/yr)	Area (ha): Start	Area (ha): Without	*	Area (ha): With	*	Total emissions (tCO_2 eq): Without	With	Balance
You can use it to describe your system													
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
					Total (ha)	0	0		0				
											Total annual cropping systems (tCO_2-e)	0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

4.1.2 Definition of the annual system

This sub-module distinguishes two components; (i) annual systems from other land use or converted to other land use and; (ii) annual systems remaining annual systems.

For the first component, the annual systems from other land use or converted to other land use consider:

a. Newly implemented systems after deforestation (annual after deforestation) or from conversion of other land use systems (annual after non-forest land use); and

b. annual systems that are converted either to plantation (converted to afforestation/reforestation) or to other land use (converted to non-forest land use change).

The corresponding cells are automatically filled in from information provided in the "Land use change" module if in the analysis there is conversion from or to annual systems.

Under this first component, the analysed systems refer typically to the reference scenario. It is assumed by default that these systems have been implemented for long period of time, and, as a consequence, that they are in equilibrium resulting in non-significant soil carbon changes (ΔC_{soil} = 0). Users can alter

this assumption and consider that systems are still losing or gaining carbon by providing the corresponding data in tC/ha/year (positive or negative) via Tier 2 approach (see **Figure 21**).

The second component considers annual systems remaining annual systems, but which are subject to changes in management. EX-ACT considers the following crops: grains, beans and pulses, tubers, barley, maize, oats, potatoes, soybeans, wheat, millet, sorghum, rye, peanuts, dry beans, root crops. A default option is also available.

4.1.3 CO_2 emission from soil management

In this module, EX-ACT assumes there are zero CO_2 emissions and removals from biomass (IPCC, 2019). Annual crops are planted and harvested within one year and therefore, there will be no net gain or loss of biomass in annual cropping systems. In general, annual croplands have little or no dead wood or litter. Therefore, EX-ACT does not take into account carbon stock changes of dead wood and litter (DOM) for annual systems.

Management of annual cropping systems can significantly affect the amount of carbon stock in soil. The carbon storage potential depends on the type of crop and soil, prevalent climate and soil management practices. EX-ACT calculates related CO_2 emissions and removals, distinguishing between type of crop, its residue management, tillage practices, fertilizer management (both mineral fertilizers and organic amendments), irrigation management and intensity of cropping management (i.e. continuous cropping versus cropping rotations with periods of bare fallow or mixed systems with cropping and pasture or hay in rotating sequences).

Tier 1 method assumes that SOC stocks of annual cropping systems are in equilibrium as long as there is no change in land use, inputs, management during the previous 20 years. If there are changes during the past 20 years, then the change in SOC stocks in annual cropping systems is calculated.

The methodology used for calculating the annual rates of SOC stock changes in mineral soils is based on the difference of SOC stocks between with and without the project scenario as described in Section 1.3 and repeated below (see Equation 10).

Annual change in organic carbon stocks in mineral soils:

$$SOC_{mineral} = \sum (SOC_{ref} * F_{Lu} * F_{MG} * F_I * A)$$

(Eq. 10) [11]

Where:

$SOC_{mineral}$ = total mineral SOC at a defined time, in tC;

SOC_{ref} = SOC in the reference condition, in tC/ha;

F_{Lu} = stock change factor for mineral SOC land use system or sub-systems, dimensionless;

F_{MG} = stock change factor for mineral SOC for management regime, dimensionless;

F_I = stock change factor for mineral SOC for the inputs of organic amendments; dimensionless and

A = land area under the different management, in ha.

EX-ACT estimates the increase/decrease in SOC_{ref} following changes in management practices on a given land and following a land use changes and associated management practices, if any, on the converted area. The estimates are carried over 20 years, the default time required for a transition between equilibrium SOC values.

Default soil stock change factors for land use, management and inputs (FL_u, F_{MG}, F_I) represent the influence of activities on soil to a depth of 30 cm. Default values are taken from the updated Table 5.5 of IPCC (2019) (see **Table 54**).

[11] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

Table 54. Relative stock change factors (FL_u, F_{MG}, F_I) over 20 years for management practices on cropland

IPCC climate zones	FL_u	F_{MG} full tillage	F_{MG} reduced tillage	F_{MG} no tillage	F_I low carbon input	F_I medium carbon input	F_I high carbon input, no manure	F_I high carbon input, with manure
Boreal dry	0.77	1.00	0.98	1.03	0.92	1.00	1.11	1.44
Boreal moist	0.70	1.00	1.04	1.09	0.95	1.00	1.04	1.37
Cool temperate dry	0.77	1.00	0.98	1.03	0.95	1.00	1.04	1.37
Cool temperate moist	0.70	1.00	1.04	1.09	0.92	1.00	1.11	1.44
Warm temperate dry	0.76	1.00	0.99	1.04	0.95	1.00	1.04	1.37
Warm temperate moist	0.69	1.00	1.05	1.10	0.92	1.00	1.11	1.44
Tropical dry	0.92	1.00	0.99	1.04	0.95	1.00	1.04	1.37
Tropical moist	0.83	1.00	1.04	1.10	0.92	1.00	1.11	1.44
Tropical wet	0.83	1.00	1.04	1.10	0.92	1.00	1.11	1.44
Tropical montane	**0.64**	1.00	**1.09**	**1.16**	0.94	1.00	1.08	1.41

Note: Values in bold are from IPCC (2006).

Source: Authors' own elaboration based on Table 5.5 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl and in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

To trigger the calculations, users have to specify the surface of areas (in ha) for each annual cropping system separately. With and without project scenarios may require providing information is more than one line, but the total land areas of annual cropping systems must remain the same at the start, without and with the project scenario. The user must also specify the crop type can (from a dropdown list) and the cropland management practices by selecting the type of tillage, input of organic material and residue management (again, from the dropdown lists). The available practices to choose from are described below, following Table 5.5 of IPCC (2019).

Long-term cultivated (F_{LU}): Represents area that has been converted from native conditions and continuously managed for predominantly annual crops over 50 years.

Tillage management (F_{MG}): Represents the different tillage practices in cropland, (IPCC, 2019).

- **Full:** Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (i.e. <30 percent) of the surface is covered by residues.
- **Reduced:** Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30 percent coverage by residues at planting.
- **No-till:** Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.

Input of organic material (F_I): Represents the different levels of C input to soil (IPCC, 2019).

- **Low:** Low residue return occurs when there is removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (i.e. vegetables, tobacco and cotton), no mineral fertilization or N-fixing crops.
- **Medium:** Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed, then supplemental organic matter (i.e. manure) is added. Also requires mineral fertilization or N-fixing crop in rotation.
- **High without manure:** Represents significantly greater crop residue inputs over medium carbon 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.
- **High with manure:** Represents significantly higher carbon input over medium carbon input cropping systems due to an additional practice of regular addition of animal manure.

Residue management: Represents the type of residue management practices in annual cropping systems (IPPC, 2019).

- **Burned:** agriculture crop residues are burned.
- **Retained:** agriculture crop residues are retained in the field.
- **Exported:** agriculture crop residues are removed from the field (i.e. fed to animals).

4.1.4 Non-CO_2 emissions from crop residues burning

CH_4 and N_2O emissions from residues burning

Non-CO_2 emissions from burning crop residues consist of methane (CH_4) and nitrous oxide (N_2O) gases produced by the combustion of (a percentage of) crop residues burnt on-site. CO_2 emissions from burning agricultural residues do not have to be reported, since the carbon released during the combustion process is assumed to be reabsorbed by the vegetation during the next growing season (IPCC, 2019).

EX-ACT estimates the associated non-CO_2 emissions from crop residue burning based on the generic methodology summarized in Section 1.3 of Part 1. The associated calculations will be triggered if the residue management option is set to "burned".

The biomass available for burning (MB) is the above-ground residue dry matter(AGDM), of a specific crop (in kg d.m/ha). AGDM is estimated using the method in the updated Table 11.2 of IPCC (2019) and crop yield data (t d.m/ha) for the year of 2013 obtained from FAOSTAT (FAO, 2019). The combustion factor (C_f), which is a measure of the proportion of the biomass actually combusted is of 0.90 for wheat residues, 0.80 for maize residues and 0.85 for other agricultural residues (see Table 2.6 of IPCC [2019] for further details). The emission factor G_{ef} gives the amount of a particular GHG emitted per unit of crop residue dry matter combusted (g/kg d.m. burnt). EX-ACT uses the default mean values of G_{ef} 2.7 gCH_4/kg d.m. burnt and 0.07 gN_2O/kg d.m. burnt (see Table 2.5 of IPCC [2019] for further details).

Direct N_2O emissions from crop residues

Retention of crop residues can stimulate soil N_2O emissions via regulating soil carbon and nitrogen availability and microbial activities. Crop residues may play multiple roles, for example they can act as organic N fertilizer, organic carbon substrate and energy provider in regulating soil N_2O production and emission and therefore, N_2O emissions associated with crop residues should be estimated.

The methodology used to quantify the effect of crop residue retention on N_2O emissions follows Equation 11.2 of IPCC (2019), as described in Equation 11.

$$N_2O_{Direct} - N = F_{CR} * EF_1$$

(Eq. 11)[12]

Where:

$N_2O_{Direct} - N$ = the annual direct N_2O–N emissions produced from managed soils, in kg/y;

F_{CR} = the total amount of N in crop residues (above-ground and below-ground), including N-fixing crops, returned to soils, in kg N;

EF_1 = the emission factors to estimate direct N_2O emissions from managed soils due to N additions from crop residues, in kg N_2O–N/kg N.

EX-ACT uses the following default values for EF_1: 0.006 kg N_2O–N/kg N for all climates wet and moist, 0.005 kg N_2O–N/kg N for dry climates and 0.010 kg N_2O–N/kg N for an aggregated climate (see Table 11.1 of IPCC [2019] for further details).

F_{CR} is calculated using Equation 12 (see Equation 11.6 of IPCC [2019] for further details):

$$F_{CR} = AGR_{(T)}N_{AG(T)} + BGR_{(T)}N_{BG(T)}$$

(Eq. 12)[13]

Where:

$AGR_{(T)}$ = the annual total amount of above-ground crop residue for crop T, in kg d.m/yr;

$N_{AG(T)}$ = N content of above-ground residues for crop T, in kg N/kg d.m;

$N_{BG(T)}$ = the N content of below-ground residues for crop T, in kg N/kg d.m;

$BGR_{(T)}$ = annual total amount of below-ground crop residue for crop T, in kg d.m./yr.

With BGR estimated as:

$$BGR_t = (CROP_t + AG_{dm(t)}) * RS_t * AREA_t * FRAC_{renewt}$$

(Eq. 13)[14]

Where:

$BGR_{(T)}$ = annual total amount of below-ground crop residue for crop T, in kg d.m./yr;

$Crop_{(T)}$ = the harvested annual dry matter yield for crop T, in kg d.m./ha;

$AG_{DM(T)}$ = the above-ground residue dry matter for crop T, in kg d.m./ha; and

$RS_{(T)}$ = the ratio of below-ground root biomass to above-ground shoot biomass for crop T, in kg d.m. /ha/ (kg d.m. /ha).

Default values for $N_{AG(T)}$, $N_{BG(T)}$, $RS_{(T)}$ are reported in **Table 55**.

N_2O–N emissions are converted into CO_2-e using the following factors: CO_2 = N_2O–N x 44/28.

Crop yield for the following crop items: grains, beans and pulses, tubers, barley, maize, oats, potatoes, soybeans, wheat, millet sorghum, rye, peanuts, dry bean, root crops are retrieved from FAOSTAT for the year of 2017 (FAO, 2019).

[12] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

[13] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

[14] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

Table 55. Default values for nitrogen content of above-ground residues ($N_{AG(T)}$), below-ground residues ($N_{BG(T)}$) and ratio of below-ground to above-ground biomass ($RS_{(T)}$)

Crops	No. content of above-ground residues	No. content of below-ground residues	Ratio of below-ground biomass to above-ground biomass
Generic value	0.008	0.009	0.22
Generic grains	0.006	0.009	0.22
Winter wheat	0.006	0.009	0.23
Spring wheat	0.006	0.009	0.28
Barley	0.007	0.014	0.22
Oats	0.007	0.008	0.25
Maize	0.006	0.007	0.22
Rye	0.005	0.011	-
Millet	0.007	-	-
Sorghum	0.007	0.006	-
Beans and pulses	0.008	0.008	0.19
Soybeans	0.008	0.008	0.19
Potatoes and tubers	0.019	0.014	0.20
Peanuts	0.016	-	-

Source: Authors' own elaboration based on Table 11.1A in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

4.1.5 Surface and greenhouse gas emissions

Users must provide data about the changes in surface with each successive system described above. The dynamics are set by default to linear but can be changed (see Part 1). More details regarding the implementation of activities or lack thereof, of the project and the associated dynamics are described in Part 1.

Based on areas indicated and also considering vegetation characteristics and details indicated in other parts the GHG balances in CO_2-e are calculated for the biomass and soil pool.

Note that for annual crop systems remaining annual crop systems, surface areas must be the same at the beginning and at the end (with or without project). GHG balances in CO_2-e is the sum of changes in soil carbon from management practices and eventually CO_2-e emissions from residue burning.

Together with changes and oxidation of SOC storage, land use management is also accompanied by mineralization of nitrogen (N), which is an additional source of N available for N_2O emissions. Where soil carbon losses occur, the release of N by mineralization is estimated according to Equation 14:

$$F_{SOM} = \sum ((\Delta C_{mineral} \times 1/R) \times 1000)$$

(Eq. 14)[15]

Where:

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, in kg N;

$\Delta C_{mineral}$ = average annual loss of soil carbon for each land use type, in tonnes C;

R = C:N ratio of the soil organic matter.

[15] Equation based on Chapter 11 in Volume 4 of IPCC (2019).

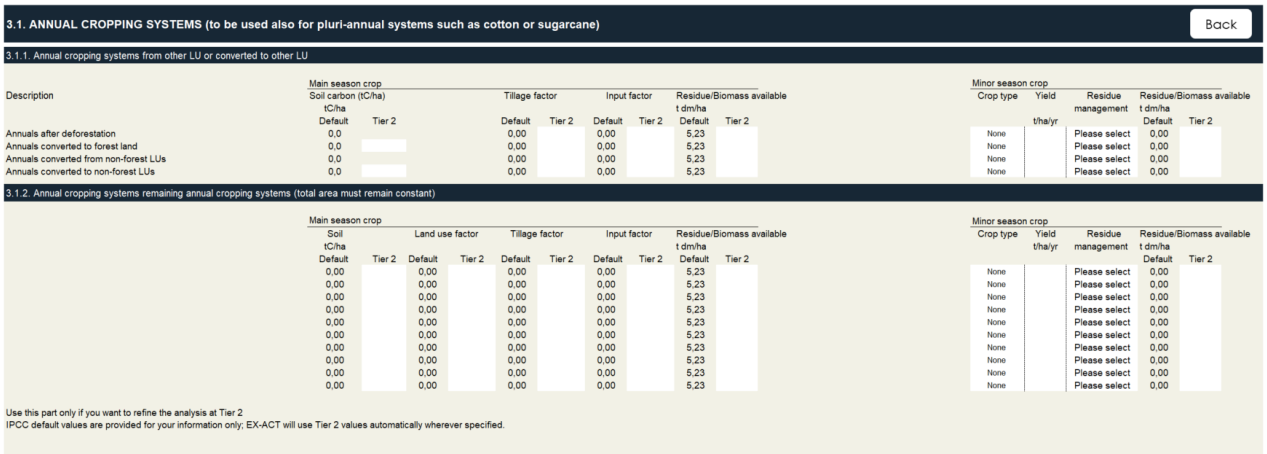
For R, a default value of 10 for cropland remaining cropland is applied. Default values are provided in Chapter 11 of IPCC (2019).

4.1.6 Tier 2 options

Users have the possibility to define here its own management category by adding specific stock change factor, the rate of soil carbon sequestration and the biomass of residues available in the white cell as seen in **Figure 25**.

Finally, it is possible to add a minor crop season here by insert information on the crop type, its yield and the residue management practices (burned, exported or retained).

Figure 25. Tier 2 approach of the annual sub-module in EX-ACT



3.1. ANNUAL CROPPING SYSTEMS (to be used also for pluri-annual systems such as cotton or sugarcane) — Back

3.1.1. Annual cropping systems from other LU or converted to other LU

Description	Main season crop: Soil carbon (tC/ha) Default	Soil carbon (tC/ha) Tier 2	Tillage factor Default	Tillage factor Tier 2	Input factor Default	Input factor Tier 2	Residue/Biomass available t dm/ha Default	Residue/Biomass available t dm/ha Tier 2	Minor season crop: Crop type	Yield t/ha/yr	Residue management	Residue/Biomass available t dm/ha Default	Residue/Biomass available t dm/ha Tier 2
Annuals after deforestation	0,0		0,00		0,00		5,23		None		Please select	0,00	
Annuals converted to forest land	0,0		0,00		0,00		5,23		None		Please select	0,00	
Annuals converted from non-forest LUs	0,0		0,00		0,00		5,23		None		Please select	0,00	
Annuals converted to non-forest LUs	0,0		0,00		0,00		5,23		None		Please select	0,00	

3.1.2. Annual cropping systems remaining annual cropping systems (total area must remain constant)

Main season crop: Soil tC/ha Default	Soil tC/ha Tier 2	Land use factor Default	Land use factor Tier 2	Tillage factor Default	Tillage factor Tier 2	Input factor Default	Input factor Tier 2	Residue/Biomass available t dm/ha Default	Residue/Biomass available t dm/ha Tier 2	Minor season crop: Crop type	Yield t/ha/yr	Residue management	Residue/Biomass available t dm/ha Default	Residue/Biomass available t dm/ha Tier 2
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	
0,00		0,00		0,00		0,00		5,23		None		Please select	0,00	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

4.2 Perennial systems

4.2.1 Methodology

Material used to develop this module can be found in Chapter 2 ("Generic Methodology Applicable to Multiple Land use Categories"), Chapter 5 ("Cropland") and Chapter 11 ("N_2O emissions from managed soils and CO_2 emissions from lime and urea application") of IPCC (2019).

4.2.2 Definition of the perennial system

Agroforestry systems can help to mitigate climate change by storing carbon in biomass and removing CO_2 from the atmosphere. Perennial woody crops accumulate C for an amount of time equal to a nominal harvest maturity cycle (IPCC, 2019). This assumption implies that perennial woody crops accumulate biomass for a finite period until they are removed through harvest or reach a steady state where there is no net accumulation of carbon in biomass because growth rates have slowed and incremental gains from growth are offset by losses from natural mortality pruning or other losses (Tier 1 assumption).

In EX-ACT, the perennial sub-module is divided into two components: (i) perennial systems from other land use or converted to other land use and; (ii) perennial systems remaining perennial systems.

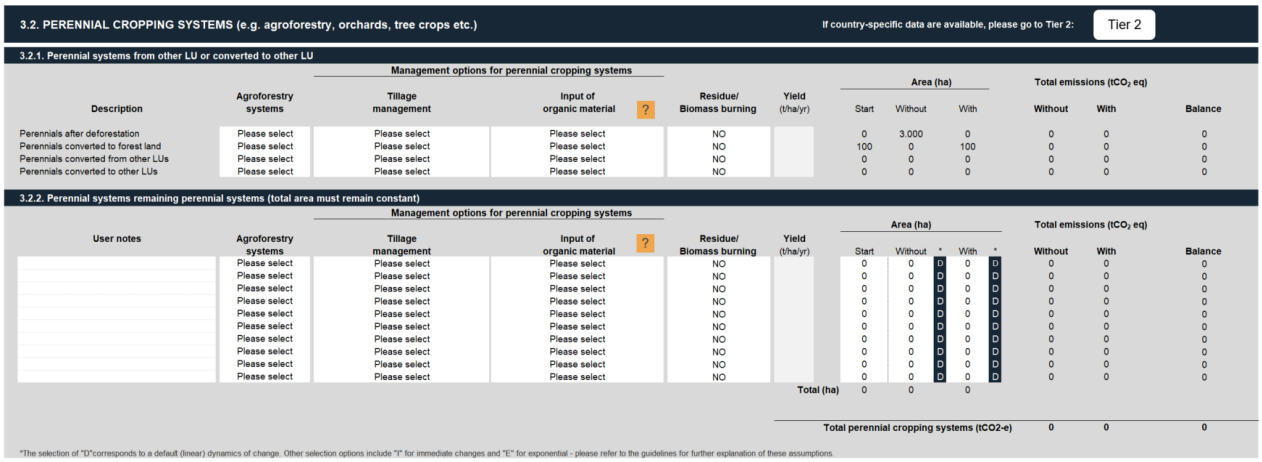
The first component includes two elements:

- The first component is reserved for newly implemented systems after deforestation (perennial after deforestation) or from conversion of other land use systems (perennial after non-forest land use).
- Perennial systems that are converted either to plantation forest or converted to other land use changes.

It is automatically built from information filled in the "Land use Changes" module (deforestation, afforestation/reforestation and other land use changes modules).

The second component concerns perennial systems remaining perennial systems with or without project implementation. Whereas the first component does not require any information on the surface of the area concerned (sourcing it from "Land use Changes" module), users have to specify the surface area for the second component (to identify areas with different management practices). In both components, users have to specify the different management practices that affect the soil carbon stock.

Figure 26. Perennial systems sub-module in EX-ACT



3.2. PERENNIAL CROPPING SYSTEMS (e.g. agroforestry, orchards, tree crops etc.) — If country-specific data are available, please go to Tier 2: Tier 2

3.2.1. Perennial systems from other LU or converted to other LU

Description	Agroforestry systems	Management options for perennial cropping systems: Tillage management	Input of organic material ?	Residue/ Biomass burning	Yield (t/ha/yr)	Area (ha): Start	Area (ha): Without	Area (ha): With	Total emissions (tCO_2 eq): Without	With	Balance
Perennials after deforestation	Please select	Please select	Please select	NO		0	3.000	0	0	0	0
Perennials converted to forest land	Please select	Please select	Please select	NO		100	0	100	0	0	0
Perennials converted from other LUs	Please select	Please select	Please select	NO		0	0	0	0	0	0
Perennials converted to other LUs	Please select	Please select	Please select	NO		0	0	0	0	0	0

3.2.2. Perennial systems remaining perennial systems (total area must remain constant)

User notes	Agroforestry systems	Management options for perennial cropping systems: Tillage management	Input of organic material ?	Residue/ Biomass burning	Yield (t/ha/yr)	Area (ha): Start	Area (ha): Without	*	Area (ha): With	*	Total emissions (tCO_2 eq): Without	With	Balance
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
	Please select	Please select	Please select	NO		0	0	D	0	D	0	0	0
					Total (ha)	0	0		0				
					Total perennial cropping systems (tCO2-e)						0	0	0

*The selection of "D"corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

4.2.3 CO_2 emissions and removals

For croplands with perennial woody crops such as agroforestry systems, changes in carbon concern soil and biomass. As Tier 1 method assumes that dead wood and litter stocks are at equilibrium in agroforestry systems, EX-ACT estimates carbon stock changes in the above-ground and below-ground biomass only, along the changes in SOC driven by changes in management practices.

Default values used in EX-ACT are taken from Table 5.2 and Table 5.3 of IPCC (2019) and are presented in **Tables 56** to **72**. Unless users specify their own above-ground biomass growth rate in Tier 2, EX-ACT takes into account the maximum above-ground biomass stock at harvest provided in Table 5.1 of IPCC (2019) within the computations of carbon sequestration in the above-ground biomass (see **Tables 56** to **63**).

Table 56. Default above-ground biomass growth rate, in tC/ha/yr, for monoculture agroforestry system according to the climate characteristics

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Temperate (all) and boreal (all)	0.46	0.43	0.28	3.2	0	0	0.7
Tropical (all)	0	0	0	0	2.4	3.0	0.7
All	0	0	0	0	0	0	0.7

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 57. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for cool temperate dry and moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.27			0.87				1.12	1.81
Asia	1.88			0.87				2.97	1.81
Europe	1.39			0.87				1.12	2.17
Oceania	1.27			0.87				1.12	1.81
North America	0.81			0.87				0.59	0.97
South and Central America and the Caribbean	1.06			0.87				1.12	1.18

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 58. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr for boreal climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.37			0.87				0.91	2.33
Asia	1.37			0.87				0.91	2.33
Europe	1.37			0.87				0.91	2.33
Oceania	1.37			0.87				0.91	2.33
North America	1.37			0.87				0.91	2.33
South and Central America and the Caribbean	1.37			0.87				0.91	2.33

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate. For Boreal climate, the default values of temperate were used.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 59. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for warm temperate climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	1.37			0.87				0.91	2.33
Asia	1.37			0.87				0.91	2.33
Europe	1.37			0.87				0.52	3.11
Oceania	1.37			0.87				0.91	2.33
The Americas and the Caribbean	1.37			0.87				0.91	2.33

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 60. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.74	1.88	5.61	0.48	1.63	0.59	2.40	6.24	3.07
Asia	2.85	2.79	5.61	0.48	1.63	0.59	2.40	6.24	3.07
Europe	2.79	2.27	5.61	0.48	1.63	0.59	2.40	6.24	3.07
Oceania	2.79	2.27	5.61	0.48	1.63	0.59	2.40	6.24	3.07
The Americas and the Caribbean	2.79	2.27	5.61	0.48	1.63	0.59	2.40	6.24	3.07

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 61. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.74	2.75	5.30	0.47	2.98	0.59	1.82	5.09	2.91
Asia	2.31	2.59	5.30	0.47	3.03	0.59	2.07	1.50	2.91
Europe	2.49	2.59	5.30	0.47	3.02	0.59	2.43	2.63	2.91
Oceania	2.49	2.59	5.30	0.47	3.02	0.59	2.43	2.63	2.91
North America	2.49	2.59	5.30	0.47	3.02	0.59	2.43	2.63	2.91
South America	2.57	2.59	5.30	0.47	3.02	0.59	3.06	2.63	2.91
Central America	2.45	2.28	5.30	0.47	3.02	0.59	2.43	2.63	2.91
Caribbean	2.49	2.59	5.30	0.47	3.02	0.59	2.43	2.63	2.91

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 62. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical wet climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.35	1.88	6.21	0.43	2.89	0.59	3.16	3.61	0.06
Asia	1.90	1.88	2.00	0.43	4.83	0.59	1.79	3.61	0.06
Europe	2.10	1.88	4.59	0.43	3.25	0.59	2.36	3.61	0.06
Oceania	2.10	1.88	4.59	0.43	3.25	0.59	2.36	3.61	0.06
North America	2.10	1.88	4.59	0.43	3.25	0.59	2.36	3.61	0.06
South America	2.09	1.88	4.59	0.43	3.25	0.59	2.28	3.61	0.06
Central America	2.11	1.88	4.76	0.43	2.60	0.59	2.96	3.61	0.06
Caribbean	2.10	1.88	4.59	0.43	3.25	0.59	2.36	3.61	0.06

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 63. Above-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical montane climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	2.16	2.37	3.12	0.67	3.25	0.59	2.40	2.26	2.62
Asia	2.32	2.37	4.42	0.67	3.25	0.59	2.40	2.26	2.62
Europe	2.32	2.37	4.42	0.67	3.25	0.59	2.40	2.26	2.62
Oceania	2.32	2.37	4.42	0.67	3.25	0.59	2.40	2.26	2.62
The Americas and the Caribbean	2.32	2.37	4.42	0.67	3.25	0.59	2.40	2.26	2.62

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 64. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for cool temperate dry and moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.33			0.23				0.28	0.48
Asia	0.49			0.23				0.77	0.48
Europe	0.36			0.23				0.28	0.56
Oceania	0.33			0.23				0.28	0.48
North America	0.16			0.23				0.14	0.11
The Americas and the Caribbean	0.34			0.23				0.28	0.52

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 65. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for boreal climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.39			0.23				0.23	0.70
Asia	0.39			0.23				0.23	0.70
Europe	0.39			0.23				0.23	0.70
Oceania	0.39			0.23				0.23	0.70
North America	0.39			0.23				0.23	0.70
The Americas and the Caribbean	0.39			0.23				0.23	0.70

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate. For boreal climate, the default values of Temperate were used.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 66. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for warm temperate climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.39			0.23				0.23	0.70
Asia	0.39			0.23				0.23	0.70
Europe	0.47			0.23				0.14	1.03
Oceania	0.39			0.23				0.23	0.70
The Americas and the Caribbean	0.39			0.23				0.23	0.70

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 67. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical dry climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.85	0.45	2.54	0.12	0.46	0.21	0.55	1.62	0.84
Asia	0.63	0.67	0.53	0.12	0.46	0.21	0.55	1.62	0.84
Europe	0.79	0.54	1.95	0.12	0.46	0.21	0.55	1.62	0.84
Oceania	0.79	0.54	1.95	0.12	0.46	0.21	0.55	1.62	0.84
The Americas and the Caribbean	0.79	0.54	1.95	0.12	0.46	0.21	0.55	1.62	0.84

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 68. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical moist climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.67	0.59	1.27	0.11	0.72	0.21	0.44	1.22	0.79
Asia	0.57	0.58	1.27	0.11	0.73	0.21	0.50	0.35	0.79
Europe	0.61	0.58	1.27	0.11	0.73	0.21	0.57	0.62	0.79
Oceania	0.61	0.58	1.27	0.11	0.73	0.21	0.57	0.62	0.79
North America	0.61	0.58	1.27	0.11	0.73	0.21	0.57	0.62	0.79
South America	0.63	0.58	1.27	0.11	0.73	0.21	0.71	0.62	0.79
Central America	0.61	0.55	1.27	0.11	0.73	0.21	0.57	0.62	0.79
Caribbean	0.61	0.58	1.27	0.11	0.73	0.21	0.57	0.62	0.79

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 69. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical wet climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.57	0.45	1.49	0.10	0.69	0.21	0.71	0.89	0.01
Asia	0.47	0.45	0.48	0.10	1.16	0.21	0.42	0.89	0.01
Europe	0.53	0.45	1.10	0.10	0.91	0.21	0.54	0.89	0.01
Oceania	0.53	0.45	1.10	0.10	0.91	0.21	0.54	0.89	0.01
North America	0.53	0.45	1.10	0.10	0.91	0.21	0.54	0.89	0.01
South America	0.51	0.45	1.10	0.10	0.78	0.21	0.51	0.89	0.01
Central America	0.53	0.45	1.14	0.1	0.70	0.21	0.71	0.89	0.01
Caribbean	0.53	0.45	1.10	0.10	0.91	0.21	0.54	0.89	0.01

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 70. Below-ground biomass growth rate for various agroforestry systems, in tC/ha/yr, for tropical montane climate

Geographical regions	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Africa	0.59	0.55	1.12	0.17	0.80	0.21	0.55	0.56	0.75
Asia	0.63	0.55	1.49	0.17	0.80	0.21	0.55	0.56	0.75
Europe	0.63	0.55	1.49	0.17	0.80	0.21	0.55	0.56	0.75
Oceania	0.63	0.55	1.49	0.17	0.80	0.21	0.55	0.56	0.75
The Americas and the Caribbean	0.63	0.55	1.49	0.17	0.80	0.21	0.55	0.56	0.75

Notes: Values for agroforestry systems are the average of a given regional range. Values in red indicate generic values for all regions under the same climate.

Source: Authors' own elaboration based on Table 5.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 71. Maximum above-ground biomass at harvest for various agroforestry systems, in tC/ha, according to climate

IPCC climate zones	Agroforestry	Alley cropping	Perennial fallow	Hedgerow	Multistrata	Parkland	Shaded perennial	Silvoarable	Silvopasture
Tropical	**41.7**	47.4	22.1	9.4	65	11.8	48	72.2	58.2
Temperate and boreal	**39.7**	**47.4**	**22.1**	26.1	65	11.8	48	27.3	69.9
Tropical montane	**40.7**	**47.4**	**22.1**	**17.75**	**65**	**11.8**	**48**	**49.75**	**64.05**

Notes: Values in bold are the default values provided by the IPCC for a specific climate but applied to other climate in the absence of data. Tropical montane system values are the average between tropical and temperate.

Source: Authors' own elaboration based on Table 5.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 72. Maximum above-ground biomass at harvest for various monoculture agroforestry systems, in tC/ha, according to climate

IPCC climate zones	Olive	Orchard	Vine	Short rotation coppice	Oil palm	Rubber	Tea
Tropical	**9.1**	**8.5**	**5.5**	**12.69**	60	80.2	20.7
Temperate and boreal	9.1	8.5	5.5	12.69	**60**	**80.2**	20.7
Tropical montane	**9.1**	**8.5**	**5.5**	**12.69**	**60**	**80.2**	**20.7**

Notes: Values in bold are the default values provided by the IPCC for a specific climate but applied to other climate in the absence of data. Tropical montane system values are the average between tropical and temperate.

Source: Authors' own elaboration based on Table 5.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Cropland management modifies the soil carbon stock to varying degrees depending on how specific practices influence carbon input and output from the soil system. The main management practices that affect the soil carbon stocks in cropland are the type of residue management, tillage management, fertilizer management (both mineral fertilizers and organic amendments), choice of crop and intensity of cropping management, irrigation management and mixed systems with cropping and pasture or hay in rotating sequences.

The total change in soil organic carbon stock for perennial is estimated using Equation 2.24 in Chapter 2 of IPCC (2019), which combines the change in soil organic carbon stock for mineral and organic soils.

Changes in soil carbon need to be estimated for perennial crops as with annual cropland. The soil organic carbon stock changes for mineral soils of agroforestry systems are computed in EX-ACT from the default reference soil organic carbon stocks (SOC_{REF}) and default stock change factors (F_{LU}, F_{MG}, F_I) following Equation 1 as described in Section 1.3. Users can change the default soil reference and stock change factors using the corresponding Tier 2 section.

4.2.4 Non-CO_2 emissions

Non-CO_2 emission from burning of pruning residues

Non-CO_2 emissions from burning pruning materials consist of CH_4 and N_2O produced by the combustion of pruning. CO_2 emissions from burning pruning materials do not have to be reported, since the carbon released during the combustion process is assumed to be reabsorbed by the vegetation during the next growing season (IPCC, 2019).

Non-CO_2 emissions from burning pruning materials are calculated based on the generic Equation 2.27 of IPCC (2019), described in Section 1.3. The amount of biomass available for burning (MB) is set by default to be equal to 50 percent of the AGB yearly growth rate, but users can enter Tier 2 values and specify the pruning biomass available for burning. The generic value of combustion factor C_f of 0.85 is taken from Table 2.6 of IPCC (2019). The emission factor G_{ef} gives the amount of a particular GHG emitted per unit of crop residue dry matter combusted (g/kg d.m. burnt). Under this section, EX-ACT uses the default mean values of G_{ef} for savannah and grassland summarised in Table 2.5 of IPCC (2019): i.e. 2.3 gCH_4/kg d.m. burnt and 0.21 gN_2O/kg d.m.

If users specify that there is a use of fire, they can adjust the frequency of fire, set by default to 1/year (i.e. one fire incident occurs every year) in Tier 2.

Mineralised N resulting from loss of soil organic carbon stocks in mineral soils through land use change or management practices

Together with changes and oxidation of SOC storage, land use management is also accompanied by mineralization of nitrogen (N), which is an additional source of N available for N_2O emissions. Where soil carbon losses occur, the release of N by mineralization is estimated according to Equation 15:

$$F_{SOM} = \sum ((\Delta C_{mineral} \times 1/R) \times 1000)$$

(Eq. 15)[16]

Where:

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, in kg N;

$\Delta C_{mineral}$ = average annual loss of soil carbon for each land use type, in tonnes C;

R = C:N ratio of the soil organic matter.

For R, a default value of 10 for cropland remaining cropland is applied. Default values are provided in Chapter 11 of IPCC (2019).

4.2.5 Surface and greenhouse gas emissions

Users must inform the changes in surface with each successive system described in the component "perennial systems remaining perennial systems". The dynamics are set by default to linear but can be changed (see background part). More details regarding the implementation or lack thereof of the project and the associated dynamics are described in the background part. Based on areas indicated, the vegetation characteristics and details on the residues management and soil management (tillage and input of organic material), the GHG balances in CO_2-e is calculated for the biomass and soil pool.

Note that for perennial systems remaining perennial systems, surface areas must be the same at the beginning and at the end (with or without project). For perennial systems coming from other land use and/or converted to other land use, users only have to specify about the land use and residues management.

4.2.6 Tier 2 options

Users have the possibility to replace the default value with Tier 2 values for above-ground and below-ground biomass growth rate, soil carbon stock, stock change factors (land use, tillage and input factors), quantity of residues burned and the fire periodicity (see **Figure 27**).

[16] Equation based on Chapter 11in Volume 4 of IPCC (2019).

Figure 27. Tier 2 approach for the perennial systems sub-module in EX-ACT

3.2. Perennial cropping systems — Back

3.2.1. Perennial systems from other LU or converted to other LU

Perennial systems from (or to) other land uses	Above-ground tC/ha/yr Default	Above-ground Tier 2	Below-ground tC/ha/yr Default	Below-ground Tier 2	Soil carbon tC/ha Default	Soil carbon Tier 2	Tillage factor Default	Tillage factor Tier 2	Input factor Default	Input factor Tier 2	Residues burned tdm/ha Default	Residues burned Tier 2	Fire periodicity year Default	Fire periodicity Tier 2
Perennials after deforestation	0,00		0,00		0,0		0,00		0,00		0,00		1	
Perennials converted to forest land	0,00		0,00		0,0		0,00		0,00		0,00		1	
Perennials converted from non-forest LUs	0,00		0,00		0,0		0,00		0,00		0,00		1	
Perennials converted to non-forest LUs	0,00		0,00		0,0		0,00		0,00		0,00		1	

3.2.2. Perennial systems remaining perennial systems (total area must remain constant)

Perennial systems remaining perennial systems	Above-ground tC/ha/yr Default	Above-ground Tier 2	Below-ground tC/ha/yr Default	Below-ground Tier 2	Soil carbon tC/ha Default	Soil carbon Tier 2	Land use factor Default	Land use factor Tier 2	Tillage factor Default	Tillage factor Tier 2	Input factor Default	Input factor Tier 2	Residues burned tdm/ha Default	Residues burned Tier 2	Fire periodicity year Default	Fire periodicity Tier 2
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	
Please select	0,00		0,00		0,00		0,00		0,00		0,00		0,00		1	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

4.3 Flooded rice systems

4.3.1 Methodology

Material used to develop this module is drawn from Volume 4 (AFOLU) of IPCC (2019), Chapter 2 for the soil and GHG emissions from residues burning, Chapter 5 for methane emission from rice cultivation and Chapter 11 for the quantity of residues.

The "Flooded rice module" concerns only flooded (permanently or part of the year) rice fields. Upland rice is not a source of CH_4, since it is grown in aerated soils that never become flooded for a significant period of time. Thus, upland rice is considered an annual crop in EX-ACT. Users should enter information associated with upland (non-flooded) rice in the "Annual cropping systems" sub-module.

GHG covered by the "flooded rice module" are: (i) CH_4 emission produced from anaerobic decomposition of organic matter; (ii) CH_4 and N_2O emissions from residues burning when occurring; and (iii) CO_2 emissions from soil, if occurring. CO_2 emissions from residues burning do not have to be considered since the carbon release during the combustion is assumed to be reabsorbed by the vegetation during the next growing season. N_2O emissions from N-fertilizer applied in rice fields is accounted for via the "Inputs" module (see Part 10).

4.3.2 Definition of the flooded rice systems

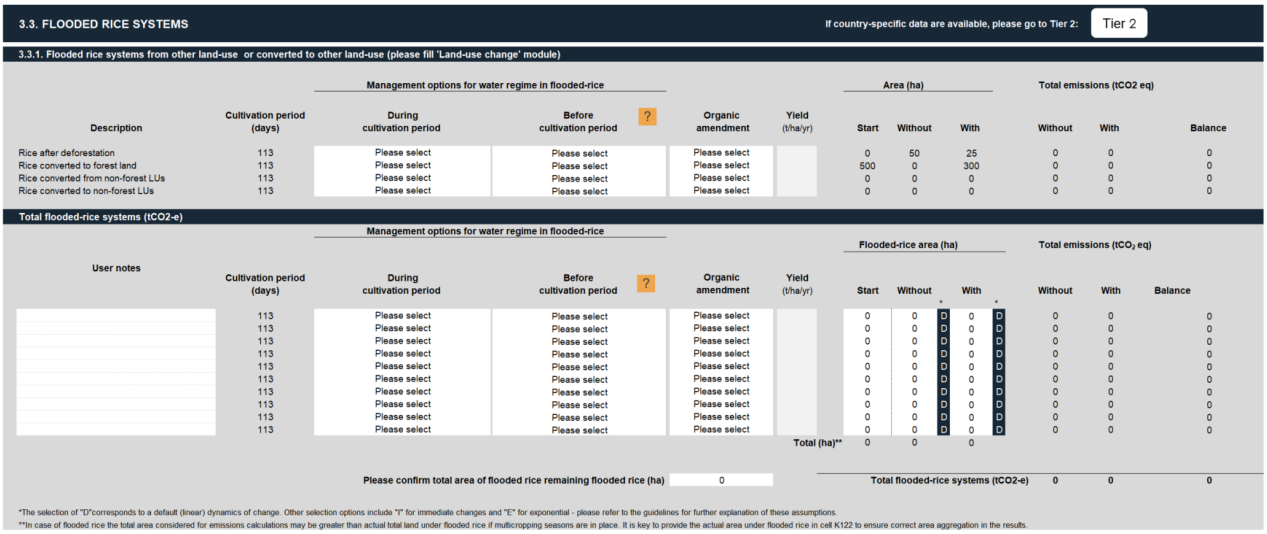
The "flooded rice system" concerns only flooded (permanently or part of the year) rice fields. It consists of two components (see **Figure 28**): (i) flooded rice systems from other land use or converted to other land use and; and (ii) flooded rice systems remaining flooded rice systems.

The first component includes two elements:

- Newly implemented systems after deforestation (rice after deforestation) or from conversion of other land use systems (rice after non-forest land use);
- Flooded-rice systems that are converted either to plantation forest or converted to other land use changes.

The second component calculates the GHG balance of flooded-rice fields that have not undergone any land use conversion for a period of at least 20 years. The different carbon-balances associated with each flooded rice is attributed to environmental factors, climate and different agronomic practices such as water regime and management which can favour or lower the actual emission rates.

Figure 28. Flooded rice systems in EX-ACT



3.3. FLOODED RICE SYSTEMS — If country-specific data are available, please go to Tier 2: Tier 2

3.3.1. Flooded rice systems from other land-use or converted to other land-use (please fill 'Land-use change' module)

Description	Cultivation period (days)	Management options for water regime in flooded-rice: During cultivation period	Before cultivation period	Organic amendment	Yield (t/ha/yr)	Area (ha): Start	Without	With	Total emissions (tCO2 eq): Without	With	Balance
Rice after deforestation	113	Please select	Please select	Please select		0	50	25	0	0	0
Rice converted to forest land	113	Please select	Please select	Please select		500	0	300	0	0	0
Rice converted from non-forest LUs	113	Please select	Please select	Please select		0	0	0	0	0	0
Rice converted to non-forest LUs	113	Please select	Please select	Please select		0	0	0	0	0	0

Total flooded-rice systems (tCO2-e)

User notes	Cultivation period (days)	Management options for water regime in flooded-rice: During cultivation period	Before cultivation period	Organic amendment	Yield (t/ha/yr)	Flooded-rice area (ha): Start	Without	*	With	*	Total emissions (tCO_2 eq): Without	With	Balance
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	113	Please select	Please select	Please select		0	0	D	0	D	0	0	0
					Total (ha)**	0	0		0				

Please confirm total area of flooded rice remaining flooded rice (ha): 0

Total flooded-rice systems (tCO2-e): 0 | 0 | 0

*The selection of "D"corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

**In case of flooded rice the total area considered for emissions calculations may be greater than actual total land under flooded rice if multicropping seasons are in place. It is key to provide the actual area under flooded rice in cell K122 to ensure correct area aggregation in the results.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

4.3.3 CO_2 emissions and removals

Emissions from biomass, litter and dead wood pools are set to zero assuming that there are no net gains or losses of living biomass in flooded rice systems. Only CO_2 emissions from residues burning and soils are calculated from rice cultivation.

CO_2 emission rates are calculated based on Equation 2.25 in Chapter 2 of the IPCC (2019, see Section 1.3 for further details). For paddy rice, tillage and input factors are not used. Therefore, the IPCC Equation 2.25 is simplified accordingly, (see Equation 16).

$$SOC_{mineral} = SOC_{ref} * F_{Lu} * A$$

(Eq. 16)

Where:

$SOC_{mineral}$ = total mineral SOC at a defined time, in tC;

SOC_{ref} = SOC in the reference condition, in tC/ha;

F_{Lu} = stock change factor for mineral SOC land use system or sub-systems, dimensionless; and

A = land area under the different management, in ha.

EX-ACT uses IPCC default values for SOC_{ref} for mineral soils differentiated by climate and soil type, the default value for land use factor (F_{Lu}), 1.35, from Table 5.5 of IPCC (2019).

4.3.4 Non-CO_2 emissions

Methane emissions from rice cultivation

The methodology used for estimating CH_4 emissions from rice cultivation follows Equation 5.1 of IPCC (2019) as described in Equation 17.

CH_4 Emissions from rice cultivation:

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k}\ t_{i,j,k}\ A_{i,j,k}\ 10^{-6})$$

(Eq. 17)[17]

Where:

$CH_{4\ Rice}$ = annual CH_4 emissions from rice cultivation, in $kgCH_4$/ha/yr (subsequently converted to tCO_2-e/ha/yr);

$EF_{i,j,k}$ = a daily emission factor for i, j, and k conditions, in $kgCH_4$/ha/day;

$t_{i,j,k}$ = cultivation period of rice for i, j, and k conditions, in day;

$A_{i,j,k}$ = harvested area of rice for i, j, and k conditions, in ha/yr. i, j, and k represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.

EX-ACT uses the default values, disaggregated by region, for the rice cultivation period, proposed by the IPCC (see Table 5.11A of IPCC [2019]) and reported in **Table 73**.

Table 73. Default cultivation period of rice

Geographical regions	Cultivation period, in days	Error range, in days
Africa	113	74–152
East Asia	112	73–147
Southeast Asia	102	78–150
South Asia	112	90–140
Europe	123	111–153
North America	139	110–165
South America	124	110–146
Global	113	74–152

Source: Authors' own elaboration based on Table 5.11A in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Under Tier 1, the adjusted daily emission factor for a particular harvested area, EFi, is estimated based on Equation 5.2 of IPCC (2019), as described in Equation 18 here below. Scaling factors are used to adjust the baseline emission factor.

$$EF_i = EF_c * SF_w * SF_p * SF_0$$

(Eq. 18)[18]

Where:

EF_i = the adjusted daily emission factor for a particular harvested area, $kgCH_4$/ha/day;

EF_c = the baseline emission factor for continuously flooded fields without organic amendments, dimensionless;

SF_w = the scaling factor to account for the differences in water regime during the cultivation period, dimensionless;

[17] Equation based on Chapter 5 in Volume 4 of IPCC (2019).

[18] Equation based on Chapter 5 in Volume 4 of IPCC (2019).

SF_p = the scaling factor to account for the differences in water regime in the pre-season before the cultivation period, dimensionless; and

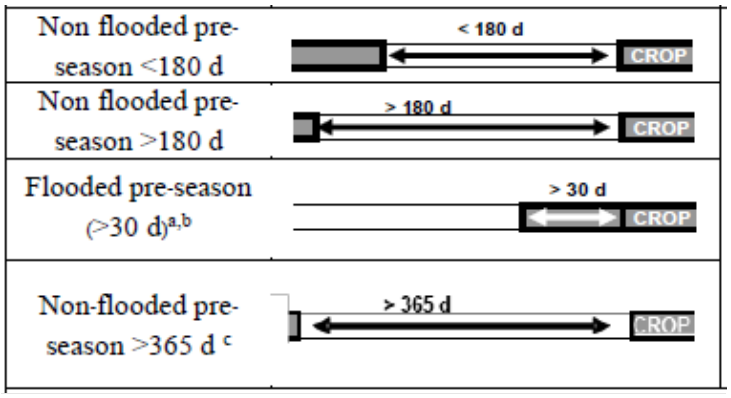
SF_0 = the scaling factor that is varied by type and amount of organic amendment applied in the field.

Default baseline emission factor, scaling factors and emission factor for organic amendments used to estimate CH_4 emission from rice cultivation are provided in Tables 5.11 to 5.14 of IPCC (2019). They are described from **Table 74** to **76**.

Concerning the water regime during the cultivation period, the three categories cover the following situations:

- **Irrigated – continuously flooded:** fields have standing water throughout the rice growing season and may only dry out for harvest (end-season drainage);
- **Irrigated – intermittently flooded:** fields have at least one aeration period of more than three days during the cropping period. EX-ACT distinguishes between single or multiple aeration;
- **Rainfed and deep water:** fields are flooded for a significant period of time and water regime depends solely on precipitation. It includes the following subcases: (i) regular rainfed (the water level may rise up to 50 cm during the cropping season); (ii) drought prone (drought periods occur during every cropping season); and (iii) deep water rice (floodwater rises to more than 50 cm for a significant period of time during the cropping season).

Figure 29. Description of the different water regime before the cultivation period



Source: Table 5.13 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 74. Baseline emission factor (EF_c) according to regions, in $kgCH_4$/ha/day

Geographical regions	Baseline emission factor
Africa	1.19
East Asia	1.32
Southeast Asia	1.22
South Asia	0.85
Europe	1.56
North America	0.65
South America	1.27
Global	1.19

Note: EFc was determined in the following conditions: i.e. (i) no flooding for less than 180 days prior to rice cultivation; and (ii) continuous flooding condition without organic amendments during the rice cultivation period.

Source: Authors' own elaboration based on Table 5.11 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 75. Default methane emission scaling factor for water regime during the cultivation period

Water regimes	Scaling factor (SFw)
Irrigated, continuously flooded	1.00
Irrigated, single drainage period	0.71
Irrigated, multiple drainage periods	0.55
Rainfed, wet season (regular rainfed)	0.54
Rainfed, dry season (drought prone)	0.16
Rainfed, deep water	0.06

Source: Authors' own elaboration based on Table 5.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 76. Default methane emission scaling factor for water regimes prior to rice cultivation

Water regimes	Scaling factor (SFp)
Non flooded pre-season <180 d	1.00
Non flooded pre-season >180 d	0.89
Flooded pre-season (>30 d)	2.41

Source: Authors' own elaboration based on Table 5.13 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Methane emissions associated with organic amendments applied (compost, farmyard manure, green manure and rice straw), are estimated using Equation 5.3 of IPCC (2019), as described in Equation 19:

Adjusted CH_4 emission scaling factors for organic amendments:

$$SF_0 = (1 + \sum ROA_j \text{ x } COA_j)^{0.59}$$

(Eq. 19)[19]

Where:

SF_0 = the scaling factor for both type and organic amendment applied;

ROA_j = the application rate of organic amendment (i) in dry weight for straw, in t/ha;

COA_j = the conversion factor for organic amendment (i).

The amount of rice straw, in t d.m./ha, is based on the Equation 11.6 of IPCC (2019) and crop yield data obtained from FAOSTAT (FAO, 2022) or estimated following the methodology provided in Table 11.2 of IPCC (2019).

Five default values are proposed for the organic amendments (see **Table 77**). Straw application refers to the straw that is incorporated into the soil; it does not include the case in which straw is placed on soil surface (as this option is not considered in IPCC [2019] nor IPCC [2006]).

[19] Equation based on Chapter 5 in Volume 4 of IPCC (2019).

Table 77. Default conversion factor for various types of organic amendments

Organic amendments	Conversion factor (COA)
Straw incorporated shortly (<30 days) before cultivation	1.00
Straw incorporated long (>30 days) before cultivation	0.19
Compost	0.17
Farmyard manure	0.21
Green manure	0.45

Source: Authors' own elaboration based on Table 5.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Non-CO_2 greenhouse gas emissions (CH_4 and N_2O) from residues burning

Non-CO_2 GHG emissions from residues burning are based on the generic method presented for all biomass in Chapter 2 of IPCC (2019), and as described in the generic methodology section (see Part 1 for more details). The default value of straw is estimated according to the methodology presented in the previous paragraph. MB corresponds to ROA coefficient in the case of trash residues (see above). CF corresponds to the proportion of pre-fire fuel biomass consumed by fire. It is set to 0.8 using the combustion factor proposed for rice residues in Table 2.6 of IPCC (2019). G_{ef} is set to 0.07 kgN_2O/t d.m. for N_2O and 2.7 kgCH_4/t d.m. for CH_4, using the default values proposed for the agricultural residues in Table 2.5 of IPCC (2019). N_2O and CH_4 emissions are converted into CO_2-e using the respective GWP (see Section 1.3).

4.3.5 Surface and greenhouse gas emissions

Users should enter information on the surface area of flooded rice at the start (baseline), without and with the project scenarios. These areas have to share the same rice ecosystem types (irrigated, rainfed and deep-water rice), flooding pattern before and during the cultivation period and the type and amount of organic amendments.

If more than one rice crop is harvested on a given area of land during a crop year and the growing conditions vary among the cropping seasons, calculations should be performed for each season (one line per season in EX-ACT). Users should then indicate the total area of rice cultivated at the bottom of the module in order to avoid over counting of areas in the final carbon balance given in tCO_2-e per hectare per year.

4.3.6 Tier 2 options

It is recommended to use more specific values, if available, using the Tier 2 section (see **Figure 30**). Users have the possibility to change the default values for:

- the cultivation period;
- soil carbon;
- land use factor;
- the adjusted daily emission factor for a particular harvested area;
- the baseline emission factor for continuously flooded fields without organic amendments;
- the scaling factor to account for the differences in water regime during the cultivation period;
- the scaling factor to account for the differences in water regime in the pre-season before the cultivation period;
- the scaling factor that is varied by type and amount of organic amendment applied in the field; and
- the quantity of rice straw.

Figure 30. Tier 2 approach of the flooded rice systems sub-module in EX-ACT

3.3. Flooded rice systems Back

3.3.1. Flooded rice systems from other land-use or converted to other land-use (please fill 'Land-use change' module)

Daily emission factor for rice EF = EF-basis x SF-Before x CF-or Amendment

EFc and EFi are in kg CH4 per ha per day

Flooded rice systems from (or to) other LU	Cultivation period (days)		Soil carbon (tC/ha)		EFc (baseline EF, continously flooded rice w/out organic amendments)		SFw (SF, water regime during cultivation period)		SFp (SF, water regime before cultivation period)		SFo (SF, organic amendement applied)		EFi (adjusted daily EF)		Rice straw (Main season crop) (t dm/ha)	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
Rice after deforestation	113		70,2		1,19		0,00		0,00		0,00		0,00		5,08	
Rice converted to forest land	113		70,2		1,19		0,00		0,00		0,00		0,00		5,08	
Rice converted from non-forest LUs	113		70,2		1,19		0,00		0,00		0,00		0,00		0,00	
Rice converted to non-forest LUs	113		70,2		1,19		0,00		0,00		0,00		0,00		0,00	

3.3.2. Flooded rice systems remaining flooded rice systems

Daily emission factor for rice EF = EF-basis x SF-Before x CF-or Amendment

EFc and EFi are in kg CH4 per ha per day

Flooded rice syst remaining rice systems	Cultivation period (days)		Soil carbon (tC/ha)		Land use factor		EFc (baseline EF, continously flooded rice w/out organic amendments)		SFw (SF, water regime during cultivation period)		SFp (SF, water regime before cultivation period)		SFo (SF, organic amendement applied)		EFi (adjusted daily EF)		Rice straw (Main season crop) (t dm/ha)	
Description	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	
	113		0,00		0,00		1,19		0,00		0,00		0,00		0,00		0,00	

Use this part only if you want to refine the analysis at Tier 2

IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 5. Grassland and livestock module

The grassland and livestock module consists of two sub-modules: (i) grassland systems and (ii) livestock management.

5.1 Grassland management

5.1.1 Methodology

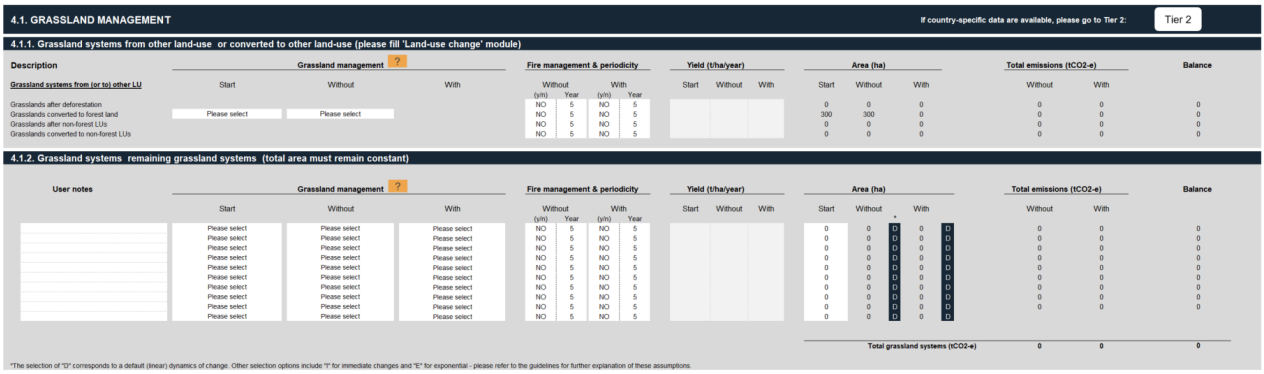
Material used to develop this sub-module can be found in Chapter 6 "Grassland" and Chapter 2 "Generic Methodology Applicable to Multiple Land use Categories" in IPCC (2019).

The "Grassland management" sub-module calculates the GHG balance associated with soil carbon stock changes and periodic burning of the grasslands.

5.1.2 Definition of the grassland system

The grasslands sub-module distinguishes two components: (i) the grassland systems from other land use or converted to other land use; thus built on information filled in the "Land use change" module; and (ii) grasslands systems remaining grasslands systems (see **Figure 31**).

Figure 31. Grassland management sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

The second component addresses changes in grassland management activities that are known to influence carbon input to the soil and thus SOC stocks. The management activities on grasslands that improve SOC stocks include irrigation, fertilization, liming, organic amendments, more productive grass varieties (labelled as improved), medium or high inputs. Prolonged heavy grazing or biomass removal will lead to degradation of grassland and hence to SOC stock losses.

Users need to select an appropriate grassland management level at start, without and with project scenarios, together with the corresponding area of grassland in hectares. The possible choices are outlined in **Table 78**.[20] Users can also specify the fire occurrence and its periodicity (in years) for both scenarios. The default value is set to five, which indicates that there will be a fire event once every five years.

[20] Improving grasslands from one management state to the next occurs every 20 years. For example, non-degraded grassland can become improved grassland over 20-year period, while further improvement into "improved grassland with medium inputs" will require another 20 years.

Table 78. Grassland management and associated definition

Grassland management	Definition
Severely degraded	Implies major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.
High intensity grazing	Represents high intensity grazing systems (or cutting and removal of vegetation) with shifts in vegetation composition and possibly productivity but is not severely degraded.
Non-degraded (nominally managed)	Represents low or medium intensity grazing regimes, in addition to periodic cutting and removal of above-ground vegetation, without significant management improvements.
Improved grassland	Represents grassland which is sustainably managed with light to moderate grazing pressure (or cutting and removal of vegetation) and that receive at least one improvement (i.e. fertilization, species improvement and irrigation).
Improved grassland with medium inputs	Applies only to improved grassland where no additional management inputs have been used.
Improved grassland with high inputs	Applies to improved grassland where one or more additional management inputs/improvements have been used (beyond that required to be classified as improved grassland).

Source: Authors' own elaboration based on Table 6.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

5.1.3 CO_2 emissions

Biomass carbon stocks in grassland are influenced by human activities including harvesting, grazing, fires, soil and vegetation rehabilitation. EX-ACT aligns with the IPCC default assumption that biomass is at steady state in grasslands remaining grasslands (IPCC, 2019). EX-ACT only accounts for changes in biomass carbon stock caused by fire events. The default values retained in EX-ACT are taken from Table 6.4 of IPCC (2006) and reported below (see **Table 79**).

Table 79. Default above-ground biomass, in t d.m./ha, in grasslands stratified by climate region

IPCC climate zones	Above-ground biomass
Boreal–dry and wet	1.7
Cool temperate–dry	1.7
Cool temperate–moist	2.4
Warm temperate–dry	1.6
Warm temperate–moist	2.7
Tropical–dry	2.3
Tropical–moist	6.2
Tropical–wet	6.2

Source: Authors' own elaboration based on Table 6.4 in Volume 4 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

The SOC difference between the with project scenario (SOC_{With}) and without project scenario ($SOC_{W/out}$) indicates changes due to grassland management in the topsoil (0–30 cm. See **Table 2**) over a period of 20 years. The SOC stock changes are expressed in tC/ha. The SOC stocks are calculated from SOC_{ref} under native vegetation and default stock change factors for grassland management (F_{LU}, F_{MG}, F_I),

(see **Tables 2** and **80**), using Equation 2.25 of IPCC (2019). SOC changes are converted into tCO_2 using the conversion factor 44/12.

Table 80. Relative stock change factors for grassland management

Factor	Level	Climate regime	IPCC default
Land use, FL_u	All	All	1.0
Management, F_{MG}	Nominally managed (non-degraded)	All	1.0
	High intensity grazing	All	0.90
	Severely degraded	All	0.7
	Improved grassland	Temperate/boreal	1.14
		Tropical	1.17
		Tropical montane	1.16
Input, F_I	Medium	All	1.0
	High	All	1.11

Source: Authors' own elaboration based on Table 6.2 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Given the large uncertainties associated with Tier 1 method, users are strongly encouraged to enter country-specific data of SOC stocks for the relevant grassland management classes defined above.

5.1.4 Non-CO_2 emissions from periodic biomass burning

Grasslands may be subject to fire as a result of management practices. The resulting non-CO_2 emissions should also be reported. As with cropland, CO_2 emissions from biomass burning in grassland remaining grassland are not reported since they are largely balanced by the CO_2 reincorporated back into the biomass via photosynthetic activity within the year.

Non-CO_2 emissions from biomass burning are calculated based on the generic Equation 2.27 of IPCC (2019). The default values for combustion factor C_f representing the proportion of pre-fire fuel biomass consumed is set to 77 percent (see Table 2.6 of IPCC [2019]). The emission factor G_{ef} for CH_4 and N_2O is respectively 2.3 and 0.21 g/kg d.m. burnt (see Table 2.5 of IPCC [2019]). These default values can be refined in Tier 2.

5.1.5 Surface and greenhouse gas emissions

Users must provide the surface of the area under each grassland system of the second component (the first component related areas are taken automatically from the "Land use change" module). This, together with information on management and the use of fire will trigger the GHG fluxes calculations. Once again, the provided surfaces of concerned areas must remain the same at the start, with and without project scenarios.

5.1.6 Tier 2 options

Users have the possibility to change the default values to country or region-specific ones for the following parameters (see **Figure 32**): soil organic carbon at start, without and with project situation, above-ground biomass and combustion factor.

Figure 32. Tier 2 approach of the grassland management sub-module

4.1. GRASSLAND MANAGEMENT Back

4.1.1. Grassland systems from other land-use or converted to other land-use (please fill 'Land-use change' module)

Description	Soil carbon stocks (tC/ha)						AGB (t d.m./ha)		Combustion factor (%)	
	Start		Without		With					
Grassland systems from (or to) other LU	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
Grasslands after deforestation	52,0		52,0		52,0		0		0,77	
Grasslands converted to forest land	52,0		52,0		52,0		6,2		0,77	
Grasslands after non-forest LUs	52,0		52,0		52,0		0		0,77	
Grasslands converted to non-forest LUs	52,0		52,0		52,0		0		0,77	

4.1.2. Grassland systems remaining grassland systems (total area must remain constant)

	Soil carbon stocks (tC/ha)						AGB (t d.m./ha)		Combustion factor (%)	
	Start		Without		With					
Grasslands remaining grasslands	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	
	52,0		52,0		52,0		0,0		0,77	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

5.2 Livestock

5.2.1 Methodology

Material used to develop this module can be found in Chapter 10 "Emissions from Livestock and Manure Management" in Volume 4 (AFOLU) of IPCC (2019),

GHG covered by the livestock module (see **Figure 33**) include: (i) CH_4 emissions from enteric fermentation, (ii) CH_4 emissions from manure management, and (iii) N_2O emissions from manure management.

5.2.2 Countries categorization

Most of the methodology provided in the livestock chapter of IPCC (2019) is based on the FAO's GLEAM model, which embeds country specific emission factors. These emission factors have been aggregated by IPCC into regions, which slightly differ from the grouping of countries used in the other EXACT modules. For example, the "Oceania" region is represented by Australia, New Zealand and the numerous small island states in the Pacific for all the modules in EX-ACT but Livestock. For livestock module, following the IPCC, EX-ACT regroups only Australia and New Zealand, as their productivity system is particularly high, while the Pacific small island states are closer to low productivity systems of Asia. As a result, they are included in the livestock module under the geographic area "South Asia and South East Asia". The full regional distribution of countries in the livestock module is provided in Annex 1 to inform the users and help refine the emission factors at Tier 2 as may be desired.

5.2.3 Methane emissions from enteric fermentation

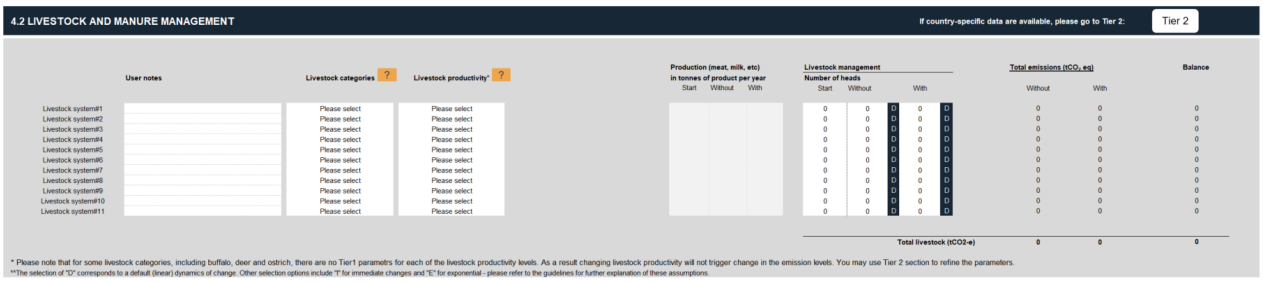
EX-ACT uses the Tier 1 method so that only animal population data (in addition to information already provided in the description module) is needed to estimate the emissions (see **Figure 33**). Users always have the possibility to use their own emission factors if available.

Users should divide the livestock population into subgroups by species and provide the corresponding animal numbers. It is recommended to use annual averages estimated with consideration for the impact of production cycles and seasonal influences on population numbers. Users can choose among cattle (dairy/other), buffalo (dairy/other), sheep (dairy/other), swine (growing/breeding), goats, camels, horses, mules and asses, deer, ostrich, poultry (chicken layer/chicken broiler), llamas and alpacas. These main categories are based on Table 10.9 of IPCC (2019) with higher level of disaggregation according to emissions factors for manure management (see next sections). These categories are further disaggregated into three levels of productivity: high-productivity, low-productivity and a default one (IPCC, 2019).

The amount of CH_4 from enteric fermentation is calculated based on the generic method: i.e. multiplying an emission factor (see **Tables 81** to **83**) per animal with the corresponding animal numbers.

For poultry (chicken layer and chicken broiler) the IPCC does not provide emission factor for enteric fermentation, due to the lack of data. Yet, poultry is one of the most important meat sources in many countries and there are large poultry flocks in many territories. Therefore, EX-ACT uses the value provided by Wang and Huang (2005) for all productivity levels of poultry animal categories.

Figure 33. Overview of the livestock sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Table 81. Methane emission factors, in kgCH_4/head/year, from enteric fermentation, for high-productivity systems

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	86	60	81	81	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
East Asia and South-East Asia	96	43	76	76	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
North America	138	64	0	0	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Latin America and the Caribbean	103	55	68	68	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Western Europe	126	52	78	78	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Eastern Europe	93	58	68	68	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Russian Federation	93	58	68	68	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Oceania	93	63	0	0	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
Near East and North Africa (NENA)/Middle East	94	61	67	67	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8
South Asia	70	41	85	85	9	9	1.5	1.5	9	18	46	10	20	5	0.00004868	0.00004868	8

Note: Proxy from Eastern Europe has been applied for Russian Federation.

Sources: Authors' own elaboration based on Tables 10.10 and 10.11 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and on Wang, S-Y., Huang, D-J. 2005. Assessment of Greenhouse Gas Emissions from Poultry Enteric Fermentation. *Asian-Australasian Journal of Animal Sciences*, 18(6): 873-878. doi.org/10.5713/ajas.2005.873 for poultry.

Table 82. Methane emission factors, in kgCH_4/head/year, from enteric fermentation, for low-productivity systems

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	66	48	81	81	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
East Asia and South-East Asia	71	56	76	76	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
North America	138	64	0	0	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Latin America and the Caribbean	78	58	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Western Europe	126	52	78	78	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Eastern Europe	93	58	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Russian Federation	93	58	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Oceania	93	63	0	0	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
NENA/Middle East	62	55	67	67	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
South Asia	74	47	85	85	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8

Note: Proxy from Eastern Europe has been applied for the Russian Federation.

Sources: Authors' own elaboration based on Tables 10.10 and 10.11 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and on Wang, S-Y., Huang, D-J. 2005. Assessment of Greenhouse Gas Emissions from Poultry Enteric Fermentation. *Asian-Australasian Journal of Animal Sciences*, 18(6): 873-878. doi.org/10.5713/ajas.2005.873 for poultry.

Table 83. Methane emission factors, in kgCH_4/head/year, from enteric fermentation, for default productivity systems

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	76	52	81	81	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
East Asia and South-East Asia	78	54	76	76	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
North America	138	64	0	0	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Latin America and the Caribbean	87	56	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Western Europe	126	52	78	78	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Eastern Europe	93	58	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Russian Federation	93	58	68	68	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
Oceania	93	63	0	0	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
NENA/Middle East	76	60	67	67	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8
South Asia	73	46	85	85	5	5	1	1	5	18	46	10	20	5	0.00004868	0.00004868	8

Notes: For sheep, swine and goat, EX-ACT uses the low-productivity proxy. For the Russian Federation, EX-ACT applies the proxy from Eastern Europe.

Sources: Authors' own elaboration based on Tables 10.10 and 10.11 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html and on Wang, S-Y., Huang, D-J. 2005. Assessment of Greenhouse Gas Emissions from Poultry Enteric Fermentation. *Asian-Australasian Journal of Animal Sciences*, 18(6): 873-878. doi.org/10.5713/ajas.2005.873 for poultry.

5.2.4 Methane emissions from manure management

The calculations of CH_4 emissions from manure management draw on Section 10.4 in Chapter 10 of IPCC (2019). These emissions correspond to CH_4 produced during the storage and treatment of manure (including both dung and urine) and from manure deposited on pastures. CH_4 emissions from manure management depend on the amount produced and the portion that decomposes in anaerobic conditions. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. The temperature and the retention time of the storage unit highly affects the amount of CH_4 produced. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose under more aerobic conditions and less CH_4 is produced (IPCC, 2019).

EX-ACT uses the advanced Tier 1a method based on the total amount of volatile solid (VS) excreted (from all livestock and categories except deer and ostrich) in each type of manure management system multiplied by an emission factor for that type of livestock category within selected productivity system, the specified climate zone and manure management system (see Equations 20 and 21 and **Tables 84** and **85** for the definition of the productivity system and manure management systems, respectively). The advanced Tier 1a approach provides an estimate for the changes in both productivity and manure management that occur via a transition from lower productivity systems to higher productivity systems.

CH_4 emissions from manure management (Tier 1a):

$$CH_4(_{mm}) = \sum [N(_{T,P}) \text{ x } VS(_{T,P}) \text{ x } AWMS(_{T,S,P}) \text{ x } EF(_{T,S,P})]/1000$$

(Eq. 20)[21]

Where :

$CH_4(_{mm})$ = CH_4 emissions from Manure Management in the country, in kg CH_4/yr;

$N(_{T,P})$ = number of head of livestock species/category T in the project area/country, for productivity system P, when applicable;

$VS(_{T,P})$ = annual average VS excretion per head of species/category T, for productivity system P, when applicable in kg VS/animal/yr (calculated by Equation 20);

$AWMS(_{T,S,P})$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless; to consider productivity class P, if using a Tier 1a approach;

$EF(_{T,S,P})$ = emission factor for direct CH_4 emissions from manure management system S, by animal species/category T, in manure management system S, for productivity system P, when applicable, in kg CH_4 /VS;

S = manure management system;

T = species/category of livestock;

P= high productivity system or low productivity system.

Annual VS excretion rate:

$$VS(_{T,P}) = VSrate(_{T,P}) \text{ x } TAM(_{T,P})/1000 \text{ x } 365$$

(Eq. 21) [22]

Where :

$VS(_{T,P})$ = annual VS excretion for livestock category T, for productivity system P (when applicable), kg VS/animal/yr;

$VSrate(_{T,P})$ = default VS excretion rate, for productivity system P (when applicable), kg VS/(1000 kg animal mass)/day;

$TAM(_{T,P})$ = typical animal mass for livestock category T, for productivity system P (when applicable), kg/animal.

Table 84. Definition of productivity systems according to livestock categories

Main livestock categories	Productivity systems
Dairy cattle	Mature cows (first lactation and beyond) that are producing milk in commercial quantities for consumption. Dairy cow population should not be confused with multi-purpose cows that may be used for more than one production purpose milk, meat or draft.
Dairy cattle or buffalo in high-productivity systems	High-yielding dairy cows that are concentrated in confinement production systems or grazing on high quality pastures with supplements. The farms are 100-percent market oriented for commercial milk production, for national markets and/or export; Purebred or crossbred cattle are genetically improved through selective breeding for milk production.

[21] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

[22] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

Main livestock categories	Productivity systems
Dairy cattle or buffalo in low-productivity systems	Low-yielding dairy cows, grazing non improved pastures, and using locally produced roughage (i.e. crop residues), and agro-industrial by-products. Local breeds or crossbred cows are bred locally, without intensive selection for milk productivity. Milk production is mostly for local market and local consumption.
Other cattle in high-productivity systems	Productivity system based on animal feeding systems using forage (i.e. high-quality grass) and concentrates in confinement production systems or grazing with supplements or on improved pastures, producing high rates of daily weight gain. Animals can be purebred or crossbred and are genetically improved through selective breeding for improved commercial meat production. Growing cattle may be finished young in "intensive grazing with supplements" or feedlot systems, and meat is produced for national markets and/or export.
Other cattle in low-productivity systems	Productivity system based on animal feeding systems where locally produced roughage (i.e. crop residues) or low-quality rangelands represent the major source of feed utilized, producing low rates of daily weight gain. Animals can be represented by local breeds or may be crossbred and can also be used for multiple purposes such as draft, meat and milk for self-consumption and markets.
Other livestock in high-productivity systems	Productivity system 100 percent market oriented with high level of capital input requirements and high level of overall herd (flock) performance. Feed is purchased from local or international market or intensively produced on farm. Animals are improved through breeding practices for commercial production. The high-productivity systems are common in swine, poultry, goats and sheep production.
Other livestock in low-productivity systems	Productivity system mainly driven by local market or by self-consumption, with low capital input requirements and low level of overall herd (fowl) performance typically using large areas for production or backyards. Locally produced feed represents the major source of feed utilized or animals are kept-free range for major part or all of their production cycle, the yield of the activity being linked to the natural fertility of the land and the seasonal production of the pastures. The low-productivity systems are common in swine, poultry, goats and sheep production

Source: Authors' own elaboration based on Chapter 10 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Emissions are summed over all manure management systems and livestock category. The VS excretion factors, default typical animal mass, CH_4 emissions factors are from respectively Table 10.13A, Table 10A.5 and Table 10.14, while default animal waste management is available in Tables from 10A.6 to 10A.9 in Chapter 10 in Annex 10A.2 of IPCC (2019). Values used in EX-ACT are reported in **Tables 86** to **126**. Further, emission factors associated with the default productivity in EX-ACT are either taken from Chapter 10 of IPCC (2019) or assumed equal to those of low-productivity systems for cattle, swine and goats (see Tables 110, 114 and 120). For deer and ostrich, EX-ACT methane emission factors as provided in Table 10.15, Chapter 10 of IPCC (2019) equal to 0.22 and 5.67 $kgCH_4$/head/year, respectively.

Calculations are done according to information on numbers of animals per category that have been provided in the previous step. Results provide the corresponding emissions in tCO_2-e.

Users have the possibility to change the manure management system in Tier 2.

Table 85. Definition and characteristics of manure management systems

Manure management systems	Definition and characteristics
Pasture/range/paddock	The manure from pasture and range grazing animals is allowed to lie as deposited and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked because of the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover. Dry lots do not require the addition of bedding to control moisture. Manure may be removed periodically and spread on fields.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water or bedding material in tanks or ponds outside the animal housing. Manure is removed and spread on fields once or more in a calendar year. Manure is agitated before removal from the tank/ponds to ensure that most of the VS are removed from the tank.
Lagoons (uncovered anaerobic)	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoons have a lower depth and a much larger surface compared to liquid slurry stores. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The supernatant water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year. Manure may be pumped out of the storage to a secondary storage tank multiple times in one year or stored and applied directly to fields. It is assumed that VS removal rates on tank emptying are >90 percent.
Anaerobic digester	Anaerobic fermentation of slurry and/or solid. Biogas is captured and flared or used as a fuel.
Burned for fuel	The dung and urine are excreted on fields. The sun-dried dung cakes are burned for fuel.
Pit storage below animal confinements	Mixture of excreta and washing water, stored within the livestock building, usually below the confined animals.
Poultry manure	Similar to cattle and swine deep bedding except usually not combined with a dry lot or pasture. Typically used for all poultry breeder flocks, for alternative systems for layers and for the production of meat type chickens (broilers) and other fowl. Litter and manure are left in place with added bedding during the poultry production cycle and cleaned between poultry cycles, typically 5 to 9 weeks in productive systems and greater in lower productivity systems.
Composting	Biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Source: Authors' own elaboration based on Chapter 10 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 86. Total animal mass, in kg, for high-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	250	302	339	339	31	31	54	200	24	238	217	130	120	120	1	0.8	65
East Asia and South-East Asia	485	310	336	336	31	31	56	160	24	238	217	130	120	120	1.4	1	65
North America	650	407	0	0	40	40	61	184	41	377	217	130	120	120	1.4	1.4	65
Latin America and the Caribbean	520	329	315	315	31	31	59	205	24	238	217	130	120	120	1.3	1.2	65
Western Europe	600	405	509	509	40	40	61	190	40	377	217	130	120	120	1.4	1.2	65
Eastern Europe	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Russian Federation	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Oceania	488	359	0	0	40	40	41	163	33	377	217	130	120	120	1.3	1.2	65
NENA/Middle East	510	362	381	381	31	31	60	157	24	238	217	130	120	120	1.2	1	65
South Asia	350	167	321	321	31	31	55	162	24	238	217	130	120	120	1.2	1	65

Source: Authors' own elaboration based on Tables 10A.5 and 10.10 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 87. Total animal mass, in kg, for low-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	270	208	339	339	31	31	33	61	24	238	217	130	120	120	0.8	0.7	65
East Asia and South-East Asia	355	296	336	336	31	31	44	102	24	238	217	130	120	120	1	0.7	65
North America	650	407	0	0	40	40	61	184	41	377	217	130	120	120	1.4	1.4	65
Latin America and the Caribbean	500	295	315	315	31	31	47	121	24	238	217	130	120	120	0.9	0.7	65
Western Europe	600	405	509	509	40	40	61	190	40	377	217	130	120	120	1.4	1.2	65
Eastern Europe	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Russian Federation	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Oceania	488	359	0	0	40	40	41	163	33	377	217	130	120	120	1.3	1.2	65
NENA/Middle East	270	232	381	381	31	31	48	99	24	238	217	130	120	120	0.7	0.5	65
South Asia	265	236	321	321	31	31	48	99	24	238	217	130	120	120	0.8	0.6	65

Source: Authors' own elaboration based on Tables 10A.5 and 10.10 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 88. Total animal mass, in kg, for default productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler	Llamas and alpacas
Sub-Saharan Africa	260	236	339	339	31	31	33	61	24	238	217	130	120	120	0.9	0.8	65
East Asia and South-East Asia	386	299	336	336	31	31	44	102	24	238	217	130	120	120	1.2	0.8	65
North America	650	407	0	0	40	40	61	184	41	377	217	130	120	120	1.4	1.4	65
Latin America and the Caribbean	508	303	315	315	31	31	47	121	24	238	217	130	120	120	1.1	0.9	65
Western Europe	600	405	509	509	40	40	61	190	40	377	217	130	120	120	1.4	1.2	65
Eastern Europe	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Russian Federation	550	389	467	467	40	40	59	204	36	377	217	130	120	120	1.3	1.1	65
Oceania	488	359	0	0	40	40	41	163	33	377	217	130	120	120	1.3	1.2	65
NENA/Middle East	349	275	381	381	31	31	48	99	24	238	217	130	120	120	0.9	0.7	65
South Asia	285	226	321	321	31	31	48	99	24	238	217	130	120	120	1	0.8	65

Source: Authors' own elaboration based on Tables 10A.5 and 10.10 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 89. Volatile solid excretion rate, in kgVs/(1 000 kg TAM)/day, for default productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Chicken layer	Chicken broiler
Sub-Saharan Africa	18.2	12	12.9	12.9	8.3	8.3	8.2	4.4	10.4	7.2	11.5	7.2	12.6	15.9
East Asia and South-East Asia	9	9.8	13.5	13.5	8.3	8.3	6.8	3.4	10.4	7.2	11.5	7.2	11.2	15.7
North America	9.3	7.6	0	0	8.2	8.2	3.9	1.8	9	5.65	11.5	7.2	14.5	16.8
Latin America and the Caribbean	7.9	8.5	11.2	11.2	8.3	8.3	6.4	2.7	10.4	7.2	11.5	7.2	13.5	15.6
Western Europe	7.5	5.7	7.7	7.7	8.2	8.2	5.3	2.4	9	5.65	11.5	7.2	12.3	16.1
Eastern Europe	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Russian Federation	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Oceania	6	8.7	0	0	8.2	8.2	5.6	2.1	9	5.65	11.5	7.2	15.4	18.3
NENA/Middle East	10.7	14.1	9.8	9.8	8.3	8.3	4.9	2.5	10.4	7.2	11.5	7.2	14.2	17.7
South Asia	14.1	12.2	0	0	8.3	8.3	8.6	4.6	10.4	7.2	11.5	7.2	14.9	17.7

Source: Authors' own elaboration based on Table 10.13a in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 90. Volatile solid excretion rate, in kgVs/(1 000 kg TAM)/day, for high-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Chicken layer	Chicken broiler
Sub-Saharan Africa	21.7	10.2	12.9	12.9	8.3	8.3	5.3	2.4	10.4	7.2	11.5	7.2	12.3	16
East Asia and South-East Asia	8.1	6.8	13.5	13.5	8.3	8.3	5.1	2.3	10.4	7.2	11.5	7.2	10.6	15.6
North America	9.3	7.6	0	0	8.2	8.2	3.9	1.8	9	5.65	11.5	7.2	14.5	16.8
Latin America and the Caribbean	9	8.1	11.2	11.2	8.3	8.3	4.3	1.7	10.4	7.2	11.5	7.2	13.3	15.5
Western Europe	7.5	5.7	7.7	7.7	8.2	8.2	5.3	2.4	9	5.65	11.5	7.2	12.3	16.1
Eastern Europe	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Russian Federation	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Oceania	6	8.7	0	0	8.2	8.2	5.6	2.1	9	5.65	11.5	7.2	15.4	18.3
NENA/Middle East	8.4	10.5	9.8	9.8	8.3	8.3	4.4	2.3	10.4	7.2	11.5	7.2	14.1	17.7
South Asia	9.1	13.5	0	0	8.3	8.3	6.5	3	10.4	7.2	11.5	7.2	14.3	17.6

Source: Authors' own elaboration based on Table 10.13a in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 91. Volatile solid excretion rate, in kgVs/(1 000 kg TAM)/day, for low-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Chicken layer	Chicken broiler
Sub-Saharan Africa	15.2	12.7	12.9	12.9	8.3	8.3	9.4	6	10.4	7.2	11.5	7.2	13	15.4
East Asia and South-East Asia	9.2	10.8	13.5	13.5	8.3	8.3	8.1	4.3	10.4	7.2	11.5	7.2	14.3	17.1
North America	9.3	7.6	0	0	8.2	8.2	3.9	1.8	9	5.65	11.5	7.2	14.5	16.8
Latin America and the Caribbean	7.1	8.6	11.2	11.2	8.3	8.3	10	4.8	10.4	7.2	11.5	7.2	15.7	17.8
Western Europe	7.5	5.7	7.7	7.7	8.2	8.2	5.3	2.4	9	5.65	11.5	7.2	12.3	16.1
Eastern Europe	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Russian Federation	6.7	7.6	6.2	6.2	8.2	8.2	4.9	2	9	5.65	11.5	7.2	12.6	16
Oceania	6	8.7	0	0	8.2	8.2	5.6	2.1	9	5.65	11.5	7.2	15.4	18.3
NENA/Middle East	11.8	16.8	9.8	9.8	8.3	8.3	7.8	4.6	10.4	7.2	11.5	7.2	16.5	17.9
South Asia	16.1	12	0	0	8.3	8.3	9.5	5.5	10.4	7.2	11.5	7.2	15.7	18.2

Source: Authors' own elaboration based on Table 10.13a in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 92. Animal waste management system regional average, in percentage, for dairy cattle

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	20	29	45	0	0	6	0	0	0	0	0	0
East Asia and South-East Asia	0	1	21	29	38	0	0	11	0	0	0	0	0	0
North America	26	24	24	0	15	11	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	5	38	57	0	0	0	0	0	0	0	0	0
Western Europe	0	43	29	0	26	2	0	0	0	0	0	0	0	0
Eastern Europe	0	5	74	0	20	1	0	0	0	0	0	0	0	0
Russian Federation	0	5	74	0	20	1	0	0	0	0	0	0	0	0
Oceania	5	0	0	0	94	1	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	14	35	46	0	0	5	0	0	0	0	0	0
South Asia	0	0	1	49	30	0	0	20	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 93. Animal waste management system regional average, in percentage, for other cattle

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	15	30	50	0	0	5	0	0	0	0	0	0
East Asia and South-East Asia	0	0	29	28	36	0	0	7	0	0	0	0	0	0
North America	0	1	43	14	42	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	3	5	92	0	0	0	0	0	0	0	0	0
Western Europe	0	22	26	0	48	4	0	0	0	0	0	0	0	0
Eastern Europe	0	64	5	0	31	0	0	0	0	0	0	0	0	0
Russian Federation	0	64	5	0	31	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	100	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	5	46	42	0	0	7	0	0	0	0	0	0
South Asia	0	0	1	49	30	0	0	20	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC*
Source: Authors' own elaboration based on Table 10A.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 94. Animal waste management system regional average, in percentage, for dairy buffalo

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	10	58	29	0	0	3	0	0	0	0	0	0
North America	0	43	40	0	17	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	2	48	50	0	0	0	0	0	0	0	0	0
Western Europe	0	34	63	0	3	0	0	0	0	0	0	0	0	0
Eastern Europe	0	18	68	0	13	1	0	0	0	0	0	0	0	0
Russian Federation	0	18	68	0	13	1	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	18	35	46	0	0	1	0	0	0	0	0	0
South Asia	0	0	1	41	38	0	0	20	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 95. Animal waste management system regional average, in percentage, for other buffalo

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	6	64	28	0	0	2	0	0	0	0	0	0
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	2	5	93	0	0	0	0	0	0	0	0	0
Western Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastern Europe	0	9	64	0	27	0	0	0	0	0	0	0	0	0
Russian Federation	0	9	64	0	27	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	16	12	57	0	0	15	0	0	0	0	0	0
South Asia	0	0	1	40	39	0	0	20	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.6 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 96. Animal waste management system regional average, in percentage, for breeding swine in high-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	7	6	86	0	0	0	0	1	0	0	0	0	0
East Asia and South-East Asia	35	21	0	2	0	0	7	0	35	0	0	0	0	0
North America	28	31	4	3	0	0	0	0	0	34	0	0	0	0
Latin America and the Caribbean	11	34	12	41	0	2	0	0	0	0	0	0	0	0
Western Europe	6	51	15	0	0	1	0	0	2	25	0	0	0	0
Eastern Europe	5	31	55	1	0	0	0	0	4	4	0	0	0	0
Russian Federation	0	24	76	0	0	0	0	0	0	0	0	0	0	0
Oceania	91	0	1	8	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	10	29	0	54	0	0	7	0	0	0	0	0	0	0
South Asia	12	23	14	32	0	8	8	0	3	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.7 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 97. Animal waste management system regional average, in percentage, for breeding swine in low-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	5	30	15	15	5	5	5	0	15	5	0	0	0	0
East Asia and South-East Asia	4	28	22	13	6	6	4	0	13	4	0	0	0	0
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	5	30	15	15	5	5	5	0	15	5	0	0	0	0
Western Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	5	30	15	15	5	5	5	0	15	5	0	0	0	0
South Asia	5	30	15	15	5	5	5	0	15	5	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.7 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 98. Animal waste management system regional average, in percentage, for growing swine in high-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	7	6	86	0	0	0	0	1	0	0	0	0	0
East Asia and South-East Asia	35	21	0	2	0	0	7	0	35	0	0	0	0	0
North America	28	31	4	3	0	0	0	0	0	34	0	0	0	0
Latin America and the Caribbean	11	34	12	41	0	2	0	0	0	0	0	0	0	0
Western Europe	6	51	14	0	0	1	0	0	2	26	0	0	0	0
Eastern Europe	5	31	55	1	0	0	0	0	4	4	0	0	0	0
Russian Federation	0	24	76	0	0	0	0	0	0	0	0	0	0	0
Oceania	91	0	1	8	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	10	29	0	54	0	0	7	0	0	0	0	0	0	0
South Asia	12	23	13	35	0	7	8	2	2	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.7 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 99. Animal waste management system regional average, in percentage, for growing swine in low-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	5	30	15	15	5	5	5	0	15	5	0	0	0	0
East Asia and South-East Asia	5	27	18	14	6	6	5	0	14	5	0	0	0	0
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	5	30	15	15	5	5	5	0	15	5	0	0	0	0
Western Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	5	30	15	15	5	5	5	0	15	5	0	0	0	0
South Asia	5	30	15	15	5	5	5	0	15	5	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.7 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 100. Animal waste management system regional average, in percentage, for other sheep

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	17	3	80	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	17	3	80	0	0	0	0	0	0	0	0	0
North America	0	0	54	0	46	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	17	3	80	0	0	0	0	0	0	0	0	0
Western Europe	0	0	13	0	87	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	54	0	46	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	54	0	46	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	100	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	50	50	0	0	0	0	0	0	0	0	0
South Asia	0	0	17	3	80	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.8 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 101. Animal waste management system regional average, in percentage, for dairy sheep

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	17	3	80	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	17	3	80	0	0	0	0	0	0	0	0	0
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	17	3	80	0	0	0	0	0	0	0	0	0
Western Europe	0	0	21	0	78	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	42	0	58	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	42	0	58	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	50	50	0	0	0	0	0	0	0	0	0
South Asia	0	0	17	3	80	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.8 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 102. Animal waste management system regional average, in percentage, for goat

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	17	3	80	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	50	0	50	0	0	0	0	0	0	0	0	0
North America	0	0	50	0	50	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	17	3	80	0	0	0	0	0	0	0	0	0
Western Europe	0	0	28	0	72	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	9	0	91	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	82	0	18	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	100	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	50	50	0	0	0	0	0	0	0	0	0
South Asia	0	0	50	0	50	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.8 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 103. Animal waste management system regional average, in percentage, for chicken layer

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	0	0	0	0	0	90	10	0	0	0
East Asia and South-East Asia	0	4	0	0	1	1	0	0	0	94	0	0	0	0
North America	1	29	70	0	0	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	58	42	0	0	0	0	0	0	0	0	0	0	0
Western Europe	0	1	20	21	0	1	0	0	0	43	14	0	0	0
Eastern Europe	0	0	0	47	0	0	0	0	0	34	19	0	0	0
Russian Federation	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Oceania	0	0	0	0	23	0	0	0	0	77	0	0	0	0
NENA/Middle East	11	7	11	0	0	0	0	0	0	67	4	0	0	0
South Asia	0	0	100	0	0	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 104. Animal waste management system regional average, in percentage, for chicken broiler in high-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	0	0	0	0	0	0	100	0	0	0
East Asia and South-East Asia	0	0	0	0	0	0	0	0	0	0	100	0	0	0
North America	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Latin America and the Caribbean	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Western Europe	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Eastern Europe	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Russian Federation	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	100	0	0	0
NENA/Middle East	0	0	0	0	0	0	0	0	0	0	100	0	0	0
South Asia	0	0	0	0	0	0	0	0	0	0	100	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 105. Animal waste management system regional average, in percentage, for chicken broiler in low-productivity system

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	50	50	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	0	0	50	50	0	0	0	0	0	0	0	0
North America	0	0	0	0	50	50	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	0	0	50	50	0	0	0	0	0	0	0	0
Western Europe	0	0	0	0	50	50	0	0	0	0	0	0	0	0
Eastern Europe	0	0	0	0	50	50	0	0	0	0	0	0	0	0
Russian Federation	0	0	0	0	50	50	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	50	50	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	0	50	50	0	0	0	0	0	0	0	0
South Asia	0	0	0	0	50	50	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 106. Animal waste management system regional average, in percentage, for horse, camels, mules and asses, and other grazing animals

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	17	3	80	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	50	0	50	0	0	0	0	0	0	0	0	0
North America	0	0	50	0	50	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	17	3	80	0	0	0	0	0	0	0	0	0
Western Europe	0	0	28	0	72	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	9	0	91	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	82	0	18	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	100	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	50	50	0	0	0	0	0	0	0	0	0
South Asia	0	0	50	0	50	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 107. Animal waste management system regional average, in percentage, for ostrich

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	20	0	80	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	20	0	80	0	0	0	0	0	0	0	0	0
North America	0	0	20	0	80	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	20	0	80	0	0	0	0	0	0	0	0	0
Western Europe	0	0	20	0	80	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	20	0	80	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	20	0	80	0	0	0	0	0	0	0	0	0
Oceania	0	0	20	0	80	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	20	0	80	0	0	0	0	0	0	0	0	0
South Asia	0	0	20	0	80	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 108. Animal waste management system regional average, in percentage, for deer

Geographical regions	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Sub-Saharan Africa	0	0	0	0	100	0	0	0	0	0	0	0	0	0
East Asia and South-East Asia	0	0	0	0	100	0	0	0	0	0	0	0	0	0
North America	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Latin America and the Caribbean	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Western Europe	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Eastern Europe	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Russian Federation	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	100	0	0	0	0	0	0	0	0	0
NENA/Middle East	0	0	0	0	100	0	0	0	0	0	0	0	0	0
South Asia	0	0	0	0	100	0	0	0	0	0	0	0	0	0

Notes: PRP stands for pasture/range/paddock. Eastern Europe's proxies are used for the Russian Federation.

Source: Authors' own elaboration based on Table 10A.9 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 109. Methane emission factors from manure management, in gCH_4/kg VS, for dairy cattle in high-productivity system

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	96.5	33.8	3.2	1.6	0.6	0.2	3.2	16.1	0	33.8	0	0	0	0
Cool temperate dry	107.1	41.8	3.2	1.6	0.6	0.2	3.2	16.1	0	41.8	0	0	0	0
Boreal moist	80.4	22.5	3.2	1.6	0.6	0.2	3.2	16.1	0	22.5	0	0	0	0
Boreal dry	78.8	22.5	3.2	1.6	0.6	0.2	3.2	16.1	0	22.5	0	0	0	0
Warm temperate moist	117.4	59.5	6.4	2.4	0.6	0.8	3.7	16.1	0	59.5	0	0	0	0
Warm temperate dry	122.2	65.9	6.4	2.4	0.6	0.8	3.7	16.1	0	65.9	0	0	0	0
Tropical montane	122.2	94.9	8.0	3.2	0.6	1.6	3.7	16.1	0	94.9	0	0	0	0
Tropical wet	128.6	122.2	8.0	3.2	0.6	1.6	3.7	16.1	0	122.2	0	0	0	0
Tropical moist	128.6	117.4	8.0	3.2	0.6	1.6	3.7	16.1	0	117.4	0	0	0	0
Tropical dry	128.6	119.0	8.0	3.2	0.6	1.6	3.7	16.1	0	119	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 110. Methane emission factors from manure management, in gCH_4/kg VS, for dairy cattle in low-productivity system

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	52.3	18.3	1.7	0.9	0.6	0.1	9.2	8.7	0	18.3	0	0	0	0
Cool temperate dry	58.4	22.6	1.7	0.9	0.6	0.1	9.2	8.7	0	22.6	0	0	0	0
Boreal moist	43.6	12.2	1.7	0.9	0.6	0.1	9.2	8.7	0	12.2	0	0	0	0
Boreal dry	42.7	12.2	1.7	0.9	0.6	0.1	9.2	8.7	0	12.2	0	0	0	0
Warm temperate moist	63.6	32.2	3.5	1.3	0.6	0.4	9.5	8.7	0	32.2	0	0	0	0
Warm temperate dry	66.2	35.7	3.5	1.3	0.6	0.4	9.5	8.7	0	35.7	0	0	0	0
Tropical montane	66.2	51.4	4.4	1.7	0.6	0.9	9.5	8.7	0	51.4	0	0	0	0
Tropical wet	69.7	66.2	4.4	1.7	0.6	0.9	9.5	8.7	0	66.2	0	0	0	0
Tropical moist	69.7	63.6	4.4	1.7	0.6	0.9	9.5	8.7	0	63.6	0	0	0	0
Tropical dry	69.7	64.5	4.4	1.7	0.6	0.9	9.5	8.7	0	64.5	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 111. Methane emission factors from manure management, in gCH_4/kg VS, for other cattle in high-productivity system

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	72.4	25.3	2.4	1.2	0.6	0.1	2.4	12.1	0	25.3	0	0	0	0
Cool temperate dry	80.8	31.4	2.4	1.2	0.6	0.1	2.4	12.1	0	31.4	0	0	0	0
Boreal moist	60.3	16.9	2.4	1.2	0.6	0.1	2.4	12.1	0	16.9	0	0	0	0
Boreal dry	59.1	16.9	2.4	1.2	0.6	0.1	2.4	12.1	0	16.9	0	0	0	0
Warm temperate moist	88	44.6	4.8	1.8	0.6	0.6	2.7	12.1	0	44.6	0	0	0	0
Warm temperate dry	91.7	49.4	4.8	1.8	0.6	0.6	2.7	12.1	0	49.4	0	0	0	0
Tropical montane	91.7	71.2	6	2.4	0.6	1.2	2.8	12.1	0	71.2	0	0	0	0
Tropical wet	96.5	91.7	6	2.4	0.6	1.2	2.8	12.1	0	91.7	0	0	0	0
Tropical moist	96.5	88	6	2.4	0.6	1.2	2.8	12.1	0	88	0	0	0	0
Tropical dry	96.5	89.2	6	2.4	0.6	1.2	2.8	12.1	0	89.2	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 112. Methane emission factors from manure management, in gCH_4/kg VS, for other cattle in low-productivity system and buffalo (dairy and other)

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	52.3	18.3	1.7	0.9	0.6	0.1	9.2	8.7	0	18.3	0	0	0	0
Cool temperate dry	58.4	22.6	1.7	0.9	0.6	0.1	9.2	8.7	0	22.6	0	0	0	0
Boreal moist	43.6	12.2	1.7	0.9	0.6	0.1	9.2	8.7	0	12.2	0	0	0	0
Boreal dry	42.7	12.2	1.7	0.9	0.6	0.1	9.2	8.7	0	12.2	0	0	0	0
Warm temperate moist	63.6	32.2	3.5	1.3	0.6	0.4	9.5	8.7	0	32.2	0	0	0	0
Warm temperate dry	66.2	35.7	3.5	1.3	0.6	0.4	9.5	8.7	0	35.7	0	0	0	0
Tropical montane	66.2	51.4	4.4	1.7	0.6	0.9	9.5	8.7	0	51.4	0	0	0	0
Tropical wet	69.7	66.2	4.4	1.7	0.6	0.9	9.5	8.7	0	66.2	0	0	0	0
Tropical moist	69.7	63.6	4.4	1.7	0.6	0.9	9.5	8.7	0	63.6	0	0	0	0
Tropical dry	69.7	64.5	4.4	1.7	0.6	0.9	9.5	8.7	0	64.5	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 113. Methane emission factors from manure management, in gCH_4/kg VS, for swine (breeding and growing) in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	180.9	63.3	6	3	0.6	0.3	6	30.2	18.1	63.3	0	0	0	0
Cool temperate dry	202	78.4	6	3	0.6	0.3	6	30.2	24.1	78.4	0	0	0	0
Boreal moist	150.8	42.2	6	3	0.6	0.3	6	30.2	12.1	42.2	0	0	0	0
Boreal dry	147.7	42.2	6	3	0.6	0.3	6	30.2	12.1	42.2	0	0	0	0
Warm temperate moist	220.1	111.6	12.1	4.5	0.6	1.5	6.8	30.2	39.2	111.6	0	0	0	0
Warm temperate dry	229.1	123.6	12.1	4.5	0.6	1.5	6.8	30.2	45.2	123.6	0	0	0	0
Tropical montane	229.1	177.9	15.1	6	0.6	3	7	30.2	75.4	177.9	0	0	0	0
Tropical wet	241.2	229.1	15.1	6	0.6	3	7	30.2	114.6	229.1	0	0	0	0
Tropical moist	241.2	220.1	15.1	6	0.6	3	7	30.2	108.5	220.1	0	0	0	0
Tropical dry	241.2	223.1	15.1	6	0.6	3	7	30.2	126.6	223.1	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 114. Methane emission factors from manure management, in gCH_4/kg VS, for swine (breeding and growing) in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	116.6	40.8	3.9	1.9	0.6	0.2	20.6	19.4	11.7	40.8	0	0	0	0
Cool temperate dry	130.2	50.5	3.9	1.9	0.6	0.2	20.6	19.4	15.5	50.5	0	0	0	0
Boreal moist	97.2	27.2	3.9	1.9	0.6	0.2	20.6	19.4	7.8	27.2	0	0	0	0
Boreal dry	95.2	27.2	3.9	1.9	0.6	0.2	20.6	19.4	7.8	27.2	0	0	0	0
Warm temperate moist	141.8	71.9	7.8	2.9	0.6	1	21.1	19.4	25.3	71.9	0	0	0	0
Warm temperate dry	147.7	79.7	7.8	2.9	0.6	1	21.1	19.4	29.1	79.7	0	0	0	0
Tropical montane	147.7	114.6	9.7	3.9	0.6	1.9	21.2	19.4	48.6	114.6	0	0	0	0
Tropical wet	155.4	147.7	9.7	3.9	0.6	1.9	21.2	19.4	73.8	147.7	0	0	0	0
Tropical moist	155.4	141.8	9.7	3.9	0.6	1.9	21.2	19.4	69.9	141.8	0	0	0	0
Tropical dry	155.4	143.8	9.7	3.9	0.6	1.9	21.2	19.4	81.6	143.8	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 115. Methane emission factors from manure management, in gCH_4/kg VS, for poultry (chicken layer and chicken broiler) in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	156.8	54.9	5.2	2.6	0.6	0	5.2	2.6	0	54.9	0	0	0	0
Cool temperate dry	175.1	67.9	5.2	2.6	0.6	0	5.2	2.6	0	67.9	0	0	0	0
Boreal moist	130.7	36.6	5.2	2.6	0.6	0	5.2	2.6	0	36.6	0	0	0	0
Boreal dry	128	36.6	5.2	2.6	0.6	0	5.2	2.6	0	36.6	0	0	0	0
Warm temperate moist	190.7	96.7	10.5	3.9	0.6	0	10.5	2.6	0	96.7	0	0	0	0
Warm temperate dry	198.6	107.1	10.5	3.9	0.6	0	10.5	2.6	0	107.1	0	0	0	0
Tropical montane	198.6	154.2	13.1	5.2	0.6	0	13.1	2.6	0	154.2	0	0	0	0
Tropical wet	209	198.6	13.1	5.2	0.6	0	13.1	2.6	0	198.6	0	0	0	0
Tropical moist	209	190.7	13.1	5.2	0.6	0	13.1	2.6	0	190.7	0	0	0	0
Tropical dry	209	193.4	13.1	5.2	0.6	0	13.1	2.6	0	193.4	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 116. Methane emission factors from manure management, in gCH_4/kg VS, for poultry (chicken layer and chicken broiler) in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Cool temperate dry	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Boreal moist	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Boreal dry	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Warm temperate moist	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Warm temperate dry	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Tropical montane	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Tropical wet	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Tropical moist	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0
Tropical dry	2.4	2.4	2.4	2.4	0.6	2.4	2.4	2.4	2.4	2.4	2.4	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 117. Methane emission factors from manure management, in gCH_4/kg VS, for sheep in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	2.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	2.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	2.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	2.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	5.1	1.9	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	5.1	1.9	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	6.4	2.5	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	6.4	2.5	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	6.4	2.5	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	6.4	2.5	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 118. Methane emission factors from manure management, in gCH_4/kg VS, for sheep in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	3.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	3.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 119. Methane emission factors from manure management, in gCH_4/kg VS, for goat in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	2.4	1.2	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	2.4	1.2	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	2.4	1.2	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	2.4	1.2	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	4.8	1.8	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	4.8	1.8	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	6	2.4	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	6	2.4	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	6	2.4	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	6	2.4	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 120. Methane emission factors from manure management, in gCH_4/kg VS, for goat in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	1.7	0.9	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	3.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	3.5	1.3	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	4.4	1.7	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 121. Methane emission factors from manure management, in gCH_4/kg VS, for camels in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	8.7	0	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	8.7	0	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	8.7	0	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	8.7	0	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 122. Methane emission factors from manure management, in gCH_4/kg VS, for camels in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	2.8	1.4	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	2.8	1.4	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	2.8	1.4	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	2.8	1.4	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	5.6	2.1	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	5.6	2.1	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	7	2.8	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	7	2.8	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	7	2.8	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	7	2.8	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 123. Methane emission factors from manure management, in gCH_4/kg VS, for horses in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	4	2	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	4	2	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	4	2	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	4	2	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	8	3	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	8	3	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	10.1	4	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	10.1	4	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	10.1	4	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	10.1	4	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 124. Methane emission factors from manure management, in gCH_4/kg VS, for horses in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 125. Methane emission factors from manure management, in gCH_4/kg VS, for mules and asses in high-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	4.4	2.2	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	4.4	2.2	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	4.4	2.2	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	4.4	2.2	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	8.8	3.3	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	8.8	3.3	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	11.1	4.4	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	11.1	4.4	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	11.1	4.4	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	11.1	4.4	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 126. Methane emission factors from manure management, in gCH_4/kg VS, for mules and asses in low-productivity systems

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Cool temperate dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal moist	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Boreal dry	0	0	3.5	1.7	0.6	0	0	0	0	0	0	0	0	0
Warm temperate moist	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Warm temperate dry	0	0	7	2.6	0.6	0	0	0	0	0	0	0	0	0
Tropical montane	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical wet	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical moist	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0
Tropical dry	0	0	8.7	3.5	0.6	0	0	0	0	0	0	0	0	0

Note: PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.14 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

5.2.5 Nitrous oxide emissions from manure management

These emissions correspond to N_2O produced, directly or indirectly, during the storage and treatment of manure (solids and liquids). Calculations are based on Tier 1 approach that consists in multiplying the total amount of N excretion of species category by a default emission factor (see Section 10.5 of IPCC [2019] for further details).

Direct emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Emissions of N_2O from manure during storage and treatments depend on the nitrogen and carbon content of manure as well as on the duration of the storage and type of treatment.

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of NH_3 (ammonia) and NO_x (nitrogen oxide). The fraction of excreted organic nitrogen that is mineralized to ammonium nitrogen during manure collection and storage depends primarily on oxygen supply, time and temperature. Nitrogen losses begin at the point of excretion in animal production areas and continue through on-site management in storage and treatment systems: i.e. manure management systems. Nitrogen is also lost through runoff and leaching into soils from the solid storage of manure at outdoors areas, in feedlots, pastures, ranges or paddocks.

Direct N_2O emissions from manure management

EX-ACT applies the Tier 1a methodology to estimate direct N_2O emissions from manure management according to Equation 22. Direct N_2O emissions depend on the total amount of N excretion (from all livestock species/categories) in each type of manure management system, related to the emission factor for that type of manure management system.

Direct N_2O emissions from manure management:

$$N_2OD(_{mm}) = \sum_S(\sum_{T,P}(N(_{T,P}) \text{ x } Nex(_{T,P}) \text{ x } AWMS(_{T,S,P}) \text{ x } EF_{3(S)}) \text{ x } 44/28$$

(Eq. 22)[23]

Where:

$N_2OD(_{mm})$ = direct N_2O emissions from Manure Management in the country, in kg N_2O/yr;

$N(_{T,P})$ = number of head of livestock species/category T in the country and for productivity system P;

$Nex(_{T,P})$ = annual average N excretion per head of species/category T in the country and productivity system P, in kg N/animal/yr;

$AWMS(_{T,S,P})$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless; to consider productivity class P, if using a Tier 1a approach;

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system S in the country, in kg N_2ON/kg N;

S = manure management system;

T = species/category of livestock;

P = productivity class: high, low or default (Tier 1 a);

44/28 = conversion factor of N_2O-N emissions to $N_2OD_{(mm)}$ emissions.

Default AWMS used in EX-ACT are provided in **Tables 127** to **129**; and $EF_{3(S)}$ in **Tables 130** and **131**.

The annual average N excretion per head of livestock category T in the country and productivity system P, $Nex_{(T,P)}$, estimated according to Equation 23.

Annual N excretion rates:

$$Nex(_{T,P}) = Nrate(_{T,P}) \text{ x } TAM(_{T,P})/1000 \text{ x } 365$$

(Eq. 23)[24]

Where:

$Nex(_{T,P})$ = annual N excretion for livestock category T and production level P, in kg N/animal/ yr;

$Nrate(_{T,P})$ = default N excretion rate for animal category T and production level P, in kg N/(1000 kg animal mass)/day;

$TAM(_{T,P})$ = typical animal mass for livestock category T and production level P, in kg/animal.

Default N excretion rate, Nrate, used in EX-ACT are provided in **Tables 127** to **129**. TAM default values are provided in **Tables 86** to **88**.

Emissions are summed over all manure management systems. The Tier 1a method is applied using IPCC default N_2O emission factors, default nitrogen excretion data and default manure management system data (for default animal weights and manure management system allocations see Tables 10A.5 to 10A.9 in Annex 10A.2 in Chapter 10 of IPCC [2019]). Default emissions factors for direct N_2O emissions used in EX-ACT are provided in **Tables 130** and **131**.

[23] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

[24] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

Table 127. Default values for nitrogen excretion rates, in kgN/1 000kg TAM/day, for all livestock categories

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler
Sub-Saharan Africa	0.44	0.44	0.41	0.41	0.32	0.32	0.49	0.29	0.34	0.46	0.46	0.46	0.67	0.34	1.29	1.4
East Asia and South-East Asia	0.44	0.38	0.44	0.44	0.32	0.32	0.7	0.37	0.34	0.46	0.46	0.46	0.67	0.34	1.1	1.35
North America	0.6	0.4	0	0	0.35	0.35	0.46	0.24	0.46	0.3	0.38	0.3	0.67	0.34	1.45	1.59
Latin America and the Caribbean	0.39	0.31	0.41	0.41	0.32	0.32	0.73	0.35	0.34	0.46	0.46	0.46	0.67	0.34	1.2	1.23
Western Europe	0.5	0.42	0.45	0.45	0.36	0.36	0.76	0.38	0.46	0.26	0.38	0.26	0.67	0.34	0.99	1.14
Eastern Europe	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Russian Federation	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Oceania	0.72	0.46	0	0	0.43	0.43	0.72	0.31	0.42	0.3	0.38	0.3	0.67	0.34	1.42	1.59
NENA/Middle East	0.5	0.55	0.39	0.39	0.32	0.32	0.73	0.4	0.34	0.46	0.46	0.46	0.67	0.34	1.29	1.43
South Asia	0.65	0.44	0.57	0.57	0.32	0.32	0.76	0.43	0.34	0.46	0.46	0.46	0.67	0.34	1.62	1.58

Note: EX-ACT uses proxies from Eastern Europe for the Russian Federation.

Source: Authors' own elaboration based on Table 10.19 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 128. Nitrogen excretion rates, in kgN/1 000kg TAM/day, for all livestock categories in low-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler
Sub-Saharan Africa	0.45	0.45	0.41	0.41	0.32	0.32	0.54	0.35	0.34	0.46	0.46	0.46	0.67	0.34	1.44	1.58
East Asia and South-East Asia	0.41	0.38	0.44	0.44	0.32	0.32	0.76	0.43	0.34	0.46	0.46	0.46	0.67	0.34	1.62	1.84
North America	0.6	0.4	0	0	0.35	0.35	0.46	0.24	0.46	0.3	0.38	0.3	0.67	0.34	1.45	1.59
Latin America and the Caribbean	0.28	0.29	0.41	0.41	0.32	0.32	0.8	0.43	0.34	0.46	0.46	0.46	0.67	0.34	2.14	2.39
Western Europe	0.5	0.42	0.45	0.45	0.36	0.36	0.76	0.38	0.46	0.26	0.38	0.26	0.67	0.34	0.99	1.14
Eastern Europe	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Russian Federation	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Oceania	0.72	0.46	0	0	0.43	0.43	0.72	0.31	0.42	0.3	0.38	0.3	0.67	0.34	1.42	1.59
NENA/Middle East	0.51	0.58	0.39	0.39	0.32	0.32	0.6	0.37	0.34	0.46	0.46	0.46	0.67	0.34	1.79	1.95
South Asia	0.7	0.4	0.57	0.57	0.32	0.32	0.76	0.47	0.34	0.46	0.46	0.46	0.67	0.34	1.83	2.11

Note: EX-ACT uses proxies from Eastern Europe for the Russian Federation.

Source: Authors' own elaboration based on Table 10.19 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 129. Nitrogen excretion rates, in kgN/1 000kg TAM/day, for all livestock categories in high-productivity system

Geographical regions	Dairy cattle	Other cattle	Dairy buffalo	Other buffalo	Dairy sheep	Other sheep	Growing swine	Breeding swine	Goats	Horses	Camels	Mules and asses	Deer	Ostrich	Chicken layer	Chicken broiler
Sub-Saharan Africa	0.41	0.42	0.41	0.41	0.32	0.32	0.39	0.21	0.34	0.46	0.46	0.46	0.67	0.34	1.16	1.34
East Asia and South-East Asia	0.55	0.36	0.44	0.44	0.32	0.32	0.63	0.32	0.34	0.46	0.46	0.46	0.67	0.34	1.0	1.31
North America	0.6	0.4	0	0	0.35	0.35	0.46	0.24	0.46	0.3	0.38	0.3	0.67	0.34	1.45	1.59
Latin America and the Caribbean	0.6	0.36	0.41	0.41	0.32	0.32	0.69	0.32	0.34	0.46	0.46	0.46	0.67	0.34	1.13	1.21
Western Europe	0.5	0.42	0.45	0.45	0.36	0.36	0.76	0.38	0.46	0.26	0.38	0.26	0.67	0.34	0.99	1.14
Eastern Europe	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Russian Federation	0.42	0.47	0.35	0.35	0.36	0.36	0.77	0.36	0.44	0.3	0.38	0.3	0.67	0.34	0.96	1.12
Oceania	0.72	0.46	0	0	0.43	0.43	0.72	0.31	0.42	0.3	0.38	0.3	0.67	0.34	1.42	1.59
NENA/Middle East	0.49	0.51	0.39	0.39	0.32	0.32	0.75	0.41	0.34	0.46	0.46	0.46	0.67	0.34	1.27	1.42
South Asia	0.51	0.63	0.57	0.57	0.32	0.32	0.74	0.37	0.34	0.46	0.46	0.46	0.67	0.34	1.48	1.47

Notes: EX-ACT uses proxies from Eastern Europe for the Russian Federation.

Source: Authors' own elaboration based on Table 10.19 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 130. Default emission factors for direct N_2O emissions from manure management, in kg N_2O-N/kg N excreted, for cattle, poultry and pigs

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	**0.003**	**0.0075**	0.02	0.004	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Cool temperate dry	0	**0.003**	**0.0075**	0.02	0.002	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Boreal moist	0	**0.003**	**0.0075**	0.02	0.004	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Boreal dry	0	**0.003**	**0.0075**	0.02	0.002	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Warm temperate moist	0	**0.003**	**0.0075**	0.02	0.004	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Warm temperate dry	0	**0.003**	**0.0075**	0.02	0.002	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Tropical montane	0	**0.003**	**0.0075**	0.02	0.002	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Tropical wet	0	**0.003**	**0.0075**	0.02	0.006	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Tropical moist	0	**0.003**	**0.0075**	0.02	0.004	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**
Tropical dry	0	**0.003**	**0.0075**	0.02	0.002	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.0075**

Notes: Bold values are the average over a given range. PRP stands for pasture, range and paddock.

Source: Authors' own elaboration based on Tables 10.21 and 11.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 131. Default emission factors for direct N_2O emissions from manure management, in kg N_2O-N/kg N excreted, for sheep and others livestock categories

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Cool temperate dry	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Boreal moist	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Boreal dry	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Warm temperate moist	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Warm temperate dry	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Tropical montane	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Tropical wet	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Tropical moist	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**
Tropical dry	0	**0.003**	**0.01**	0.02	0.003	0	0.0006		0.002	0.002	0.001	**0.04**	**0.0065**	**0.03**

Notes: Bold values are the average over a given range. PRP stands for pasture, range and paddock.

Source: Authors' own elaboration based on Tables 10.21 and 11.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Indirect N_2O emissions from manure management

N volatilisation

EX-ACT applies the Tier 1 methodology to estimate the indirect N_2O emissions from N volatilisation in the form of NH_3 and NO_x from manure management systems according to Equation 24. This methodology is based on the multiplication of the amount of N excreted and managed in each manure management system by a fraction of volatilised N. N losses are then summed overall manure management systems, as described below.

Indirect N_2O emissions due to volatilisation of N from manure management:

$$N_2O_{G(mm)} = N_{vol.(MMS)} \text{ x } EF_4 \text{ x } 44/28$$

(Eq. 24)[25]

Where:

$N_2O_{G(mm)}$ = indirect N_2O emissions due to volatilization of N from Manure Management in the country, in kg N_2O/yr;

$N_{vol.(MMS)}$ = amount of manure N that is lost due to volatilisation of NH_3 and NO_x, in kg N/yr;

EF_4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, in kg N_2O-N/(kg NH_3-N + NO_x-N volatilised).

With the amount of manure nitrogen lost due to volatilisation of NH_3 and NO_x, $N_{vol.(MMS)}$, estimated according to Equation 25.

N losses due to volatilisation from manure management:

$$N_{vol.(MMS)} = \sum_S [\sum_{T,P} ((N_{(T,P)} \text{ x } Nex_{(T,P)}) \text{ x } AWMS_{(T,S,P)}) \text{ x } Frac_{gasMS(T,S)}]$$

(Eq. 25)[26]

Where:

$N_{vol.(MMS)}$ = amount of manure N that is lost due to volatilisation of NH_3 and NO_x, in kg N/yr;

$N_{(T,P)}$ = number of head of livestock species/category T and productivity system P (low, high or default);

$Nex_{(T,P)}$ = annual average N excretion per head of species/category T and productivity system P (low, high or default), in kg N/animal/yr;

AWMS (T,S,P) = fraction of total annual N excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless; to consider productivity class P (low, high or default);

$Frac_{GasMS}$ = fraction of managed manure N for livestock category T that volatilises as NH_3 and NO_x in the manure management system S.

The fraction of managed manure N, $Frac_{GasMS}$ and the emission factor for N_2O emissions, EF_4, are provided respectively in Table 10.22 and Table 3 of IPCC (2019). Default emissions factors used in EX-ACT are listed in **Tables 132** to **136**.

N leaching

EX-ACT applies the Tier 1 methodology to estimate the indirect N_2O emissions from N leached and runoff from manure management systems according to Equation 26. This methodology is based on the multiplication of the amount of N excreted and managed in each manure management system by a

[25] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

[26] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

fraction of leached N. N losses are then summed overall manure management systems, as described below.

Indirect N_2O emissions due to leaching from manure management:

$$N_2O_{L(mm)} = N_{L.(MMS)} \text{ x } EF_5 \text{ x } 44/28$$

(Eq. 26)[27]

Where:

$N_2O_{L(mm)}$ = indirect N_2O emissions due to leaching and runoff from Manure Management in the country, in kg N_2O/yr;

$N_{l.(MMS)}$ = amount of manure N that is lost due leaching, in kg N/yr;

EF_5 = emission factor for N_2O emissions from N leaching and runoff, in kg N_2O-N/kg N leached and runoff.

With the amount of manure nitrogen lost due to volatilisation of NH_3 and NO_x, $N_{L.(MMS)}$, estimated according to Equation 27.

N losses due to leaching from manure management:

$$N_{L.(MMS)} = \sum S[\sum_{T,P} ((N(_{T,P}) \text{ x } Nex(_{T,P})) \text{ x } AWMS(_{T,S,P})) \text{ x } Frac_{L.MS(T,S)}]$$

(Eq. 27)[28]

Where:

$N_{l.(MMS)}$ = amount of manure N that is lost due to volatilisation of NH_3 and NO_x, in kg N/yr;

$N_{(T,P)}$ = number of head of livestock species/category T and productivity system P (low, high or default);

$Nex_{(T,P)}$ = annual average N excretion per head of species/category T and productivity system P (low, high or default), in kg N/animal/yr;

AWMS(T,S,P) = fraction of total annual N excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless; to consider productivity class P (low, high or default);

$Frac_{L.MS}$ = fraction of managed manure N for livestock category T that is leached the manure management system S.

The fraction of managed manure N, $Frac_{L.MS}$ and the emission factor for N_2O emissions (EF_5) are provided respectively in Table 10.22 in Chapter 10 and Table 3 in Chapter 11 of IPCC (2019). Default emissions factors used in EX-ACT are listed in **Table 137**.

All N losses (volatilisation, leaching and runoff) are summed up across all management systems, the same that are used to estimate CH_4 and direct N_2O emissions. By default, EX-ACT takes into account the regional manure management systems that can be changed in Tier 2.

For lamas and alpacas, the IPCC does not provide any emissions factor to account for nitrogen excretion rates. Therefore direct and indirect N_2O emissions for this category are not accounted for in EX-ACT.

[27] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

[28] Equation based on Chapter 10 in Volume 4 of IPCC (2019).

Table 132. Default values for nitrogen loss fraction due to volatilisation of NH_3 and NOx of nitrogen from manure management (FracGasMS) from swine (growing and breeding pigs)

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Cool temperate dry	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Boreal moist	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Boreal dry	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Warm temperate moist	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Warm temperate dry	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Tropical montane	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Tropical wet	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Tropical moist	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85
Tropical dry	0.40	**0.29**	**0.36**	0.45	0.21	0.07	0.28	0.00	0.25	0.25	0.00	0.4	**0.625**	0.85

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 133. Default values for nitrogen loss fraction due to volatilisation of NH3 and NOx of nitrogen from manure management (FracGasMS) from dairy cow

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Cool temperate dry	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Boreal moist	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Boreal dry	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Warm temperate moist	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Warm temperate dry	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Tropical montane	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Tropical wet	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Tropical moist	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85
Tropical dry	0.35	**0.29**	**0.23**	0.30	0.21	0.07	**0.28**	0.00	0.28	0.28	0.00	0.25	**0.475**	0.85

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 134. Default values for nitrogen loss fraction due to volatilisation of NH_3 and NOx of nitrogen from manure management (FracGasMS) from poultry (chicken layer and chicken broiler)

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Cool temperate dry	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Boreal moist	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Boreal dry	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Warm temperate moist	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Warm temperate dry	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Tropical montane	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Tropical wet	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Tropical moist	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0
Tropical dry	0.40	0.40	**0.33**	0.00	0.21	0.07	**0.28**	0.00	0.28	0.28	**0.44**	0.3	**0.625**	0

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 135. Default values for nitrogen loss fraction due to volatilisation of NH_3 and NOx of nitrogen from manure management (FracGasMS) from other cattle

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Cool temperate dry	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Boreal moist	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Boreal dry	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Warm temperate moist	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Warm temperate dry	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Tropical montane	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Tropical wet	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Tropical moist	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85
Tropical dry	0.35	**0.29**	**0.36**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.25	**0.625**	0.85

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 136. Default values for nitrogen loss fraction due to volatilisation of NH_3 and NOx from manure management (FracGasMS) from other animal categories

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Cool temperate dry	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Boreal moist	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Boreal dry	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Warm temperate moist	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Warm temperate dry	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Tropical montane	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Tropical wet	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Tropical moist	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27
Tropical dry	0.35	**0.09**	**0.09**	0.30	0.21	0.07	**0.28**	0.00	0.25	0.25	0.00	0.4	**0.19**	0.27

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Table 137. Default values for nitrogen loss fraction due to leaching of nitrogen from manure management (FracL.MS) from all animal categories

IPCC climate zones	Lagoon	Liquid/slurry	Solid storage	Dry lot	PRP	Daily spread	Digester	Burned for fuel	Pit<1 month	Pit>1 month	Poultry manure	Deep bedding	Composting	Aerobic treatment
Cool temperate moist	0.00	0.00	**0.02**	0.035	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Cool temperate dry	0.00	0.00	**0.02**	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Boreal moist	0.00	0.00	**0.02**	0.035	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Boreal dry	0.00	0.00	**0.02**	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Warm temperate moist	0.00	0.00	**0.02**	0.035	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Warm temperate dry	0.00	0.00	**0.02**	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Tropical montane	0.00	0.00	**0.02**	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Tropical wet	0.00	0.00	**0.02**	0.035	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Tropical moist	0.00	0.00	**0.02**	0.035	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0
Tropical dry	0.00	0.00	**0.02**	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.035	**0.04**	0

Notes: Bold values are the average over a given range. PRP stands for pasture/range/paddock.

Source: Authors' own elaboration based on Table 10.22 in Chapter 10 and Table 11.3 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

5.2.6 Tier 2 options

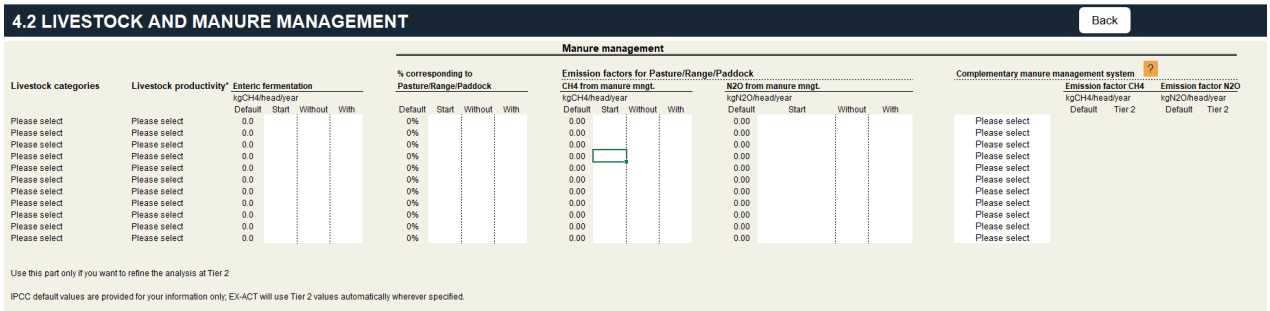
Some information can be refined using the Tier 2 approach of the livestock module (see **Figure 34**).

Users have the possibility to specify their own emission factors for CH_4 from enteric fermentation, CH_4 from manure management in pasture/range/paddock (PRP) and N_2O from manure management in pasture/range/paddock (PRP).

Users can change the percentage of animal on PRP for the start, without and with project scenarios. EX-ACT will automatically re-estimate the share of emissions coming from the other manure management systems using a default value, unless users specify another manure management system to complement the PRP's one. The default is calculated as the regional average of the different manure management systems.

Users also have the possibility to specify their own emissions factors for CH_4 from the complementary manure management system (or a new average for the regional share) and N_2O from the complementary manure management system (or a new average for the regional share).

Figure 34. Tier 2 approach of the livestock sub-module



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 6. Forest degradation and management

The "Forest degradation and management" module focuses exclusively on GHG emissions associated with changes in forest management and degradation levels. The emissions associated with deforestation and afforestation/reforestation are calculated in the "Land use change" module, described in Part 3.

6.1 Methodology

The module consists of four sections: (i) definition of the vegetation, (ii) forest state (degradation level) at the start, without and with project implementation together with the occurrence of fire and its severity, and (iii) the surface of the forested area (see **Figure 35**).

Figure 35. Forest degradation and management module in EX-ACT

5.1 FOREST DEGRADATION & MANAGEMENT — If country-specific data are available, please go to Tier 2: Tier 2

Type of forest vegetation that will be managed	Forest degradation level			Fire occurrence		Fire periodicity		Impact (% burnt)		Forested area (ha)					Total emissions (tCO2-e)		Balance
	Start	Without	With	Without (y/n)	With (y/n)	Without (year)	With (year)	Without	With	Start	Without	*	With	*	Without	With	
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
Please select	Please select	Please select	Please select	NO	NO	1	1	100%	100%	0	0	D	0	D	0	0	0
										Total forest degradation and management (tCO2-e)					0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

6.2 Definition of the vegetation

The first part is dedicated to the description of the vegetation (native or forest plantation) undergoing management or degradation. According to the climatic and geographical information provided in the "Description" module, different types of vegetation and associated default carbon stocks in the five pools are provided (see Part 1 for further details).

The distinction between forest and plantation is based on the growth rate of trees, which strongly depends on the management regime. Therefore, a distinction should be made between intensive forest management (i.e. plantation forestry) and extensive forest management (naturally re-growing stands with reduced or minimum human intervention).

6.3 Forest degradation level

In this part of the worksheet, users can indicate the initial state of the forest and identify its expected final states in both scenarios (without project and with project). Currently, there is no internationally recognized methodology to assess forest degradation. The different available states within EX-ACT have been set at an average level of degradation, expressed in terms of percentage of degraded area/biomass loss. These percentages help to estimate the relative carbon stock changes in the above-ground biomass, below-ground biomass, litter and deadwood. Available options of degradation include none, very low (by default set up to 10 percent), low (20 percent), moderate (40 percent), large (60 percent) and extreme (80 percent).

The existing Tier 1 default emission factors are insufficient for the quantification of the effects of forest management by climatic zones. As a consequence, it is generally assumed under Tier 1 that soil carbon stock does not change with forest management (IPCC, 2019). EX-ACT applies the same assumption for forest degradation and estimates CO_2 emissions or removals for the above-ground biomass, below-ground biomass, litter and deadwood only. Users can assume a change in SOC in the Tier 2 section of this module, changing the default SOC change factor (set to one).

If the forest is subject to fire, users can also indicate this in both scenarios and determine the fire severity and frequency. The default value of the frequency of fire is set to one (one fire per year) with a default impact (percentage of all carbon pools burnt except the soil) value of 100 percent (both defaults are modifiable).

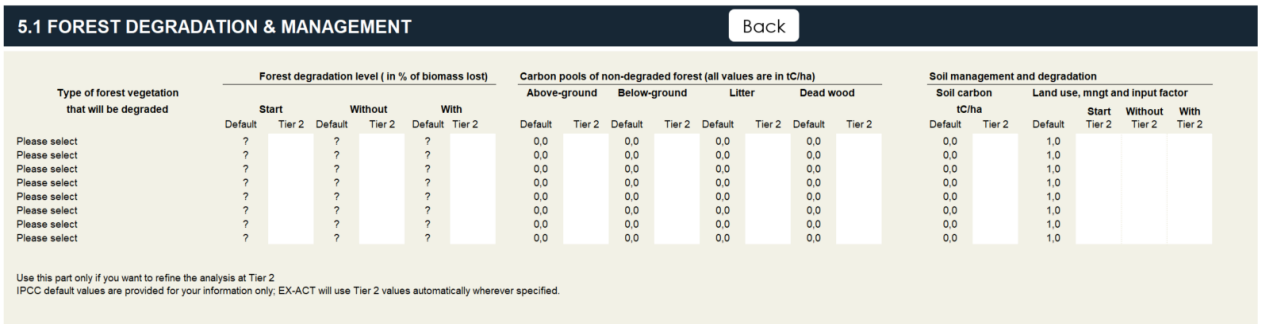
6.4 Surface and greenhouse gas emissions

Users must provide data on initial forest area in ha of forest, or forest plantation, associated with each degradation level selected in the previous step. This will trigger the calculation of the carbon balance in tCO_2-e.

6.5 Tier 2 options

Users have the possibility to change the default values for: above-ground biomass, below-ground biomass, litter and deadwood; percentage associated with the nominal degradation level; carbon stock for soil; and the combined land use, management and input factors, set by default to 1 (see **Figure 36**).

Figure 36. Tier 2 approach of the forest degradation and management module in EX-ACT



5.1 FOREST DEGRADATION & MANAGEMENT

Back

Type of forest vegetation that will be degraded	Forest degradation level (in % of biomass lost)						Carbon pools of non-degraded forest (all values are in tC/ha)								Soil management and degradation					
	Start		Without		With		Above-ground		Below-ground		Litter		Dead wood		Soil carbon tC/ha		Land use, mngt and input factor			
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Start Tier 2	Without Tier 2	With Tier 2
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			
Please select	?		?		?		0,0		0,0		0,0		0,0		0,0		1,0			

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 7. Inland wetlands

7.1 General structure and methodology

This module calculates GHG balance associated with the management of inland wetlands, with a particular focus on the inland organic soils management. It allows to consider both, large organic wetland areas and individual patches of inland organic soils across a landscape defined mostly by another soil type.

Organic soils, or Histosols, are defined as (FAO [2015] cited by IPCC [2019])[29]:

1. Starting at the soil surface and having a thickness of ≥ 10 cm and directly overlying ice, continuous rock or technic hard material or coarse fragments, the interstices of which are filled with organic material; or
2. Starting ≤ 40 cm from the soil surface and having within ≤ 100 cm of the soil surface a combined thickness of either ≥ 60 cm, if ≥ 75 percent (by volume) of the materials consist of moss fibres, or ≥ 40 cm in other materials.

The inland wetlands module comprises of four major parts:

- land use change including deforestation, afforestation/reforestation and other land use changes;
- land use management including forest management and other land use management;
- peat extraction;
- inland waterbodies.

Material used to develop this module can be found in Chapter 7 "Wetlands" in Volume 4 (AFOLU) of IPCC (2006), which was updated and completed with Chapters 2 and 3 of IPCC (2014). The IPCC (2014) provides supplementary guidance to the IPCC (2006) for estimating on-site and off-site CO_2 and non-CO_2 emissions from management in drained organic soils, peatland undergoing peat extraction and rewetted organic soils. There is no further guidance and or refinement within the IPCC (2019) for estimating GHG emissions from drainage, rewetting and peat extraction in inland organic soils; IPCC (2019) Chapter 2 is used only to estimate carbon losses and gains from land use conversion and biomass and residues burning.

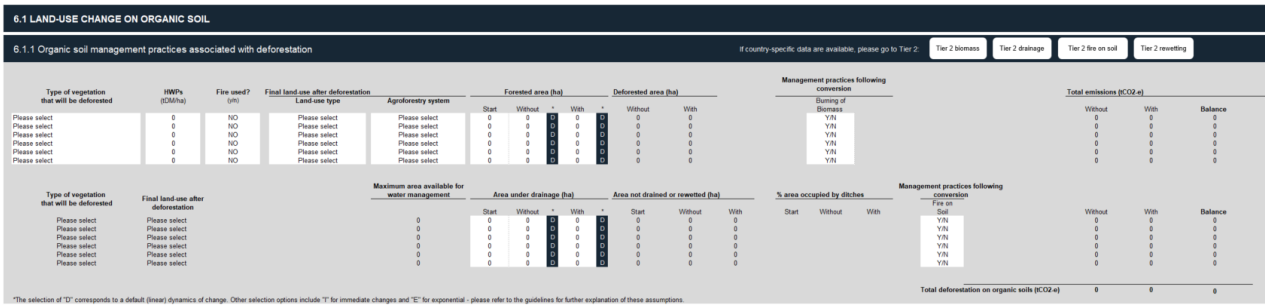
This Chapter focuses only on the methodological approach to calculate the GHG emissions from changes in water table management, soil organic fire, peat extraction and methane emissions from flooded land. For other sources of GHG emissions or emission reduction, the methodology is the same as for mineral soils and users are invited to read the "Land use changes" (see Part 3) and "Forest degradation and management" (see Part 6) for the estimation of carbon stock changes in above-ground biomass, below-ground biomass, litter and dead wood, as well as non-CO_2 emission from residues and biomass burning.

[29] Additionally, according to FAO (1998) Soils are classified as "organic soils" when they also satisfy the following statements (1 and 2, or 1 and 3):
1) Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.
2) Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e. about 35 percent organic matter).
3) Soils are subject to water saturation episodes and have either i) at least 12 percent organic carbon by weight (i.e. about 20 percent organic matter) if the soil has no clay; or ii) at least 18 percent organic carbon by weight (i.e. about 30 percent organic matter) if the soil has 60 percent or more clay; or iii) an intermediate, proportional amount of organic carbon for intermediate amounts of clay.

7.2 Surface and greenhouse gas emissions

For the land use change and land management parts, users have to provide general information on the areas concerned by activities at the start, without and with project scenarios in the same way as described in Part 3 and Part 6. This will trigger calculations of carbon balance associated with the land use activities. Additionally, the module allows to input information related to water table management and associated emissions to the carbon balance (see **Figures 37** to **41**). The following sections describe the available options.

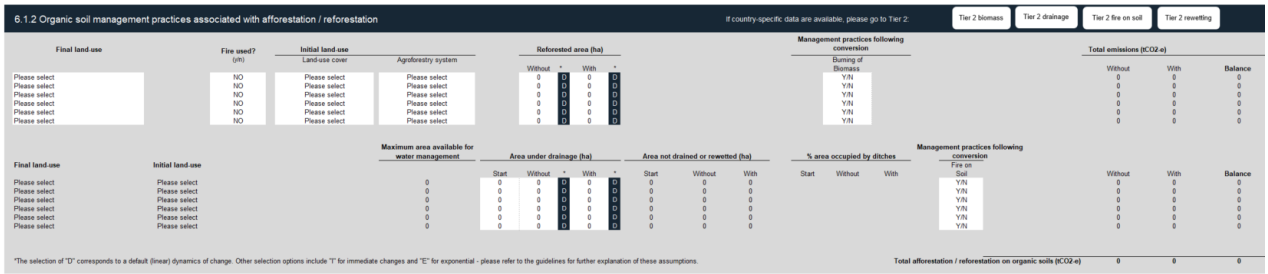
Figure 37. Organic soil management associated with deforestation in the wetlands module



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

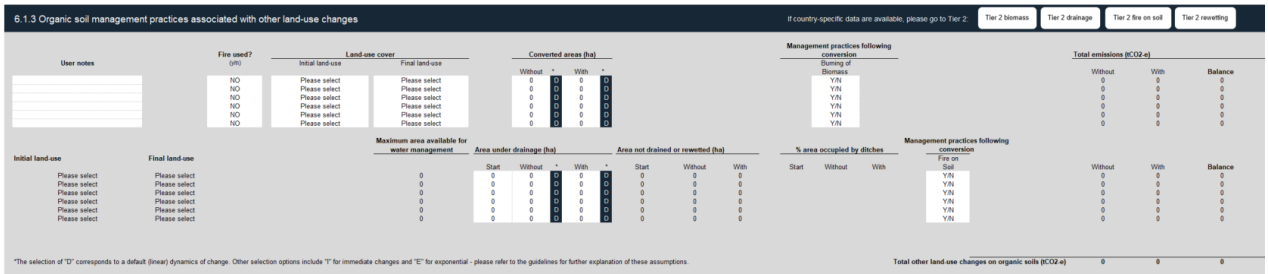
Figure 38. Organic soil management practices associated with afforestation/reforestation in the wetlands module



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

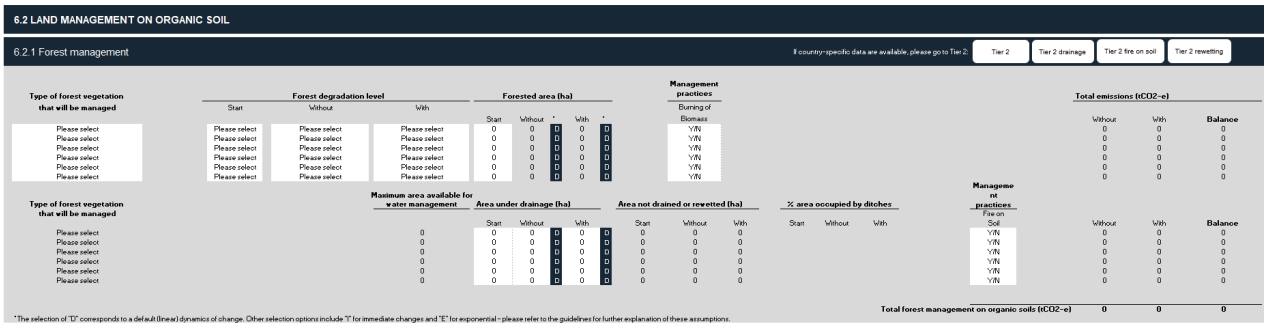
Figure 39. Organic soil management associated with other land use changes in the inland wetlands module



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Figure 40. Organic soil management associated with forest management section in the inland wetlands module



6.2 LAND MANAGEMENT ON ORGANIC SOIL

6.2.1 Forest management

If country-specific data are available, please go to Tier 2: Tier 2 | Tier 2 drainage | Tier 2 fire on soil | Tier 2 rewetting

Type of forest vegetation that will be managed	Forest degradation level: Start	Forest degradation level: Without	Forest degradation level: With	Forested area (ha): Start	Forested area (ha): Without	*	Forested area (ha): With	*	Management practices: Burning of Biomass	Total emissions (tCO2-e): Without	Total emissions (tCO2-e): With	Total emissions (tCO2-e): Balance
Please select	Please select	Please select	Please select	0	0	D	0	D	Y/N	0	0	0
Please select		Please select	Please select	0	0	D	0	D	Y/N	0	0	0
Please select		Please select	Please select	0	0	D	0	D	Y/N	0	0	0
Please select		Please select	Please select	0	0	D	0	D	Y/N	0	0	0
Please select		Please select	Please select	0	0	D	0	D	Y/N	0	0	0
Please select		Please select	Please select	0	0	D	0	D	Y/N	0	0	0

Type of forest vegetation that will be managed	Maximum area available for water management	Area under drainage (ha): Start	Area under drainage (ha): Without	*	Area under drainage (ha): With	*	Area not drained or rewetted (ha): Start	Area not drained or rewetted (ha): Without	Area not drained or rewetted (ha): With	% area occupied by ditches: Start	% area occupied by ditches: Without	% area occupied by ditches: With	Management practices: Fire on Soil	Total emissions (tCO2-e): Without	Total emissions (tCO2-e): With	Total emissions (tCO2-e): Balance
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0
Please select	0	0	0	D	0	D	0	0	0				Y/N	0	0	0

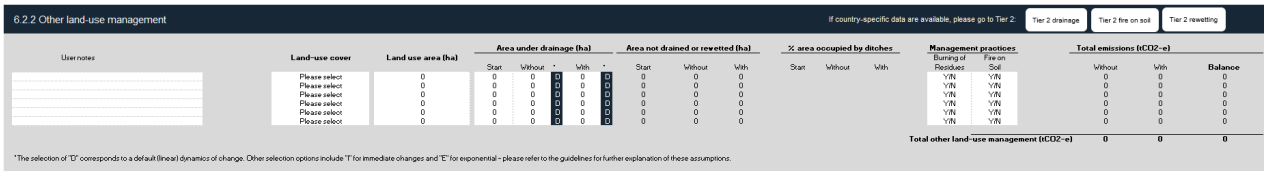
Total forest management on organic soils (tCO2-e): 0 | 0 | 0

* The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential – please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Figure 41. Organic soils management associated with other land use management in the inland wetlands module



6.2.2 Other land-use management

If country-specific data are available, please go to Tier 2: Tier 2 drainage | Tier 2 fire on soil | Tier 2 rewetting

User notes	Land-use cover	Land use area (ha)	Area under drainage (ha): Start	Area under drainage (ha): Without	*	Area under drainage (ha): With	*	Area not drained or rewetted (ha): Start	Area not drained or rewetted (ha): Without	Area not drained or rewetted (ha): With	% area occupied by ditches: Start	% area occupied by ditches: Without	% area occupied by ditches: With	Management practices: Burning of Residues	Management practices: Fire on Soil	Total emissions (tCO2-e): Without	Total emissions (tCO2-e): With	Total emissions (tCO2-e): Balance
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0
	Please select	0	0	0	D	0	D	0	0	0				Y/N	Y/N	0	0	0

Total other land-use management (tCO2-e): 0 | 0 | 0

* The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential – please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Drainage and rewetting emissions are dependent on the specific type of land use selected in each project situation. Depending on the extension of drained organic soil in each project situation, the tool calculates the relative amount of hectares subject to drainage or rewetting activities. Users can populate the tool as needed, including the percentage of the total area occupied by the ditches in case there is drained land. Additionally, users can refine the default emissions factors with their own if available for drainage, rewetting and fire on organic soils (see **Figure 42** for the Tier 2 section related to drainage).

Figure 42. Tier 2 section for drainage of organic soils associated with deforestation

6.1.1 Emission factors for drainage associated with deforestation Back

Initial land-use	On-site emission factors						Off-site emission factors			
	CO2		CH4		N2O		DOC		CH4	
	tC/ha/yr		kgCH4/ha/yr		kgN2O-N/ha/yr		tC/ha/yr		kgCH4/ha/yr	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	

Please indicate the dominant quality of peat, this can influence the emission factors above: Nutrient poor

Final land-use	On-site emission factors						Off-site emission factors			
	CO2		CH4		N2O		DOC		CH4	
	tC/ha/yr		kgCH4/ha/yr		kgN2O-N/ha/yr		tC/ha/yr		kgCH4/ha/yr	
	Below-grou	Litter	Below-groun	Litter	Below-ground	Litter	Below-grou	Litter	elow-groun	Litter
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	
Please select	0,00		0,00		0,00		0,00		0,00	

Please indicate the dominant quality of peat, this can influence the emission factors above: Nutrient poor

Use this part only if you want to refine the analysis at Tier 2

IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

7.3 Greenhouse gas emissions from drainage in inland organic soil

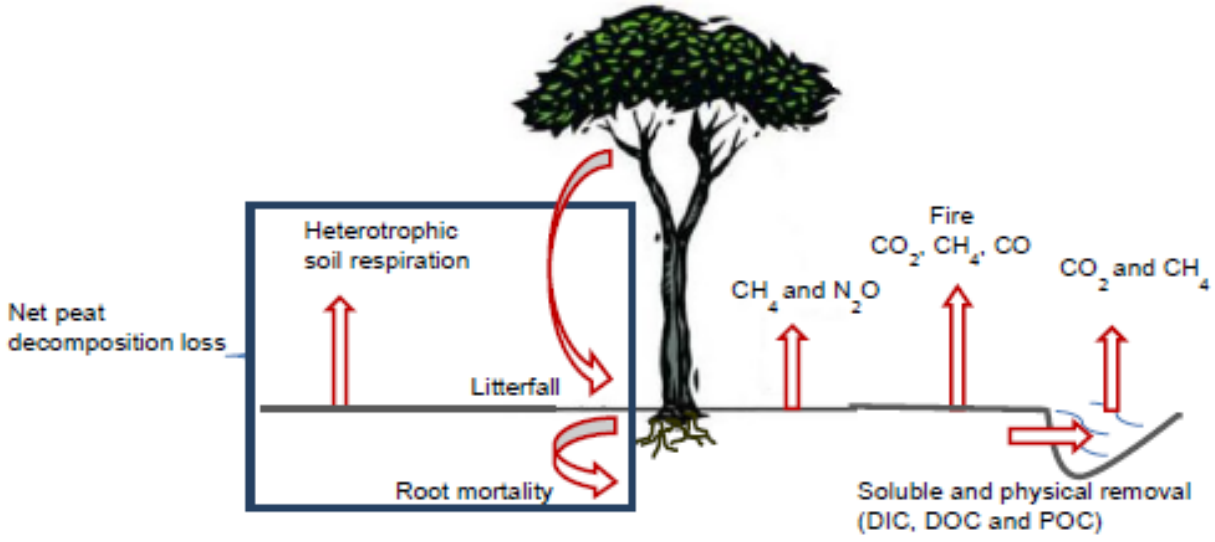
7.3.1 Definition

Drainage is a practice used in agriculture and forestry to improve site conditions for plant growth. EX-ACT allows for calculating the impact of drainage of organic soils on several types of land uses, namely: forest, plantations, annual, perennial, flooded rice, grassland and other land (non-vegetated). Other land (non-vegetated) includes settlement and other land use categories.

In wetlands, inputs of organic matter can exceed decomposition losses under anaerobic conditions, which are common in undrained organic soils. As a result, considerable amounts of organic matter can accumulate over time. Carbon stored in organic soils will readily decompose when conditions become aerobic following soil drainage, with an increase in CO_2 and N_2O emissions due to increased oxidation of soil organic material, and a loss of dissolved organic carbon (DOC) leading to off-site CO_2 emissions, particulate organic carbon (POC) and waterborne transport of dissolved inorganic carbon (DIC) (see **Figure 43**). On the other hand, drainage will decrease CH_4 emissions of the land, although there is evidence of increases in CH_4 associated with ditches (IPCC, 2014).

Currently, there is no methodology to assess emissions from POC and DIC; as a result, these are not taken into account in EX-ACT.

Figure 43. Summary of fluxes from drained organic soils



Source: IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

7.3.2 Emissions factors associated with drainage of inland organic soils

The basic methodology to assess soil stock changes and associated GHG fluxes is to stratify managed organic soils by climate region and assign a climate specific annual carbon loss rate. Land areas are multiplied by emission factors to get the emissions in tCO_2-e. EX-ACT uses emission factors in Tables 2.1 to 2.5 (IPCC, 2014) and provided in **Tables 138** to **145**.

EX-ACT allows for calculating the impact of drainage of organic soils according to seven types of land uses defined in IPCC (2014): forest, plantations, annual crops, perennial crops, flooded rice, grasslands and peat extraction. The EX-ACT land use definitions are associated with each of these categories to provide with specific emission factors. If one, or more, of the selected land uses is "Degraded land" or "Other land (non-vegetated)", EX-ACT will not perform calculations as no related Tier 1 emission factors are provided - these are not available in IPCC (2014). To trigger calculations, users need to provide specific emission factors for the area of their interest using the corresponding Tier 2 section.

When water table management activities target land remaining under the same land use, the emission factors are calculated based on the specified land use. When management activity includes a land use conversion, EX-ACT associates the initial and final (without and with project) emission factors according to the respective portions of land under each land use.

EX-ACT will estimate the following changes in GHG fluxes when organic soils are drained:

a. On-site emissions: (i) CO_2 emissions removals from organic soils due to organic matter decomposition, (ii) CH_4 emissions and removals, and (iii) N_2O emissions.

b. Off-site emissions: loss of DOC and CH_4 in the drainage waters.

In the second part of each sub-module, dealing specifically with water table management, users should indicate the surface area of organic soils that are drained in the initial and final states (future with and without project). Users can refine GHG emissions associated with drainage by using the corresponding Tier 2 section.

CO_2 emissions

On-site CO_2 emissions/removal from drained inland organic soil

The basic methodology to assess stock changes is to stratify managed organic soils by climate region, mean annual water table depth and nutrient status. Land areas are multiplied by an emission factor according to climate as reported in **Tables 138** and **139** (respectively nutrient-poor and nutrient-rich) and Equation 2.3 (Chapter 2 of IPCC [2014]). The emission factor is relative to the climate domain, nutrient class and drainage class. At Tier 1, the typical range of mean annual water table is unknown; the general assumption is to consider that the organic soil is deep-drained as it is the most suitable for a wide range of management intensities. The emission factors are by default set for nutrient-poor soil. Users have the possibility to change the nutrient class in Tier 2, in the drainage section. It will automatically update emission factors also for other activities such as rewetting of organic soils.

Off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils

Waterborne carbon comprises different fractions of DOC, POC, DIC, CH_4 and particulate inorganic carbon (PIC) in negligible quantity. As DOC forms the largest component of waterborne carbon export, and there is no current methodology for DIC and POC, off-site CO_2 emissions are estimated from the loss of carbon from conversion of DOC. The basic methodology for estimating annual off-site CO_2 emissions associated with waterborne carbon loss from drained inland organic soils is the land area multiplied by an emission factor (EF_{DOC} drained), which is a function of the climate domain and the nutrient status. EF_{DOC} drained is calculated according to Equation 2.5 (Chapter 2 of IPCC [2014]) and reported in **Table 140**.

Table 138. CO_2 emission removal factors, in tCO_2-C/ha/yr, for drained organic nutrient-poor soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	0.31	0.31	7.9	7.9	0	5.7	2.8
Boreal moist	0.31	0.31	7.9	7.9	0	5.7	2.8
Cool temperate dry	2.6	2.6	7.9	7.9	0	5.3	2.8
Cool temperate moist	2.6	2.6	7.9	7.9	0	5.3	2.8
Warm temperate dry	2.6	2.6	7.9	7.9	0	5.3	2.8
Warm temperate moist	2.6	2.6	7.9	7.9	0	5.3	2.8
Tropical dry	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical moist	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical wet	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical montane	5.3	15.3	14.0	14.0	9.4	9.6	2.0

Source: Authors' own elaboration based on Table 2.1 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 139. CO_2 emission removal factors, in tCO_2-C/ha/yr, for drained organic nutrient-rich soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	0.93	0.93	7.9	7.9	0	5.7	2.8
Boreal moist	0.93	0.93	7.9	7.9	0	5.7	2.8
Cool temperate dry	2.6	2.6	7.9	7.9	0	4.85	2.8
Cool temperate moist	2.6	2.6	7.9	7.9	0	4.85	2.8
Warm temperate dry	2.6	2.6	7.9	7.9	0	4.85	2.8
Warm temperate moist	2.6	2.6	7.9	7.9	0	4.85	2.8
Tropical dry	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical moist	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical wet	5.3	15.3	14.0	14.0	9.4	9.6	2.0
Tropical montane	5.3	15.3	14.0	14.0	9.4	9.6	2.0

Source: Authors' own elaboration based on Table 2.1 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 140. Emission factors for dissolved organic carbon (DOC), in tC/ha/yr, on drained organic soils

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Boreal moist	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Cool temperate dry	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Cool temperate moist	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Warm temperate dry	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Warm temperate moist	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Tropical dry	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Tropical moist	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Tropical wet	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Tropical montane	0.82	0.82	0.82	0.82	0.82	0.82	0.82

Source: Authors' own elaboration based on Table 2.2 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Non-CO_2 emissions

CH_4 emissions and removal from drained inland organic soils

By lowering the water table, drainage affects edaphic parameters of the soil, the amount of decomposable organic matter, and the activity of methanogens and methanotrophs. Generally, when organic soil is drained, the natural production of CH_4 is reduced and the soil may even act as a CH_4 sink once the methanotrophs dominate in the CH_4 cycle. CH_4 emissions can occur from the drained land surface and also from the ditch network during drainage. The basic methodology for estimating annual on-site and off-site CH_4 emissions associated with drained land, ditches and drainage canals, is the land area and the area occupied by the drainage ditch network (in percentage of the drained land surface in EX-ACT) multiplied by their respective emission factors (EF_{CH4} land and EF_{CH4} ditch). All are function of

the climate domain and the nutrient status. Default value for EF_{CH4} land and EF_{CH4} ditch are given in **Tables 141** to **143**.

N_2O emission from drained inland organic soils

N_2O emissions from soils are produced by the microbiological processes of nitrification and denitrification, controlled by the water-filled pore space, temperature and concentration of mineral nitrogen. When drained, organic soils emit significant amount of CO_2 and N_2O from the mineralization of the organic matter. The basic methodology to take into account N_2O emissions is to multiply the land area by an emission factor. This last one is disaggregated by land use type, climatic zone and nutrient status, as reported in **Tables 144** and **145**.

Table 141. Methane emission/removal factors, in kg CH_4/ha/yr, on drained nutrient-poor organic soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	7	7	0	0	0	1.4	6.1
Boreal moist	7	7	0	0	0	1.4	6.1
Cool temperate dry	2.5	2.5	0	0	0	1.8	6.1
Cool temperate moist	2.5	2.5	0	0	0	1.8	6.1
Warm temperate dry	2.5	2.5	0	0	0	1.8	6.1
Warm temperate moist	2.5	2.5	0	0	0	1.8	6.1
Tropical dry	4.9	9.6	7.0	7.0	143.5	7.0	0
Tropical moist	4.9	9.6	7.0	7.0	143.5	7.0	0
Tropical wet	4.9	9.6	7.0	7.0	143.5	7.0	0
Tropical montane	4.9	9.6	7.0	7.0	143.5	7.0	0

Source: Authors' own elaboration based on Table 2.3 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 142. Methane emission/removal factors, in kgCH_4/ha/yr, on drained nutrient-rich organic soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	2	2	0	0	0	1.4	6.1
Boreal moist	2	2	0	0	0	1.4	6.1
Cool temperate dry	2.5	2.5	0	0	0	27.5	6.1
Cool temperate moist	2.5	2.5	0	0	0	27.5	6.1
Warm temperate dry	2.5	2.5	0	0	0	27.5	6.1
Warm temperate moist	2.5	2.5	0	0	0	27.5	6.1
Tropical dry	4.9	9.6	7	7	143.5	7	0
Tropical moist	4.9	9.6	7	7	143.5	7	0
Tropical wet	4.9	9.6	7	7	143.5	7	0
Tropical montane	4.9	9.6	7	7	143.5	7	0

Source: Authors' own elaboration based on Table 2.3 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 143. Methane emission/removal factors, in kgCH_4/ha/yr, in drainage ditches

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	217	217	1 165	1 165	0	527	542
Boreal moist	217	217	1 165	1 165	0	527	542
Cool temperate dry	217	217	1 165	1 165	0	527	542
Cool temperate moist	217	217	1 165	1 165	0	527	542
Warm temperate dry	217	217	1 165	1 165	0	527	542
Warm temperate moist	217	217	1 165	1 165	0	527	542
Tropical dry	2 259	2 259	2 259	2 259	2 259	2 259	0
Tropical moist	2 259	2 259	2 259	2 259	2 259	2 259	0
Tropical wet	2 259	2 259	2 259	2 259	2 259	2 259	0
Tropical montane	2 259	2 259	2 259	2 259	2 259	2 259	0

Source: Authors' own elaboration based on Table 2.4 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 144. Nitrous oxide emission/removal factors, in kgN_2O-N/ha/yr, on drained nutrient-poor organic soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	0.22	0.22	13	13	0	9.5	0.3
Boreal moist	0.22	0.22	13	13	0	9.5	0.3
Cool temperate dry	2.8	2.8	13	13	0	4.3	0.3
Cool temperate moist	2.8	2.8	13	13	0	4.3	0.3
Warm temperate dry	2.8	2.8	13	13	0	4.3	0.3
Warm temperate moist	2.8	2.8	13	13	0	4.3	0.3
Tropical dry	2.4	2.25	5	5	0.4	5	3.6
Tropical moist	2.4	2.25	5	5	0.4	5	3.6
Tropical wet	2.4	2.25	5	5	0.4	5	3.6
Tropical montane	2.4	2.25	5	5	0.4	5	3.6

Source: Authors' own elaboration based on Table 2.5 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 145. Nitrous oxide emission/removal factors, in kgN_2O-n/ha/yr, on drained nutrient-rich organic soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland	Peat extraction
Boreal dry	3.2	3.2	13	13	0	9.5	0.3
Boreal moist	3.2	3.2	13	13	0	9.5	0.3
Cool temperate dry	2.8	2.8	13	13	0	4.9	0.3
Cool temperate moist	2.8	2.8	13	13	0	4.9	0.3
Warm temperate dry	2.8	2.8	13	13	0	4.9	0.3
Warm temperate moist	2.8	2.8	13	13	0	4.9	0.3
Tropical dry	2.4	2.25	5	5	0.4	5	3.6
Tropical moist	2.4	2.25	5	5	0.4	5	3.6
Tropical wet	2.4	2.25	5	5	0.4	5	3.6
Tropical montane	2.4	2.25	5	5	0.4	5	3.6

Source: Authors' own elaboration based on Table 2.5 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

7.4 Greenhouse gas emissions from rewetting of inland organic soils

7.4.1 Definition

Rewetting is "the deliberate action of raising the water table on drained soils to re-establish water saturated conditions (i.e. by blocking drainage ditches, disabling pumping facilities or breaching obstructions)" (IPCC, 2014). Rewetting can have several objectives including wetland restoration or allowing other management practices on saturated organic soils such as paludiculture. Rewetting re-establishes the carbon sink function if covered with vegetation, resulting in a balance between CO_2 and CH_4 emissions and removals. N_2O emissions from rewetting activities are assumed to be negligible at Tier 1. Default emissions factors in this section are derived from flux measurements over organic soils covered with moss and/or herbaceous vegetation and/or dwarfs shrubs. Thus, default emission factors integrate all carbon fluxes from the soil as well as above-ground biomass and below-ground biomass other than trees.

7.4.2 Default emission factors

Emission factors are dependent on climate and nutrient status of the rewetted soil. Boreal and temperate inland organic soil are divided into nutrient-poor and nutrient-rich soils, while tropical inland organic soils are nutrient-poor. Most nutrient-poor wetlands, undrained or rewetted, receive water and nutrients from precipitation only, while nutrient-rich wetlands also receive water from the surroundings. If the nutrient status of rewetted organic soils is unknown, users should use nutrient-poor organic soils in boreal countries and nutrient-rich organic soils in temperate countries. Default emission factors in EX-ACT are based on those in Tables 3.1 to 3.3 in Chapter 3 of IPCC (2014). Emission factors for nutrient-poor soil are provided by default in EX-ACT, but users can change the nutrient class of the soil in the Tier 2 section for drainage.

EX-ACT allows for calculating the impact of rewetting of organic soils according to six types of land uses defined in IPCC (2014): forest, plantations, annual crops, perennial crops, flooded rice and grasslands. The EX-ACT land use definitions are associated to each of these categories to provide with specific emission factors. If one, or more, of the selected land uses is "Degraded land" or "Other land (non-vegetated)", EX-ACT does not provide Tier 1 emission factors as these are not available in IPCC (2014). Users should refer to Tier 2 to provide specific emission factors for the area of their interest.

On-site and off-site CO_2 emissions

On-site and off-site CO_2 emissions include carbon emissions/removals from soil and non-tree vegetation, off-site emissions from DOC (exported from rewetted soil) and emissions from burning of rewetted soils.

Annual on-site and off-site carbon emissions are estimated as the product of land areas targeted by the activity with the rewetting emission factor, disaggregated by climate zone, land use and nutrient status, when possible (if not, refer above to select the most appropriate variable), as shown in **Tables 146** to **148**. The nutrient status of targeted land areas can be updated at the start and for the two scenarios (without or with project).

Table 146. Emission factors for CO_2, in tCO_2-C/ha/yr, for rewetted inland organic nutrient-poor soils

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland
Boreal dry	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34
Boreal moist	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34
Cool temperate dry	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Cool temperate moist	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Warm temperate dry	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Warm temperate moist	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Tropical dry	0	0	0	0	0	0
Tropical moist	0	0	0	0	0	0
Tropical wet	0	0	0	0	0	0
Tropical montane	0	0	0	0	0	0

Source: Authors' own elaboration based on Table 3.1 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 147. Emission factors for CO_2, in tCO_2-C/ha/yr, for rewetted inland organic nutrient-rich soils

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland
Boreal dry	-0.55	-0.55	-0.55	-0.55	-0.55	-0.55
Boreal moist	-0.55	-0.55	-0.55	-0.55	-0.55	-0.55
Cool temperate dry	0.5	0.5	0.5	0.5	0.5	0.5
Cool temperate moist	0.5	0.5	0.5	0.5	0.5	0.5
Warm temperate dry	0.5	0.5	0.5	0.5	0.5	0.5
Warm temperate moist	0.5	0.5	0.5	0.5	0.5	0.5
Tropical dry	0	0	0	0	0	0
Tropical moist	0	0	0	0	0	0
Tropical wet	0	0	0	0	0	0
Tropical montane	0	0	0	0	0	0

Source: Authors' own elaboration based on Table 3.1 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 148. Emission factors for dissolved organic carbon, in tC/ha/yr, for rewetted inland organic soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland
Boreal dry	0.08	0.08	0.08	0.08	0.08	0.08
Boreal moist	0.08	0.08	0.08	0.08	0.08	0.08
Cool temperate dry	0.24	0.24	0.24	0.24	0.24	0.24
Cool temperate moist	0.24	0.24	0.24	0.24	0.24	0.24
Warm temperate dry	0.24	0.24	0.24	0.24	0.24	0.24
Warm temperate moist	0.24	0.24	0.24	0.24	0.24	0.24
Tropical dry	0.51	0.51	0.51	0.51	0.51	0.51
Tropical moist	0.51	0.51	0.51	0.51	0.51	0.51
Tropical wet	0.51	0.51	0.51	0.51	0.51	0.51
Tropical montane	0.51	0.51	0.51	0.51	0.51	0.51

Source: Authors' own elaboration based on Table 3.2 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Non-CO_2 emissions/removals from rewetted organic soils

CH_4 emissions and removals from rewetted soils result from (i) the balance between CH_4 production and oxidation, and (ii) emission of CH_4 produced by the combustion of soil organic matter due to fire. N_2O emissions are controlled by the quantity of N available for nitrification and denitrification and the quantity of dissolved oxygen available, which is controlled by water table depth. At Tier 1, N_2O emissions are considered negligible, because the decay of organic matter under an anoxic condition is decreased and NH_{4+} concentration is reduced, while both are needed for denitrification processes to occur. Users can still take them into account, if needed, using the Tier 2 section.

Annual non-CO_2 emissions are estimated as the product of land areas targeted by the activity and the rewetting emission factor, disaggregated by climate zone, land use and nutrient status, when possible (if not, refer above to select the most appropriate variable), as shown in **Tables 143** to **145**. The nutrient status of targeted land areas can be updated at the start and for the two scenarios (without or with project).

In **Tables 149** and **150**, CH_4-C emissions are converted into CH_4 multiplying fluxes with the factor 16/12. CH_4 emissions are converted into CO_2-e using its GWP as described in Part 1. N_2O-N emissions are converted into N_2O emissions by multiplying fluxes by 44/28. N_2O emissions are then converted into CO_2-e emissions using its GWP as described in Part 1.

Table 149. Emission factors for CH_4, in kg CH_4-C/ha/yr, for rewetted inland organic nutrient-poor soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland
Boreal dry	41	41	41	41	41	41
Boreal moist	41	41	41	41	41	41
Cool temperate dry	92	92	92	92	92	92
Cool temperate moist	92	92	92	92	92	92
Warm temperate dry	92	92	92	92	92	92
Warm temperate moist	92	92	92	92	92	92
Tropical dry	41	41	41	41	41	41
Tropical moist	41	41	41	41	41	41
Tropical wet	41	41	41	41	41	41
Tropical montane	41	41	41	41	41	41

Source: Authors' own elaboration based on Table 3.3 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 150. Emission factors for CH_4, in kg CH_4-C/ha/yr, for rewetted inland organic nutrient-rich soil

IPCC climate zone	Forest	Plantation	Annual	Perennial	Flooded rice	Grassland
Boreal dry	137	137	137	137	137	137
Boreal moist	137	137	137	137	137	137
Cool temperate dry	216	216	216	216	216	216
Cool temperate moist	216	216	216	216	216	216
Warm temperate dry	216	216	216	216	216	216
Warm temperate moist	216	216	216	216	216	216
Tropical dry	41	41	41	41	41	41
Tropical moist	41	41	41	41	41	41
Tropical wet	41	41	41	41	41	41
Tropical montane	41	41	41	41	41	41

Source: Authors' own elaboration based on Table 3.3 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

7.5 Greenhouse gas emissions from fire on organic soils

7.5.1 Definition

Fires on organic soils (uncontrolled wildfires and managed, prescribed fires) can be very severe. Fires consume surface vegetation (above-ground biomass, litter and duff) and ground fires burn into and below the surface, consuming the soil organic matter and deadwood biomass, both of which generate CO_2, CO and CH_4 emissions. Ground fires may persist over a long period of time and over different depths in response to soil moisture and water table depth, which are also affected by site characteristics, land management, weather, climate and type of fire.

7.5.2 Default emission factors

The quantification of GHG emissions from fire is dependent on the surface of burnt area, the mass of fuel available for the combustion: i.e. the mass of dry matter (see **Table 151**) and emission factors for each gas: i.e. CO_2, CO and CH_4 (see **Table 152**).

Estimation of greenhouse gas emissions from fire:

$$GHG_{fire} = A \times M_{biomass} \times C_F \times G_{ef}$$

(Eq. 28)[30]

Where:

GHG_{fire} = amount of CO_2 and non-CO_2 emissions from fire, kg of each GHG i.e. CO, CH_4 or N_2O;

A = total area burned annually, ha;

$M_{biomass}$ = mass of fuel available for combustion, tonne/ha;

C_F = combustion factor, dimensionless;

G_{ef} = emission factor for each gas, g/kg dry matter burnt.

Table 151. Mass of fuel available for combustion, in tonne of dry matter/hectare

IPCC climate zones	Wildfire undrained peat	Wildfire drained peat	Prescribed fire (i.e. land management)
Boreal dry	66	336	0
Boreal moist	66	336	0
Cool temperate dry	66	336	0
Cool temperate moist	66	336	0
Warm temperate dry	66	336	0
Warm temperate moist	66	336	0
Tropical dry	0	353	155
Tropical moist	0	353	155
Tropical wet	0	353	155
Tropical montane	0	353	155

Source: Authors' own elaboration based on Table 2.6 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 152. Emission factors for CO_2, CO and CH_4 for fire on organic soil, in g/kg of dry matter burned

IPCC climate zones	CO_2	CO	CH_4
Boreal dry	362	207	9
Boreal moist	362	207	9
Cool temperate dry	362	207	9
Cool temperate moist	362	207	9
Warm temperate dry	362	207	9
Warm temperate moist	362	207	9
Tropical dry	464	210	21
Tropical moist	464	210	21
Tropical wet	464	210	21
Tropical montane	464	210	21

Source: Authors' own elaboration based on Table 2.7 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

[30] Equation based on Chapter 2 in Volume 4 of IPCC (2019).

In EX-ACT users have to specify if fire occurs and for which situation, i.e. without project, with project, or both. Then users must specify the following information in the Tier 2 section of "fire on soil":

a. Fire periodicity and severity (i.e. fire events and impact on percentage of the surface area).
b. Type of fire (wildfire on drained or undrained peat and prescribed fire).

By default the periodicity of fire is set up to 1 fire event every year having an impact on 100 percent of the surface area. Users can adjust these two parameters according to as required.

The estimation of GHG emissions from fire on peat soil concerns both, drained and rewetted peatland.

7.6 Greenhouse gas emissions from peatlands undergoing active peat extraction

The reader is invited to read the description of the drained inland organic soil component first, as the "peatlands undergoing extraction" is built using the same approach and the text below makes reference to it.

7.6.1 Methodology

Materials used are based on methodology, guidance and default emission factors from Chapter 7 of IPCC (2006), complemented with Tables 2.1 to 2.5 from Chapter 2 of IPCC (2014) for emission factors associated with drainage.

7.6.2 Definition

Peat is widely used with about half for energy, while the remainder for horticulture, landscapes, industrial wastewater treatment and other purposes (International Peat Society, 2004). Peat extraction starts with drainage (i.e. construction of draining ditches, lowering of the water table and vegetation clearing). The clearing process stops carbon sequestration from living biomass. In the second phase, peat is extracted and stockpiled. This process continues until the peat extraction is no longer profitable. The final land can be either abandoned, restored or converted to another use.

Two types of peat are considered in EX-ACT: (i) nutrient-poor peat and (ii) nutrient-rich peat, which are associated with higher emissions.

Nutrient-poor peatlands (bogs) predominate in boreal regions, while in temperate regions, nutrient-rich peatlands (fens and mires) are more common. Types of peatlands can be inferred from the end-use of peat: sphagnum peat, dominant in oligotrophic (nutrient-poor) bogs (acidic wetland that receives water exclusively from stifled flow of nutrient-poor rainwater) is preferred for horticultural uses, while sedge peat, more common in minerotrophic (nutrient rich) fens (waterlogged habitat that tends to be alkaline and nourished by mineral-rich surface and groundwater) is more suitable for energy generation. Boreal countries that do not have information on areas of nutrient-rich and nutrient-poor peatlands should use the emission factor for nutrient-poor peatlands. Temperate countries that do not have such data should use the emission factor for nutrient-rich peatlands. Only one default factor is provided for tropical regions, so disaggregating peatland area by soil fertility is not necessary for tropical countries using the Tier 1 method.

Users should indicate the area of peatland that is going to be extracted from the initial to the final situation, with and without project.

7.6.3 Off-site CO_2 emissions from peat use

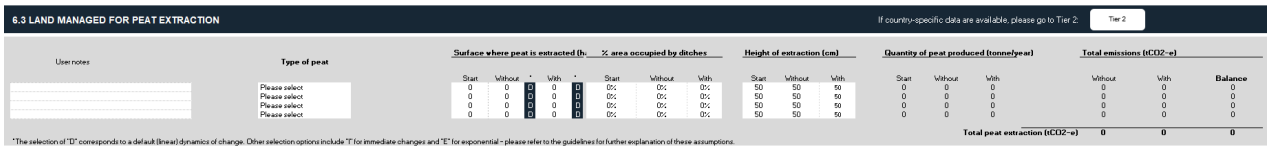
GHG emissions associated with drainage of peatlands are calculated using the same methodology outlined above, with associated emission factors reported in **Tables 138** to **145**. Additionally, once the peat extracted, it can be used for different purposes that may lead to additional emissions (off-site CO_2 emissions) depending on the quantity of peat extracted. Emissions are calculated by multiplying a conversion factor with the quantity extracted per year, and converted in tCO_2-e. By default, the conversion factors proposed by the IPCC are 0.34 tC/t air dry peat for tropical humus climate zone, 0.4 for nutrient-

rich boreal and temperate climate zones, 0.45 for nutrient-poor boreal and temperate climate (see Table 7.5 in Chapter 7 of IPCC [2006]).

7.6.4 Surface and GHG emissions

Users must inform the changes in the surface of the area, the type of peat (nutrient-poor versus nutrient-rich, when relevant) and the height of extraction for all scenarios (see **Figure 44**).

Figure 44. Peat extraction sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Non-CO_2 emissions are converted into tCO_2-e emissions using appropriate factors and corresponding GWP (see Part 1). Total emission in tCO_2-e for the without and with-project situation are the sum of the different CO_2 and non-CO_2 components including:

a. CO_2 and non-CO_2 emissions from drainage and ditches, i.e. DOC loss, CH_4 and N_2O emissions from drained land and CH_4 emission from ditches;

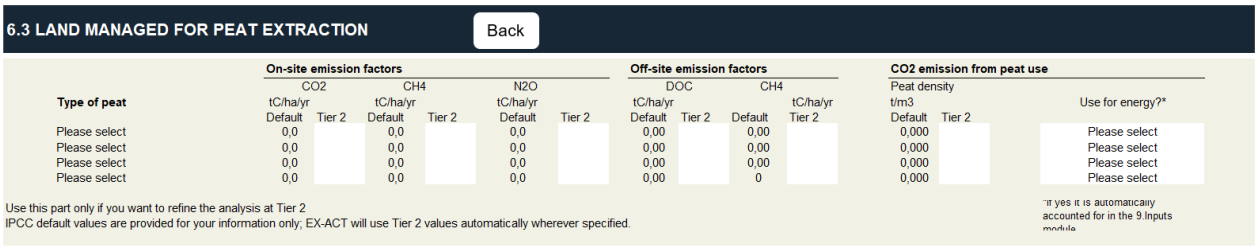
b. CO_2 off-site emissions from the horticultural use of peat.

The GHG emissions from peat used as fuel are reported in the energy consumption module (see Part 10).

7.6.5 Tier 2 options

Users can refine estimates using the Tier 2 approach for the active peat extraction section (see **Figure 45**) for on-site emissions CO_2 emission factor from stock deposit, off-site emissions of CO_2 (DOC) from drained peatland, CH_4 emission/removal factor for drained peatland undergoing extraction, CH_4 emission/removal factor for drained peatland associated to ditches, N_2O emission/removal factor for drained peatland undergoing peat extraction and peat density.

Figure 45. EX-ACT screenshot of the Tier 2 for peat extraction



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Finally, by setting up "Yes" in the CO_2 emission from peat use part, users can specify if the peat is used as a source of energy, which will automatically report, for the three situations (start, without and with) GHG emissions from peat consumption in the "Inputs" module under "Energy consumption" (see Part 10).

7.7 Greenhouse gas emissions for inland waterbodies

7.7.1 Methodology

Materials used are based on methodology, guidance and default emission factors from Chapter 7 of the IPCC (2019).

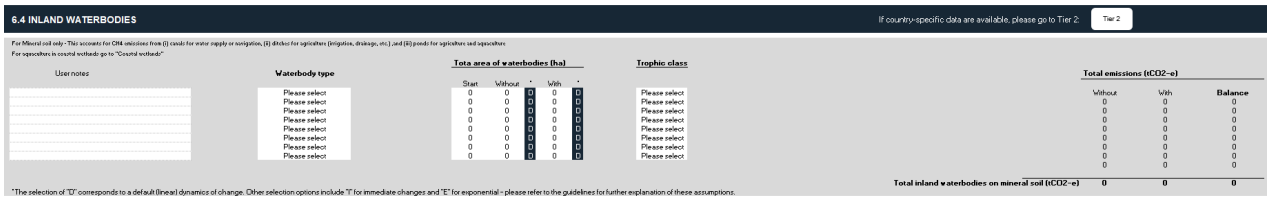
7.7.2 Definition of inland waterbodies

Flooded lands are defined as "waterbodies where human activities have caused changes in the amount of surface area covered by water typically through water level regulation". This includes: (1) waterbodies where human activities changed the hydrology of existing natural waterbodies, thereby altering water residence times and/or sedimentation rates, which in turn caused changes to the natural flux of greenhouse gases; and (2) waterbodies that were created by excavation, such as canals, ditches and ponds.

Flooded land emits CO_2, CH_4 and N_2O in significant quantities, depending on a variety of characteristics such as age of the waterbody, land use prior to flooding, climate, upstream catchment characteristics and management practices.

EX-ACT takes into account GHG emissions, mainly CH_4, from freshwater ponds, brackish water ponds and canals and ditches (see **Figure 46**).

Figure 46. Inland water bodies sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

7.7.3 CO_2 emissions in inland waterbodies

These emissions are primarily the result of decomposition of soil organic matter and other organic matter within the waterbody or entering the waterbody from catchments, as well as respiration of biota. These emissions are not considered as they might be accounted for elsewhere (IPCC, 2019).

7.7.4 Non-CO_2 emissions

Nitrous oxide emissions from "Flooded land remaining flooded land" are largely related to the inputs of organic and inorganic nitrogen from the watershed. These inputs from leaching, runoff or deposition are largely driven by anthropogenic activities such as land use change, wastewater disposal, fertilizer application or feed in aquaculture. It is not addressed here to avoid double-counting of N_2O emissions: i.e. N_2O emissions from managed soils (Chapter 11 of IPCC [2019]). N_2O emissions from aquaculture ponds are addressed in fisheries and aquaculture module (see Part 8 and Chapter 4 of IPCC [2014] for further details).

Methane emissions from flooded lands have multiple sources including: CH_4 from anoxic conditions in the sediments; diffusive, ebullitive and downstream emissions from small lakes, ponds and reservoirs; drainage ditches, aquaculture and flooded pastures; small-constructed waterbodies where nutrient loadings from agriculture and other sources are high (see Chapter 7 of IPCC [2019] for more details). CH_4 emissions may be reduced through aquaculture management, aeration of the ponds, periodic drainage and salinity.

EX-ACT only addresses CH_4 emissions in waterbodies (freshwater ponds, canal and ditches, saline and brackish ponds). At Tier 1, the method is similar to the one for estimating CH_4 emissions from drainage ditches in organic soils. Emissions factors are stratified by climate zone and trophic status.

Annual CH_4 emission from other constructed waterbodies (see Section 7.3.1 and Equation 7.12 in Chapter 7 of IPCC [2019] for further details):

$$F_{CH4} = A \text{ x } EF_{CH4} \text{ x } \alpha$$

(Eq. 29)[31]

Where:

F_{CH4} = total annual of CH_4 from ponds and ditches, in kg CH_4/yr;

A = area of waterbody, in ha;

EF_{CH4} = emission factor for other waterbody, in kg CH_4/ha/yr; and

α = emission factor adjustment for trophic state of other waterbody, dimensionless.

EX-ACT uses EF_{CH4} for other constructed waterbodies, following Table 7.12 in Chapter 7 of IPCC (2019) and reported in **Table 153**.

Table 153. CH_4 emission factors for other constructed waterbodies, in kg CH_4/ha/yr

IPCC climate zones	Freshwater pond	Brackish water pond	Canals and ditches	Saline pond
Cool temperate moist	183	183	416	30
Cool temperate dry	183	183	416	30
Boreal moist	183	183	416	30
Boreal dry	183	183	416	30
Warm temperate moist	183	183	416	30
Warm temperate dry	183	183	416	30
Tropical montane	183	183	416	30
Tropical wet	183	183	416	30
Tropical moist	183	183	416	30
Tropical dry	183	183	416	30

Source: Authors' own elaboration based on Table 7.12 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Users can also specify the trophic class of the waterbody from a dropdown list, with the following options: default, oligotrophic, mesotrophic, eutrophic and hypertrophic. EX-ACT uses default values for the emission factor adjustment for trophic state of other waterbody estimated according to the Equation 30 and based on Equation 7.11 in Chapter 7 of IPCC (2019). The default value for α is 1 (IPCC, 2019).

$$\alpha_i = 0.26 \text{ x } [\text{Chlo.a}]_i$$

(Eq. 30)[32]

[31] Equation based on Chapter 7 in Volume 4 of IPCC (2019).

[32] Equation based on Chapter 7 in Volume 4 of IPCC (2019).

Where:

α = emission factor adjustment for trophic state i of other waterbody, dimensionless;

Chlo.a = mean annual chlorophyll-a concentration in reservoir i, in µg/L.

Table 154. Trophic state adjustment factor, dimensionless, and range mean annual chlorophyll-a concentration in µg/L

Trophic state	Trophic state adjustment factor	Range of the mean annual chlorophyll-a concentration
Default	1	N/A
Oligotrophic	**0.7**	0–2.6
Mesotrophic	**3.0**	2.6–20
Eutrophic	**9.9**	20–56
Hypereutrophic	**26.9**	56–>155

Notes: Bold values are the average of a given range. The range of mean annual chlo-a concentration is provided for ease of reference.

Source: Authors' own elaboration based on Table 7.11 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

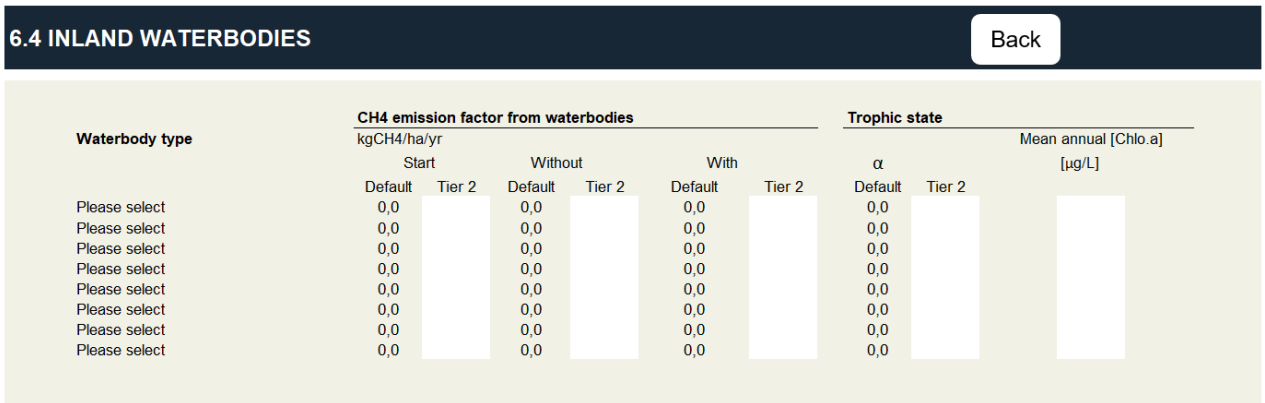
7.7.5 Surface and greenhouse gas emissions

Users have to specify the type of waterbody from the dropdown list, specify its area (in ha) at the start, without project and with project, and the trophic state. If the last variable is unknown, users can select the "default". The total surface of the area must remain the same at the start, without and with project situation. Additionally, users may specify the fish or pond production. The dynamics are set by default to linear but can be changed. Non-CO_2 emissions are converted into CO_2-e emissions using appropriate factors and corresponding GWP (see Part 1). Total emission in tCO_2-e for the without and with-project situation are the sum of CH_4 emission from waterbodies in relation to the trophic state (dependent of the chlorophyll-a concentration).

7.7.6 Tier 2 options

Users can revisit the default emission factors including (see **Figure 47**): CH_4 emission factor EF_{CH4} from waterbodies at the start, without project and with project, in kg CH_4/ha/yr; emission factor adjustment for trophic state of other waterbody (α) associated with the selected trophic state, and mean annual chlorophyll-a concentration, in µg/L.

Figure 47. Tier 2 section in inland waterbodies sub-module in EX-ACT



6.4 INLAND WATERBODIES

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Waterbody type	CH4 emission factor from waterbodies kgCH4/ha/yr						Trophic state		
	Start		Without		With		α		Mean annual [Chlo.a] [µg/L]
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		
Please select	0,0		0,0		0,0		0,0		

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 8. Coastal wetlands

8.1 Methodology

Materials used to develop this module can be found in Chapter 4 of the IPCC (2014). It allows to estimate CO_2 emission/removal from management practices in coastal wetlands, such as (i) extraction/excavation, (ii) drainage and (iii) rewetting, and CH_4 emissions associated with rewetting of drained land with brackish waters (i.e. salinity <18. See **Table 155**). Users are invited to read the section on deforestation for the methodologies on carbon stock changes in above-ground biomass, below-ground biomass, litter and deadwood.

Table 155. Salinity-based definitions for waterbodies

Common description	Salinity (particle per thousand [ppt])*
Tidal fresh water	< 0.5
Brackish water	0.5–18
Saline water	> 18

Note: * ppt is part per thousands (%) and is roughly equivalent to grams of salt per litre of water.

Source: Annex 4A.1 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

8.1.1 Definition of coastal wetland

Coastal wetland is a wetland covered by vascular plants at or near to the coast that is influenced by brackish/saline water and/or astronomical tides and which may occur on both organic and mineral soils (IPCC, 2014). Wetlands covered in this chapter include mangrove, seagrass and tidal marsh.

The coastal wetland management module is built according to three components (see **Figure 48**):

- Emissions from loss of SOC and biomass associated with excavation/extraction of soils (1 m depth, all the carbon is oxidized within the year of extraction).
- Emissions from the loss of SOC and biomass associated with the drainage of soils.
- Carbon sequestration in soil and biomass associated with restoration activities in coastal wetlands, following restoration of the hydrology.

EX-ACT considers variation in carbon stock difference between the without and with project scenario for the above-ground biomass, below-ground biomass, litter and deadwood for all listed management activities, as well as changes in SOC associated with extraction activities. For rewetting and drainage, EX-ACT considers rates of carbon changes of SOC described in section below.

Figure 48. Management of coastal wetlands sub-module in EX-ACT

7.1 MANAGEMENT OF COASTAL WETLANDS (mangroves, tidal marsh and seagrass meadow) — If country-specific data are available, please go to Tier 2: Tier 2

7.1.1. Extraction and excavation (port construction, construction of aquaculture or salt production)

Type of vegetation	Area (ha)	% excavated		Area excavated (ha)		Maximum area available for drainage			Total emissions (tCO2-e)		Balance
	Start	Without	With	Without	With	Start	Without	With	Without	With	
Mangrove	200	10%	20%	20	40	200	180	160	30.432	60.864	30.432 ▲
Tidal marsh	0	0%	0%	0	0	0	0	0	0	0	0
Seagrass	0	0%	0%	0	0	0	0	0	0	0	0
Please select	0	0%	0%	0	0	0	0	0	0	0	0
Please select	0	0%	0%	0	0	0	0	0	0	0	0
Please select	0	0%	0%	0	0	0	0	0	0	0	0
								Total for extraction and excavation (tCO2-e)	30.432	60.864	30.432

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

7.1.2 Drainage — If country-specific data are available, please go to Tier 2: Tier 2

Please specify area in the "Extraction and Excavation" module above.

Type of vegetation	% drained					Area drained (ha)			Total emissions (tCO2-e)		Balance
	Start	Without	*	With	*	Start	Without	With	Without	With	
Mangrove	20%	20%	D	0%	D	40	36	0	36.785	0	-36.785 ▼
Tidal marsh	0%	0%	D	0%	D	0	0	0	0	0	0
Seagrass	0%	0%	D	0%	D	0	0	0	0	0	0
Please select	0%	0%	D	0%	D	0	0	0	0	0	0
Please select	0%	0%	D	0%	D	0	0	0	0	0	0
Please select	0%	0%	D	0%	D	0	0	0	0	0	0
								Total for drainage (tCO2-e)	36.785	0	-36.785

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

7.1.3 Rewetting & revegetation — If country-specific data are available, please go to Tier 2: Tier 2

Type of vegetation	Area rewetted (ha)				Percentage of nominal biomass restored		Total emissions (tCO2-e)		Balance
	Without	*	With	*	Without	With	Without	With	
Please select	0	D	0	D	0%	0%	0	0	0
Please select	0	D	0	D	0%	0%	0	0	0
Please select	0	D	0	D	0%	0%	0	0	0
Please select	0	D	0	D	0%	0%	0	0	0
Please select	0	D	0	D	0%	0%	0	0	0
Please select	0	D	0	D	0%	0%	0	0	0
						Total for rewetting & revegetation (tCO2-e)	0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshots of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

8.1.2 Extraction/Excavation component

Definition

Extraction activities refer to excavation with associated dredging used to provide soil for raising the elevation of land, or excavation for construction of harbour, marina and aquaculture/salt ponds. Excavation implies the removal of the above and below-ground biomass, litter and deadwood, and soil extraction over 1 m depth. This results in GHG emission when the removal is done from saturated (anaerobic) to unsaturated (aerobic) conditions. At Tier 1 the IPCC (2014) methodology assumes that the biomass, litter, deadwood and soil are all removed and exposed under aerobic conditions, in which all the carbon is converted into CO_2 within the first year of the extraction.

CO_2 emissions

EX-ACT uses default data for estimation of carbon stock changes in coastal wetland ecosystems provided in Chapter 4 of IPCC (2014) and reported in **Tables 156** to **159**. Mangroves are distributed in the tropical and subtropical climate zones. In EX-ACT sub-tropical regions are under the warm temperate climate zone category.

The soil carbon stock is dependent on the type of vegetation, i.e. mangrove, tidal marsh and seagrass, as well as the type of soil, i.e. organic or mineral (see definition in the inland organic soil section). SOC stocks for organic and mineral soils represent the top 1 metre depth of soil undergoing extraction/excavation (see **Tables 160** to **162**). It is assumed that 96 percent of the SOC stock in 1 m depth is oxidized immediately after extraction, and only 4 percent of the SOC stock is considered refractory. If it is not known whether the soil is organic or mineral the aggregated value can be used.

Table 156. Default values for above-ground biomass, in t d.m./ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	0	0
Boreal moist	N/A	0	0
Cool temperate dry	N/A	0	0
Cool temperate moist	N/A	0	0
Warm temperate dry	75	0	0
Warm temperate moist	75	0	0
Tropical dry	92	0	0
Tropical moist	192	0	0
Tropical wet	192	0	0

Note: Proxies from tropical wet are used for tropical moist.

Source: Authors' own elaboration based on Table 4.3 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 157. Default values for the root to shoot ratio, in t root d.m./t shoot d.m., in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass	Tidal marsh Mediterranean
Boreal dry	N/A	0	0	N/A
Boreal moist	N/A	0	0	N/A
Cool temperate dry	N/A	2.10	1.30	N/A
Cool temperate moist	N/A	2.10	1.30	N/A
Warm temperate dry	0.96	3.65	2.40	3.63
Warm temperate moist	0.96	3.65	2.40	3.63
Tropical dry	0.29	3.65	1.70	3.63
Tropical moist	0.49	3.65	1.70	N/A
Tropical wet	0.49	3.65	1.70	N/A

Note: Proxies from tropical wet are used for tropical moist.

Source: Authors' own elaboration based on Table 4.5, Table 4.9 and Table 4.10 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 158. Default values for litter, in tC/ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	0	0
Boreal moist	N/A	0	0
Cool temperate dry	N/A	0	0
Cool temperate moist	N/A	0	0
Warm temperate dry	0.7	0	0
Warm temperate moist	0.7	0	0
Tropical dry	0.7	0	0
Tropical moist	0.7	0	0
Tropical wet	0.7	0	0

Source: Authors' own elaboration based on Table 4.7 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 159. Default values for deadwood, in tC/ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	0	0
Boreal moist	N/A	0	0
Cool temperate dry	N/A	0	0
Cool temperate moist	N/A	0	0
Warm temperate dry	10.7	0	0
Warm temperate moist	10.7	0	0
Tropical dry	10.7	0	0
Tropical moist	10.7	0	0
Tropical wet	10.7	0	0

Source: Authors' own elaboration based on Table 4.7 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 160. Default carbon stock for mineral soil for the first top metre depth, in tC/ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	226	108
Boreal moist	N/A	226	108
Cool temperate dry	N/A	226	108
Cool temperate moist	N/A	226	108
Warm temperate dry	286	226	108
Warm temperate moist	286	226	108
Tropical dry	286	226	108
Tropical moist	286	226	108
Tropical wet	286	226	108

Source: Authors' own elaboration based on Table 4.11 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 161. Default carbon stock for organic soil for the first top metre depth, in tC/ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	340	0
Boreal moist	N/A	340	0
Cool temperate dry	N/A	340	0
Cool temperate moist	N/A	340	0
Warm temperate dry	471	340	0
Warm temperate moist	471	340	0
Tropical dry	471	340	0
Tropical moist	471	340	0
Tropical wet	471	340	0

Source: Authors' own elaboration based on Table 4.11 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Table 162. Default carbon stock for aggregated soil for the first top metre depth, in tC/ha, in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	255	0
Boreal moist	N/A	255	0
Cool temperate dry	N/A	255	0
Cool temperate moist	N/A	255	0
Warm temperate dry	386	255	0
Warm temperate moist	386	255	0
Tropical dry	386	255	0
Tropical moist	386	255	0
Tropical wet	386	255	0

Source: Authors' own elaboration based on Table 4.11 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Improved Tier 1 values for soil carbon stocks

Since 2014 these ecosystems have been considered within GHG emissions reporting through the wetland supplement of the IPCC (2014). Subsequently, a growing body of scientific literature reported on ecosystem carbon stocks in coastal wetlands. EX-ACT includes data from Atwood *et al.* (2017) for mangrove soil carbon stocks, as reported in **Table 163**. Original data are disaggregated across hemispheres, latitudes, countries and mangrove community compositions and are made available to users via Tier 2 section, by selecting the option "Tier1a". By default EX-ACT uses the IPCC values (see Table 4.11 in Chapter 4 of IPCC [2014]).

Table 163. Mangrove total area in 2014, in km$_2$, averaged soil carbon stock for the first top metre depth and standard deviation, in tC/ha

Country	No.	Area	Soil carbon stock	sd
Angola	0	213	**283**	
Antigua and Barbuda	0	2	**283**	
Australia	269	3 315	249	154
Bahamas	2	37	81	15
Bangladesh	11	1 773	118	29
Barbados	0	0	**283**	
Belize	13	302	647	70
Benin	3	7	235	52
Bermuda	0	0	**283**	
Brazil	41	7 663	308	131
Brunei Darussalam	0	103	**283**	
Cambodia	0	320	**283**	
Cameroon	6	1 113	597	348
China	34	31	186	67
Colombia	4	1 672	449	164
Comoros	0	1	**283**	
Congo	3	70	470	385
Costa Rica	0	335	**283**	
Côte d'Ivoire	0	23	**283**	

Country	No.	Area	Soil carbon stock	sd
Indonesia	40	23 143	359	181
Iran (Islamic Republic of)	0	0	**283**	
Jamaica	0	44	**283**	
Japan	47	8	274	136
Kenya	48	230	446	422
Liberia	0	47	**283**	
Madagascar	7	850	167	75
Malaysia	35	4 692	424	400
Maldives	0	0	**283**	
Mexico	38	2 985	370	176
Micronesia (Federated States of)	27	7	453	244
Morocco	0	0	**283**	
Mozambique	6	1 223	153	7
Myanmar	0	2 508	**283**	
New Caledonia	7	98	401	76
New Zealand	92	77	209	52
Nicaragua	0	552	283	
Nigeria	11	2 653	235	44
Oman	0	0	**283**	

Country	No.	Area	Soil carbon stock	sd
Cuba	0	1 624	**283**	
Democratic Republic of the Congo	3	146	936	85
Djibouti	0	0	**283**	
Dominican Republic	9	101	419	88
Ecuador	12	935	327	61
Egypt	43	0	185	55
El Salvador	0	236	**283**	
Equatorial Guinea	0	155	**283**	
Eritrea	0	1	**283**	
Fiji	0	401	**283**	
French Guiana	31	698	185	129
Gabon	3	1 081	736	192
Gambia	0	48	**283**	
Ghana	3	23	245	40
Grenada	0	1	**283**	
Guadeloupe	31	698	185	129
Guatemala	0	253	**283**	
Guinea	0	820	**283**	
Guinea-Bissau	2	745	126	56
Guyana	0	188	**283**	
Haiti	0	42	**283**	
Honduras	18	524	397	142
India	160	791	253	91

Country	No.	Area	Soil carbon stock	sd
Pakistan	3	12	181	7
Palau	7	48	482	84
Panama	10	1 323	299	46
Papua New Guinea	6	4 169	140	25
Peru	0	14	283	
Philippines	8	2 060	227	162
Puerto Rico	0	46	**283**	
Saudi Arabia	31	0	71	53
Senegal	2	155	139	71
Seychelles	0	5	**283**	
Sierra Leone	0	655	**283**	
Singapore	1	2	330	
Solomon Islands	0	393	**283**	
Somalia	0	8	**283**	
South Africa	7	7	235	47
Sri Lanka	6	35	503	163
Saint Vincent and the Grenadines	0	0	**283**	
Sudan	0	0	**283**	
Suriname	0	510	**283**	
Taiwan	3	1	122	31
United Republic of Tanzania	30	478	243	83
Thailand	14	1 876	246	82

Notes: n is the number of observations. Values in bold are countries with missing soil carbon data. For these countries total carbon stocks were estimated using the average global soil carbon stock per unit area of 283 tC/ha.

Source: Authors' own elaboration based on Table S1 of Atwood, T.B., Connolly, R.M., Almahasheer, H., Carell, P.E., Duarte, C.M., Ewers Lewis, C.J., Irigoien, X., Kelleway, J.J., Lavery, P.S., Macreadie, P.I., Serrano, O.S., Sanders, C.J., Santos, I., Steven, A.D.L. & Lovelock, C.E. 2017. Global patterns in mangrove soil carbon stocks and losses. *Nature Climate Change*, 7: 523–528. https://doi.org/10.1038/nclimate3326

Surface and greenhouse gas emissions

Users must provide the surface at the start of the project and the percentage of it undergoing excavation without and with project (see **Figure 48**). The remaining area is considered available for drainage. The total emissions in tCO_2-e are estimated from the surface area undergoing excavation/extraction multiplied by the carbon stock of all the carbon components.

Tier 2 options for the extraction and excavation sub-module

In this section (see **Figure 49**), users can revisit default values including: above-ground biomass, below-ground biomass, litter and deadwood; type of soil - mineral (by default), organic or aggregated; type of default values for soil - IPCC or Tier1a from Atwood *et al.* (2017); soil carbon stocks for the top 1 m depth; percentage of carbon lost after excavation, by default set to 96 percent.

Figure 49. Tier 2 approach for the extraction and excavation sub-module in coastal wetlands

7.1 MANAGEMENT OF COASTAL WETLANDS (mangroves, tidal marsh and seagrass meadow) Back

7.1.1. Extraction and excavation (port construction, construction of aquaculture or salt production)

All values are in tC/ha

Type of vegetation	Above-ground		Below-ground		Litter		Deadwood		Type of soil	Soil (1 m depth)			% C lost after excavation	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2		Tier	Default	Tier 2	Default	Tier 2
Mangrove	86,6		42,4		0,7		10,7		Mineral	IPCC	286		96%	
Tidal marsh	0,0		0,0		0,0		0,0		Mineral	IPCC	226		96%	
Seagrass	0,0		0,0		0,0		0,0		Mineral	IPCC	108		96%	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		96%	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		96%	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		96%	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

8.1.3 Drainage in coastal wetlands

Definition

Coastal wetlands have been diked and drained to create pastures, cropland and settlements since before the eleventh century. Drainage may be accompanied by land clearing resulting in changes in biomass and deadwood carbon stocks, discussed previously. Drainage will also cause soils to dry and increase the organic matter decomposition, resulting in CO_2 emissions from the soil. Emissions are dependent on the climate, salinity and lability of the organic matter, among other parameters (IPCC, 2014).

By default GHG emissions from drainage in EX-ACT are calculated assuming a complete removal of the biomass and deadwood stock with loss of carbon stock the first year and that drainage is full, i.e. the water table has been changed to 1 m below the soil surface of organic and mineral soils. The drainage occurs in-situ: i.e. the soil is not extracted or excavated, but the biomass (above, below-ground, litter and deadwood) is removed.

CO_2 emissions

EX-ACT uses default data for estimation of carbon stock changes in coastal wetlands ecosystems provided in Chapter 4 of IPCC (2014) and reported in **Tables 155** to **158**.

Soil carbon emissions are based on the following assumption: (i) emissions will persist as long as the soil is drained or as long as it will be needed for soil C stocks from undrained/natural settings to be oxidized, and (ii) the drainage is considered over a 1 m depth. For drained mangroves and tidal marshes, EX-ACT applies the default value 7.9 tC/ha/yr (see Table 4.13 in Chapter 4 of IPCC [2014]). Greenhouse gas emissions are estimated until the soil carbon stock is depleted (see Table 4.11 in Chapter 4 of IPCC [2014]), which also determines the time frame for emissions from drainage, regardless of whether a land use change occurs.

Surface and greenhouse gas emissions

The available surface for drainage is determined by the difference between surface area at the start of the project defined in the extraction/excavation component and the one which has undergone extraction/excavation in the without and with-project situations. Users have to specify the percentage of the surface area at the start of the project, which will undergo drainage activities in the without and with project situations to trigger calculations of the carbon balance.

Tier 2 approach for the drainage sub-module

In this section (see **Figure 50**), users can refine the default emissions factors including above-ground biomass, below-ground biomass, litter and deadwood; type of soil - mineral (by default), organic or

aggregated; default values for soil, IPCC or Tier1a from Atwood *et al.* (2017); soil carbon stock for the top one m depth, and; emission factor for drainage.

Figure 50. Tier 2 approach for the drainage sub-module in coastal wetlands

7.1.2 Drainage

All values are in tC/ha

Type of vegetation	Above-ground		Below-ground		Litter		Deadwood		Type of soil	Soil (1 m depth)			EF drainage (tC/ha/yr)	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2		Tier	Default	Tier 2	Default	Tier 2
Mangrove	86,6		42,4		0,7		10,7		Mineral	IPCC	286		7,9	
Tidal marsh	0,0		0,0		0,0		0,0		Mineral	IPCC	226		7,9	
Seagrass	0,0		0,0		0,0		0,0		Mineral	IPCC	108		7,9	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		0,0	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		0,0	
Please select	0,0		0,0		0,0		0,0		Mineral	IPCC	0		0,0	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

8.1.4 Rewetting and revegetation of coastal wetlands

Definition

Rewetting is a natural precursor to the establishment of mangrove and tidal marsh vegetation, or to a change of environmental conditions as a natural precursor to the establishment of seagrass vegetation in already waterlogged soils.

CO_2 emissions

Biomass and dead organic matter concerns mangroves only. EX-ACT uses the default values for biomass and deadwood carbon previously described (see **Tables 155**, **156** and **158**). EX-ACT assesses the change in carbon stocks during project implementation as a percentage of the biomass restored or degraded on the given area.

Soil. Upon rewetting and (human induced) revegetation of previously drained soil, the re-establishment of vegetation allows soil carbon accumulation at a rate instantaneously equivalent to that in natural settings (see **Table 164**).

Table 164. Emission factor for carbon associated with rewetting and revegetation in coastal wetlands

IPCC climate zones	Mangrove	Tidal marsh	Seagrass
Boreal dry	N/A	-0.91	-0.43
Boreal moist	N/A	-0.91	-0.43
Cool temperate dry	N/A	-0.91	-0.43
Cool temperate moist	N/A	-0.91	-0.43
Warm temperate dry	-1.62	-0.91	-0.43
Warm temperate moist	-1.62	-0.91	-0.43
Tropical dry	-1.62	-0.91	-0.43
Tropical moist	-1.62	-0.91	-0.43
Tropical wet	-1.62	-0.91	-0.43

Source: Authors' own elaboration based on Table 4.12 of IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.* Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

Non-CO_2 emissions

In brackish water, the shift from an aerobic to an anaerobic environment when restoring hydrological properties leads to CH_4 emissions from the microbial decomposition of organic matter, with approximately 193.7 kg CH_4/ha/yr for mangroves, seagrass and tidal marshes (see Section 4.3.1 in Chapter 4 of IPCC [2014] for further details). For soil, saturated with water of salinity > 18, microbial reduction of sulphate to sulphide will generally occur before methanogenesis.

Surface and greenhouse gas emissions

Users must specify the surface of the area concerned with rewetting. GHG emissions (CO_2 and CH_4 if salinity is less than 18) are estimated by multiplying the land area by the respective emission factors. Users should specify the percentage of successfully restored biomass in the area for the without and with project situations to trigger calculations of the carbon balance (see **Figure 48**).

Tier 2 options for the rewetting and revegetation sub-module

Users can revisit default emissions factors (see **Figure 51**) including: above-ground biomass, below-ground biomass, litter and deadwood; soil carbon stock for the top one m depth; average salinity in the area, by default set to <18; CO_2 emission factor, and; CH_4 emission factor.

Figure 51. Tier 2 approach for the drainage sub-module in coastal wetlands

7.1.3 Rewetting & revegetation

All values are in tC/ha

Type of vegetation	Above-ground		Below-ground		Litter		Deadwood		Average salinity	EF CO2 (tC/ha/yr)		EF CH4 (kgCH4/ha/yr)	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	ppt	Default	Tier 2	Default	Tier 2
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	
Please select	0,0		0,0		0,0		0,0		<18	0,00		0,0	

Use this part only if you want to refine the analysis at Tier 2
IPCC default values are provided for your information only; EX-ACT will use Tier 2 values automatically wherever specified.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

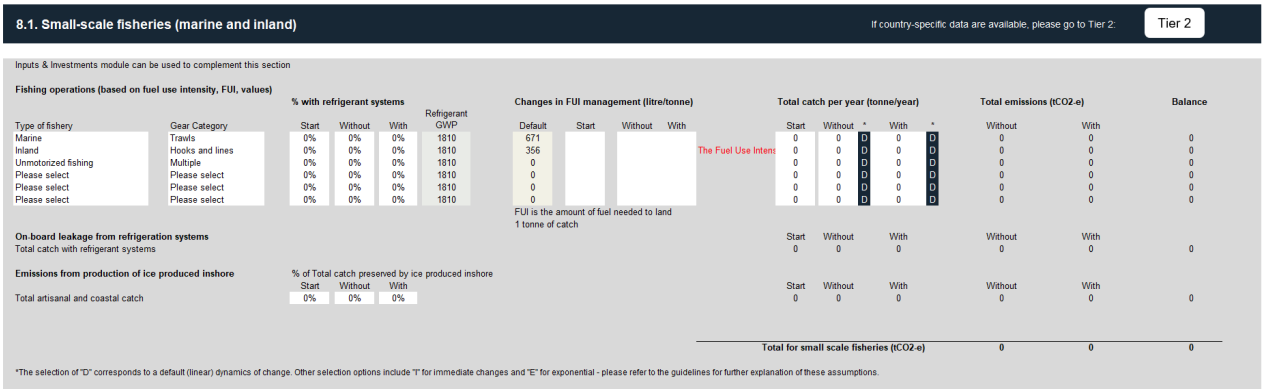
PART 9. Fisheries and aquaculture

9.1 Small scale fisheries (marine and inland)

9.1.1 Methodology

This module estimates the main GHG fluxes generated by fuel consumption and refrigerant leakage during capture, as well as those created by onshore ice production in the small-scale fisheries (SSF) sector. While there is no formal or universal definition of small scale, large scale fisheries or artisanal fisheries, SSF generally refer to fisheries with small amount of production taking place at a family or community level while LSF generally refers to fisheries at an industrial level (FAO, 2010). Other emissions, such as the transportation of fish to factories or market, can be assessed using the energy consumption module (Inputs module, see Part 10).

Figure 52. Small scale fisheries sub-module in EX-ACT



8.1. Small-scale fisheries (marine and inland) — If country-specific data are available, please go to Tier 2: Tier 2

Inputs & Investments module can be used to complement this section

Fishing operations (based on fuel use intensity, FUI, values)

Type of fishery	Gear Category	% with refrigerant systems: Start	Without	With	Refrigerant GWP	Changes in FUI management (litre/tonne): Default	Start	Without	With	Total catch per year (tonne/year): Start	Without	*	With	*	Total emissions (tCO2-e): Without	With	Balance
Marine	Trawls	0%	0%	0%	1810	671				0	0	D	0	D	0	0	0
Inland	Hooks and lines	0%	0%	0%	1810	356				0	0	D	0	D	0	0	0
Unmotorized fishing	Multiple	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0

The Fuel Use Intens

FUI is the amount of fuel needed to land 1 tonne of catch

On-board leakage from refrigeration systems

	Start	Without	With	Without	With	
Total catch with refrigerant systems	0	0	0	0	0	0

Emissions from production of ice produced inshore

	% of Total catch preserved by ice produced inshore: Start	Without	With	Start	Without	With	Without	With	
Total artisanal and coastal catch	0%	0%	0%	0	0	0	0	0	0

	Total emissions (tCO2-e): Without	With	Balance
Total for small scale fisheries (tCO2-e)	0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

9.1.2 GHG emission from fuel, refrigerant leakage and ice production

Greenhouse gas emissions from fuel consumption during the catch phase

The data used in the small-scale or artisanal fishery module are derived from fuel use information collected as part of the *Illuminating Hidden Harvests* (IHH) project (WorldFish, FAO, Duke University 2018), which is based upon the original *Hidden Harvests* project from 2012 (World Bank, 2012).

EX-ACT estimates CO_2 emissions from the catch, i.e. multiplying the quantity of fish caught by the standardized metric Fuel Use Intensity, FUI, which is the litres of fuel used to land one metric tonne (t) of catch. Fuel Use Intensity values come from the IHH database and are aggregated globally depending on the type of fishery (marine or inland) and the type of gear used in the fishing activities. The Tier 1 emission factor for vessel fuel included in the EX-ACT small-scale or artisanal fisheries module is 3.3 kg CO_2-e GHG per litre of fuel combusted (Parker *et al.*, 2018). Unmotorized vessels do not use fuel. As a result, they do not have any emissions. However, users are able to account for catch via unmotorized vessels in order to track activities with this type of vessels as well as changes from unmotorized vessels to motorized vessels (or vice versa).

The first part of the module is dedicated to defining the fishing activity according to fishery type (marine or inland) and the gear class. Seven gear categories are available: trawls, gillnets and entangling nets, hooks and lines, multiple gears, pots and traps, surrounding nets and dredges. If no data on the type of gear is available it is possible to use the "not specified" category, representing an average of available values of FUI for the remaining gears in the same type of fishery.

It is necessary to specify the annual fish catch in tonnes. The users' selection of fishery type and gear class queries a fuel use intensity value from the extract of fuel use information. The fuel use intensity is multiplied by the yearly catch, the sum of which is divided by the rate of emissions (i.e. 3.3 kg CO_2-e/ litre of fuel). The resulting statistic is the estimated carbon impact of the given small-scale or artisanal fishing activity. The methodology used for calculating the carbon balance is based on the difference of emissions between fishery management with the project and in the reference scenario.

Default data provided by the tool is based on IHH FUI values (see **Table 165**). These values can be adjusted in the Tier 2 section if more specific data is available.

Table 165. Small scale fisheries Tier 1 fuel use intensities

Gear	Marine	Inland	Unmotorized
Trawls	671	N/A	0
Gillnets	336	247	0
Hooks and lines	607	N/A	0
Multiple	1415	465	0
Pots and traps	884	N/A	0
Surrounding nets	73	N/A	0
Dredges	880	N/A	0
Not specified	695	356	0

Source: WorldFish, FAO & Duke University. 2018. *Illuminating Hidden Harvests: The Contribution Of Small-Scale Fisheries To Sustainable Development*.http://pubs.iclarm.net/resource_centre/Program-Brief-Illuminating-hidden-harvests.pdf

$$C_{balance} = (FUI * Q * EF_{fuel}) + (Pct_{ice} * Q * EF_{ice}) + ((Pct_R * Q) * L * EF_R)$$

(Eq. 31)

Where:

$C_{balance}$ = the carbon balance;

Q = quantity of catch in tonnes;

FUI = the fuel use intensity;

EF_{fuel} = the emission factor for fuel;

Pct_{ice} = the percentage of catch frozen with onshore produced ice;

EF_{ice} = the emission factor for ice;

Pct_R = the percentage of catch refrigerated on board;

L = the leakage of the refrigerant; and

EF_R = the emission factor for the refrigerant used.

Greenhouse gas emissions from on-board refrigerant leakage

Fisheries are known to use storage to preserve fresh catch. Especially among large-scale fisheries, refrigeration is used, and leakage of compressed refrigerants presents a non-zero impact on global warming. As a proportion of catch, leakage of refrigerants has been estimated to be as low as .03g of R-22 refrigerant per tonne of fish (Svanes, Vold and Hanssen 2011). Yet, R-22 is a refrigerant with a very high global warming potential of 1810, (Devotta and Sicars, 2005) and R-22 is estimated to be used on 70-80 percent of all ships in the marine segment, globally (UNIDO, 2009).

EX-ACT accounts for R-22 leakage based upon a study of leakage across several species, the values of which come from a comprehensive study on refrigerant leakage in marine fisheries (Iribarren *et al.*, 2011). For the small-scale or artisanal fisheries module, leakage of refrigerant is estimated as 83 g of

R-22/tonne of landed catch, which is the mean leakage for coastal fisheries described in the study (Iribarren *et al.*, 2011). If users have special knowledge of other refrigeration systems in use, they can input alternative refrigerant leakage estimates in the Tier 2 portion of the module. Further information on the global warming potential of such refrigerants is also available in the *United Nations Industrial Development Organization 2009 report* on refrigerants (UNIDO, 2009).

Greenhouse gas emissions from ice produced on land

The onshore production of ice for fish preservation is characteristic of many traditional fishing settings. In EX-ACT, ice production relies on electricity consumption generating GHG emissions. The calculation of electricity emissions is in line with the electricity section of the Inputs module (see Part 10). EX-ACT considers that the average ratio ice/fish is about 2.8 (kg of ice per kg of fish) and electricity consumption is by default 60 kWh for the production of 1 tonne of ice (FAO, 2010; Gosh *et al.*, 2014).

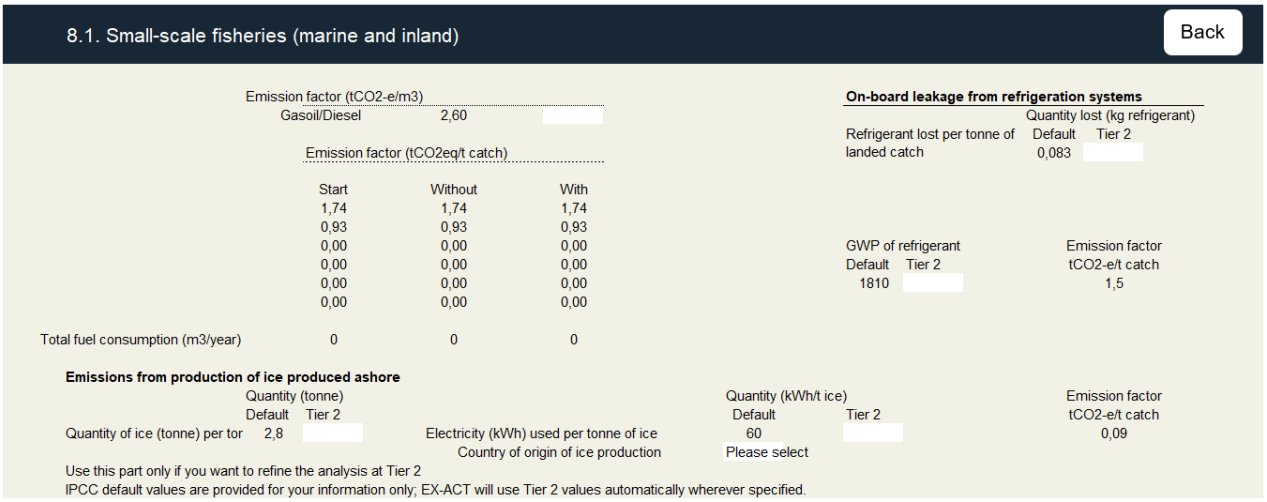
9.1.3 Greenhouse gas emissions from the fishery management

GHG emissions from the small-scale fishery sector are estimated from: (i) the type of fishery (marine or inland), (ii) the associated gear type, (iii) the total annual catch, (iv) the proportion of the catch kept with on-board refrigerant systems and/or (v) with ice produced ashore. Users also have the ability to account for changes to the fuel use intensity due to management activities that will impact the FUI (litres per tonne).

9.1.4 Tier 2 options

Users can revisit default emissions factors including (see **Figure 53**): fuel use intensity; emission factor for diesel; quantity of refrigerant lost per tonne of fish landed; GWP of the refrigerant; quantity of ice produced ashore needed to preserve the catch; country of origin of ice production, and; quantity of electricity to produce one tonne of ice.

Figure 53. Tier 2 approach for small scale fisheries sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

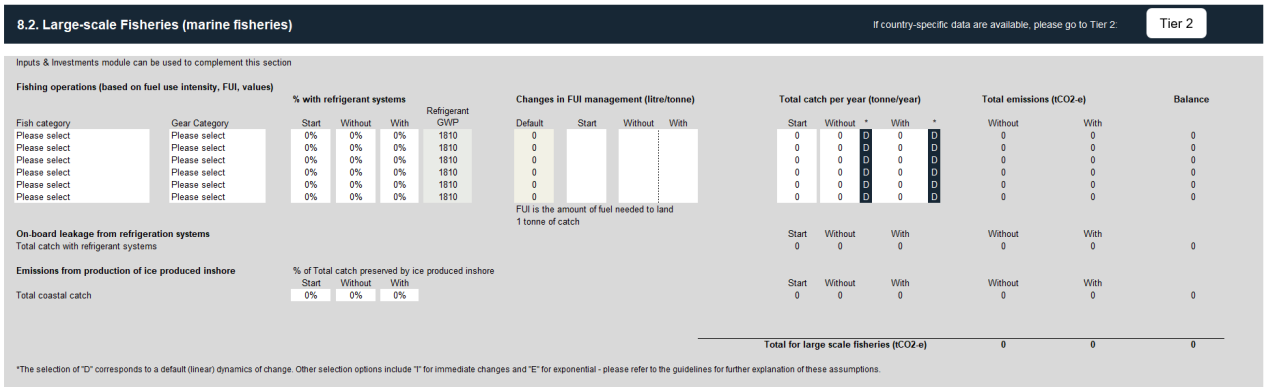
9.2 Large scale fisheries

9.2.1 Methodology

This module estimates the main GHG fluxes generated by fuel consumption and refrigerant leakage during capture, as well as those created by onshore ice production in the large-scale fishery (LSF) sector. While there is no formal or universal definition of small scale, large scale fisheries or artisanal fisheries,

SSF generally refer to fisheries with small amount of production taking place at a family or community level while LSF generally refers to fisheries at an industrial level (FAO, 2010). Large scale fisheries are typically those with vessels 12 metres in length or greater. Other emissions such as the transportation of fish to factories or market can be assessed using the energy consumption module (inputs module, see Part 10). Calculations for emissions from refrigerant leakage and ice production onshore are similar to that of small-scale fisheries described earlier.

Figure 54. Large scale fisheries sub-module in EX-ACT



8.2. Large-scale Fisheries (marine fisheries) — If country-specific data are available, please go to Tier 2: Tier 2

Inputs & Investments module can be used to complement this section

Fishing operations (based on fuel use intensity, FUI, values)

Fish category	Gear Category	% with refrigerant systems Start	Without	With	Refrigerant GWP	Changes in FUI management (litre/tonne) Default	Start	Without	With	Total catch per year (tonne/year) Start	Without	*	With	*	Total emissions (tCO2-e) Without	With	Balance
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0
Please select	Please select	0%	0%	0%	1810	0				0	0	D	0	D	0	0	0

FUI is the amount of fuel needed to land 1 tonne of catch

On-board leakage from refrigeration systems

	Start	Without	With	Without	With	
Total catch with refrigerant systems	0	0	0	0	0	0

Emissions from production of ice produced inshore

	% of Total catch preserved by ice produced inshore Start	Without	With	Start	Without	With	Without	With	
Total coastal catch	0%	0%	0%	0	0	0	0	0	0
Total for large scale fisheries (tCO2-e)							0	0	0

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

9.2.2 LSF GHG emission from fuel, refrigerant leakage and ice production

Greenhouse gas emissions from the fuel consumption during the catch phase

The data used in the large-scale fishery module are derived from the Fuel and Energy Use Database (FEUD) of Dalhousie University (Parker and Tyedmers, 2015), and are reported in **Table 166**. FEUD is a compendium of records of fuel inputs to fishing activity globally. Records are grouped by species group and gear class, which provides high numbers of observations per summary statistic while also providing a high level of detail for the analyst using this specific module within EX-ACT.

EX-ACT estimates CO_2 emissions from the catch, i.e. multiplying the quantity of fish caught by the standardized metric Fuel Use Intensity, FUI, which is the litres of fuel used to land one metric tonne (t) of catch. Similar to the SSF submodule, the emission factor for vessel fuel included in the EX-ACT large scale fisheries sub-module is 3.3 kg CO_2-e GHG per litre of fuel combusted (Parker *et al.*, 2018). Within the EX-ACT large scale fisheries module, a user inputs their fishing activity according to species group and the gear class. This information is required, without which the LSF module will not be able to calculate the carbon balance. To complete the input, the user needs to provide the total catch in tonnes. The users' selection of species class and gear class queries a median fuel use intensity value from the FEUD extract. Similar to the small-scale fisheries submodule, the LSF fuel use intensity is multiplied by the yearly catch, the sum of which is divided by the rate of emissions (i.e. 3.3 kg CO_2-e/ litre of fuel). The resulting statistic is the estimated carbon impact of the given large scale fishing activity.

Table 166. Large scale fisheries Tier 1 fuel use intensities

Species group	Bottom trawl	Gillnets and entangling nets	Hooks and lines	Midwater trawls	Traps and lift nets	Surrounding nets	Dredges	Mobile seine	Other or mixed	Not specified
Abalones, winkles and conchs	N/A	2 162	N/A	N/A	484	N/A	N/A	N/A	839	**791**
Clams, cockles and ark shells	N/A	N/A	N/A	N/A	1 430	N/A	835	N/A	430	**787**
Cods, hakes and haddocks	490	511	702	138	N/A	512	N/A	N/A	436	**463**
Flounders, halibuts and soles	2 903	502	570	982	N/A	694	N/A	N/A	1 094	**1 822**
Herrings, sardines and anchovies	91	602	0	118	559	68	N/A	146	287	**145**
Jacks, mullets and sauries	492	496	1 836	489	N/A	434	445	N/A	497	**641**
Krill and plankton	N/A	N/A	N/A	121	N/A	N/A	N/A	N/A	N/A	**121**
Lobsters and spiny-rock lobsters	5 200	N/A	N/A	1 667	3 564	N/A	N/A	N/A	1 028	**3 937**
Mackerels, snoeks and cutlassfish	922	N/A	322	167	0	39	N/A	N/A	106	**208**
Miscellaneous marine crustaceans	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2 230	**2 230**
Miscellaneous marine fishes	171	N/A	N/A	350	N/A	N/A	N/A	N/A	1 903	**637**
Miscellaneous marine molluscs	2 904	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	**2 904**
Mussels	N/A	N/A	N/A	N/A	N/A	N/A	20	N/A	13	**20**
Redfish, basses and congers	754	304	472	232	921	254	N/A	N/A	912	**467**
Salmons, trots and smelts	N/A	886	835	N/A	N/A	304	N/A	N/A	N/A	**622**
Scallops and pectens	1 405	N/A	N/A	1 787	N/A	N/A	577	N/A	834	**697**
Sea-spiders and crabs	N/A	N/A	1 031	N/A	1074	N/A	N/A	N/A	1 062	**1 069**
Shads	N/A	N/A	N/A	16	N/A	N/A	N/A	N/A	N/A	**16**
Sharks and rays	982	661	365	494	153	118	N/A	N/A	253	**606**
Shrimps and prawns	2 550	630	N/A	3 074	N/A	N/A	N/A	N/A	1 224	**2 569**
Squat lobsters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	165	**165**
Squids, cuttlefish and octopuses	313	N/A	N/A	406	N/A	N/A	N/A	N/A	N/A	**325**
Tunas, bonitos and billfishes	N/A	683	1 554	1 649	N/A	433	N/A	N/A	915	**1 295**
Not specified	**1 475**	**744**	N/A	**854**	N/A	**779**	N/A	N/A	**1 169**	**317**

Notes: When gear class or species is not known, users can select "not specified", highlighted in bold and calculated from the other available values. For gear class, "not specified" values are the weighted average of all other gear class for each species group. For species, "not specified" FUI values are the median FUI values by each gear class.

Sources: Parker, R.W.R. & Tyedmers, P.H. 2015. Fuel consumption of global fishing fleets: current understanding and knowledge gaps. *Fish and Fisheries,* 16(4), 684-696. https://doi.org/10.1111/faf.12087

Greenhouse gas emissions from on-board refrigerant leakage and from ice produced on land

EX-ACT accounts for R-22 leakage based upon a study of leakage across several species, the values of which come from a comprehensive study on refrigerant leakage in marine fisheries (Iribarren *et al.*, 2011). The mean refrigerant leakage for offshore large-scale fisheries is estimated as 487.34 g of R-22 / tonne of landed catch. If users have special knowledge of other refrigeration systems in use, they can input alternative refrigerant leakage estimates in the Tier 2 portion of the module. Further information on the global warming potential of such refrigerants is also available in the *United Nations Industrial Development Organization 2009 report* on refrigerants (UNIDO, 2009). Using the same methodology, the mean leakage for offshore, large-scale fisheries is estimated as 487.34 g of R-22 / tonne of landed catch.

The onshore production of ice for fish preservation is characteristic of many traditional fishing setting. In EX-ACT, ice production relies on electricity consumption generating GHG emissions. The calculation of electricity emissions is in line with the electricity section of the Inputs module. EX-ACT considers that the average ratio ice/fish is about 2.8 (kg of ice per kg of fish) and electricity consumption is by default 60 kWh for the production of one tonne of ice (FAO, 2010; Gosh *et al.,* 2014).

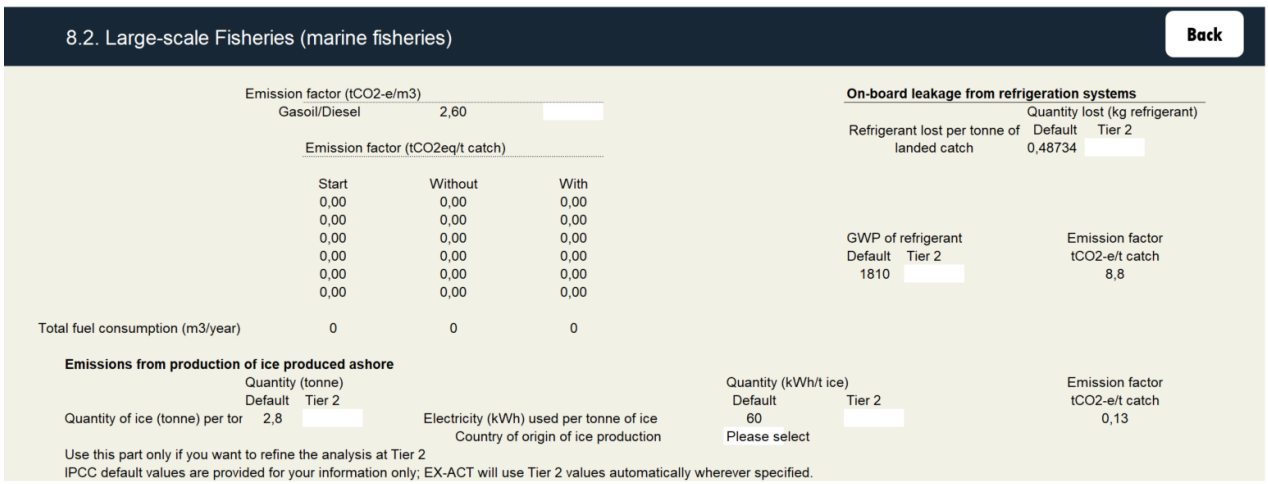
9.2.3 Greenhouse gas emissions from the fishery management

GHG emissions from the large-scale fishery sector are estimated from: (i) species class, (ii) the associated gear type, (iii) the total annual catch, (iv) the proportion of the catch kept with on-board refrigerant systems and/or (v) with ice produced ashore. Users also have the ability to account for changes to the fuel use intensity due to management activities that will impact the FUI (litres per tonne). Users can change default values with their own specific coefficients as described above via Tier 2 as shown in **Figure 55**.

9.2.4 Tier 2 options

Users can revisit default emissions factors including (see **Figure 55**): fuel use intensity; emission factor for diesel; quantity of refrigerant lost per tonne of fish landed; GWP of the refrigerant; quantity of ice produced ashore needed to preserve the catch; country of origin of ice production, and; quantity of electricity to produce one tonne of ice.

Figure 55. Tier 2 approach for small scale fisheries sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

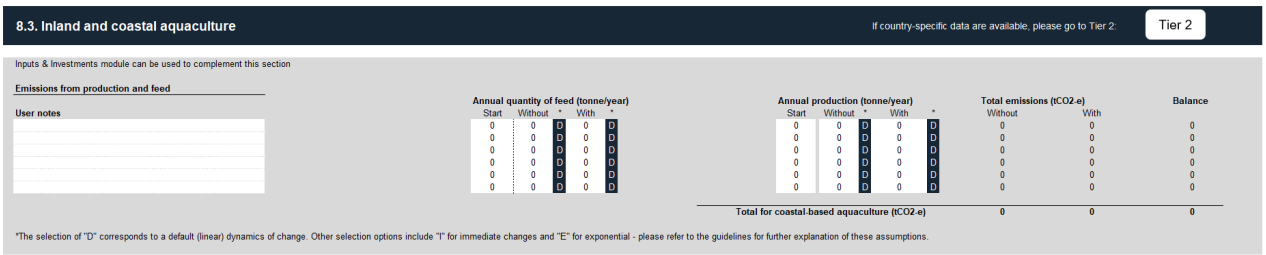
9.3 Coastal wetlands-based aquaculture sub-module

9.3.1 Methodology

Materials used to develop this sub-module can be found in Chapter 4 of IPCC (2014), for the "N_2O emissions during aquaculture use in mangroves, tidal marshes and seagrass meadow" and in Chapter 7 of IPCC (2019). GHG emissions associated with feed can be significant, stemming from the manufacturing of feed and transportation (Winther *et al.*, 2009; Avadí *et al.*, 2014; Fréon *et al.*, 2017). As a result, EX-ACT also proposes to include them in the calculations under the aquaculture related Tier 2 section.

The module consists of two sections: (i) the GHG associated with the use of the feed and their associated carbon footprint (the corresponding emission factors must be provided by the user in Tier 2), and (ii) N_2O emission from the production of fish (see **Figure 56**).

Figure 56. Aquaculture sub-module in EX-ACT



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

9.3.2 Non-CO_2 emissions

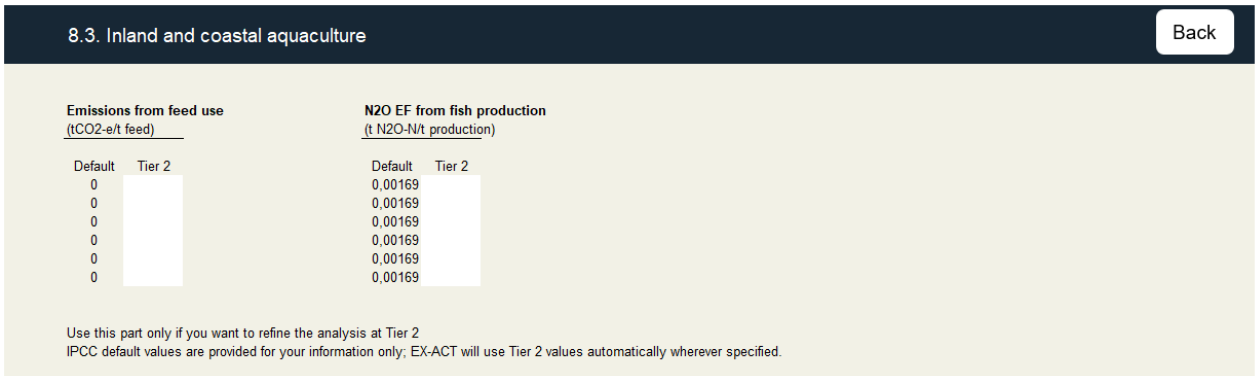
N_2O emissions from fish production

Emissions from aquaculture mostly originate in the form of N_2O emissions. They represent about a third of the global anthropogenic N_2O emissions (IPCC, 2014). N_2O is a by-product of fish rearing, resulting from the nitrification and denitrification of ammonia excreted by the fish. Thus it is possible to quantify N_2O emission from the fish production data, when aquaculture systems are in the stocked phase. EX-ACT uses the global emission factor, 0.791 tCO_2-e per tonne of fish produced, provided by IPCC (see Section 4.3.2 of IPCC [2014] for further details).

9.3.3 Tier 2 options

In this section (see **Figure 57**), users can revisit default emissions factors including the emission factor for N_2O emissions and the carbon footprint of feed.

Figure 57. Tier 2 approach aquaculture sub-module



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

PART 10. Inputs and investments module

10.1 Agricultural inputs

10.1.1 Methodology

Materials used to develop this sub-module can be found in Chapter 11 of IPCC (2019) titled "N_2O emissions from managed soils, and CO_2 emissions from lime, urea application" and Lal (2004).

This sub-module allows estimating the following GHG emissions: (i) CO_2 emissions from lime application, (ii) CO_2 emissions from urea application, (iii) N_2O emissions from synthetic and organic nitrogen-based fertilizers (except manure management treated in Livestock Module), (iv) embodied emissions (in tCO_2-e) from production, transportation storage and transfer of agricultural chemicals (see **Figure 58**).

Figure 58. Agricultural input sub-module in EX-ACT

9.1 INPUTS (liming, fertilizers, pesticides) — If country-specific data are available, please go to Tier 2: Tier 2

Fertilizers	Amount applied per year (in tonne)					Total emissions at field level (tCO2-e)				Emissions from production, transportation, storage and transfer (tCO2-e)		Total emissions (tCO2-e)		
						CO2 emissions		N2O emissions						
	Start	Without	*	With	*	Without	With	Without	With	Without	With	Without	With	Balance
Lime application														
Limestone (tonnes per year)	0,00	0,00	D	0,00	D	0	0	-	-	0	0	0	0	0
Dolomite (tonne per year)	0,00	0,00	D	0,00	D	0	0	-	-	0	0	0	0	0
Not-specified (tonnes per year)	0,00	0,00	D	0,00	D	0	0	-	-	0	0	0	0	0
Synthetic fertilizers														
Urea (tonnes of Urea per year)	0,00	0,00	D	0,00	D	0	0	0	0	0	0	0	0	0
Synthetic N-fertilizers other than Urea (tonnes of N per year)	0,00	0,00	D	0,00	D	-	-	0	0	0	0	0	0	0
Phosphorus (tonnes of P2O5 per year)	0,00	0,00	D	0,00	D	-	-	-	-	0	0	0	0	0
Potassium (tonnes of K2O per year)	0,00	0,00	D	0,00	D	-	-	-	-	0	0	0	0	0
N-fertilizers on irrigated rice														
N-fertilizer in continously irrigated rice (tonnes of N per year)	0,00	0,00	D	0,00	D	-	-	0	0	0	0	0	0	0
N-fertilizer in wet and dry irrigated rice (tonnes of N per year)	0,00	0,00	D	0,00	D	-	-	0	0	0	0	0	0	0
Organic N-fertilizers														
Sewage (tonnes per year)	0,00	0,00	D	0,00	D	-	-	0	0	-	-	0	0	0
Compost (tonnes per year)	0,00	0,00	D	0,00	D	-	-	0	0	-	-	0	0	0
Rendering waste, brewery waste, guano (tonnes per year)	0,00	0,00	D	0,00	D	-	-	0	0	-	-	0	0	0
Pesticides														
Fungicides (tonnes of active ingredient)	0,00	0,00	D	0,00	D	-	-	-	-	0	0	0	0	0
Herbicides (tonnes of active ingredient)	0,00	0,00	D	0,00	D	-	-	-	-	0	0	0	0	0
Insecticides (tonnes of active ingredient)	0,00	0,00	D	0,00	D	-	-	-	-	0	0	0	0	0
Animal feed (in tonnes per year)														
User defined (Tier 2)	0,00	0,00	D	0,00	D							0	0	0
											Total inputs (tCO2-e)	0	0	0

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

10.1.2 CO_2 emissions

CO_2 emissions from lime application

Liming is the addition of carbonates to soils in the form of calcic limestone or dolomite, which lead to CO_2 emissions from carbonate dissolution. CO_2 emissions are estimated from the quantity of lime applied on the soil associated with a default emission factors, i.e. 0.12 tC/t for limestone and 0.13 tC/t for dolomite (PCC, 2019). User may change the default emission factors bearing in mind that they must be less than the default emission factor as the default values correspond to the carbon content of the materials.

CO_2 emissions from urea application

The addition of urea ($CO(NH_2)_2$) to the soils leads to a loss of CO_2, in proportion to amount of urea fertilization (in tonne urea) applying the default coefficient 0.2 tC/t urea that corresponds to the equivalent of carbon content of urea on a weight basis (IPCC, 2019). Additionally, users have the option to include atmospheric CO_2 removal during the urea manufacturing in the Tier 2 section.[33]

[33] The CO_2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector, IPCC, 2019).

CO_2 emission from animal feed

EX-ACT includes emissions from animal feed to allow for a complete assessment of GHG fluxes linked to livestock activities. Users can refer to Tier 2 in order to specify an emission factor to be used in the calculation of feed emissions whenever livestock feed is created and manufactured outside the perimeter of the project. If feed is instead produced through cultivation or sourced from grasslands within the project's perimeter, users should include the related information in the corresponding sections of the tool (i.e. cropland and grassland modules. See Part 4 and 5)

10.1.3 Non-CO_2 emissions

N_2O emissions from nitrogen application on managed soils

This section covers direct N_2O emissions from: (i) Synthetic N fertilizers, (ii) N fertilizer in irrigated rice systems, and (iii) organic fertilizers. It excludes N_2O emissions from the manure left on pasture as it is already covered in the "Livestock and manure management" sub-module.

Emissions are calculated based on amount of N-fertilizer applied and an emission factor associated with the type of input (see **Table 167**).

Table 167. Direct N_2O emission factors for managed soils, in kg N_2O-N/kg N

IPCC climate region	Synthetic N-fertilizer	Other N inputs
Dry	0.005	0.005
Wet	0.016	0.006
Moist	0.0105	0.0055
Tropical montane	0.005	0.005

Notes: The average of wet and dry is used as a proxy for moist climate.

Source: Authors' own elaboration based on Table 11.1 in Volume 4 of IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva, Switzerland. www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Indirect emissions may arise from N application. Yet, there are many uncertainties around the related estimations, and they may originate from a nitrogen source outside the perimeter of the project, for example N_2O emissions associated with N deposition from chemical industries. As a result, these emissions are not included in EX-ACT.

Emissions from production, transportation, storage and transfer of agricultural inputs

Embodied GHG emissions associated with the production, transportation storage and transfer of agricultural chemicals are automatically accounted for based on the amount of inputs specified and emission factors from Lal (2004), reported in **Table 168**.

Table 168. Emission factors from production, transportation, storage and transfer of agricultural inputs, in tCO_2-e/t of product

Type of input	Emission coefficient used by EX-ACT
Nitrogen-fertilizers	4.77
Phosphorus-fertilizer	0.73
Potassium-fertilizer	0.55
Lime and dolomite	0.59
Herbicides	23.10
Insecticides	18.70
Fungicides	14.30

Note: emission factors were originally in tonne of carbon equivalent and were converted in CO_2-e using the factor 44/12.

Source: Authors' own elaboration based on Table 5 of Lal, R. 2004. Carbon Emission from Farm Operations. *Environment International,* 30: 981–990.

10.1.4 Tier 2 options

Users have possibility to change all the default emission factors described above (see **Figure 59**).

Figure 59. Tier 2 section of the agricultural inputs sub-module

9.1 INPUTS (liming, fertilizers, pesticides) Back

Emissions factors

Fertilizers

	Emissions at field level: CO2 emissions			Emissions at field level: N2O emissions			Emissions from production, transportation, storage and transfer: CO2-e emissions		
	Unit	Default	Tier 2	Unit	Default	Tier 2	Unit	Default	Tier 2
Limestone (tonnes per year)	tC/t lime	0,120					tCO2/t lime	0,587	
Dolomite (tonne per year)	tC/t lime	0,130					tCO2/t lime	0,587	
Not-specified (tonnes per year)	tC/t lime	0,125					tCO2/t lime	0,587	
Urea (tonnes of Urea per year)	tC/t Urea	0,200		kg N-N2O/kg N	0,011		tCO2/t N	4,767	
Synthetic N-fertilizers other than Urea (tonnes of N per year)				kg N-N2O/kg N	0,011		tCO2/t N	4,767	
Phosphorus (tonnes of P2O5 per year)							tCO2/t P2O5	0,733	
Potassium (tonnes of K2O per year)							tCO2/t K2O	0,550	
N-fertilizer in continously irrigated rice (tonnes of N per year)				kg N-N2O/kg N	0,003		tCO2/t N	4,767	
N-fertilizer in wet and dry irrigated rice (tonnes of N per year)				kg N-N2O/kg N	0,005		tCO2/t N	4,767	
Sewage (tonnes per year)				kg N-N2O/kg N	0,006				
Compost (tonnes per year)				kg N-N2O/kg N	0,006				
Rendering waste, brewery waste, guano (tonnes per year)				kg N-N2O/kg N	0,006				
Fungicides (tonnes of active ingredient)							tCO2-e/t active ingredient	14,3	
Herbicides (tonnes of active ingredient)							tCO2-e/t active ingredient	23,1	
Insecticides (tonnes of active ingredient)							tCO2-e/t active ingredient	18,7	
User defined (Tier 2)							tCO2-e/t feed		

Urea CO2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector by the country where urea was produced.
By default EX-ACT considers that urea is imported and do not account for this sink, but you can force the calculation to do so: **Account the manufacturing sink?** NO

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

10.2 Energy consumption

10.2.1 Methodology

Material used to develop this sub-module can be found in Volume 2 of IPCC (2006) on energy (fuel and solid biofuels) and in UNFCCC's list of methodologies for estimating emissions from energy consumption assembled by the International Financial Institutions (IFI) Technical Working Group.

EX-ACT estimates GHG emissions from (i) electricity consumption and (ii) fuel consumption (see **Figure 60**) using the generic methodology for non-CO_2 emissions of IPCC (2019) (see Equation 2.6) with default emission factors provided in **Tables 169** and **170**.

Figure 60. Energy consumption sub-module

9.2. ENERGY CONSUMPTION (electricity, fuel...) except for irrigation, i.e. see next section If country-specific data are available, please go to Tier 2: Tier 2

Description and unit to report	Quantity consumed per year: Start	Without	*	With	*	Total emissions (tCO2-e): Without	With	Balance
Electricity (MWh per year)								
Country of origin of electricity								
Please select	0,00	0,00	D	0,00	D	0	0	0
User defined (Tier 2)	0,00	0,00	D	0,00	D	0	0	0
Liquid or gaseous (in m3 per year)								
Please select	0,00	0,00	D	0,00	D	0	0	0
Please select	0,00	0,00	D	0,00	D	0	0	0
Please select	0,00	0,00	D	0,00	D	0	0	0
Please select	0,00	0,00	D	0,00	D	0	0	0
User defined (Tier 2)	0,00	0,00	D	0,00	D	0	0	0
Solid (in tonnes of dry matter per year)								
Wood	0,00	0,00	D	0,00	D	0	0	0
Peat	0,00	0,00	D	0,00	D	0	0	0
Charcoal	0,00	0,00	D	0,00	D	0	0	0
Peat (from peatlands)	0,00	0,00	D	0,00	D	0	0	0
User defined (Tier 2)	0,00	0,00	D	0,00	D	0	0	0
						Total energy (tCO2-e) 0	0	0

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

10.2.2 Non-CO_2 emissions

Greenhouse gas emissions from electricity consumption

For electricity consumption, EX-ACT proposes two sets of emission factors related to the energy grid following the Harmonized IFI Default Grid Factors (IFI, 2021). The default is the Operating Margin (OM) emission factor, representing electricity generation from existing power plants with the highest variable operating costs to dispatch the electricity across the system.

Users can also choose to adopt a Combined Margin (CM) emission factor, which additionally accounts for the annual emission intensities of new electricity generation projected over the next 8 years under the Stated Policy Scenario (STEPS) of the most recent IEA World Economic Outlook. As a result, CM emission factors thus take stock of projected changes in emissions of the electricity generation systems.

Users have to provide the annual electricity consumption in MWh per year at the start of the project, the without and with project scenarios. Default emission factors are provided in **Table 169**. Users should specify the country of origin of electricity (see Tier 2 approach), as some projects located near the border of a determined country may use the energy from a neighbouring country.

Greenhouse gas emissions from fuel consumption

Users have to provide the annual consumption of liquid and gaseous (in m_3/yr) and solid biofuels (in t d.m./yr) at the start of the project and the without and with project situation. Default emission factors are described in **Table 170**.

Two options are proposed to estimate GHG emissions from the solid biofuels consumption, i.e. wood, peat and charcoal: (i) accounting CO_2, CH_4 and N_2O emissions or (ii) accounting for CH_4 and N_2O only. It is generally assumed that the CO_2 emitted during the biomass burning will be removed by growing trees during photosynthesis, thus making the overall impact neutral. By default CO_2 emissions from solid burning are not reported in EX-ACT, but it can be changed in the Tier 2 section.

Table 169. Electricity grid emission factor, in tCO_2-e/MWh

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Afghanistan	Southern Asia	0.414	0.193
Åland Islands	Europe	N/A	0.256
Albania	Europe	N/A	0.256
Algeria	Northern Africa	0.528	0.397
American Samoa	Oceania	0.753	0.516
Andorra	Europe	0.188	0.070
Angola	Central Africa	1.476	0.748
Anguilla	Caribbean	0.753	0.472
Antigua and Barbuda	Caribbean	0.753	0.489
Argentina	South America	0.478	0.288
Armenia	Western Asia	0.390	0.205
Aruba	Caribbean	0.753	0.421
Australia	Oceania	0.808	0.421
Austria	Europe	0.242	0.113
Azerbaijan	Western Asia	0.534	0.384
Bahamas	Caribbean	0.753	0.441
Bahrain	Western Asia	0.726	0.454
Bangladesh	Southern Asia	0.528	0.412
Barbados	Caribbean	0.749	0.484
Belarus	Europe	0.400	0.292

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Belize	Central America	0.403	0.183
Belgium	Europe	0.252	0.124
Benin	Western Africa	0.745	0.576
Bermuda	North America	0.753	0.342
Bhutan	Southern Asia	N/A	0.388
Bolivia (Plurinational State of)	South America	0.604	0.393
Bonaire, Sint Eustatius and Saba	Caribbean	0.753	0.400
Bosnia and Herzegovina	Europe	1.197	0.739
Botswana	Southern Africa	1.486	1.070
Bouvet Island	South America	N/A	0.290
Brazil	South America	0.284	0.139
British Indian Ocean Territory	Eastern Africa	N/A	0.418
British Virgin Islands	Caribbean	N/A	0.420
Brunei Darussalam	South-Eastern Asia	0.681	0.407
Bulgaria	Europe	0.911	0.495
Burkina Faso	Western Africa	0.753	0.539
Burundi	Eastern Africa	0.414	0.197
Cabo Verde	Western Africa	0.753	0.505
Cambodia	South-Eastern Asia	1.046	0.588
Cameroon	Central Africa	0.659	0.354
Canada	North America	0.372	0.156
Cayman Islands	Caribbean	0.753	0.373
Central African Republic	Central Africa	0.188	0.077
Chad	Central Africa	0.753	0.581
Chile	South America	0.657	0.371
China	Eastern Asia	0.899	0.547
China, Hong Kong Special Administrative Region	Eastern Asia	0.899	0.547
China, Macao Special Administrative Region	Eastern Asia	N/A	0.512
Christmas Island	Oceania	N/A	0.451
Cocos (Keeling) Islands	Oceania	N/A	0.451
Colombia	South America	0.410	0.208
Comoros	Eastern Africa	0.753	0.589
Congo	Central Africa	0.659	0.405
Cook Islands	Oceania	0.753	0.422
Costa Rica	Central America	0.108	0.039
Côte d'Ivoire	Western Africa	0.466	0.314
Croatia	Europe	0.294	0.168
Cuba	Caribbean	0.559	0.391
Curaçao	Caribbean	0.876	0.506
Cyprus	Western Asia	0.751	0.438
Czechia	Europe	0.902	0.461
Democratic People's Republic of Korea	Eastern Asia	0.754	0.359
Democratic Republic of the Congo	Central Africa	N/A	0.0004

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Denmark	Europe	0.362	0.155
Djibouti	Eastern Africa	0.753	0.575
Dominica	Caribbean	0.753	0.433
Dominican Republic	Caribbean	0.601	0.426
Ecuador	South America	0.560	0.280
Egypt	Northern Africa	0.554	0.406
El Salvador	Central America	0.547	0.275
Equatorial Guinea	Central Africa	0.632	0.361
Eritrea	Eastern Africa	0.915	0.704
Estonia	Europe	1.057	0.625
Eswatini	Southern Africa	N/A	0.652
Ethiopia	Eastern Africa	N/A	0.00014
Falkland Islands (Malvinas)	South America	0.753	0.316
Faroe Islands	Europe	0.753	0.320
Fiji	Oceania	0.640	0.334
Finland	Europe	0.267	0.114
France	Europe	0.158	0.068
French Guiana	South America	0.423	0.200
French Polynesia	Oceania	0.753	0.412
French Southern Territories	Eastern Africa	N/A	0.418
Gabon	Central Africa	0.946	0.533
Gambia	Western Africa	0.753	0.591
Georgia	Western Asia	0.289	0.135
Germany	Europe	0.650	0.313
Ghana	Western Africa	0.495	0.276
Gibraltar	Europe	0.779	0.369
Greece	Europe	0.507	0.346
Greenland	North America	0.264	0.105
Grenada	Caribbean	0.753	0.523
Guadeloupe	Caribbean	0.753	0.433
Guam	Oceania	0.753	0.428
Guatemala	Central America	0.798	0.427
Guernsey	Europe	N/A	0.256
Guernsey, Bailiwick of (Sark)	Europe	N/A	0.256
Guinea	Western Africa	0.753	0.460
Guinea-Bissau	Western Africa	0.753	0.577
Guyana	South America	0.847	0.616
Haiti	Caribbean	1.048	0.765
Heard and McDonald Islands	Oceania	N/A	0.451
Holy See	Europe	N/A	0.256
Honduras	Central America	0.662	0.359
Hungary	Europe	0.296	0.191
Iceland	Europe	N/A	0.000
India	Southern Asia	0.951	0.661

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Indonesia	South-Eastern Asia	0.783	0.599
Iran (Islamic Republic of)	Southern Asia	0.592	0.421
Iraq	Western Asia	1.080	0.788
Ireland	Europe	0.380	0.189
Isle of Man	Europe	0.436	0.204
Israel	Western Asia	0.394	0.258
Italy	Europe	0.414	0.224
Jamaica	Caribbean	0.711	0.498
Japan	Eastern Asia	0.471	0.286
Jersey	Europe	N/A	0.256
Jordan	Western Asia	0.529	0.382
Kazakhstan	Central Asia	0.797	0.532
Kenya	Eastern Africa	0.574	0.274
Kiribati	Oceania	0.753	0.530
Kuwait	Western Asia	0.675	0.400
Kyrgyzstan	Central Asia	0.217	0.098
Lao People's Democratic Republic	South-Eastern Asia	1.069	0.555
Latvia	Europe	0.240	0.117
Lebanon	Western Asia	0.794	0.567
Lesotho	Southern Africa	N/A	0.652
Liberia	Western Africa	0.677	0.374
Libya	Northern Africa	0.668	0.493
Liechtenstein	Europe	0.151	0.052
Lithuania	Europe	0.211	0.102
Luxembourg	Europe	0.220	0.095
Madagascar	Eastern Africa	0.876	0.567
Malawi	Eastern Africa	0.489	0.243
Malaysia	South-Eastern Asia	0.551	0.436
Maldives	Southern Asia	0.753	0.524
Mali	Western Africa	1.076	0.623
Malta	Europe	0.520	0.295
Marshall Islands	Oceania	0.753	0.561
Martinique	Caribbean	0.753	0.406
Mauritania	Western Africa	0.753	0.513
Mauritius	Eastern Africa	0.700	0.543
Mayotte	Eastern Africa	N/A	0.512
Mexico	Central America	0.531	0.360
Micronesia (Federated States of)	Oceania	0.753	0.557
Monaco	Europe	0.158	0.068
Mongolia	Eastern Asia	1.366	1.002
Montenegro	Europe	0.899	0.471
Montserrat	Caribbean	0.753	0.517
Morocco	Northern Africa	0.729	0.547
Mozambique	Eastern Africa	0.234	0.111

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Myanmar	South-Eastern Asia	0.719	0.407
Namibia	Southern Africa	0.355	0.139
Nauru	Oceania	0.753	0.521
Nepal	Southern Asia	N/A	0.000
Netherlands	Europe	0.326	0.203
New Caledonia	Oceania	0.779	0.445
New Zealand	Oceania	0.246	0.108
Nicaragua	Central America	0.675	0.372
Niger	Western Africa	0.772	0.718
Nigeria	Western Africa	0.526	0.358
Niue	Oceania	0.753	0.459
Norfolk Island	Oceania	N/A	0.451
North Macedonia	Europe	0.851	0.563
Northern Mariana Islands	Oceania	0.753	0.416
Norway	Europe	0.047	0.017
Oman	Western Asia	0.479	0.320
Pakistan	Southern Asia	0.592	0.386
Palau	Oceania	0.753	0.497
Palestine	Western Asia	N/A	0.517
Panama	Central America	0.477	0.230
Papua New Guinea	Oceania	0.597	0.315
Paraguay	South America	N/A	0.000
Peru	South America	0.473	0.252
Philippines	South-Eastern Asia	0.672	0.525
Pitcairn	Oceania	N/A	0.451
Poland	Europe	0.828	0.532
Portugal	Europe	0.389	0.228
Puerto Rico	Caribbean	0.596	0.362
Qatar	Western Asia	0.503	0.258
Republic of Korea	Eastern Asia	0.555	0.330
Republic of Moldova	Europe	0.541	0.399
Réunion	Eastern Africa	0.772	0.421
Romania	Europe	0.489	0.289
Russian Federation	Europe	0.476	0.294
Rwanda	Eastern Africa	0.712	0.416
Saint Barthélemy	Caribbean	N/A	0.461
Saint Helena	Western Africa	0.753	0.456
Saint Kitts and Nevis	Caribbean	0.753	0.477
Saint Lucia	Caribbean	0.753	0.521
Saint Martin (French Part)	Caribbean	0.753	0.484
Saint Pierre and Miquelon	North America	0.753	0.415
Saint Vincent and the Grenadines	Caribbean	0.753	0.499
Samoa	Oceania	0.753	0.434
San Marino	Europe	0.414	0.224

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Sao Tome and Principe	Central Africa	0.753	0.565
Saudi Arabia	Western Asia	0.592	0.374
Senegal	Western Africa	0.870	0.656
Serbia	Europe	1.086	0.678
Seychelles	Eastern Africa	0.753	0.479
Sierra Leone	Western Africa	0.489	0.246
Singapore	South-Eastern Asia	0.379	0.200
Sint Maarten (Dutch part)	Caribbean	0.753	0.463
Slovakia	Europe	0.332	0.164
Slovenia	Europe	0.620	0.285
Solomon Islands	Oceania	0.753	0.563
Somalia	Eastern Africa	0.753	0.582
South Africa	Southern Africa	1.070	0.747
South Georgia and the South Sandwich Islands	South America	N/A	0.290
South Sudan	Eastern Africa	0.890	0.704
Spain	Europe	0.402	0.209
Sri Lanka	Southern Asia	0.731	0.506
Sudan	Northern Africa	0.736	0.398
Suriname	South America	1.029	0.565
Svalbard and Jan Mayen Islands	Europe	N/A	0.256
Sweden	Europe	0.068	0.025
Switzerland	Europe	0.048	0.020
Syrian Arab Republic	Western Asia	0.713	0.546
Tajikistan	Central Asia	0.255	0.106
Thailand	South-Eastern Asia	0.450	0.351
Timor-Leste	South-Eastern Asia	0.753	0.589
Togo	Western Africa	0.859	0.597
Tokelau	Oceania	N/A	0.451
Tonga	Oceania	0.753	0.533
Trinidad and Tobago	Caribbean	0.559	0.370
Tunisia	Northern Africa	0.468	0.348
Turkey	Western Asia	0.376	0.309
Turkmenistan	Central Asia	0.927	0.676
Turks and Caicos Islands	Caribbean	0.753	0.451
Tuvalu	Oceania	0.753	0.497
Uganda	Eastern Africa	0.279	0.116
Ukraine	Europe	0.768	0.435
United Arab Emirates	Western Asia	0.556	0.310
United Kingdom of Great Britain and Northern Ireland	Europe	0.380	0.187
United Republic of Tanzania	Eastern Africa	0.531	0.336
United States Minor Outlying Islands	Oceania	N/A	0.451
United States of America	North America	0.416	0.220
United States Virgin Islands	Caribbean	0.650	0.373

UN country list	UN region	Operating margin (tCO2-e/MWh)	Combined margin (tCO_2-e/MWh)
Uruguay	South America	0.174	0.065
Uzbekistan	Central Asia	0.612	0.467
Vanuatu	Oceania	0.753	0.504
Venezuela (Bolivarian Republic of)	South America	0.711	0.368
Viet Nam	South-Eastern Asia	0.560	0.381
Wallis and Futuna Islands	Oceania	N/A	0.451
Western Sahara	Northern Africa	N/A	0.432
Yemen	Western Asia	0.807	0.615
Zambia	Eastern Africa	0.416	0.197
Zimbabwe	Eastern Africa	1.575	0.880

Notes: Values in red correspond to regional averages and replace missing or zero values for Combined Margin EFs. N/A values correspond to missing or zero values for Operating Margin EFs, for which representative regional estimates could not be identified.

Source: Authors' own elaboration based on IFI. 2021. *Methodological approach for the common fault grid emissions factors dataset*. Technical Working Group on Greenhouse Gas Accounting. IFI TWG- AHG-001. Version 3.0. December 2021. Cited 3 February 2022. https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting/ifi-twg-list-of-methodologies

Table 170. Default net calorific values, in TJ/Gg, emission factors for stationary and mobile combustion, in kg GHG/TJ and tCO_2-e/m_3, and fuel density, in kg/m_3

Fuel and solid biofuels type	EF fuel	Net calorific values	EF CO_2	EF CH_4	EF N_2O	Density
Stationary - motor gasoline	2.292	44.3	69 300	10	0.6	741
Stationary - gasoil/diesel oil	2.686	43.0	74 100	10	0.6	837
Stationary - waste oil/lubrificants	2.819	40.2	73 300	10	0.6	950
Stationary – Liquefied petroleum gas (LPG)	1.596	47.3	63 100	5	0.1	533
Stationary - natural gas	0.002	48.0	56 100	5	0.1	0.768
Mobile - motor gasoline	2.343	44.3	69 300	33	3.2	741
Mobile - gasoil /diesel oil	2.714	43.0	74 100	3.9	3.9	837
Mobile - natural gas	0.002	48.0	56 100	92	3	0.768
Mobile - LPG	1.645	47.3	63 100	62	0.2	533
Mobile - ethanol (cars)	0.045	27.0	1 508	18	N/A	788
Mobile - ethanol (trucks)	0.480	27.0	1 508	260	41	788
Off-road diesel	2.979	43.0	74 100	4.15	28.6	837
Off-road gasoline (2-stroke)	2.435	44.3	69 300	140	0.4	741
Off-road gasoline (4-stroke)	2.384	44.3	69 300	80	2	741
Wood	1.925 [0.178]	15.6	11 2000	300	4	
Peat	1.138 [0.104]	9.8	106 000	300	1.4	
Charcoal	3.513 [0.209]	29.5	11 2000	200	1	

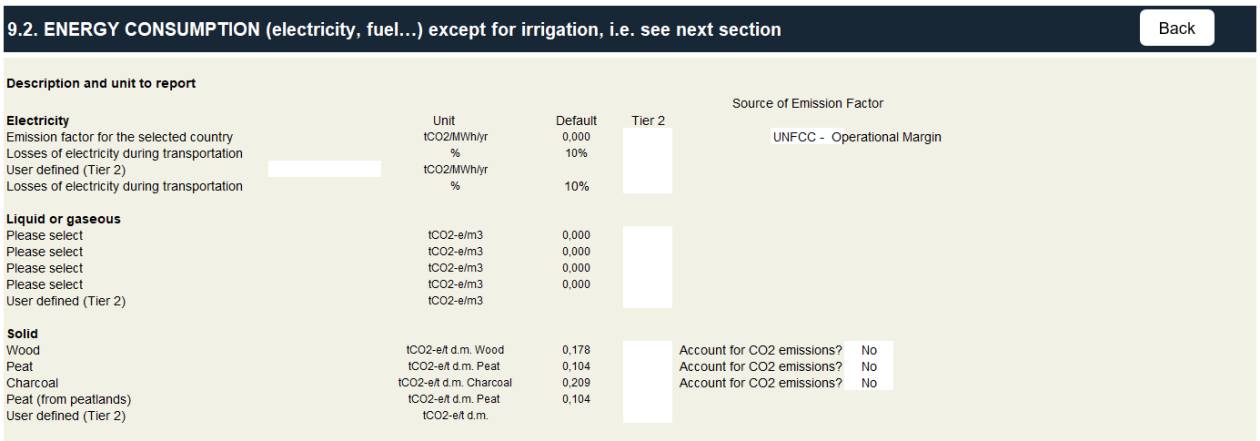
Notes: Numbers in bracket are the default emission factor for solid biofuels excluding CO_2 emissions.

Source: Authors' own elaboration based on Table 1.2 (net calorific value) Table 2.5 (GHG emission factors for stationary combustion), Tables 3.2.1 and 3.2.2 (GHG emission factors for mobile combustion), Table 3.3.1 (Emission factors for off-road mobile sources and machinery) in Volume 2 of IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa, Japan. www.ipcc-nggip.iges.or.jp/public/2006gl

10.2.3 Tier 2 options

In this section (see **Figure 61**), users can revisit the default emissions factors and parameters including: emission factor for electricity, loss of electricity during its transportation, emission factor from fuel combustion and emission factor from solid biofuels combustion.

Figure 61. Tier 2 approach for energy consumption



9.2. ENERGY CONSUMPTION (electricity, fuel...) except for irrigation, i.e. see next section — Back

Description and unit to report		Unit	Default	Tier 2	Source of Emission Factor	
Electricity						
Emission factor for the selected country		tCO2/MWh/yr	0,000		UNFCC - Operational Margin	
Losses of electricity during transportation		%	10%			
User defined (Tier 2)		tCO2/MWh/yr				
Losses of electricity during transportation		%	10%			
Liquid or gaseous						
Please select		tCO2-e/m3	0,000			
Please select		tCO2-e/m3	0,000			
Please select		tCO2-e/m3	0,000			
Please select		tCO2-e/m3	0,000			
User defined (Tier 2)		tCO2-e/m3				
Solid						
Wood		tCO2-e/t d.m. Wood	0,178		Account for CO2 emissions?	No
Peat		tCO2-e/t d.m. Peat	0,104		Account for CO2 emissions?	No
Charcoal		tCO2-e/t d.m. Charcoal	0,209		Account for CO2 emissions?	No
Peat (from peatlands)		tCO2-e/t d.m. Peat	0,104			
User defined (Tier 2)		tCO2-e/t d.m.				

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

10.3 Irrigation systems

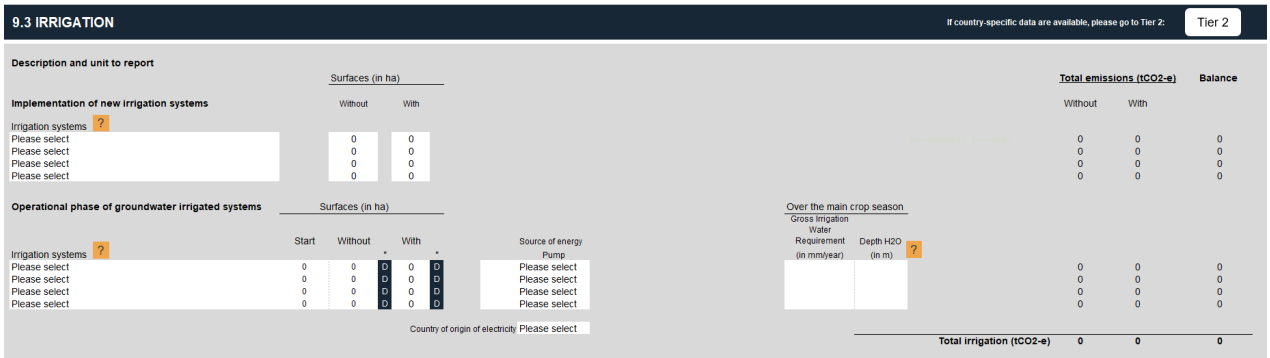
10.3.1 Methodology

Materials used to develop this submodule come from Lal (2004) and UNFCCC (2021). It estimates GHG emissions from the installation of new irrigation systems, as well as emissions linked to energy use from the operational phase of irrigation systems. The adopted definitions have been developed following to expert consultations starting from Lal (2004) irrigation categories.

10.3.2 Greenhouse gas emissions from the installation of irrigation systems

GHG emissions from the installation of new irrigation systems are calculated using the generic methodology for non-CO_2 emissions (see Equation 2.6) of IPCC (2019). Users need to provide the type of the newly implemented irrigation system as well as the area concerned by the installation for all the scenarios (see the upper block of **Figure 62**). The default emission factors are reported in **Table 171** (Lal, 2004).

Figure 62. Irrigation system in EX-ACT



9.3 IRRIGATION — If country-specific data are available, please go to Tier 2: Tier 2

Description and unit to report	Surfaces (in ha) Without	Surfaces (in ha) With	Total emissions (tCO2-e) Without	Total emissions (tCO2-e) With	Balance
Implementation of new irrigation systems					
Irrigation systems ?					
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0

Operational phase of groundwater irrigated systems	Start	Surfaces (in ha) Without		Surfaces (in ha) With		Source of energy	Over the main crop season: Gross Irrigation Water Requirement (in mm/year)	Depth H2O (in m) ?	Without	With	Balance
Irrigation systems ?											
Please select	0	0	D	0	D	Please select			0	0	0
Please select	0	0	D	0	D	Please select			0	0	0
Please select	0	0	D	0	D	Please select			0	0	0
Please select	0	0	D	0	D	Please select			0	0	0
						Country of origin of electricity: Please select		Total irrigation (tCO2-e)	0	0	0

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Table 171. Emission factor, in kgCO_2-e/ha, for installation of irrigation systems

Irrigation systems	Definition	Installation energy
Surface without irrigation runoff return system (IRRS)	Surface irrigation without an irrigation runoff return system	34.47
Surface with IRRS	Surface irrigation with an irrigation runoff return system	90.20
Solid set sprinkle	Irrigation with vertical tubes that are stationary for the duration of the irrigation season	444.77
Permanent sprinkle	Irrigation with vertical tubes that cannot be moved from the moment they are installed	130.17
Hand moved sprinkle	Irrigation with sprinklers that can be displaced throughout the irrigation season. This kind of sprinkler is usually used for smaller crop extensions as the continuous movement implies a high rate of labour	59.77
Solid roll sprinkle	A sprinkler line, mounted on wheels, irrigating in place. A mover unit powered by a small engine is located in the centre of the line. The sprinkler line is connected to a supply or mainline by a flexible hose	85.43
Centre-pivot sprinkle	Overhead sprinkler irrigation consisting of several segments of pipe, with sprinklers positioned along their length, joined together and supported by trusses, and mounted on wheeled towers. The machine moves in a circular pattern and is fed with water from the pivot point at the centre of the circle	79.20
Traveller sprinkler	Fully movable irrigation system. It does not entail the construction of any stable irrigation infrastructure on the field	61.97
Trickle	High precision, high efficiency drip irrigation	311.30

Source: Authors' own elaboration based on Table 3 of Lal, R. 2004. Carbon Emission from Farm Operations. *Environment International,* 30: 981– 990.

10.3.3 Greenhouse gas emissions from the operational phase of irrigation systems

The operational phase of groundwater pumping systems encompasses the processes involved in the abstraction, conveyance and application of water. Several factors impact the amount of energy required to pump water off the ground, such as the volume of water needed (crop water requirement), the total dynamic head (TDH), the flow rate, the on-farm irrigation system efficiency, the conveyance efficiency, and the pumping system (motor and pump) efficiency, among others. The main components of energy use associated with irrigated agriculture are primarily related to processes required to apply water to crops in the field by lifting, conveying, and in some cases, pressurizing it (Rothausen and Conway, 2011).

The total energy required (ER) for an irrigation system is estimated in Equation 32 as follows.

$$ER = \frac{ERh \times GIWR \times (PR + D)}{Efficiency}$$

(Eq. 32)[34]

Where:

ER = energy required to pump water from groundwater well, in MWh per total growing season per hectare;

ERh = energy required to lift 1 m^3 of water over 1 m height, in MWh or m^3 per metre;

GIWR = gross irrigation water requirement, in m3/ha/growing season;

PR = pressure requirement of the irrigation system including energy losses, in metres head;

D = depth of the well, in metres;

Efficiency = efficiency of the pumping system, in percentage.

Once the energy required is calculated, it is possible to estimate the GHG emissions:

$$GHG = ER \times EF \times S$$

(Eq. 33)

Where:

GHG = the GHG emissions from groundwater pumping, in tCO_2eq over a growing period;

ER = energy requirement, in MWh per growing season per ha;

EF = emission Factor of energy or fuel used, in tCO_2-e/MWh or tCO_2-e/m_3, respectively;

S = crop's area under groundwater irrigation, in ha.

Fossil fuels emission factors are based on IPCC (2006), while the emission factors for the electricity grid are country-specific based (EIA, 2007; IGES, 2019) and have been reported in the previous section (see **Tables 169** and **170**).

To trigger the calculations, users need to provide the type of irrigation system and the area concerned (in ha) for all the scenarios (see bottom block of **Figure 62**).

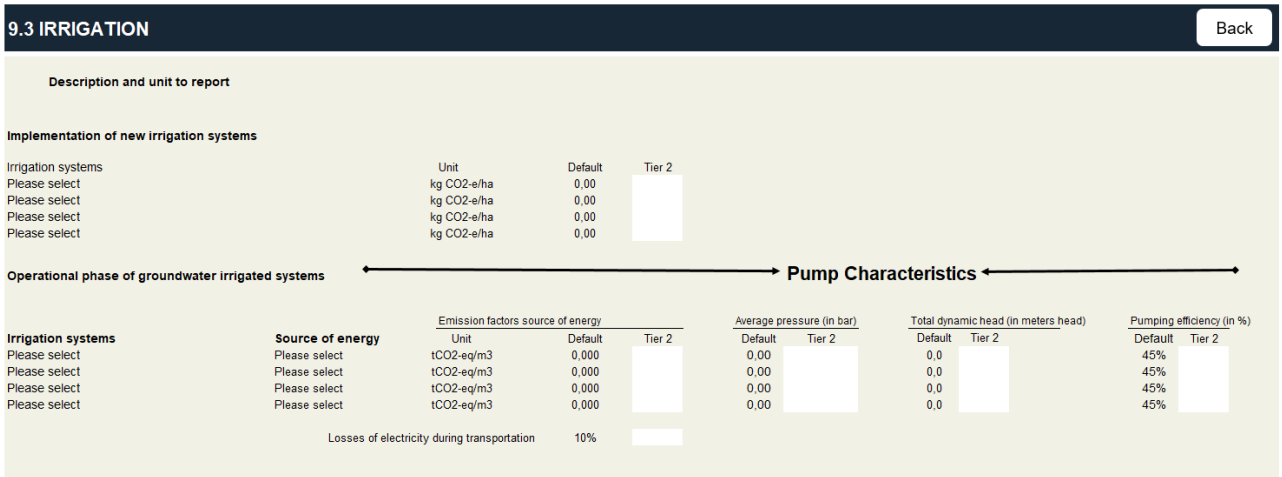
10.3.4 Tier 2 options

Installation of irrigation systems

Users can revisit default emissions factors associated with the installation of irrigation systems (see **Figure 63**).

[34] Equation from Rothausen and Conway (2011)

Figure 63. Tier 2 section for installation of irrigation systems



9.3 IRRIGATION — Back

Description and unit to report

Implementation of new irrigation systems

Irrigation systems	Unit	Default	Tier 2
Please select	kg CO2-e/ha	0,00	
Please select	kg CO2-e/ha	0,00	
Please select	kg CO2-e/ha	0,00	
Please select	kg CO2-e/ha	0,00	

Operational phase of groundwater irrigated systems — Pump Characteristics

Irrigation systems	Source of energy	Emission factors source of energy: Unit	Default	Tier 2	Average pressure (in bar): Default	Tier 2	Total dynamic head (in meters head): Default	Tier 2	Pumping efficiency (in %): Default	Tier 2
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	

Losses of electricity during transportation 10%

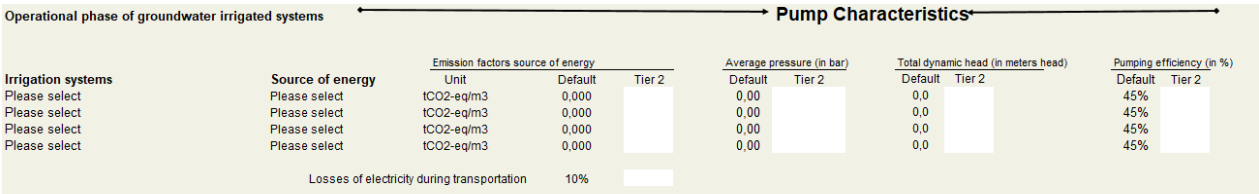
Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

Use of irrigation systems

The user can change emission factor of source of energy and also irrigation system characteristics including: the average pressure (bar) for the irrigation system installed, total head dynamic and the irrigation pumping equipment efficiency (see **Figure 64**).

Figure 64. Operational phase of irrigation system Tier 2



Operational phase of groundwater irrigated systems — Pump Characteristics

Irrigation systems	Source of energy	Emission factors source of energy: Unit	Default	Tier 2	Average pressure (in bar): Default	Tier 2	Total dynamic head (in meters head): Default	Tier 2	Pumping efficiency (in %): Default	Tier 2
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	
Please select	Please select	tCO2-eq/m3	0,000		0,00		0,0		45%	

Losses of electricity during transportation 10%

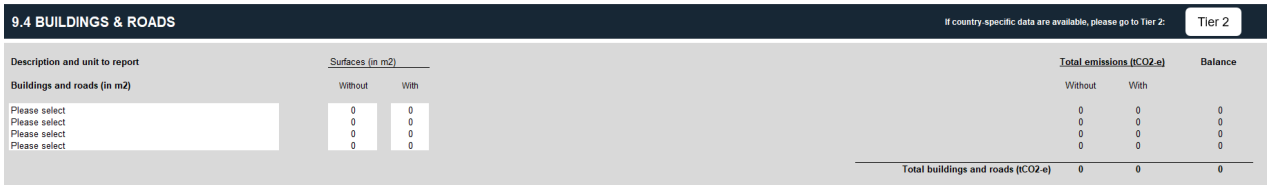
Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

10.4 Buildings and roads

This sub-module accounts for GHG emissions associated with construction of buildings and roads (see **Figure 65**). Default values are reported in **Table 172**.

Figure 65. Buildings and roads



9.4 BUILDINGS & ROADS — If country-specific data are available, please go to Tier 2: Tier 2

Description and unit to report: Buildings and roads (in m2)	Surfaces (in m2): Without	With	Total emissions (tCO2-e): Without	With	Balance
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Total buildings and roads (tCO2-e)			0	0	0

Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

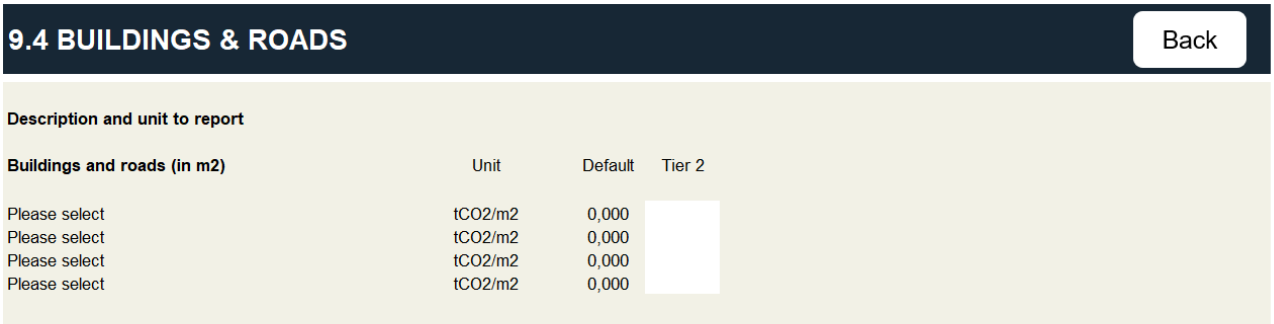
Table 172. Emission factor for construction of buildings and roads, in tCO_2-e/m_2

Type	Emission factor
Housing (concrete)	436
Agricultural buildings (concrete)	656
Agricultural buildings (metal)	220
Industrial buildings (concrete)	825
Industrial buildings (metal)	275
Garage (concrete)	656
Garage (metal)	220
Offices (concrete)	650
Offices (metal)	158
Road (bitumen)	18
Road (asphalt)	73
Road (reinforced concrete)	86
Road rehabilitated (pavement)	9
Food sales (retail or wholesale)	515.9
Food service (restaurants)	517.4
Warehouse and storage	1 568.3
Education	440
Health care (metal)	440

Source: Authors' own elaboration based on ADEME. 2020. *Resource centre for greenhouse gas accounting*. Angers, France. Cited 26 June 2020. www.bilans-ges.ademe.fr; Bresinger, M. 2012. *Greenhouse Gas Assessment Emissions Methodology*. Technical Note IDB–TN–455. Washington, DC, Inter–American Development Bank.

Users should provide the type of infrastructures and their surface for all the scenarios. All default emission factors can be changed in the Tier 2 section (see **Figure 66**).

Figure 66. Tier 2 section for buildings and roads



Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

11.1 General results for mineral and organic soils

The results module summarises all the calculations carried out throughout the tool (see **Figure 67**). It starts with a brief summary of the project specifications as provided in the description module (name of the appraised project, its duration, the continent, the dominant climate, and the soil chosen by the user). It also provides the total area of the activities accounted for in the tools.

Figure 67. Greenhouse gas accounting results in EX-ACT

DETAILED RESULTS

Project name		Project duration (in years)		Total area (ha)		Global warming potential	
Continent	Please select	Implementation	0	Mineral soil	0	CO_2	1
Country	Please select	Capitalization	0	Organic soil	0	CH_4	34
Climate	Please select	Period analysis	0	Waterbodies	0	N_2O	298
Moisture	Please select						

Tier 2 Annual emissions

PROJECT COMPONENTS		GROSS FLUXES (In tCO_2-e over the whole period analysis) WITHOUT	WITH	BALANCE	SHARE PER GHG OF THE BALANCE (In tCO_2-e over the whole period analysis) CO_2 BIOMASS	CO_2 SOIL	N_2O	CH_4	ALL NON-AFOLU EMISSIONS*	AVERAGE ANNUAL EMISSIONS (In tCO_2-e/yr) WITHOUT	WITH	BALANCE
Land use changes	Deforestation	0	0	0	0	0	0	0		0	0	0
	Afforestation	0	0	0	0	0	0	0		0	0	0
	Other land-use	0	0	0	0	0	0	0		0	0	0
Cropland	Annual	0	0	0	0	0	0	0		0	0	0
	Perennial	0	0	0	0	0	0	0		0	0	0
	Flooded rice	0	0	0	0	0	0	0		0	0	0
Grasslands & Livestock	Grasslands	0	0	0	0	0	0	0		0	0	0
	Livestock	0	0	0			0	0		0	0	0
Forest mngt.		0	0	0	0	0	0	0		0	0	0
Inland wetlands		0	0	0	0	0	0	0		0	0	0
Coastal wetlands		0	0	0	0	0	0	0	0	0	0	0
Fisheries and aquaculture		0	0	0	0	0	0	0	0			
Inputs & Invest.		0	0	0		0	0		0	0	0	0
Total emissions, tCO_2-e		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total emissions, tCO_2-e/ha		**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**			
Total emissions, tCO_2-e/ha/yr		**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**			

+ = Source / - = Sink

Results presented here include GHG fluxes on mineral and organic soils

See further down for detailed results on organic soils

* Includes fisheries, acquaculture and inputs & investments that are not included in the AFOLU definition.

Uncertainty level	tCO2-e/yr	Percent
Without	0	0%
With	0	0%
Balance	0	0%

DETAILED RESULTS

Project name		Project duration (in years)		Total area (ha)		Global warming potential	
Continent	Central Africa	Implementation	5	Mineral soil	19.522	CO_2	1
Country	Chad	Capitalization	15	Organic soil	0	CH_4	34
Climate	Tropical	Period analysis	20	Waterbodies	0	N_2O	298
Moisture	Moist						

Tier 2 Annual emissions

PROJECT COMPONENTS		GROSS FLUXES (In tCO_2-e over the whole period analysis) WITHOUT	WITH	BALANCE	SHARE PER GHG OF THE BALANCE (In tCO_2-e over the whole period analysis) CO_2 BIOMASS	CO_2 SOIL	N_2O	CH_4	ALL NON-AFOLU EMISSIONS*	AVERAGE ANNUAL EMISSIONS (In tCO_2-e/yr) WITHOUT	WITH	BALANCE
Land use changes	Deforestation	8.267.688	6.197.272	-2.070.415	-1.906.264	-75.869	-18.255	-70.027		413.384	309.864	-103.521
	Afforestation	0	0	0	0	0	0	0		0	0	0
	Other land-use	0	6.514	6.514	0	6.488	26	0		0	326	326
Cropland	Annual	-7.386	-923	6.462	0	6.462	0	0		-369	-46	323
	Perennial	0	0	0	0	0	0	0		0	0	0
	Flooded rice	0	0	0	0	0	0	0		0	0	0
Grasslands & Livestock	Grasslands	0	0	0	0	0	0	0		0	0	0
	Livestock	0	0	0			0	0		0	0	0
Forest mngt.		0	0	0	0	0	0	0		0	0	0
Inland wetlands		0	0	0	0	0	0	0		0	0	0
Coastal wetlands		67.217	60.864	-6.353	-8.238	1.885	0	0	0	3.361	3.043	-318
Fisheries and aquaculture		0	0	0	0	0	0	0	0			
Inputs & Invest.		0	0	0		0	0		0	0	0	0
Total emissions, tCO_2-e		**8.327.519**	**6.263.728**	**-2.063.791**	**-1.914.502**	**-61.032**	**-18.229**	**-70.027**	**0**	**416.376**	**313.186**	**-103.190**
Total emissions, tCO_2-e/ha		**426,6**	**320,9**	**-105,7**	**-98,1**	**-3,1**	**-0,9**	**-3,6**	**0,0**			
Total emissions, tCO_2-e/ha/yr		**21,3**	**16,0**	**-5,3**	**-4,9**	**-0,2**	**0,0**	**-0,2**	**0,0**			

+ = Source / - = Sink

Results presented here include GHG fluxes on mineral and organic soils

See further down for detailed results on organic soils

* Includes fisheries, acquaculture and inputs & investments that are not included in the AFOLU definition.

Uncertainty level	tCO2-e/yr	Percent
Without	416.376	34%
With	313.186	34%
Balance	-103.190	34%

Note: Screenshots of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

The next block summarizes the GHG fluxes by project component, where the (carbon) balance is the difference of GHG gross fluxes between the with project and the without project scenario in tCO_2-e. Positive numbers represent sources of CO_2-e emission while negative numbers represent sinks. The resulting carbon balance is also decomposed by type of emissions: CO_2 coming from biomass, CO_2 from soil, N_2O, CH_4 and all non AFOLU emissions that regroup all the results that fall out of the standard AFOLU definition adopted by IPCC (i.e. fisheries, inputs and investments).

The summary also reports average annual emissions per scenario and for the carbon balance. The Tier 2 button brings the users to the estimation of the evolution of annual emissions for the implementation and capitalisation phase (see **Figure 68**).

Figure 68. Tier 2 annual emissions for implementation and capitalisation phase

Back to Detailed Results

Annual carbon balance	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Yearly carbon balance	-11.323,10	-22.646,21	-33.969,31	-45.292,41	-56.615,51	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62	-67.938,62
Cumulative carbon balance	-11.323,10	-33.969,31	-67.938,62	-113.231,03	-169.846,54	-237.785,16	-305.723,77	-373.662,39	-441.601,00	-509.539,62	-577.478,23	-645.416,85	-713.355,47	-781.294,08	-849.232,70	-917.171,31	-985.109,93	-1.053.048,54	-1.120.987,16	-1.188.925,78

* Please note the provided annual values are an approximation of the actual annual fluxes

PROJECT COMPONENTS		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Land use changes	Deforestation	-7616,03	-15232,05993	-22848,08989	-30464,11985	-38080,14981	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978	-45696,17978
	Afforestation	-254,70717	-509,4143302	-764,1214952	-1018,82866	-1273,535825	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299	-1528,24299
	Other land-use	-3613,2075	-7226,415079	-10839,62262	-14452,83016	-18066,0377	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524	-21679,24524
Cropland	Annual	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Flooded rice	1683,7615	3367,522984	5051,284476	6735,045968	8418,807461	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895	10102,56895
Grasslands & Livestock	Grasslands	-1522,9194	-3045,838889	-4568,758333	-6091,677778	-7614,597222	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667	-9137,516667
	Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Forest mngt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Inland wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coastal wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fisheries and aquaculture		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inputs & Invest.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

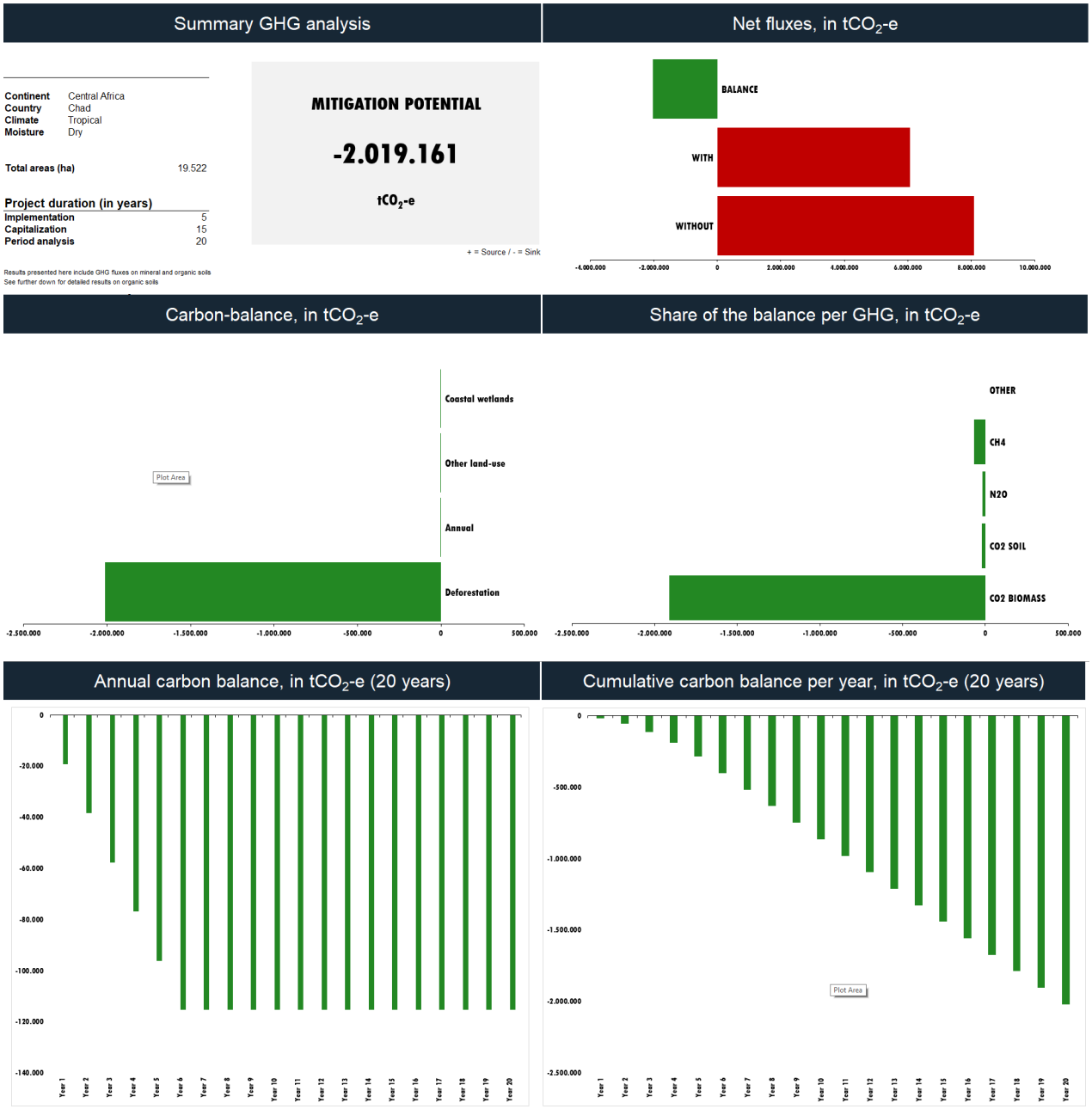
Note: Screenshot of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

11.2 Graphical representation of the project's impacts for mineral and organic soils

In addition to the detailed results, EX-ACT provides a set of graphs on: (i) carbon-balance net fluxes over the whole period analysis, in tCO_2-e; (ii) the carbon-balance per component over the whole period analysis, in tCO_2-e; (iii) the share of the balance per GHG (CO_2, N_2O, CH_4), in tCO2-e, (iv) the annual carbon balance over the period analysis (limited to 20 years), in tCO_2-e; and (v) the cumulative yearly carbon balance over the period analysis (limited to 20 years), in tCO_2-e, (see **Figure 69**).

Figure 69. Graphical representation of the project's impacts



Note: Screenshots of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

11.3 Results for organic soils

Results in EX-ACT have been further disaggregated to highlight GHG emissions, their sources from drainage, rewetting and fire, and level of uncertainty for organic soils management. Graphical representations are described as: (i) the share of the balance per GHG (CO_2, N_2O, CH_4) and their source, in tCO_2-e; (ii) carbon-balance net fluxes over the whole period analysis, in tCO_2-e; (iii) the gross fluxes for the without project situation over the whole period analysis, in tCO_2-e; and (iv) the gross fluxes for the with project situation over the whole period analysis, in tCO_2-e (see **Figure 70**).

Figure 70. General results from management on organic soils

DETAILED RESULTS ORGANIC SOILS

GROSS FLUXES

In tCO_2-e over the whole period analysis

PROJECT COMPONENTS	WITHOUT	WITH	BALANCE
Deforestation	1.103.813	65.548	-1.038.264
Forest degradation	0	0	0
Af/reforestation	86.283	-31.001	-117.283
Non-forest land-use change	0	0	0
Non-forest land management	0	0	0
Peat extraction	0	0	0
Total emissions, tCO_2-e	**1.190.095**	**34.548**	**-1.155.548**
Total emissions, tCO_2-e/ha	**793,4**	**23,0**	**-770,4**
Total emissions, tCO_2-e/ha/yr	**39,7**	**1,2**	**-38,5**

SHARE PER GHG OF THE BALANCE

In tCO_2-e over the whole period analysis

CO_2 BIOMASS	CO_2 SOIL	N_2O SOIL	CH_4 SOIL	FIRE
-99.540	-950.950	-40.975	28.362	-7.886
0	0	0	0	0
-70.742	-45.911	-2.049	1.418	0
0	0	0	0	0
0	0	0	0	0
	0	0	0	0
-170.281	**-996.861**	**-43.024**	**29.780**	**-7.886**
-113,5	**-664,6**	**-28,7**	**19,9**	**-5,3**
-5,7	**-33,2**	**-1,4**	**1,0**	**-0,3**

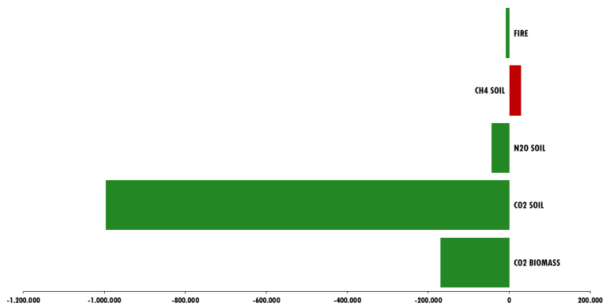
AVERAGE ANNUAL EMISSIONS

In tCO_2-e/yr

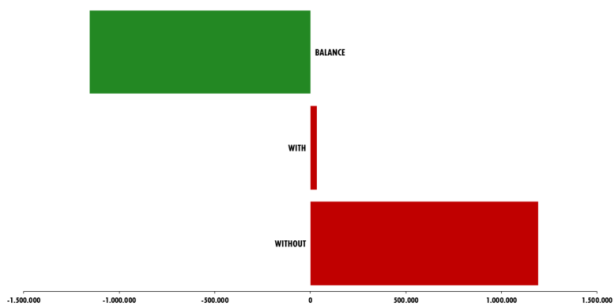
WITHOUT	WITH	BALANCE
55.191	3.277	-51.913
0	0	0
4.314	-1.550	-5.864
0	0	0
0	0	0
0	0	0
59.505	**1.727**	**-57.777**

Uncertainty level	tCO2-e/yr	Percent
Without	578.126	49%
With	67.808	44%
Balance	594.968	48%

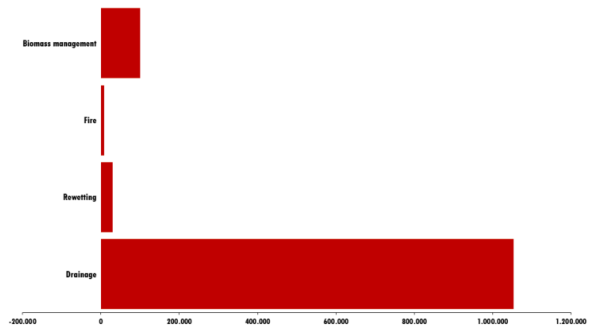
Share of the balance per GHG, in tCO_2-e



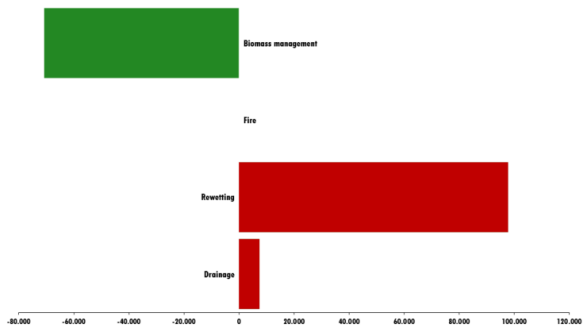
Share of the balance per activities, in tCO_2-e



Gross Fluxes Without Project, in tCO_2-e



Gross Fluxes With Project, in tCO_2-e



Note: Screenshots of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT).* Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

11.4 Estimations of the uncertainty level

The level of uncertainty is provided below the detailed results table (see **Figure 71**). EX-ACT calculations are based on either default coefficients (Tier 1 approach) or values provided by the user (Tier 2 approach), and it is extremely difficult to provide uncertainties associated with the final EX-ACT results. Most default coefficients are associated with low to extremely high uncertainties as reported in the sources of data (for example, IPCC provides the uncertainty levels for all the parameters used in EX-ACT). EX-ACT tries to indicate the uncertainty associated with the calculations by combining the known uncertainties of various parameters used into a single number. As a result, the uncertainty presented in EX-ACT is not a statistical uncertainty, but only a general indication of the reliability of the final results in terms of parameters used in the calculations. The uncertainty has been categorised into low uncertainty -10 percent; moderate -20 percent; high -30 percent; and very high -50 percent (see **Figure 71**). Shifting from Tier 1 to Tier 2 decreases the category of uncertainties, as Tier 2 uses more precise values.

Figure 71. Estimation of the uncertainty level

Uncertainties

Notes about UNCERTAINTIES

EX-ACT calculations are either on default coefficients (Tier 1 approach) or values provided by the user (Tier 2 approach). A single project may use a combination of Tier 1 and Tier 2 approaches. It is thus extremely difficult to provide uncertainties associated with the values provided by EX-ACT. Most default coefficients are associated with large to extremely large uncertainties. However, as it is important to have an idea of the uncertainties the table below provide indication of the minimum level of uncertainty user may expect. The following representation of the level of uncertainties was used:

		%
*	Low uncertainty	10
**	Moderate uncertainties	20
***	High uncertainties	33
****	Very high uncertainty	50

Without | With

Indication of the level of uncertainty

Components of the project	CO2 BIOMASS	CO2 SOIL	N2O	CH4	OTHER	CO2 BIOMASS	CO2 SOIL	N2O	CH4	OTHER	CO2 BIOMASS	CO2 SOIL	N2O	CH4	OTHER
Deforestation	***	****	**	**		46,712	65	0	0		33	50	0	0	
Forest degradation	***	****	**	**		0	0	0	0		0	0	0	0	
Afforestation and reforestation	***	****	**	**		20,389	8,844	0	0		33	50	0	0	
Non forest land use change	***	****	**	**		1,412	387	0	0		33	50	20	0	
Agriculture															
Annual	**	****	**	**		0	176	13	57		0	50	20	20	
Perennial	***	****	**	**		2,576	1,499	0	0		33	50	20	0	
Rice	**	****	**	**		0	0	0	0		0	0	0	0	
Grasslands	**	****	**	**		0	3,227	0	0		0	50	0	0	
Livestock			***	***				1,331	160				33	33	
Coastal wetlands & Aqua	***	****	****	****		3,142	9,269	6,331	0		33	50	157	0	
Waterbodies				****					0					0	
Inland wetlands															
Deforestation	***	****	****	****	****	104,834	434,720	63	1,904	0	33	50	50	50	0
Forest Degradation	***	***	****	****	***	0	0	0	0	0	0	0	0	0	0
Af/reforestation	***	****	****	****	****	176,111	329,120	17,982	27,073	0	33	50	50	50	0
Non-forest LUC	***	****	****	****	****	0	0	0	0	0	0	0	0	0	0
Non-forest land mngt		****	****	****	****		0	0	0	0		0	0	0	0
Peat extraction		****	****	****			0	0	0			0	0	0	
Other GHG emissions															
Agricultural inputs		***	***		***		0	0		226		0	0		33
Fisheries & Feeds					***					0					0
Energy use					***					0					0
Irrigation					***					0					0
Infrastructures					***					0					0
						Total uncertainty				**1,197,624**	**Global level of uncertainty (%)**				**45%**

Notes: Screenshot of the EX-ACT tool. This worksheet is not visible to the users. The same methodology is applied for the situation with and without project.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

11.5 Matrix of changes

As part of the results, the matrix of changes allows users to track land use and land use changes among the projects activities. It also allows the users to ensure the consistency of gross fluxes between the without and with project scenarios (see **Figure 72**). The matrix is provided for the mineral, organic soils and waterbodies:[35] i.e. flooded land on mineral soils (see "Inland wetlands" section for further details).

Figure 72. Detailed matrix of land use and land use changes in EX-ACT

DETAILED MATRIX OF CHANGES FOR MINERAL SOILS

WITHOUT PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest	250	0	0	0	0	0	750	**1.000**
Annual cropland	0	0	0	0	0	0	500	**500**
Agroforestry	0	0	100	0	0	0	0	**100**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	5.000	0	0	**5.000**
Degraded land	0	0	0	0	0	0	0	**0**
Other land	0	0	0	0	0	0	0	**0**
Total area without project (ha)	**250**	**0**	**100**	**0**	**5.000**	**0**	**1.250**	**6.600**

Total area (ha)	7.900
Mineral soil	6.600
Organic soil	1.300
Waterbodies	0

WITH PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest	900	0	0	0	0	0	100	**1.000**
Annual cropland	0	500	0	0	0	0	0	**500**
Agroforestry	0	0	100	0	0	0	0	**100**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	5.000	0	0	**5.000**
Degraded land	0	0	0	0	0	0	0	**0**
Other land	0	0	0	0	0	0	0	**0**
Total area with project (ha)	**900**	**500**	**100**	**0**	**5.000**	**0**	**100**	**6.600**

DETAILED MATRIX OF CHANGES FOR ORGANIC SOILS

WITHOUT PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest land	150	0	0	0	0	0	0	**150**
Annual cropland	0	500	0	0	0	0	0	**500**
Agroforestry	0	0	0	0	0	0	0	**0**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	0	0	0	**0**
Degraded	0	0	0	0	0	0	0	**0**
Other land	0	650	0	0	0	0	0	**650**
Total area without project (ha)	**150**	**1.150**	**0**	**0**	**0**	**0**	**0**	**1.300**

WITH PROJECT	Forest	Annual	Perennial	Flooded rice	Grassland	Degraded land	Other land	Total area (ha)
Forest land	150	0	0	0	0	0	0	**150**
Annual cropland	500	0	0	0	0	0	0	**500**
Agroforestry	0	0	0	0	0	0	0	**0**
Flooded rice	0	0	0	0	0	0	0	**0**
Grassland	0	0	0	0	0	0	0	**0**
Degraded	0	0	0	0	0	0	0	**0**
Other land	0	0	0	0	0	0	650	**650**
Total area with project (ha)	**650**	**0**	**0**	**0**	**0**	**0**	**650**	**1.300**

Note: Screenshots of the EX-ACT tool.

Source: FAO. 2022. *EX-Ante Carbon-balance Tool (EX-ACT)*. Version 9.3. Rome. Cited 15 March 2022. www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act

[35] Waterbodies are accounted for within "Other land (non-vegetated)".

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Annex 1. United Nations countries list and their geographical repartition in EX-ACT

Table A1. Geographical distribution of countries within EX-ACT

EX-ACT geographical division	Affiliated countries
Eastern Africa	British Indian Ocean Territory; Burundi; Comoros; Djibouti; Eritrea; Ethiopia; French Southern Territories; Kenya; Madagascar; Malawi; Mauritius; Mayotte; Mozambique; Réunion; Rwanda; Seychelles; Somalia; South Sudan; Uganda; United Republic of Tanzania; Zambia; Zimbabwe
Central Africa	Angola; Cameroon; Central African Republic; Chad; Congo; Democratic Republic of the Congo; Equatorial Guinea; Gabon; Sao Tome and Principe
Northern Africa	Algeria; Egypt; Libya; Morocco; Sudan; Tunisia; Western Sahara
Southern Africa	Botswana; Eswatini; Lesotho; Namibia; South Africa
Western Africa	Benin; Burkina Faso; Cabo Verde; Côte d'Ivoire; Gambia; Ghana; Guinea; Guinea- Bissau; Liberia; Mali; Mauritania; Niger; Nigeria; Saint Helena; Senegal; Sierra Leone; Togo
Central Asia	Kazakhstan; Kyrgyzstan; Tajikistan; Turkmenistan; Uzbekistan
Eastern Asia	China; China, Hong Kong Special Administrative Region; China, Macao Special Administrative Region; Democratic People's Republic of Korea; Japan; Mongolia; Republic of Korea
South-Eastern Asia	Brunei Darussalam; Cambodia; Indonesia; Lao People's Democratic Republic; Malaysia; Myanmar; Philippines; Singapore; Thailand; Timor-Leste; Viet Nam
Southern Asia	Afghanistan; Bangladesh; Bhutan; India; Iran (Islamic Republic of); Maldives; Nepal; Pakistan; Sri Lanka
Western Asia	Armenia; Azerbaijan; Bahrain; Cyprus; Georgia; Iraq; Israel; Jordan; Kuwait; Lebanon; Oman; Qatar; Palestine: Saudi Arabia; Syrian Arab Republic; Turkey; United Arab Emirates; Yemen
Europe	Åland Islands; Albania; Andorra; Austria; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; Croatia; Czechia; Denmark; Estonia; Faroe Islands; Finland; France; Germany; Gibraltar; Greece; Guernsey; Guernsey, Bailiwick of (Sark); Holy See; Hungary; Iceland; Ireland; Isle of Man; Italy; Jersey; Latvia; Liechtenstein; Lithuania; Luxembourg; Malta; Monaco; Montenegro; Netherlands; North Macedonia; Norway; Serbia; Slovakia; Slovenia; Spain; Svalbard and Jan Mayen Islands; Sweden; Switzerland; Ukraine; United Kingdom of Great Britain and Northern Ireland
Oceania	American Samoa; Australia; Christmas Island; Cocos (Keeling) Islands; Cook Islands; Fiji; French Polynesia; Guam; Heard and McDonald Islands; Kiribati; Marshall Islands; Micronesia (Federated States of); Nauru; New Caledonia; New Zealand; Niue; Norfolk Island; Northern Mariana Islands; Palau; Papua New Guinea; Pitcairn; Samoa; Solomon Islands; Tokelau; Tonga; Tuvalu; United States Minor Outlying Islands; Vanuatu; Wallis and Futuna Islands
North America	Bermuda; Canada; Greenland; Saint Pierre and Miquelon; United States of America
South America	Argentina; Bolivia; Bouvet Island; Brazil; Chile; Colombia; Ecuador; Falkland Islands (Malvinas); French Guiana; Guyana; Paraguay; Peru; South Georgia and the South Sandwich Islands; Suriname; Uruguay; Venezuela (Bolivarian Republic of)
Central America	Belize; Costa Rica; El Salvador; Guatemala; Honduras; Mexico; Nicaragua; Panama
Caribbean	Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; Bonaire, Sint Eustatius and Saba; British Virgin Islands; Cayman Islands; Cuba; Curaçao; Dominica; Dominican Republic; Grenada; Guadeloupe; Haiti; Jamaica; Martinique; Montserrat; Puerto Rico; Saint Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French Part); Saint Vincent and the Grenadines; Sint Maarten (Dutch part); Trinidad and Tobago; Turks and Caicos Islands; United States Virgin Islands

Source: Author's own elaboration based on United Nations Statistics Division. 2022. *Methodology – Standard country or area codes for statistical use (M49)*. Cited 25 March 2022. https://unstats.un.org/unsd/methodology/m49

Table A2. Geographical distribution of countries within EX-ACT for the livestock module

Geographical division for livestock	Affiliated countries for the livestock module
East and South-East Asia	American Samoa; Brunei Darussalam; Cambodia; China; China, Hong Kong Special Administrative Region; China, Macao Special Administrative Region; Christmas Island; Cocos (Keeling) Islands; Cook Islands; Democratic People's Republic of Korea; Fiji; French Polynesia; Guam; Heard and McDonald Islands; Indonesia; Japan; Kiribati; Lao People's Democratic Republic; Malaysia; Marshall Islands; Micronesia (Federated States of); Mongolia; Myanmar; Nauru; New Caledonia; Niue; Norfolk Island; Northern Mariana Islands; Palau; Papua New Guinea; Philippines; Republic of Korea; Samoa; Singapore; Solomon Islands; Thailand; Timor-Leste; Tokelau; Tonga; Tuvalu; United States Minor Outlying Islands; Vanuatu; Viet Nam; Wallis and Futuna Islands
Eastern Europe	Belarus; Bulgaria; Czechia; Hungary; Poland; Republic of Moldova; Romania; Slovakia; Ukraine
Latin America and the Caribbean	Anguilla; Antigua and Barbuda; Argentina; Aruba; Bahamas; Barbados; Belize; Bolivia; Bonaire, Sint Eustatius and Saba; Bouvet Island; Brazil; British Virgin Islands; Cayman Islands; Chile; Colombia; Costa Rica; Cuba; Curaçao; Dominica; Dominican Republic; Ecuador; El Salvador; Falkland Islands (Malvinas); French Guiana; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Honduras; Jamaica; Martinique; Mexico; Montserrat; Nicaragua; Panama; Paraguay; Peru; Puerto Rico; Saint Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French Part); Saint Vincent and the Grenadines; Sint Maarten (Dutch part); South Georgia and the South Sandwich Islands; Suriname; Trinidad and Tobago; Turks and Caicos Islands; United States Virgin Islands; Uruguay; Venezuela (Bolivarian Republic of)
NENA/Middle East	Algeria; Armenia; Azerbaijan; Bahrain; Cyprus; Egypt; Georgia; Iraq; Israel; Jordan; Kazakhstan; Kuwait; Kyrgyzstan; Lebanon; Libya; Morocco; Oman; Qatar; Palestine: Saudi Arabia; South Sudan; Sudan; Syrian Arab Republic; Tajikistan; Tunisia; Turkey; Turkmenistan; United Arab Emirates; Uzbekistan; Western Sahara; Yemen
North America	Bermuda; Canada; Greenland; Saint Pierre and Miquelon; United States of America
Oceania	Australia, New Zealand
South Asia	Afghanistan; Bangladesh; Bhutan; British Indian Ocean Territory; India; Iran (Islamic Republic of); Maldives; Nepal; Pakistan; Pitcairn; Sri Lanka
Sub-Saharan Africa	Angola; Benin, Botswana; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Djibouti; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; French Southern Territories; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mayotte; Mozambique; Namibia; Niger; Nigeria; Réunion; Rwanda; Saint Helena; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; Somalia; South Africa; Togo; Uganda; United Republic of Tanzania; Zambia; Zimbabwe
Southern Asia	Afghanistan; Bangladesh; Bhutan; India; Iran (Islamic Republic of); Maldives; Nepal; Pakistan; Sri Lanka
Western Europe	Åland Islands; Albania; Andorra; Austria; Belgium; Bosnia and Herzegovina; Croatia; Denmark; Estonia; Faroe Islands; Finland; France; Germany; Gibraltar; Greece; Guernsey; Guernsey, Bailiwick of (Sark); Holy See; Iceland; Ireland; Isle of Man; Italy; Jersey; Latvia; Liechtenstein; Lithuania; Luxembourg; Malta; Monaco; Montenegro; Netherlands; North Macedonia; Norway; Portugal; San Marino; Serbia; Slovenia; Spain; Svalbard and Jan Mayen Islands; Sweden; Switzerland; United Kingdom of Great Britain and Northern Ireland
South America	Argentina; Bolivia; Bouvet Island; Brazil; Chile; Colombia; Ecuador; Falkland Islands (Malvinas); French Guiana; Guyana; Paraguay; Peru; South Georgia and the South Sandwich Islands; Suriname; Uruguay; Venezuela (Bolivarian Republic of)
Central America	Belize; Costa Rica; El Salvador; Guatemala; Honduras; Mexico; Nicaragua; Panama
Caribbean	Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; Bonaire, Sint Eustatius and Saba; British Virgin Islands; Cayman Islands; Cuba; Curaçao; Dominica; Dominican Republic; Grenada; Guadeloupe; Haiti; Jamaica; Martinique; Montserrat; Puerto Rico; Saint Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French Part); Saint Vincent and the Grenadines; Sint Maarten (Dutch part); Trinidad and Tobago; Turks and Caicos Islands; United States Virgin Islands

Source: Author's own elaboration based on FAO. 2018. *Global Livestock Environmental Assessment Model*. Rome, FAO.

EX-ANTE CARBON-BALANCE TOOL [EX-ACT]

The EX-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO providing estimates of the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance. The tool helps project designers estimate and prioritize project activities with high benefits in terms of economic and climate change mitigation, and it helps decision-makers to decide on the right course to mitigate climate change in agriculture and forestry and to enhance environmental services.

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