CHAPTER 10.
Land management production emissions

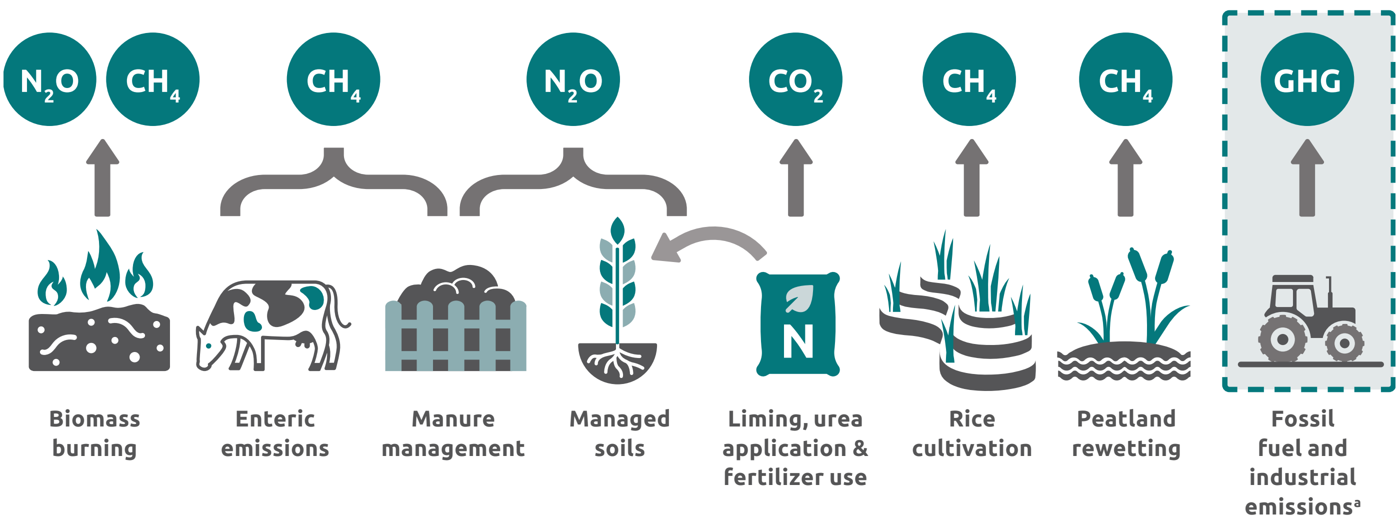
This chapter provides requirements and recommendations on accounting for GHG emissions from land management production activities across land uses from both a scope 1 and scope 3 perspective.

10.1 Overview

Land management production emissions include methane (CH_4), nitrous oxide (N_2O), and non-biogenic CO_2 emissions that occur due to recurring agricultural production and other land management actions (Figure 10.1). Together, these sources of emissions make up approximately 11 percent of annual global GHG emissions from all human activities.[1]

Companies are required to report land management production GHG emissions from all sources (Requirement 16). Emissions from on-site energy and fuel use or that occur in the life cycle of products used as inputs to production activities must also be accounted for (under "fossil fuel and industrial emissions" where data permit, or under "land management production emissions" if not). For transparency, companies must disclose whether these emissions are reported in the inventory as "fossil fuel and industrial emissions" or "land management production emissions."

Figure 10.1 Land management production emission sources



Note: a. Companies shall disclose whether emissions from on-site fuel and energy consumption, fuel combustion, air-conditioning and refrigerant use, on-site waste or wastewater management, and indirect emissions from purchased energy associated with land management are reported as land emissions or fossil and industrial emissions.

10.2 Requirements

10.2.1 Accounting requirements

REQUIREMENT 16:

Land management production emissions accounting

Companies **shall** account for land management production emissions according to the following requirements:

- **Emissions sources**: Companies **shall** account for land management production emissions from the following sources:
  - CH_4 and N_2O emissions from livestock, including emissions due to enteric fermentation, manure managed in controlled settings, and manure deposited by livestock on pastures, paddocks, and rangelands
  - N_2O and non-biogenic CO_2 emissions from soil management, including N_2O emissions due to nitrogen inputs and internal soil processes on managed soils, and CO_2 emissions resulting from soil amendments, such as lime, urea, and other inputs
  - CH_4 and N_2O emissions from biomass burning and fires
  - CH_4 emissions from rice production
  - CH_4 emissions from peatland rewetting
- **Animal products**: Companies that raise livestock, practice aquaculture, or have animal products in their value chain **shall** account for land management production emissions on lands used for livestock grazing and croplands used for feed production consumed by the livestock or other animals over their life cycle.

10.2.2 Reporting requirements

Reporting requirements for land management production emissions

Companies **shall** report:

- Production emissions in the "land management production emissions" accounting subcategory under the "land emissions" category in the physical GHG inventory.

Companies **shall** disclose the following information in their GHG report:

- **Emissions sources**: A description of the emissions sources considered, including those in the life cycle of animal products.
- **Emissions from on-site fuel and energy consumption**: Whether life cycle GHG emissions from products used to produce the agricultural products (e.g., GHG emissions from feed crops, fertilizers, and other agricultural input production), air-conditioning and refrigerant use, on-site waste or wastewater management, and indirect emissions from purchased energy associated with land management production activities are reported as "fossil fuel and industrial emissions" or "land management production emissions."

10.3 Recommendations

Fossil fuel and industrial emissions

Other CH_4, N_2O, non-biogenic CO_2, hydrofluorocarbons (HFCs), and perfluorocarbons (PCFs) emissions associated with recurring agricultural production or other land management activities that are not technically "land emissions" are often included in life cycle land management production emission factors. These types of emissions include, but are not limited to:

- Fossil-based land management production emissions, including CO_2 emissions from on-site machinery (e.g., tractors, feller bunchers, irrigation pumps, etc.)
- Life cycle GHG emissions from products used to produce the agricultural products (e.g., GHG emissions from feed crops, fertilizers, and other agricultural input production)
- HFC and PCF emissions (e.g., from air-conditioning and refrigerant use)
- Emissions from on-site waste or wastewater management
- Indirect emissions from purchased energy associated with land management production activities

Companies **should** report these emissions as "fossil fuel and industrial emissions" if data allows. If not, companies **ma**y report these emissions as "land management production emissions."

10.4 Guidance on the requirements and recommendations

10.4.1 Relationship between land management production emissions and land management net biogenic CO_2 emissions

Land management production emissions include methane (CH_4), nitrous oxide (N_2O), and non-biogenic CO_2 emissions that occur due to recurring agricultural production and other land management actions. Companies are required to report land management production GHG emissions from all sources set forth in Requirement 16 (Figure 10.1). Land management production emissions are typically accounted for by applying emission factors to a company's activity data.

Emissions from on-site energy and fuel use, as well as those produced during the life cycle of products used as inputs in production activities, must also be accounted for, preferably under "fossil fuel and industrial emissions," where data permits, or as "land management production emissions." For transparency, companies must disclose whether these emissions are reported in the inventory as "land management production emissions" or as "fossil fuel and industrial emissions" (see reporting requirements in Section 10.2.2).

Land management net biogenic CO_2 emissions (see Chapter 9) are net CO_2 emissions that occur due to ongoing management practices on land that remains in the same land use category or subcategory in the reporting year. They represent annual net losses in land-based carbon pools and are accounted for using a stock change accounting approach.

Land management production emissions are closely linked in some cases to activities that also impact land carbon stock changes (i.e., land management net biogenic CO_2 emissions or removals). Therefore, companies should use similar methods, data, and assumptions when estimating land management production emissions and net carbon stock changes due to the same or related land management activities in their operations and value chain. As highlighted in the subsections below, this alignment should be considered especially when accounting for GHG emissions and carbon stock changes from managed soils and from fires and biomass burning.

Aligned accounting of land management production emissions and carbon stock changes in managed soils

Management of soils can impact the climate through changes in soil carbon stocks as well as methane (CH_4) and nitrous oxide (N_2O) emissions from soil organic matter cycling. Soil carbon and nitrogen cycling are closely linked and affected by similar factors, including the rate and type of soil organic matter inputs (e.g., crop residues, organic fertilizers, manure, or other soil organic amendments), temperature, irrigation practices, soil tillage practices, and other variables. Companies should apply similar data and assumptions when calculating soil management-related emissions in the following contexts:

- When calculating soil emissions attributable to livestock production and management, similar data and assumptions (e.g., livestock populations, nitrogen excretion rates, manure harvesting, and manure application on managed soils) should be used when accounting for N_2O emissions from organic nitrogen inputs to soils, nitrogen deposited as urine or dung on pasture, range, and paddock, and soil carbon stock changes from manure carbon inputs.
- When calculating soil emissions attributable to crop residue management activities, similar data and assumptions should be used when accounting for N_2O emissions due to plant residue nitrogen inputs to soils, soil carbon stock changes from plant residue carbon inputs to soils, and GHG emissions from plant residue burning.

- When calculating emissions attributable to rice production, similar data and assumptions (e.g., water management regime, fertilizer use, organic amendments, and soil type) should be used to estimate CH_4 emissions from rice cultivation, N_2O emissions from nitrogen inputs to soils, and soil carbon stock changes.
- When companies apply Tier 3 model-based approaches to estimate soil carbon stock changes, the same biogeochemical model should ideally be applied to estimate nitrogen cycling and associated N_2O emissions from managed soils and CH_4 emissions from rice cultivation. While applying the same model to estimate carbon and nitrogen cycling may ensure consistent assumptions, there may also be tradeoffs with reducing uncertainty of emission estimates (e.g., the model may estimate soil carbon stock changes with much higher certainty than, for instance, N_2O emissions). Companies should consider these tradeoffs when selecting data and methods.

Aligned accounting of GHG emissions and carbon stock changes from fire and biomass burning

Fires and biomass burning result in CO_2 emissions (i.e., losses of carbon from land-based carbon pools, including biomass, dead organic matter, and soil carbon pools) and non-CO_2 GHG emissions (e.g., N_2O, CH_4). Companies should use similar data and assumptions when accounting for CO_2, CH_4, and N_2O emissions due to fires and biomass burning.

10.4.2 Accounting for direct and indirect N_2O emissions

Nitrogen management in agricultural crop and livestock systems contributes 52 percent of global anthropogenic N_2O emissions.[2] N_2O emissions can occur directly from management activities or indirectly from the transformation of nitrogen losses from those activities. Emission factors are used to calculate the quantity of nitrogen emitted as N_2O (N_2O-N) per quantity of nitrogen associated with the management activity. Direct N_2O emissions occur from nitrification (conversion of ammonia into nitrates) and denitrification (conversion of nitrates into nitrogen gas) processes. Direct N_2O emissions will vary based on the amount of nitrogen, type of nitrogen inputs, climate, soil aeration, as well as plant and microbial community composition.

Indirect N_2O emissions occur from nitrification and denitrification processes on lands or water bodies beyond the lands where the relevant management activities occurred, but due to nitrogen losses from that management system. Nitrogen can be lost to the atmosphere through volatilization of NH_3 or NO_x from nitrogen inputs to managed soils or the combustion of fossil fuels and biomass. This volatilized nitrogen may later be deposited on other lands, leading to nitrification and denitrification that generate indirect N_2O emissions. Nitrogen can also be lost through leaching or runoff, primarily in the form of NO_3^- in climates with greater precipitation. Nitrogen losses to leaching and runoff can also undergo nitrification and denitrification on other lands or water bodies, which generate indirect N_2O emissions.

Manure, urine, and dung from livestock systems emit direct N_2O emissions from sites where manure is processed or treated or lands where manure, urine, or dung are deposited, as well as indirect N_2O emissions from nitrogen losses from such systems. Section 10.5.3.1 provides calculation guidance on direct and indirect N_2O emissions from livestock where manure is managed (e.g., in stalls or barns), and guidance on estimating direct and indirect N_2O emissions from livestock where manure is unmanaged (e.g., deposited directly on rangelands or pastures).

Nitrogen inputs to managed soils that are not directly utilized by plants can result in direct N_2O emissions on the lands where those inputs are applied or indirect N_2O emissions from other nitrogen losses from such lands (see Section 10.5.3.3 for calculation guidance).

Direct N_2O emissions should be accounted for and reported in scope 1 for the company that owns or controls the land or facilities where N_2O emissions occur (e.g., from cropland soils or manure management facilities), and in scope 3 for other companies in the value chain, both upstream (e.g., fertilizer manufacturers) and downstream (e.g., companies that purchase crops or other land-based products) of the lands or facilities where N_2O emissions occur. Indirect N_2O emissions are reported in scope 1 for land managers or manure management operators, even though the indirect emissions may occur outside of lands owned or controlled by the reporting company. Indirect N_2O emissions should also be accounted for in scope 3 for other companies in value chains with managed soils and/or livestock management, both upstream and downstream.

10.4.3 Life cycle emissions of agricultural inputs and products

The guidance in Section 10.5 for calculating land management production emissions only covers the emissions from land management activities on the land (i.e., during production). The calculation guidance below does not cover the full life cycle emissions of inputs (e.g., GHG emissions from producing synthetic fertilizers) used in the production of land-based products. Guidance for accounting for the emissions in the full value chain of land-based products (e.g., in processing, refrigeration, transportation, distribution, storage, use, end-of-life, and other stages beyond the farm gate) is not covered in this chapter, but must be fully accounted for (see Requirement 3). Calculation guidance for value-chain emissions can be found in the *Scope 3 Calculation Guidance*.

Examples of life cycle emissions for land-based products that companies must account for (in conformance with the *Scope 3 Standard*) but for which calculation guidance is not covered in Chapter 10, include, but are not limited to:

- Upstream GHG emissions from fertilizer production (e.g., ammonia and nitric acid production)
- Upstream GHG emissions from the mining of agricultural inputs (e.g., phosphate, lime, potash)
- Upstream GHG emissions from feed production for livestock systems or seed production for crop systems
- Downstream GHG emissions from refrigeration of agricultural products during transportation and distribution
- Downstream GHG emissions from waste and wastewater treatment

10.5 Calculating Land Management Production Emissions

Figure 10.2 Overview of Section 10.5

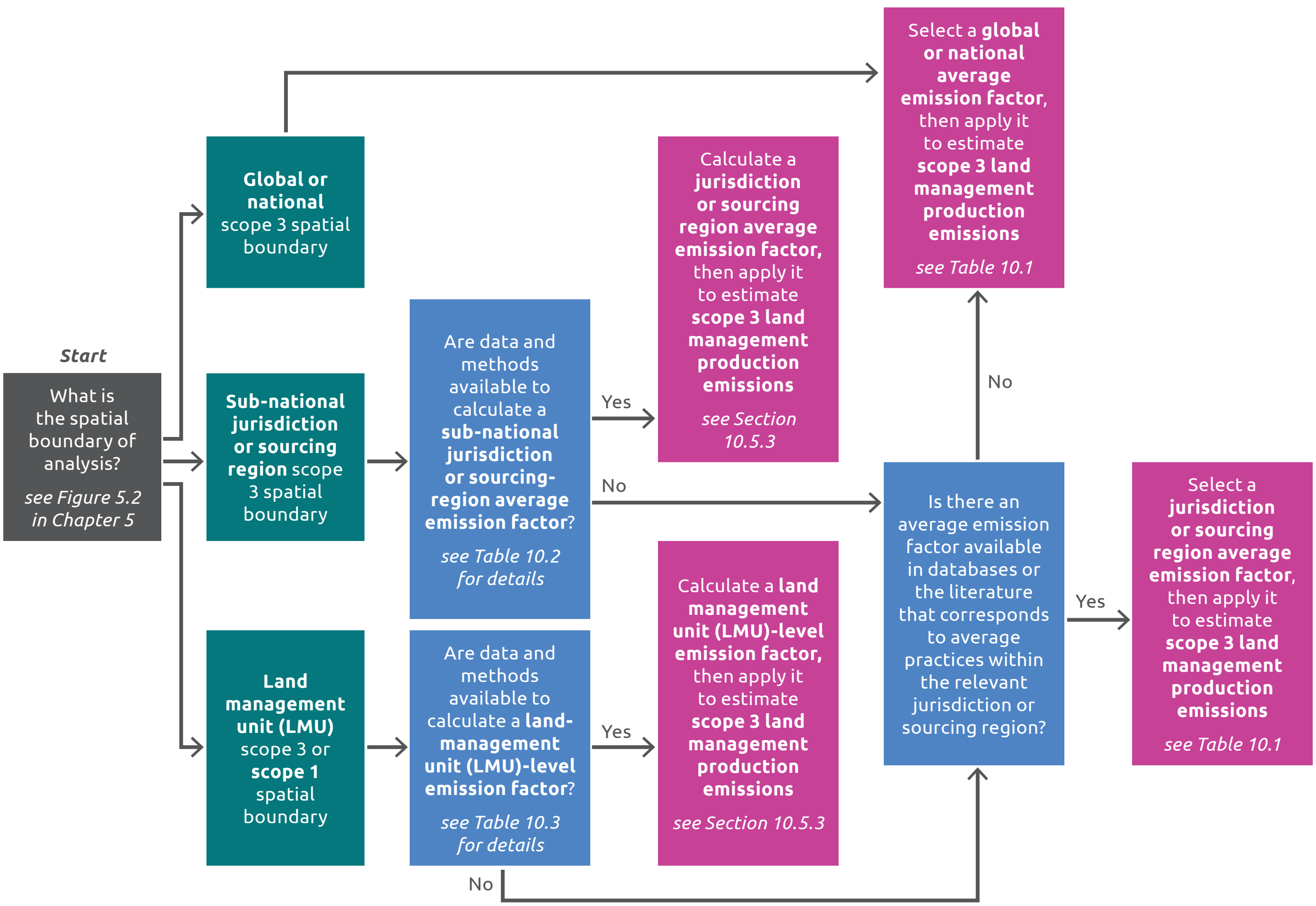
Section 10.5.1 **Choosing a land management production emission factor**	→	**Section 10.5.2** **Data for land management production emissions calculation approaches**	→	**Section 10.5.3** **Calculating land management production emissions**
How do I select or calculate an appropriate emission factor?		What data are needed to operationalize the calculation approach?		What equations are used to perform the relevant calculations?

10.5.1 Choosing a land management production emission factor

Figure 10.3 provides a high-level decision tree to help companies select or calculate an appropriate land management production emission factor, and Section 10.5.2 discusses the data required to implement each calculation approach. Generally, land management production emissions are estimated using a factor-based calculation approach (i.e., applying an emission factor to company activity data), but companies can also utilize models, direct measurement, or hybrid approaches.

As shown in Figure 10.3, the first step to selecting or calculating a land management production emission factor is to determine the spatial boundary of analysis, which depends in turn on the level of traceability the reporting company can establish (see Chapter 5 for details). The next steps to selecting or calculating the emission factor depend on data availability and methods.

Figure 10.3 Decision tree for choosing a land management production emission factor



10.5.2 Data for land management production emissions calculation approaches

Estimating different types of land management production emissions can require different data inputs, depending on the source and type of emissions and the calculation approach applied. Land management production emissions are generally estimated by applying an emission factor to company activity data (i.e., a factor-based calculation approach). Companies can select average factors and data (Table 10.2) or, depending on traceability and data availability, can select or calculate factors using more specific data, e.g., utilizing direct measurement, calibrated models, or hybrid approaches (Table 10.3).

Calculation approaches and data sources for land management production emissions can be generalized using the "tier" system in the IPCC *Guidelines for National GHG Inventories*:

- Tier 1 methods use global default emission factors and activity data on average land management practices.
- Tier 2 methods use country-level or geographically specific emission factors and activity data on average land management practices specific to those regions.
- Tier 3 methods use directly monitored emissions, modeled emissions, or site-specific emission factors (i.e., derived from actual measurements) and activity data specific to the management practice.

When selecting an average emission factor (e.g., from an LCA database) to complete the accounting for scope 3 land management production emissions, companies should be aware of the types and sources of life cycle emissions included or excluded in the selected emission factor to ensure complete and accurate accounting. Table 10.1 provides a checklist to assist companies in this evaluation.

Table 10.1 Checklist of data needed to ensure selection of a complete land management production emission factor

Data	Description
Checklist to guide land management production life cycle emission factor selection[a]	To ensure complete and accurate accounting of land management production emissions, companies should be aware of what types and sources of life cycle emissions are included or excluded when selecting a lifecycle emission factor from a database or other resource. Life cycle emission factors for land management production emissions should include the following emission sources based on the general product categories provided below: For crops: • Direct N_2O emissions due to the application of fertilizers or other N amendments on managed soils • Indirect N_2O emissions due to the application of fertilizers or other N amendments on managed soils • Non-biogenic CO_2 emissions from the application of urea or lime • CH_4 and N_2O emissions from biomass burning and fires • GHG emissions associated with fossil fuel combustion from farm equipment, irrigation, or other fuel used in crop production systems • GHG emissions associated with on-site electricity used in crop production systems • Fugitive hydrofluorocarbon (HFC) and perfluorocarbon (PFC) emissions from any refrigerants used in crop production, transportation, and storage • GHG emissions from the transportation, processing, and storage of the crop or product (see the *Scope 3 Standard* for details on where such life cycle GHG emissions should be reported in the inventory relative to the reporting company's location in the value chain) • Upstream GHG emissions associated with the mining, production, or transportation of seeds, fertilizers, soil amendments, pesticides, herbicides, and other agricultural inputs

Table 10.1 Checklist of data needed to ensure selection of a complete land management production emission factor (cont.)

Data	Description
Checklist to guide land management production life cycle emission factor selection[a] (cont.)	• GHG emissions from the disposal of agricultural residues or other wastes • CH_4 emissions from rice cultivation, if relevant • Direct and indirect N_2O emissions from the draining of organic soils, if relevant • CH_4 emissions from rewetting organic soils, if relevant • Upstream CH_4 emissions from water reservoirs for irrigated crop production systems, if relevant • Other life cycle emissions specific to the agricultural product system For animal products: • CH_4 emissions from enteric fermentation • CH_4 and N_2O emissions from the manure management system for livestock systems with managed manure • N_2O emissions from urine and dung deposited on pasture, range, or paddocks for livestock systems with unmanaged manure • GHG emissions associated with fossil fuel combustion from equipment or other fuel used in the livestock production systems • GHG emissions associated with on-site electricity used in livestock production systems • Fugitive HFC and PFC emissions from any refrigerants used in the livestock production system, or the transportation and storage of animal products • GHG emissions from the transportation, processing, and storage of the animal product (see the *Scope 3 Standard* for details on where such life cycle GHG emissions should be reported relative to the reporting company's location in the value chain) • GHG emissions from the disposal of agricultural residues, carcasses, or other wastes • Upstream GHG emissions associated with the production of feed crops used in the livestock production system (see list for crops above) • Upstream GHG emissions associated with the mining, production, or transportation of fertilizers, feed additives, pharmaceuticals, and other inputs to livestock systems • Direct and indirect N_2O emissions from the draining of organic soils, if relevant • Upstream CH_4 emissions from water reservoirs for irrigated livestock production systems, if relevant • Other life cycle emissions specific to the agricultural product system

Note: a. The checklist of types and sources of life cycle emissions provided in this table is not exhaustive.

Table 10.2 Data needed for calculating land management production emissions at a sourcing region or broader scope 3 spatial boundary

Data	Description
Average emission factor	When accounting at a sourcing region or broader scope 3 spatial boundary, the selected emission factor corresponds to average emissions due to an activity on lands in the scope 3 spatial boundary.
Average activity data	When accounting at a sourcing region or broader scope 3 spatial boundary, activity data reflect average practices applied on attributable productive lands in the scope 3 spatial boundary. For example, such data can include average types and quantities of fertilizer and soil amendments applied during the production of a given product in the sourcing area, average characteristics about livestock production systems (e.g., average herd sizes and composition, stocking rates, and physical characteristics, etc.), and average climate or soil data (e.g., regional average temperature or precipitation, soil types, etc.).

Table 10.3 Data needed for calculating land management production emissions at an LMU-level or harvested area scope 3 spatial boundary

Data	Description
LMU- or harvested area-specific emission factor	When accounting at an LMU or harvested area level, companies can apply LMU- or harvested area-specific data to calculate an LMU- or harvested area-specific emission factor. This data can be gathered through direct measurements, calibrated models, or hybrid approaches.
LMU- or harvested area-specific activity data	When accounting at an LMU or harvested area level, activity data represent the specific activities that occur on the LMU or harvested area. For example, such data can include the specific types and quantities of fertilizer and other soil amendments applied, specific characteristics about livestock and management (e.g., herd sizes, animal mass and excretion rates, and manure management practices), and farm- or field-specific climate and soil data (e.g., average temperature or precipitation, soil type, etc.).

10.5.3 Calculating land management production emissions

This section provides calculation guidance to calculate scope 1 and/or scope 3 land management production emissions:

- **Livestock emissions** (Section 10.5.3.1)
- **Aquaculture emissions** (Section 10.5.3.2)
- **N_2O emissions from managed soils** (Section 10.5.3.3)
- **Direct N_2O and CH_4 emissions from managed organic soils** (Section 10.5.3.4)
- **Non-biogenic CO_2 emissions from lime and urea application** (Section 10.5.3.5)
- **CH_4 and N_2O emissions from biomass burning and fire** (Section 10.5.3.6)
- **CH_4 and N_2O emissions from rice cultivation** (Section 10.5.3.7)
- **Other GHG emissions from land management production activities** (Section 10.3.5.8)

10.5.3.1 Calculating livestock emissions

Livestock emit CH_4 through enteric fermentation and CH_4 and N_2O (including direct and indirect N_2O) from livestock manure, urine, and dung. This includes emissions from animal wastes directly deposited on lands by livestock (i.e., where the manure is unmanaged) or where manure is collected and managed.

CO_2 emissions from livestock are not estimated because annual net CO_2 emissions from grazing and respiration are assumed to be zero (i.e., the CO_2 photosynthesized by the plants consumed by livestock is quickly returned to the atmosphere as respired CO_2). A portion of that carbon is returned to the atmosphere as CH_4, with a higher global warming potential; for this reason, CH_4 is accounted for separately.

CH_4 EMISSIONS FROM ENTERIC FERMENTATION

CH_4 is produced in livestock (e.g., cattle, buffalo, sheep, goats, etc.) as a by-product of enteric fermentation. The amount of CH_4 that is produced per animal and per unit of output (e.g., milk, meat, or other animal product) depends on several factors, such as the type of animal, the quality and composition of feed, the animal breed, genetic characteristics, and the lifespan of the animal. The greatest source of enteric CH_4 is from cattle raised for beef and dairy.

Methane emissions can be estimated using factor-based calculation approaches by multiplying the number of livestock by an emission factor (see Equation 10.1), stratified across livestock type, breeds, herds, and production systems, amongst other factors. At a minimum, livestock should be disaggregated by animal type, consistent with IPCC typology: Cattle (dairy and other); Buffalo; Sheep; Goats; Camels; Horses; Mules and Asses; Deer; Alpacas; Swine; Poultry; and Other.

Tier 2 country-specific emission factors should be used to calculate enteric CH_4 emissions, when available; alternatively, default Tier 1 IPCC emission factors may be used. If available and properly justified, emission factors can be adopted from national inventory reports (NIR) submitted to the UNFCCC.[3] Livestock activity data can be obtained from various sources, including suppliers, government statistics, and industry groups. In the scope 3 context, additional conversion factors may be needed to convert from the amount of purchased animal product(s) back to the live animal, herd, or population; conversely, allocation is required to allocate emissions from the live animal or population to animal co- and by-products. Companies can also apply emission factors specifically for animal products (e.g., in units of kg CO_2e/kg animal product) that have already accounted for allocation.

Equation 10.1 CH_4 emissions from enteric fermentation

$$CH4\_ENT = \sum_t (Q_t \times EF\_ENT_t \times 10^{-3})$$

Description		Unit	Source
$CH4\_ENT$	Total methane (CH_4) emissions from enteric fermentation in the reporting year	tonnes CH_4 (year)$^{-1}$	Calculated
Q_t	Total quantity (head) of livestock, by livestock type or other category *t*	head	User input
EF_ENT_t	Enteric methane emission factor, by livestock type or other category *t*	kg CH_4 (head)$^{-1}$ (year)$^{-1}$	User input
t	Livestock type or other category (e.g., breed, herd, production system, productivity system, etc.)		User input

Source: Adapted from Equations 10.19 and 10.20 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

If data are available, companies may choose to implement a farm- or sourcing-region-specific Tier 2 calculation that accounts for factors such as farm- or sourcing-region average feed baskets, feed use efficiency, and farm or rangeland management practices. Information on feed type can be used to calculate the net energy intake per day, which can be converted into an "implied emission factor" (CH_4 head^{-1}) using a supplier- or region-specific methane conversion factor, if available. If a conversion factor is unavailable, the IPCC provides guidance to estimate the factor based on the type of livestock and production system.[4]

To apply a Tier 2 "enhanced characterization"[5] method, companies need activity data from their operations or value chain related to livestock gross energy intake and feeding characteristics (e.g., animal age, sex, typical animal mass, energy needed for maintenance, growth, activity, work, pregnancy and lactation, and dietary requirements). In case of large herds, the procedures outlined in national inventories to model feed intake as a function of age may be adopted for dairy or beef cattle, sheep, and other livestock herds.

CH_4 AND N_2O EMISSIONS FROM MANURE MANAGEMENT

Manure management refers to the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, construction, or other purposes. Manure management releases both methane and nitrous oxide. These emissions occur when manure collects in animal confinements (stalls, pens, barns, etc.) and during subsequent storage, if any. The quantity of these emissions is influenced by the amount of manure produced, the type of management system (e.g., slurry, dry lot, deep bedding), the frequency of manure removal, and whether the manure is stored in a liquid or solid state.

Methane is most readily emitted under anaerobic conditions when the density of animals is high in a barn or pen, manure is stored in liquid rather than solid form, and waste is left uncovered. Methane emission factors vary by regional climate, where warmer conditions lead to higher emission rates. Methane production has a non-linear relationship to temperature, so calculating methane emissions from manure management using average temperatures over longer time periods may underestimate methane emissions.[6] For instance, in some cooler regions, most annual methane production occurs during a few warm months of the year. Nitrous oxide emissions from manure management occur due to a combination of nitrification and denitrification processes. N_2O emissions are positively correlated with manures with higher nitrogen content, in systems where aeration is low, and manure is left uncovered.[7]

Calculating CH_4 emissions from manure management requires data on livestock quantity (head) by animal type and average annual temperature, in combination with relevant emission factors (see Equation 10.2). If applicable, companies can also use default volatile solid (VS) excretion rates and the fraction of VS by livestock type stored in different manure management systems. Tier 2 country-specific, temperature-dependent CH_4 emission factors should be used, where available; alternatively, Tier 1 default IPCC emission factors may be used. Average annual temperature data can be obtained from international and national weather centers, as well as academic sources.

Methane emissions from manure management depend primarily on the methane conversion factor (MCF) and the daily volatile solids (VS) produced by certain livestock. The MCF is based on the climate of the region (cool, temperate, or warm) and other aspects of the manure management system (e.g., dry lot, slurry). Default MCFs by manure management system and climate zone are provided by the IPCC.[8] Tier 3 calculations apply these parameters at the farm level. However, a Tier 2 MCF and national management system information can be used to generate a country-level emission factor, if the country of origin is known (e.g., this information may be found in a country's National Inventory Report).

Equation 10.2 CH_4 emissions from manure management

$$CH4\_MM = \sum_{t,s,z}(Q_{t,z} \times VS_t \times AWMS_{t,s} \times EF\_MM_{t,s,z})$$

Description		Unit	Source
$CH4\_MM$	Total methane (CH_4) emissions from manure management (MM) in the reporting year	kg CH_4 (year)$^{-1}$	Calculated
$Q_{t,z}$	Total quantity (head) of livestock, by livestock type or category *t*, by climate zone *z*	head	User input
VS_t	Annual average excretion of volatile solids (VS) per head, by livestock type or other category *t*, if applicable	kg VS (head)$^{-1}$ (year)$^{-1}$	User input
$AWMS_{t,s}$	Fraction of total annual VS for each livestock type *t* managed in manure management system *s*, if applicable	dimensionless	User input
$EF\_MM_{t,s,z}$	Manure management methane emission factor, by livestock type or other category *t*, climate zone *z*, and manure management system *s*	kg CH_4 (head)$^{-1}$ (year)$^{-1}$ [if applicable, kg CH_4 (kg VS)$^{-1}$]	User input
t	Livestock type or other category (e.g., breed, herd, production category, productivity class, etc.)		User input
s	Manure management system		User input
z	Climate zone		User input

Source: Equation adapted from Equation 10.22 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

To estimate N_2O emissions from manure management systems, the total amount of nitrogen excretion (across all livestock categories) in each type of manure management system is multiplied by an emission factor for that type of manure management system (see Equation 10.3). The calculation includes the following general steps:

- Collect livestock data by livestock type or category *t*
- Determine the annual average N excretion rate per head for each defined livestock category *t* (see Equation 10.4)
- Determine the fraction of total annual N excretion for each livestock category *t* that is managed in each manure management system *s*
- Select N_2O emission factors for each manure management system *s*
- For each manure management system type, multiply the total amount of nitrogen managed (from all livestock categories) in that system by the corresponding emission factor to estimate N_2O emissions from that manure management system

Equations 10.3 and 10.5–10.6 provide the calculation approach for quantifying direct and indirect N_2O emissions, respectively, from manure management and animal wastes left on pasture, range, or paddock.

Equation 10.3 Direct N_2O emissions from manure management and from animal wastes deposited on pasture, range, or paddock

$$N2O\_MMdir = \left[\sum_s \left[\left[\sum_t (Q_t \times N\_ex_t \times f\_MM\_N_{t,s})\right] \times EF\_MM_s\right]\right] \times \frac{44}{28} \times 10^{-3}$$

$$N2O\_PRPdir = \left[\left[\sum_t (Q_t \times N\_ex_t \times f\_PRP\_N_t)\right] \times EF\_PRP_z\right] \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_MMdir$	Total direct nitrous oxide (N_2O) emissions from manure management (MM) in the reporting year	tonnes N_2O (year)$^{-1}$	Calculated
$N2O\_PRPdir$	Total direct nitrous oxide (N_2O) emissions from animal wastes deposited on pasture, range, or paddock (PRP)	tonnes N_2O (year)$^{-1}$	Calculated
Q_t	Total quantity (head) of livestock, by livestock type or category *t*	head	User input
N_ex_t	Annual N excretion, by livestock type or other category *t*	kg N (head)$^{-1}$ (year)$^{-1}$	Equation 10.4
$f\_MM\_N_{t,s}$	Fraction of total annual N excretion (*N_ext*) managed in MM system *s*, by livestock type or other category *t*	dimensionless	User input
$f\_PRP\_N_t$	Fraction of total annual N excretion (*N_ext*) that is deposited on PRP, by livestock type or other category *t*	dimensionless	User input
EF_MM_S	Manure management direct N_2O emission factor, by MM system *s*	kg N_2O-N (kg N)-1	User input
EF_PRP_Z	Emission factor for direct N_2O from animal wastes on PRP by climate zone *z*	kg N_2O-N (kg N)$^{-1}$	User input
t	Livestock type or other category (e.g., breed, herd, production category, productivity class, etc.)		User input
s	Manure management (MM) system		User input
z	Climate zone		User input
$44/28$	Conversion factor: N_2O-N to N_2O		Constant

Source: Equation adapted from Equations 10.25, 11.2, and 11.5 in the IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Equation 10.4 Annual livestock N excretion rate

$$N\_ex_t = N\_rate_t \times \left(\frac{TAM_t}{1000}\right) \times 365$$

Description		Unit	Source
N_ex_t	Annual N excretion for livestock type *t*	kg N (head)$^{-1}$ (year)$^{-1}$	Calculated
N_rate_t	Default N excretion rate, by livestock type or category *t*	kg N (tonne animal mass)$^{-1}$ (day)$^{-1}$	User input
TAM_t	Typical animal mass of livestock type *t*	kg (head)$^{-1}$	User input
t	Livestock type or other category (e.g., breed, herd, production category, productivity class, etc.)		User input

Source: Adapted from Equation 10.30 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

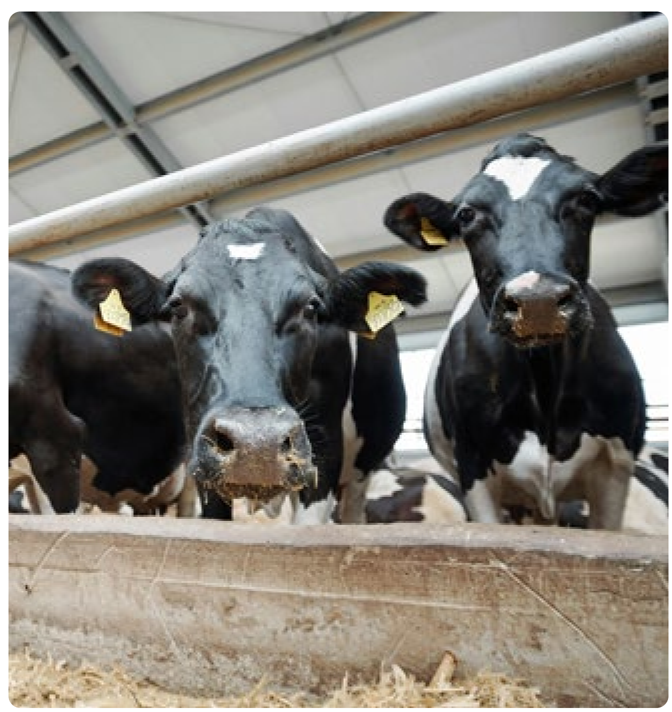
Indirect N_2O emissions from manure management result from nitrogen losses from volatilization, leaching, and runoff. Tier 1 calculation approaches for indirect N_2O emissions due to manure management follow Equations 10.5 and 10.6.

N_2O EMISSIONS FROM URINE AND DUNG DEPOSITED ON PASTURE, RANGE, AND PADDOCK

When livestock graze on pasture, range, and paddock, nitrogen is deposited on the soil via their waste. Some of this deposited nitrogen is taken up by plant growth, while other forms of nitrogen are lost from the system, including N_2O emissions and indirect N_2O emissions from nitrogen losses to volatilization, leaching, or runoff.

Tier 1 calculation approaches for direct N_2O emissions due to animal wastes deposited on pasture, range, and paddock follow Equation 10.3 combined with IPCC Tier 1 emission factors stratified by livestock type and climate.[9] Tier 1 calculation approaches for indirect N_2O emissions due to animal wastes deposited on pasture, range, and paddock follow Equations 10.5 and 10.6.

Detailed research on N_2O emissions from nitrogen deposition is underway in some countries, which accounts for local circumstances, and therefore, Tier 2 emissions factors may be available in some areas. Companies should use similar data and assumptions on livestock populations, nitrogen excretion rates, and manure management systems as those used when calculating GHGs from other livestock sources.



Equation 10.5 Indirect N_2O emissions due to volatilization and leaching of N from manure management or animal wastes deposited on pasture, range, or paddock

$$N2O\_MMindir = N2O\_MMvol + N2O\_MMleach$$

$$N2O\_PRPindir = N2O\_PRPvol + N2O\_PRPleach$$

$$N2O\_MMvol = N\_MMvol \times EF_4 \times \frac{44}{28}$$

$$N2O\_PRPvol = N\_PRPvol \times EF_4 \times \frac{44}{28}$$

$$N2O\_MMleach = N\_MMleach \times EF_5 \times \frac{44}{28}$$

$$N2O\_PRPleach = N\_PRPleach \times EF_5 \times \frac{44}{28}$$

Description		Unit	Source
$N2O\_MMindir$	Total indirect N_2O emissions from manure management (MM) in the reporting year	tonne N_2O (year)$^{-1}$	Calculated
$N2O\_PRPindir$	Total indirect N_2O emissions from animal wastes deposited on pasture, range, or paddock (PRP) in the reporting year	tonne N_2O (year)$^{-1}$	Calculated
$N2O\_MMvol$	Total indirect N_2O emissions due to volatilization of N from MM	tonne N_2O (year)$^{-1}$	Calculated
$N2O\_PRPvol$	Total indirect N_2O emissions due to volatilization of N from PRP	tonne N_2O (year)$^{-1}$	Calculated
$N2O\_MMleach$	Total indirect N_2O emissions due to leaching and runoff of N from MM	tonne N_2O (year)$^{-1}$	Calculated
$N2O\_PRPleach$	Total indirect N_2O emissions due to leaching and runoff of N from PRP	tonne N_2O (year)$^{-1}$	Calculated
N_MMvol	Total N loss due to volatilization of N from MM	tonne N (year)$^{-1}$	Equation 10.6
N_PRPvol	Total N loss due to volatilization of N from PRP	tonne N (year)$^{-1}$	Equation 10.6
$N\_MMleach$	Total N loss due to leaching and runoff of N from MM	tonne N (year)$^{-1}$	Equation 10.6
$N\_PRPleach$	Total N loss due to leaching and runoff of N from PRP	tonne N (year)$^{-1}$	Equation 10.6
EF_4	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	tonne N_2O-N (kg NH_3-N + NO_X-N volatilized)$^{-1}$	User input
EF_5	Emission factor for N_2O emissions from N leaching and runoff	tonne N_2O-N (kg N leached or runoff)$^{-1}$	User input
$44/28$	Conversion factor: N_2O-N to N_2O		

Source: Adapted from Equations 10.28, 10.29, 11.9, and 11.10 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Equation 10.6 N losses due to volatilization and leaching from manure management or animal wastes deposited on pasture, range, or paddock

$$N\_MMvol = \sum_s \left[\sum_t (Q_t \times N\_ex_t \times f\_MM\_N_{t,s}) \times (f\_MMgas_{t,s}) \right] \times 10^{-3}$$

$$N\_MMleach = \sum_s \left[\sum_t (Q_t \times N\_ex_t \times f\_MM\_N_{t,s}) \times (f\_MMleach_{t,s}) \right] \times 10^{-3}$$

$$N\_PRPvol = \left[\sum_t (Q_t \times N\_ex_t \times f\_PRP\_N_t) \times (f\_PRPgas_t) \right] \times 10^{-3}$$

$$N\_PRPleach = \left[\sum_t (Q_t \times N\_ex_t \times f\_PRP\_N_t) \times (f\_PRPleach_t) \right] \times 10^{-3}$$

Description		Unit	Source
N_MMvol	Total N loss due to volatilization of N from manure management (MM)	tonne N $(year)^{-1}$	Calculated
N_PRPvol	Total N loss due to volatilization of N deposited on pasture, range, or paddock (PRP)	tonne N $(year)^{-1}$	Calculated
$N\_MMleach$	Total N loss due to leaching and runoff of N from MM	tonne N $(year)^{-1}$	Calculated
$N\_PRPleach$	Total N loss due to leaching and runoff of N deposited on PRP	tonne N $(year)^{-1}$	Calculated
Q_t	Total quantity (head) of livestock, by livestock type or category *t*	head	User input
N_ex_t	Annual N excretion for livestock type *t*	kg N $(head)^{-1}$ $(year)^{-1}$	Equation 10.4
$f\_MM\_N_{t,s}$	Fraction of total annual N excretion (*N_ext*) managed in MM system s, by livestock type or other category *t*	dimensionless	User input
$f\_PRP\_N_t$	Fraction of total annual N excretion (*N_ext*) that is deposited on PRP, by livestock type or other category *t*	dimensionless	User input
$f\_MMgas_{t,s}$	Fraction of managed manure N for livestock category t that volatilizes as NH_3 and NO_x in the MM system *s*	dimensionless	User input
f_PRPgas_t	Fraction of managed manure N for livestock category *t* that volatilizes as NH_3 and NO_x from PRP	dimensionless	User input
$f\_MMleach_{t,s}$	Fraction of managed manure N for livestock category *t* that is leached from the MM system *s*	dimensionless	User input
$f\_PRPleach_t$	Fraction of managed manure N for livestock category *t* that is leached from PRP	dimensionless	User input
t	Livestock type or other category (e.g., breed, herd, production category, productivity class, etc.)		User input
s	Manure management system		User input

Source: Adapted from Equations 10.26, 10.27, 11.9, and 11.10 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

10.5.3.2 Calculating aquaculture emissions

Aquaculture (farming of fish, crustaceans, mollusks, etc.) is a land-based management activity, as land is often required for both aquaculture ponds where aquaculture organisms are raised and to produce feedstocks consumed by the aquaculture species (including in inshore or offshore aquaculture systems). Globally, aquaculture is responsible for a small but non-trivial quantity of annual, anthropogenic GHGs due to activities such as pond fertilization, on-farm energy consumption, and applied nitrogen and land use change from feed production.

At the time of publication of version 1 of this *Guidance*, there are a limited number of peer-reviewed studies that provide complete life cycle GHG data for aquaculture products.[10] The IPCC has identified aquaculture emission factors as a current gap in knowledge and data. Data that disaggregate aquaculture emissions between CO_2 and non-CO_2 emission sources may also not be readily available at this time. The GHG impacts of aquaculture production is an active area of research and companies with aquaculture in their operations or value chains should monitor research developments in this space and integrate best available data as they become available.

10.5.3.3 Calculating managed soil N_2O emissions

This section provides guidance for calculating N_2O emissions (both direct and indirect N_2O) from nitrogen inputs to managed soils, including mineral and organic soils. Soil management activities across land uses (e.g., croplands, grasslands, and forest lands) cause N_2O emissions through nitrogen inputs from different sources (e.g., nitrogen fertilizers, organic amendments, crop residues, and soil organic matter mineralization).

N_2O emissions from drained organic soils are covered separately (in Section 10.5.3.4) and non-biogenic CO_2 emissions from lime and urea soil applications are covered in Section 10.5.3.5. Note that fossil-based CO_2 emissions emitted due to soil management activities should be reported in the inventory separately as "fossil fuel and industrial emissions." Soil management also impacts soil carbon stocks; calculation guidance for soil carbon emissions and removals is provided in Chapter 9 and Chapter 13, respectively.

DIRECT N_2O EMISSIONS FROM MANAGED MINERAL SOILS

Nitrogen is an essential macronutrient necessary for plant growth and is commonly controlled through soil management practices (e.g., residue and tillage management to mineralize organic forms of nitrogen available in crop residues and soil organic matter), crop rotations (e.g., including diverse rotations with nitrogen-fixing crops) or supplemental nitrogen application (e.g., applying synthetic nitrogen fertilizers or organic soil amendments) to increase soil fertility. Nitrogen inputs to soils are derived from a variety of sources, each of which should be considered when estimating direct and indirect N_2O emissions from managed soils:

- Synthetic N fertilizers (e.g., urea, ammonium nitrate, and other NPK fertilizer blends)
- Organic N inputs (e.g., manure, compost, and organic soil amendments)
- Crop residues (e.g., N returned to the soil from stover left on the field)
- Soil organic matter mineralization (e.g., N mineralized due to land use change or soil tillage)

Two other main sources of direct N_2O emissions from soils are covered in separate sections elsewhere in this chapter:

- Urine and dung deposited by livestock on pasture, range, or paddock (e.g., manure N passively deposited by grazing animals); see Section 10.5.3.1
- Drained organic soils (e.g., N mineralized due to peatland drainage); see Section 10.5.3.4

Different crops in different regions require different amounts of nitrogen. Nitrogen uptake by plants depends on the source, rate, method, and timing of inputs. Careful matching of plant nitrogen uptake (demand) with nitrogen application (supply) is often difficult. If additional nitrogen is added beyond crop requirements, this leads to denitrification and nitrification processes that generate N_2O emissions and other forms of N pollution. These N_2O emissions may occur at the site of application, or they may occur indirectly if N volatilizes to the atmosphere or leaches into a water source and is emitted elsewhere.

Tier 1 calculation approaches for direct N_2O emissions from managed soils follow Equations 10.7–10.11 in combination with global or regional average emission factors for direct N_2O emissions from managed soils. Equations 10.7–10.11 are adapted from equations in Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories*.[11] Tier 1 emission factors are available in lookup tables in the *2019 Refinement*. Where available, companies should apply Tier 2 country- or management-specific emission factors from peer-reviewed publications, national inventory reports, or internationally recognized research institutes. When data are available, companies may also use Tier 3 model-based approaches to estimate N_2O emissions from soils, ensuring that all relevant N inputs are included and that both direct and indirect N_2O emissions are accounted for. Companies should use similar data, methods, and assumptions to estimate N_2O emissions from managed soils as those applied to estimate GHG emissions from livestock systems and soil carbon stock changes.

To calculate direct N_2O emissions from managed mineral soils, Equation 10.7 sums the different types of N inputs to managed soils—synthetic N fertilizers, organic amendments, crop residues, and soil organic matter—and multiplies this quantity by an emission factor. Calculation guidance for each N input source is provided in Equations 10.8–10.11 below.

Note that direct N_2O emissions from rice cultivation and N_2O emissions from organic soils are not covered in Equation 10.7. N_2O emissions from organic soils are covered separately in Equation 10.14. Direct N_2O and other emissions from rice cultivation are covered separately in Equations 10.18–10.21.

Equation 10.7 Direct N_2O emissions from managed mineral soils

$$N2O\_MSdir = \left[(F\_SN + F\_ON + F\_CR + F\_SOM) \times EF1_z\right] \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_MSdir$	Total direct N_2O emissions from managed mineral soils (MS) in the reporting year	tonne N_2O $(year)^{-1}$	Calculated
F_SN	Quantity of synthetic fertilizer N applied to soils	kg N $(year)^{-1}$	User input
F_ON	Quantity of N in applied animal manure, compost, sewage sludge, and other organic N additions applied to soils	kg N $(year)^{-1}$	Equation 10.8
F_CR	Quantity of N in crop residues (above- and below-ground) returned to soils	kg N $(year)^{-1}$	Equation 10.10
F_SOM	Quantity of N in mineral soils that is mineralized	kg N $(year)^{-1}$	Equation 10.11
$EF1_z$	Emission factor for N_2O emissions from N inputs to soils in climate zone *z*	kg N_2O-N (kg N input)$^{-1}$	User input
z	Climate zone		User input
$44/28$	Conversion factor: N_2O-N to N_2O		Constant

Source: Adapted from Equation 11.1 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

N INPUTS FROM SYNTHETIC FERTILIZER (F_SN)

Where possible, companies should obtain activity data from operations or management records on the annual mass of N in synthetic fertilizers applied to soils on land management units (e.g., farm, pasture, plantation). Where data on synthetic N inputs are not available, companies may use activity data on the average synthetic fertilizer N rates by cropping system in their sourcing region or country.

N INPUTS FROM ORGANIC SOIL AMENDMENTS (F_ON)

Organic soil amendments include animal manure, sewage, compost, or other organic materials applied to soils (Equation 10.8). Where possible, companies should obtain activity data from operations or management records on the annual mass of N in organic soil amendments applied to soils on land management units (e.g., farm, pasture, plantation). Calculations of N_2O emissions on lands where manure is applied should use similar data, methods, and assumptions for calculations of emissions from manure management systems and from livestock (see Section 10.5.3.1). Where data on organic soil amendments are not available, companies may use activity data on the average organic amendment N rates by cropping system in their sourcing region or country.

Equation 10.8 N from organic N applied to managed soils

$$F\_ON = F\_AM + F\_SEW + F\_COMP + F\_OOA$$

Description		Unit	Source
F_ON	Quantity of N in applied animal manure, compost, sewage sludge, and other organic N additions applied to soils	kg N $(year)^{-1}$	Calculated
F_AM	Quantity of N in animal manure applied to soils	kg N $(year)^{-1}$	Equation 10.9
F_SEW	Quantity of N in sewage applied to soils	kg N $(year)^{-1}$	User input
F_COMP	Quantity of N in compost applied to soils	kg N $(year)^{-1}$	User input
F_OOA	Quantity of N in other organic amendments applied to soils	kg N $(year)^{-1}$	User input

Source: Adapted from Equation 11.3 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Equation 10.9 N from animal manure applied to soils

$$F\_AM = Navb\_MM \times [1 - (f\_Feed + f\_Fuel + f\_CNST)]$$

Description		Unit	Source
F_AM	Quantity of N in animal manure applied to soils	kg N $(year)^{-1}$	Calculated
$Navb\_MM$	Quantity of managed manure N available for soil application, feed, fuel, or construction	kg N $(year)^{-1}$	User input*
f_Feed	Fraction of managed manure used for feed	dimensionless	User input
f_Fuel	Fraction of managed manure used for fuel	dimensionless	User input
f_CNST	Fraction of managed manure used for construction	dimensionless	User input

Source: Adapted from Equation 11.4 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Note: *For further calculation guidance, see Equation 10.34 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use.*

N INPUTS FROM CROP RESIDUES (F_CR)

N inputs from crop residues can be estimated using Equation 10.10 to determine the amount of dry matter left on the field and the average N content in above-ground and below-ground residues by crop type. Tier 1 emission factors are provided by IPCC national inventory guidance and Tier 2 emission factors may be available from national inventory reports or peer-reviewed publications. Where possible, companies should obtain activity data from operation and management records on the harvested area, crop dry matter yields, and residue management systems on land management units (e.g., farm, pasture, plantation).

Equation 10.10 N from crop residues and forage/pasture renewal

$$F\_CR = \sum_{c} \{[AGR_c \times N\_AG_c \times (1 - f\_Remove_c - (f\_Burnt_c \times CF))] + (BGR_c \times N\_BG_c)\}$$

$$AGR_c = AG\_DM_c \times Area_c$$

$$BGR_c = (Crop_c + AG\_DM_c) \times RS_c \times Area_c \times f\_Renew_c$$

$$AG\_DM_c = Crop_c \times RAG_c$$

Description		Unit	Source
F_CR	Quantity of N in crop residues returned to soils	kg N (year)$^{-1}$	Calculated
AGR_c	Annual total above-ground (AG) crop residue for crop *c*	kg dry matter (DM) (year)$^{-1}$	Calculated
N_AG_c	N content of AG crop residue for crop *c*	kg N (kg DM)$^{-1}$	User input
f_Remove_c	Fraction of AG residues for crop c removed annually for feed, bedding, construction, and other purposes	dimensionless	User input
f_Burnt_c	Fraction of annual harvested area of crop *c* that is burnt	dimensionless	User input
CF	Combustion factor	dimensionless	User input
BGR_c	Annual total below-ground (BG) crop residue for crop *c*	kg DM (year)$^{-1}$	Calculated
N_BG_c	N content of BG crop residue for crop *c*	kg N (kg DM)$^{-1}$	User input
$Area_c$	Total annual harvested area of crop *c*	ha (year)$^{-1}$	User input
$Crop_c$	Harvested annual dry matter (DM) yield for crop *c*	kg DM (ha)$^{-1}$	User input
AG_DM_c	AG residue dry matter (DM) for crop *c*	kg DM (ha)$^{-1}$	User input
RS_c	Ratio of BG root biomass to AG shoot biomass for crop *c*	kg DM ha^{-1} (kg DM ha^{-1})$^{-1}$	User input
f_Renew_c	Fraction of total area under crop *c* that is renewed annually	dimensionless	User input
RAG_c	Ratio of AG residue DM to harvested yield for crop *c*	kg DM ha^{-1} (kg DM ha^{-1})$^{-1}$	User input
c	Crop or forage type		User input

Source: Adapted from Equation 11.6 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

N INPUTS FROM SOIL ORGANIC MATTER MINERALIZATION (F_SOM)

Companies should estimate N inputs from soil organic matter mineralization based on the carbon to nitrogen ratio (C:N) of soil types and soil carbon stock losses on lands they own or control, or that are in their value chain, using Equation 10.11. To estimate soil carbon stock losses, companies should follow the accounting guidance for carbon stock changes due to land management (see Chapter 9) and due to land use change (see Chapter 7). Companies should use similar methods, data, and assumptions when estimating land management production emissions and net carbon stock changes for similar land management activities.

Equation 10.11 N mineralized in mineral soils

$$F\_SOM = \sum_{LU}\left[\left(\Delta C\_Mineral_{LU} \times \left(\frac{1}{R\_CN}\right) \times 1000\right)\right]$$

Description		Unit	Source
F_SOM	Quantity of N in mineral soils that is mineralized	kg N $(year)^{-1}$	Calculated
$\Delta C\_Mineral_{LU}$	Loss of soil carbon (C) by land use type *LU*	tonnes C	User input
R_CN	Carbon to nitrogen (C:N) ratio of the soil organic matter	tonnes C $(tonnes\ N)^{-1}$	User input
LU	Land use and/or management system type		User input

Source: Adapted from Equation 11.8 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

INDIRECT N_2O EMISSIONS FROM MANAGED MINERAL SOILS

Indirect N_2O emissions from managed mineral soils are a result of nitrogen losses from managed mineral soils due to volatilization, leaching, and runoff. When calculating indirect N_2O emissions from nitrogen losses on managed mineral soils, companies should use the same activity data and assumptions used to calculate nitrogen inputs to—and direct N_2O emissions from—managed mineral soils, as described above. Companies should also use similar data and assumptions when calculating direct and indirect N_2O emissions from nitrogen deposited on pasture, range, and paddock, as described above.

Equation 10.12 is used to calculate indirect N_2O emissions from nitrogen volatized from managed soils. Equation 10.13 is used to calculate indirect N_2O emissions from nitrogen lost to leaching or runoff on managed land. When calculating indirect N_2O emissions from managed soils, IPCC Tier 1 emission factors can be used, or where available, Tier 2 country-specific emission factors should be applied.

Equation 10.12 Indirect N_2O emissions from atmospheric deposition of N volatilized from managed soils

$$N2O\_MSvol = [(F\_SN \times f\_Gas\_SN) + F\_ON \times f\_Gas\_ON)] \times EF_4 \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_MSvol$	Total indirect N_2O emissions due to volatilized N on managed soils (MS)	tonne N_2O (year)$^{-1}$	Calculated
F_SN	Quantity of synthetic fertilizer N applied to soils	kg N (year)$^{-1}$	User input
F_ON	Quantity of N in applied animal manure, compost, sewage sludge, and other organic N additions applied to soils	kg N (year)$^{-1}$	Equation 10.8
f_Gas_SN	Fraction of synthetic fertilizer N applied to managed soils that volatilizes as NH_3 and NO_X	kg N volatilized (kg of N applied)$^{-1}$	User input
f_Gas_ON	Fraction of applied organic N fertilizer materials (FON) applied to managed soils that volatilizes as NH_3 and NO_X	kg N volatilized (kg of N applied)$^{-1}$	User input
EF_4	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	kg N_2O-N (kg NH_3-N + NO_X–N volatilized)$^{-1}$	User input
$44/28$	Conversion factor: N_2O-N to N_2O		Constant

Source: Adapted from Equation 11.9 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors. Note, see Equation 10.5 in this *Guidance* for indirect N_2O emission from animal wastes deposited directly on pasture, range, or paddock.

Equation 10.13 Indirect N_2O emissions from leaching and runoff on managed soils

$$N2O\_MSleach = [(F\_SN + F\_ON + F\_CR + F\_SOM) \times f\_MSleach \times EF_5] \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_MSleach$	Total indirect N_2O emissions due to leached N on managed soils (MS)	tonne N_2O (year)$^{-1}$	Calculated
F_SN	Quantity of synthetic fertilizer N applied to soils	kg N (year)$^{-1}$	User input
F_ON	Quantity of N in applied animal manure, compost, sewage sludge, and other organic N additions applied to soils	kg N (year)$^{-1}$	Equation 10.8
f_CR	Quantity of N in crop residues returned to soils	kg N (year)$^{-1}$	Equation 10.10
f_SOM	Quantity of N in mineral soils that is mineralized	kg N (year)$^{-1}$	Equation 10.11
$f\_MSleach$	Fraction of all N added to and mineralized in managed soils that is lost through leaching and runoff	kg N leached and runoff (kg of N applied)$^{-1}$	User input
EF_5	Emission factor for N_2O emissions from N leaching and runoff	kg N_2O-N (kg N leached and runoff)$^{-1}$	User input
$44/28$	Conversion factor: N_2O-N to N_2O		Constant

Source: Adapted from Equation 11.10 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors. Note, see Equation 10.5 in this *Guidance* for indirect N_2O emissions from animal wastes deposited directly on pasture, range, or paddock.

Case study: Tate & Lyle—Accounting for N_2O emissions

Tate & Lyle is a world leader in ingredient solutions for healthier food and beverages, producing a range of corn-based ingredients, amongst other products. Corn purchased from the US market is procured through Primient (a leading producer of food and industrial ingredients made from plant-based, renewable sources). The quantities of corn procured by Primient for Tate & Lyle are tracked through enrollment in Truterra's sustainable agriculture program, which has been in place since 2018.[a] Traceability is achieved to a set of corn sourcing regions at the county level. This is specific to plants and wet mills from which Tate & Lyle buys its products, so the estimated emissions include all attributable managed lands in the sourcing region.

This case study considers Tate & Lyle's scope 3 GHG emissions, focusing on emissions from managed soils as a result of nitrogen fertilizer application. Through Truterra's program, farmers report on field management practices. One of the metrics captured as primary data from the enrolled acres is the fertilizer application rate. For 2023, the average nitrogen fertilizer application rate on Tate & Lyle's acres was 192 lbs/acre per corn crop cycle.

We have used Tier 1 calculation methods using primary data and global default emission factors, as defined by the IPCC.[b] Tier 1 methods are conservative due to global uncertainty ranges in the assumptions.

The following calculations from the guidance have been used to obtain the emissions presented in the tables below:

- Equation 10.7: Direct N_2O from managed soils;
- Equation 10.12: Indirect N_2O from atmospheric deposition of N volatilized from managed soils; and
- Equation 10.13: Indirect N_2O from managed soils in regions where leaching/run-off occurs.

In these equations, it has been assumed that the fertilizer applied is ammonia nitrate, with a nitrogen proportion of 34 percent.[c] The Global Warming Potential from the IPCC's *5th Assessment Report* used in the analysis for N_2O is 265.[d]

Equation 10.7 Direct N_2O from managed soils

Total N (kg)	EF (kgN_2O-N per kg N)	N_2O-N (kg)	N_2O (kg)	CO_2e (kg/acre)
29.38	0.01	0.29	0.46	122.33

Equation 10.12 Indirect N_2O from atmospheric deposition of N volatilized from managed soils

Total N (kg)	Fraction volatilized (%)	N volatilized (kg)	EF (kgN_2O per kg NH_3-N and NO_x-N)	N_2O (kg)	CO_2e (kg/acre)
29.38	11	3.23	0.01	0.051	13.46

Equation 10.13 Indirect N_2O from managed soiled in regions where leaching/run-off occurs

Total N (kg)	Fraction lost (%)	N lost (kg)	EF (kgN_2O per kg N)	N_2O (kg)	CO_2e (kg/acre)
29.38	24	7.05	0.011	0.122	32.30

Notes: a. Tate & Lyle, Primient, Truterra. Disclaimer: The GHG Protocol has not reviewed and is not endorsing resources shared outside of this text box.; b. IPCC 2019a; vol. 4; c. Nadarajan, S. and S. Sukumaran (2021), Chapter 12, p. 195-229; d. WRI and WBCSD (2024).

Case study: Corteva Agriscience—Accounting for reduced N_2O emissions in the value chain

As a global agricultural chemical and seed company, Corteva Agriscience plays a significant role in farming activities along the value chain, from providing seeds and other critical inputs to growing food to feed a growing population. The Corteva product Optinyte™ is a nitrification inhibitor that reduces the growth of naturally occurring soil bacteria and associated ammonium metabolism, maintaining ammonium nitrogen from inorganic fertilizer application in the root zone for a longer period of time, which improves crop utilization and reduces N_2O emissions. When Corteva's customers mix Optinyte™ products with nitrogen fertilizers, their scope 1 N_2O emissions and Corteva's scope 3, category 11 emissions decrease compared with conventional application.

Corteva used Equations 10.7 (Direct N_2O emissions from managed mineral soils), 10.12 (Indirect N_2O emissions from atmospheric deposition of N volatilized from managed soils), and 10.13 (Indirect N_2O emissions from leaching and runoff on managed soils) to estimate direct and indirect emissions from managed soils in the downstream value chain. The company used activity data on the average application rates of synthetic nitrogen fertilizers (kg N/ha/yr) by region (e.g., North America) and cropping system (e.g., maize), and IPCC factors for direct and indirect emissions from managed soils (emissions per unit of nitrogen input). Corteva estimated the application area from Optinyte™ sales and recommended application rates. IPCC factors are global averages and do not capture regional or practice-specific variation in emissions. This should be considered an area for future research.

Corteva evaluated peer-reviewed meta-analyses synthesizing research on the effect of nitrification inhibitors—including nitrapyrin, the active ingredient in Optinyte™—on emissions, prioritizing field-based, full-year studies in the same crop and geography. A study by Thapa et al. (2016) was used to estimate reduced direct emissions, and another by Wu et al. (2021) to estimate increased ammonia volatilization. These two studies incorporated analysis of uncertainty and statistical significance using an accepted meta-analytical methodology, weighting studies by variance or sample size to produce bias-corrected confidence intervals with MetaWin 2.1 software.

To estimate reductions in indirect N_2O emissions, Corteva multiplied EF_1 by 0.57, reflecting a 43 percent average reduction (Thapa et al. 2016; confidence interval of 27 to 54 percent). To estimate changes in indirect N_2O emissions from leaching and runoff, Corteva modified the input to Equation 10.13 and multiplied EF_5 by a factor of 0.84, reflecting a 16 percent average reduction (Wolt, 2004; confidence interval of 14 to 17 percent). To reflect the 36 percent average increase in indirect N_2O emissions via volatilization that accompanies nitrification inhibitor use (Wu et al. 2021; confidence interval of 26 to 47 percent), Corteva modified the input to Equation 10.12, multiplying EF_4 by 1.36. It then projected baseline and reduced N_2O emissions from Optinyte™ customers for the sales-estimated application acreage.

The table below shows the detailed calculation of CO_2e emissions corresponding to 1,000 acres of irrigated corn production. For this sample calculation, which focuses on synthetic nitrogen inputs (F_{SN}), the assumption is that urea is applied at a rate of 170 kg/ac (78 kg/ac as nitrogen).

Emission	Without Optinyte	With Optinyte	% change
Direct N_2O	520.91	296.92	-43%
Indirect N_2O—volatilization	68.37	92.98	+36%
Indirect N_2O—leaching	85.95	72.20	-16%
CO_2 volatilization from urea	124.64	124.64	0%
Total life-cycle emissions	799.87	586.74	-27%

All emissions are measured in tonnes of CO_2e, with N_2O emissions converted to CO_2e at a GWP of 265. Emission factors are from IPCC (2019) for direct N_2O release (0.016 kg N_2O-N per kg N applied), indirect N_2O by volatilization (15 percent volatilized and 0.014 kg N_2O-N per kg N volatilized), and indirect N_2O by leaching (24 percent leached and 0.011 kg N_2O-N emitted per kg N leached). Emission factors for CO_2 volatilization from urea are from IPCC (2006).

10.5.3.4 Calculating direct N_2O and CH_4 emissions from managed organic soils

DIRECT N_2O EMISSIONS FROM MANAGED ORGANIC SOILS (E.G., PEATLANDS)

Managed organic soils, including managed peatlands, can generate significant N_2O emissions when oxidized through draining, disturbance, or other management activities that impact soil moisture and structure. Note that managed organic soils also emit significant CO_2 emissions; these emissions are accounted for in Chapter 9.

N_2O emissions from drained organic soils and peatlands on lands that remain in the same land use category or subcategory are calculated using Equation 10.14. N_2O emissions from drained organic soils and peatlands due to land use change are calculated using Equation 10.14, but must be allocated over the LUC assessment period following the calculation guidance for LUC emissions in Chapter 7. Companies should apply similar data, methods, and assumptions when accounting for N_2O and other emissions from drained organic soils and peatlands, whether due to land use change or land management activities.

Where data are available, companies should calculate soil organic matter losses and the resulting direct N_2O emissions from organic soils and peatlands using Tier 3 methods. Where data are not available, companies can apply Tier 1 emission factors from IPCC guidance using Equation 10.14 to estimate direct N_2O emissions from drained organic soils.

Equation 10.14 Direct N_2O emissions from drained organic soils

$$N2O\_OSdir = \Big[\big(F\_OS_{CG,Temp} \times EF2_{CG,Temp}\big) + \big(F\_OS_{CG,Trop} \times EF2_{CG,Trop}\big) + \big(F\_OS_{F,Temp,NR} \times EF2_{F,Temp,NR}\big) + \big(F\_OS_{F,Temp,NP} \times EF2_{F,Temp,NP}\big) + \big(F\_OS_{F,Trop} \times EF2_{F,Trop}\big) + \big(F\_OS_{CG,Bor} \times EF2_{CG,Bor}\big) + \big(F\_OS_{F,Bor,NR} \times EF2_{F,Bor,NR}\big) + \big(F\_OS_{F,Bor,NP} \times EF2_{F,Bor,NP}\big)\Big] \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_OSdir$	Total direct N_2O emissions due to draining or other disturbance of organic soils (OS), including peatlands	tonne N_2O (year)$^{-1}$	Calculated
$F\_OS_{l,z,n}$	Quantity of synthetic fertilizer N applied to organic soils	kg N (year)$^{-1}$	User input
$EF2_{l,z,n}$	Emission factor for N_2O emissions from drained/managed organic soils	kg N_2O-N (ha)$^{-1}$ (year)$^{-1}$	User input*
44/28	Conversion factor: N_2O-N to N_2O		Constant
l	Land use category (*Note: the subscripts CG and F refer to Cropland and Grassland and Forest Land, respectively*)		
z	Climate zone (*Note: the subscripts Temp, Trop, and Bor refer to Temperate, Tropical, and Boreal, respectively*)		
n	Nutrient status (*Note: the subscripts NR and NP refer to Nutrient Rich and Nutrient Poor, respectively*)		

Source: Adapted from Equation 2.7 in IPCC (2014) and Equation 11.1 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Note: *Companies should refer to guidance and tables in IPCC (2014). For Tier 1 emission factors, see Table 2.5 in Chapter 2 in IPCC (2014).

DIRECT CH_4 EMISSIONS FROM REWETTED ORGANIC SOILS (E.G., PEATLANDS)

Peatlands are natural sources of methane (CH_4). Because of the very large CO_2 emissions from disturbed peatlands, rewetting drained peatlands is understood as an important mitigation activity. Rewetting peatlands can stimulate an increase in CH_4 emissions, but the radiative forcing of this short-lived CH_4 is generally considered of minor consequence compared to the positive climate effect of halted CO_2 and N_2O emissions from drained peatlands. Where data are available, companies should calculate CH_4 emissions due to peatland rewetting using Tier 3 methods. Where data are not available, companies can apply Tier 1 emission factors from Chapter 3 of the 2013 Supplement to the 2006 IPCC *Guidelines for National Greenhouse Gas Inventories*.[12]

10.5.3.5 Calculating non-biogenic CO_2 emissions from lime and urea application

Liming is used to reduce soil acidity and improve plant growth in managed soils. Adding carbonates to soils in the form of lime (e.g., calcic limestone [$CaCO_3$] or dolomite [$CaMg(CO_3)_2$]) leads to CO_2 emissions as the carbonate limes dissolve, releasing bicarbonate ($2HCO_3^-$), which evolves into CO_2 and water (H_2O). Companies can estimate CO_2 emissions from liming using Equation 10.15 based on the mass of lime applied to soils they own or control or in their value chain. If lime is applied in a mixture with fertilizers, that proportion should be used.

Equation 10.15 Non-biogenic CO_2 emissions due to liming

$$CO2\_LIME = (Q\_LIME \times EF\_LIME + Q\_DOLO \times EF\_DOLO) \times \frac{44}{12}$$

Description		Unit	Source
CO2_LIME	Total CO_2 emissions due to applied lime or dolomite	tonne CO_2 (year)$^{-1}$	Calculated
Q_LIME	Quantity of applied calcic limestone ($CaCO_3$)	tonnes (year)$^{-1}$	User input
Q_DOLO	Quantity of applied dolomite ($CaMg(CO_3)_2$)	tonnes (year)$^{-1}$	User input
EF_LIME	Emission factor, limestone	tonne C (tonne limestone)$^{-1}$	User input
EF_DOLO	Emission factor, dolomite	tonne C (tonne dolomite)$^{-1}$	User input
44/12	Conversion factor: C to CO_2		Constant

Source: Adapted from Equation 11.12 in IPCC (2006), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

Urea ($CO(NH_2)_2$) is commonly applied to land as a nitrogen fertilizer and leads to a release of CO_2 in soils as the nitrogen becomes available to plants. Companies can estimate CO_2 emissions from urea using Equation 10.16 based on the mass of urea applied to soils they own or control or in their value chain.

Equation 10.16 Non-biogenic CO_2 emissions due to urea fertilization

$$CO2\_UREA = Q\_UREA \times EF\_UREA \times \frac{44}{12}$$

Description		Unit	Source
CO2_UREA	Total CO_2 emissions due to applied urea	tonne CO_2 (year)$^{-1}$	Calculated
Q_UREA	Quantity of applied urea [$CO(NH_2)_2$]	tonnes (year)$^{-1}$	User input
EF_UREA	Emission factor, urea	tonne C (tonne urea)$^{-1}$	User input
44/12	Conversion factor: C to CO_2		Constant

Source: Adapted from Equation 11.13 in IPCC (2006), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, conversion, and other default factors.

10.5.3.6 Calculating CH_4 and N_2O emissions from biomass burning and fires

Fires, whether they are the result of natural disturbances or management activities, result in biogenic CO_2 emissions, as well as other GHG emissions, including CH_4 and N_2O. This section provides guidance to calculate CH_4 and N_2O emissions from biomass burning and fires on lands that remain in the same land use.

Gross biogenic CO_2 emissions from biomass burning and fires on lands that remain in the same land use are accounted for as land management net biogenic CO_2 emissions (see Chapter 9). CO_2, CH_4, and N_2O emissions from biomass burning and fires due to a land use change (e.g., slash and burn) are accounted for as land use change emissions (see Chapter 7).

Companies should account for CH_4 and N_2O emissions from biomass burning and fire using similar data and assumptions as used to estimate any carbon stock losses from fire. Factor-based approaches can be applied to estimate GHG emissions from fire (i.e., gross biogenic CO_2, CH_4, and N_2O) using information on the area of the fire, the amount of fuel available for combustion within that area, a combustion factor (i.e., the proportion of the fuel combusted), and an emission factor. The mass of fuel available for combustion should include biomass, litter, and deadwood. When Tier 1 methods are used, litter and deadwood can be considered zero except in cases where there is land use change.

The IPCC *Guidelines for National GHG Inventories* provide a generalized equation (Equation 10.17) and Tier 1 default values to calculate GHG emissions from fire separately for each GHG across different types of burning and vegetation types.[13] Higher-tier methods using country-specific activity data, remote sensing-based approaches for detecting fires, or model-based approaches to better estimate fuel availability, fire behavior, and carbon stock losses over time may also be applied to estimate GHG emissions from fire.

Box 10.1 provides additional guidance on how to calculate GHG emissions from biomass burning and fire for different land use types.

Equation 10.17 CH_4 and N_2O emissions from biomass burning

$$GHG\_BB = A\_BURN \times M\_BURN \times CF \times EF\_BB \times 10^{-3}$$

Description		Unit	Source
GHG_BB	CH_4 and N_2O emissions from biomass burning (BB)	tonne CH_4, N_2O (year)$^{-1}$	Calculated
A_BURN	Area of land burnt in the reporting year	ha	User input
M_BURN	Mass of fuel available for combustion	tonnes (ha)$^{-1}$	User input
CF	Combustion factor	dimensionless	User input
EF_BB	Emission factor for biomass burning	g CH_4, N_2O (kg dry matter burnt)$^{-1}$	User input

Source: Adapted from Equation 2.27 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, combustion, and other default factors.

Box 10.1 Calculating GHG emissions from biomass burning, by land use types

Forest lands: IPCC *Guidelines for National GHG Inventories* assume that at the felling of a tree, the non-merchantable components, such as the bark, branches, foliage, and so on, left on the ground are transferred to the dead organic matter pool. Any CH_4 and N_2O emissions from forest residue burning or prescribed burning on forest lands should be reported in accordance with the methods described above (see Equation 10.17) and reported within the relevant scope.

Grasslands: Any CH_4 and N_2O emissions from incomplete combustion of prescribed burning on grassland should be reported in accordance with the methods described above and reported within the relevant scope.

Croplands: Crop residues are often burned during the harvest cycle, which releases CO_2, CH_4, and N_2O. Burning of crop residues or other biomass (e.g., shrubs or trees on croplands) generates carbon stock losses. Carbon stock losses from crop residue or other biomass burning on croplands should be accounted for as either losses in the dead organic matter carbon pool or the biomass carbon pool using the stock change accounting approach described in Chapter 9.

Any CH_4 and N_2O emissions from agricultural residue burning or other biomass burning on croplands should be reported in accordance with the methods described above (see Equation 10.17) and reported within the relevant scope. Companies should apply similar data and assumptions when calculating emissions from the burning of crop residues or other cropland biomass as when calculating N_2O emissions from nitrogen inputs from crop residues and soil carbon stock changes on croplands.

10.5.3.7 Calculating rice cultivation emissions

DIRECT N_2O EMISSIONS FROM RICE CULTIVATION

This section provides guidance on how to calculate direct N_2O emissions from rice cultivation. Rice is commonly grown in flooded fields, primarily in tropical regions. Nitrogen inputs to managed (i.e., flooded) soils under rice cultivation systems cause direct and indirect N_2O emissions. Calculating direct N_2O emissions due to rice cultivation follows the same general calculation guidance as direct N_2O emissions from other managed mineral soils (Equation 10.18, adapted from Equation 10.7 above). Refer to the calculation guidance in Section 10.5.3.3 (Equations 10.12 and 10.13) to quantify indirect N_2O emissions due to rice production.

Nitrogen inputs to rice cultivation systems are calculated using Equations 10.8–10.11. Tier 1 direct N_2O rice cultivation emission factors are provided in the *2019 Refinement*.[14] Tier 2 emission factors that reflect country-specific management practices may be available from national inventory reports or peer-reviewed publications. Where possible, companies should obtain activity data from operations and management records on the harvested area, nitrogen inputs, and residue and irrigation management systems for land management units (e.g., paddies).

Equation 10.18 Direct N_2O emissions from rice cultivation

$$N2O\_MSRICEdir = \left[(F\_SN + F\_ON + F\_CR + F\_SOM) \times EF_{1_r}\right] \times \frac{44}{28} \times 10^{-3}$$

Description		Unit	Source
$N2O\_MSRICEdir$	Total direct N_2O emissions from managed mineral soils (MS) under rice cultivation in the reporting year	tonne N_2O (year)$^{-1}$	Calculated
F_SN	Quantity of synthetic fertilizer N applied to soils	kg N (year)$^{-1}$	User input
F_ON	Quantity of N in applied animal manure, compost, sewage sludge, and other organic N additions applied to soils	kg N (year)$^{-1}$	Equation 10.8
F_CR	Quantity of N in crop residues (above- and below-ground) returned to soils	kg N (year)$^{-1}$	Equation 10.10
F_SOM	Quantity of N in mineral soils that is mineralized	kg N (year)$^{-1}$	Equation 10.11
EF_{1_r}	Emission factor for N_2O emissions from N inputs to soils in conditions *r*	kg N_2O-N (kg N input)$^{-1}$	User input
r	Production factors, including ecosystem, water regime, type and quantity of organic amendments, and other conditions (e.g., irrigated, rainfed, or upland production systems) that impact rice N_2O emissions		User input
$44/28$	Conversion factor: N_2O-N to N_2O		Constant

Source: Adapted from Equation 11.1 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See Table 11.1 and relevant tables therein for Tier 1 emission, conversion, and other default factors.

CH_4 EMISSIONS FROM RICE CULTIVATION

This section provides guidance on how to calculate CH_4 emissions from rice cultivation. Rice is commonly grown in flooded fields, primarily in tropical regions. This flooding creates anaerobic conditions, and microbes that decompose organic matter (e.g., from rice residues, soils, or other organic soil amendments) in these conditions produce methane (CH_4). The rates of methane production vary based on the water management regime, rice cultivar, climate, soil type, and organic matter inputs to the rice production system.

To calculate emissions from rice production, companies can apply Equations 10.19–10.21 using IPCC Tier 1 emissions factors and activity data on rice production systems.[15] Activity data on the harvested area, cultivation period, and other factors that influence rice cultivation CH_4 emissions should be based on operations or management records on lands where rice was produced. For scope 3 accounting where such data are not available,

companies can use data on the average yields or cultivation periods in the sourcing region or country, which may be available from the national statistics agency or agricultural research institutes.

A Tier 2 method applies the same methodological approach as Tier 1, but country-specific emission factors and/or scaling factors should be used (Equation 10.20). Where data are available, Tier 2 country- or management-specific baseline daily emission factors should be used and may be obtained from national inventory reports, agricultural research institutions (e.g., FAO, International Rice Research Institute), and other peer-reviewed scientific literature. Where such emission factors are not available, the most recently published IPCC regional default values should be used.

When activity data specific to the rice cultivation practices are available, along with calibration data specific to the producing region, companies should apply Tier 3 model-based approaches to estimate CH_4 emissions from rice cultivation. Where companies apply Tier 3 model-based approaches (e.g., using the DNDC model) to estimate CH_4 emissions from rice cultivation, the same biogeochemical model should be applied to estimate nitrogen cycling and associated N_2O emissions from soils, as well as soil carbon stock changes.

Equation 10.19 CH_4 emissions from rice cultivation

$$CH4\_RICE = \sum_{r} (EF\_RICECH4_r \times t_r \times A\_RICE_r \times 10^{-3})$$

Description		Unit	Source
$CH4\_RICE$	Total CH_4 emissions from rice cultivation	tonne CH_4 $(year)^{-1}$	Calculated
$EF\_RICECH4_r$	Daily CH_4 emission factor for conditions *r*	kg CH_4 $(ha)^{-1}(day)^{-1}$	User input; Equation 10.20
t_r	Cultivation period for rice in conditions *r*	day	User input
A_RICE_r	Annual harvested area of rice in conditions *r*	ha yr^{-1}	User input
r	Rice management system (based on particular production factors, including ecosystem, water regime, type and quantity of organic amendments, and other conditions (e.g., irrigated, rainfed, or upland production systems) that impact rice CH_4 emissions)		User input

Source: Adapted from Equation 5.1 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, combustion, and other default factors.

Equation 10.20 Adjusted daily CH_4 emission factor for rice cultivation

$$EF\_RICECH4_r = EF\_RICE \times SF\_W_r \times SF\_P_r \times SF\_O_r \times SF\_S_r \times SF\_R_r$$

Description		Unit	Source
$EF\_RICECH4_r$	Rice cultivation daily CH_4 emission factor adjusted for a particular harvested area *r*	kg CH_4 $(ha)^{-1}$ $(day)^{-1}$	Calculated
EF_RICE	Baseline emission factor for continuously flooded fields without organic amendments	kg CH_4 $(ha)^{-1}$ $(day)^{-1}$	User input
SF_W_r	Scaling factor to account for the differences in water regime during the cultivation period for rice management system *r*	dimensionless	User input
SF_P_r	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period for rice management system *r*	dimensionless	User input
SF_O_r	Scaling factor to account for both type and amount of organic amendment applied for rice management system *r*	dimensionless	Equation 10.21
SF_S_r	Scaling factor to account for soil type for rice management system *r*	dimensionless	User input
SF_R_r	Scaling factor to account for rice cultivar for rice management system *r*	dimensionless	User input
r	Rice management system (based on particular production factors, including ecosystem, water regime, type and quantity of organic amendments, and other conditions (e.g., irrigated, rainfed, or upland production systems) that impact rice CH_4 emissions)		User input

Source: Adapted from Equations 5.2 and 5.2(a) in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 emission, combustion, and other default factors.

Equation 10.21 Adjusted rice cultivation CH_4 emissions scaling factor for organic amendments

$$SF\_O_r = \left(1 + \sum_{oa} ROA_{oa} \times CFOA_{oa}\right)^{0.59}$$

Description		Unit	Source
SF_O_r	Scaling factor to account for both type and amount of organic amendment applied for rice management system *r*	dimensionless	Calculated
ROA_{oa}	Application rate of organic amendment *oa*	tonne $(ha)^{-1}$ (tonne dry weight for straw, fresh weight for other amendments)	User input
$CFOA_{oa}$	Conversion factor for organic amendment *oa*	dimensionless	User input
oa	Organic amendment		User input

Source: Adapted from Equation 5.3 in IPCC (2019a), *Volume 4: Agriculture, Forestry, and Other Land Use*. See relevant tables therein for Tier 1 scaling, conversion, and other default factors.

10.5.3.8 Calculating other GHG emissions from land management production activities

This section provides general calculation guidance for other GHG emissions (fossil CO_2, fluorocarbons, etc.) that occur due to land management production activities but are not covered in other sections in Chapter 10. Note that land-based products have life cycle GHG emissions beyond the farm gate (e.g., emissions relating to processing, refrigeration, and other stages beyond the farm gate), but these life cycle emissions are not included in this section. Accounting and calculation guidance on other life cycle emissions categories can be found in the *Scope 3 Calculation Guidance*.

GHG COMBUSTION EMISSIONS FROM ON-SITE FUEL AND ENERGY USE AND OTHER INDUSTRIAL EMISSIONS

Other CH_4, N_2O, non-biogenic CO_2, hydrofluorocarbons (HFCs), and perfluorocarbons (PCFs) emissions associated with recurring agricultural production or other land management activities that are not technically "land emissions" are often included in life cycle land management production emission factors. These types of emissions include, but are not limited to:

- Fossil-based land management production emissions, including CO_2 emissions from on-site machinery (e.g., tractors, feller-bunchers, irrigation pumps, etc.), and life cycle energy emissions embedded in production inputs (e.g., fertilizer, chemical inputs, etc.)
- HFC and PCF emissions (e.g., from air conditioning and refrigerant use)
- Emissions from on-site waste or wastewater management
- Indirect emissions from purchased energy associated with land management production activities

Companies should report these emissions as "fossil fuel and industrial emissions" if data allow. This may require companies to obtain life cycle GHG emission factors that are disaggregated by fossil fuel and industrial emissions, LUC emissions, land management net biogenic CO_2 emissions, land management production emissions, and biogenic product emissions.

Companies may include these emissions as land management production emissions if such emissions are not included under fossil and industrial emissions. As set forth in the reporting requirements in Section 10.2.2 in the *Standard,* companies must disclose where these types of emissions are reported in the inventory (i.e., as "land management production emissions" or "fossil fuel and industrial emissions").

Endnotes

1 IPCC 2022.

2 Tian et al. 2020

3 Available at https://unfccc.int/ghg-inventories-annex-i-parties/2021

4 See Chapter 10 in Volume 4 of IPCC 2019a.

5 Enhanced characterization is a term derived from IPCC national inventory guidance. See Chapter 10 in Volume 4 of IPCC 2019a.

6 See discussion in Section 10B.5 in Volume 4 of IPCC 2019a.

7 Hegde et al. 2025.

8 See Table 10.17 in Chapter 10 in Volume 4 of IPCC 2019a.

9 IPCC 2019; Volume 4, Chapter 11, Table 11.1.

10 See, e.g., Gephart et al. 2021 and MacLeod et al. 2020

11 IPCC 2019a; Volume 4, Chapters 10 & 11.

12 See Equations 3.7 and 3.8 in IPCC 2014.

13 IPCC 2019a; Volume 4, Chapter 2, Section 2.4.

14 IPCC 2019a; Volume 4, Chapter 11.

15 IPCC 2019a; Volume 4, Chapter 5, Section 5.5.

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