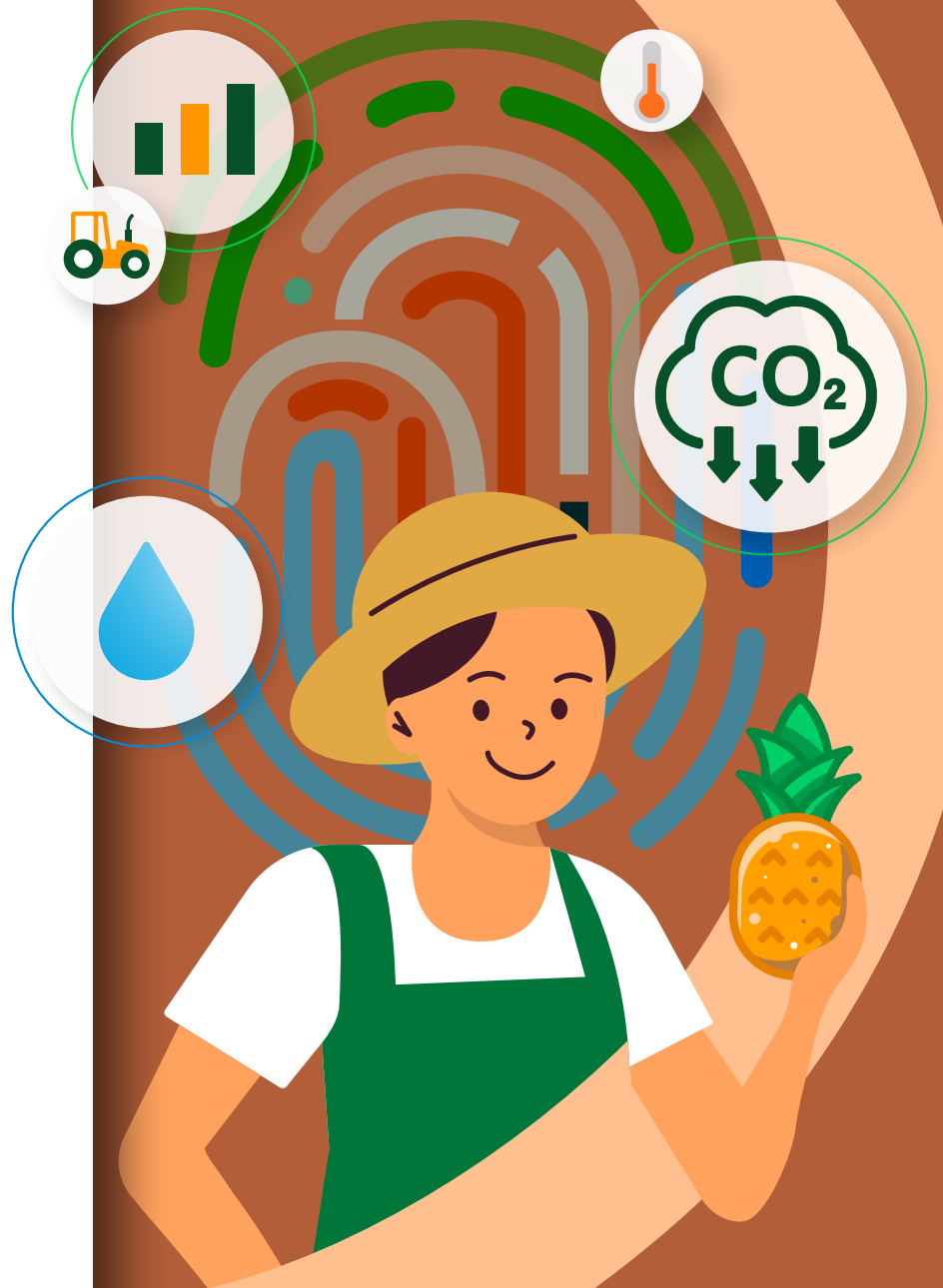




Food and Agriculture
Organization of the
United Nations



MEASURING CARBON AND WATER FOOTPRINTS IN PINEAPPLE VALUE CHAINS

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ABBREVIATIONS

AWARE	available water remaining methodology
BEF	biomass expansion factors
BOD	biochemical oxygen demand
CF	characterization factor
COD	chemical oxygen demand
CTUe	comparative toxic units of ecotoxicity
CTUh	comparative toxic units of human toxicity
DEFRA	United Kingdom's Department for Environment, Food and Rural Affairs
EF	emission factor
EPA	United States Environmental Protection Agency
ET	evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gases
GWP	global warming potential
ha	hectare
HFCs	hydrofluorocarbons
IMN	Instituto Meteorológico Nacional de Costa Rica
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IWW	industrial wastewater
kg	kilogram
L	litre
LB	live biomass
MSDS	material safety data sets
MSW	municipal solid waste
OWW	ordinary wastewater
PAF	potentially affected species
PFCs	perfluorocarbons
POD	spodic soils
SAN	sandy soils
SOC	organic carbon stock
USDA	United States Department of Agriculture
VOL	volcanic soils
WET	wetland soils
WRB	World Reference Base for Soil Resources
WULCA	water use in lifecycle assessment

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The guide was prepared by Verónica Vargas Madrigal, Miguel Ángel Vallejo Solís, Ana Lorena Vallejo Chaverri. Diagrams and illustration were designed by Stephanie Rojas Ávila. Edwin Rodríguez created the final layout.

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1. INTRODUCTION

The pineapple value chain is an important source of livelihoods in developing countries and the fruit is a valuable part of food and nutrition security in producing and importing countries. At the same time, the agriculture sector, including pineapple value chains, is facing increased scrutiny over its sustainability. Concerns about greenhouse gas emissions, water usage and water contamination are growing and can have an impact on consumer choice, and access to markets and finance.

The agriculture sector, and tropical fruit in particular, are at risk from the negative impacts of climate change driven by rising temperatures, extreme weather events including tropical cyclones, and associated challenges such as water stress and increased pests and diseases. The combined challenges of climate change and water management pose significant risks for the long-term sustainability of production and trade of tropical fruits including pineapples.



The atmosphere is made up of different types of gases, some of which have a good capacity to absorb solar radiation. These are known as greenhouse gases (GHG) and play an important role in warming the atmosphere and, consequently, creating an adequate temperature on Earth to support life. This process is known as the natural greenhouse effect. However, human activities have led to an increase in GHG emissions. This has resulted in a greater amount of GHG in the atmosphere, increasing the capture of solar radiation, and thus increasing the average temperature of the Earth. This phenomenon and its main consequence, an increase in the global average temperature, is known as climate change.

By quantifying and reducing GHG emissions, companies in the pineapple value chain can become more efficient, reduce costs, enhance the resilience of their operations and mitigate climate change.

Water, on the other hand, is an essential resource for human life and ecosystems, which cannot be replaced by any other substance. Its availability worldwide varies depending on the region. In some regions this resource is scarce, having negative impacts on human health and biodiversity. Even where there are no scarcity issues, overexploitation and contamination of water sources due to industrial and agricultural uses can lead to negative impacts on human health and biodiversity.

Water-related challenges are compounded by climate change, which is expected to increase pressure on water sources. Quantifying water use and pollution and assessing the environmental impact under a life-cycle approach are fundamental steps to reduce negative impacts on water and ensure its quantity, quality and continuity for a company and the people and environment that share the resource.

Recognizing these challenges, the [Responsible Fruits Project](#) has developed this technical guide on measuring carbon and water footprints

for the pineapple industry. The project builds on more than a decade of FAO experience working with the private sector on tropical fruits.¹ It works with businesses, farmer organizations and cooperatives, importers and exporters (henceforth collectively referred to as “companies”) and other actors in the pineapple value chain.

This guide is part of a series of demand-driven products prepared by the project. The topic, measuring carbon and water footprints, was selected in partnership with project participants as a priority area in the context of building resilient and sustainable businesses. It is closely linked to the project’s technical guide [Adapting to climate change in the tropical fruit industry: a technical guide for pineapple producers and exporters](#) (FAO, 2024).

This technical guide has two main objectives: Introduce companies in the pineapple value chain to a methodology to estimate the carbon footprint of their operations. Introduce companies in the pineapple value chain to a methodology to estimate the footprint of their direct water use.

The quantification of GHG emissions derives from years of research and was promoted in 1997 with the approval of the Kyoto Protocol, during the Third Conference of the Parties on Climate Change. There are different methodological references for the quantification of emissions, including the Intergovernmental Panel on Climate Change (IPCC) Guidelines, the guidelines published by the Greenhouse Gas Protocol (GHG Protocol), voluntary standards such as PAS 2060, and the set of voluntary standards of the International Organization for Standardization (ISO), ISO 14064, which cover the development of national, organizational or product inventories. In this technical guide,

¹ This includes facilitating the World Banana Forum and its work on reducing carbon and water footprints on banana plantations (see <https://www.fao.org/world-banana-forum/projects/reducing-carbon-and-water-footprints-in-banana-plantations>), and work with over 30 leading agrifood enterprises and industry associations to apply the risk-based due diligence recommendations of the OECD-FAO Guidance for responsible agricultural supply chains.

carbon footprint estimation is based on ISO 14064 “Greenhouse gases - Part 1: specification with guidance, at the organization level, for the quantification and reporting of greenhouse gas emissions and removals”.² Additionally, it relies on the GHG Protocol guidelines and the IPCC Guidelines as emission quantification methodologies.

The concept of water footprints has evolved over time. In this technical guide, estimating a water footprint is based on ISO 14046 “Environmental Management - Water footprint - Principles, requirements and guidelines”.³ This methodology is more comprehensive when evaluating the management of water resources in a company or product and thus provides a more meaningful indicator compared to other methods. It allows the company to analyse and understand its impact, identify risks and opportunities related to water management, and monitor and communicate performance to the company’s stakeholders. In addition, the global market is moving towards the concept of life-

cycle analysis, on which ISO 14046 is based. Given the high degree of technical complexity with both footprints, this guide is oriented to technical staff, environmental engineers or professionals in related areas, who are responsible for the quantification of carbon footprints and/or water footprints in pineapple companies. Ideally, readers of this guide should have knowledge of emissions inventories, carbon neutrality and water management

² See <https://www.iso.org/standard/66453.html>

³ See <https://www.iso.org/standard/43263.html>



2. CALCULATING MY COMPANY'S CARBON FOOTPRINT



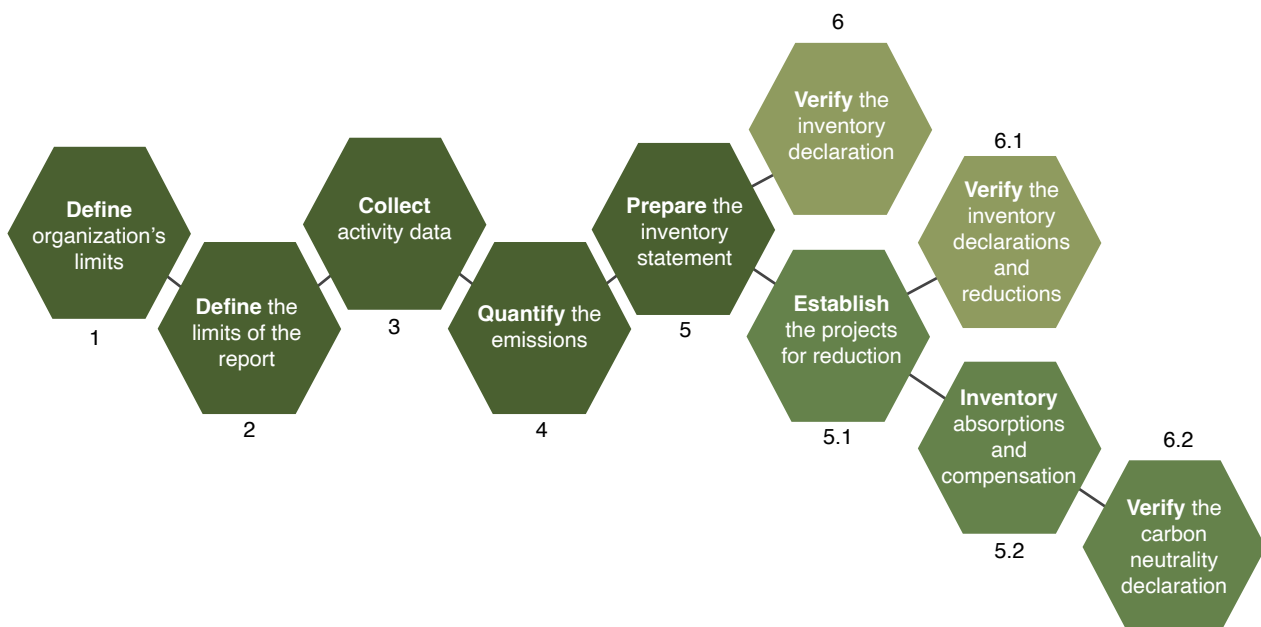
This chapter presents a detailed description of the procedure that companies in the pineapple sector, specifically producers and packers, must follow to adequately quantify and report their GHG emissions. It addresses the fundamental aspects to be considered, as well as the recommended calculation method to carry out the quantification of their carbon footprint.

Figure 1 describes the recommended steps to follow for the quantification and declaration of the

carbon footprint of companies in the pineapple sector.

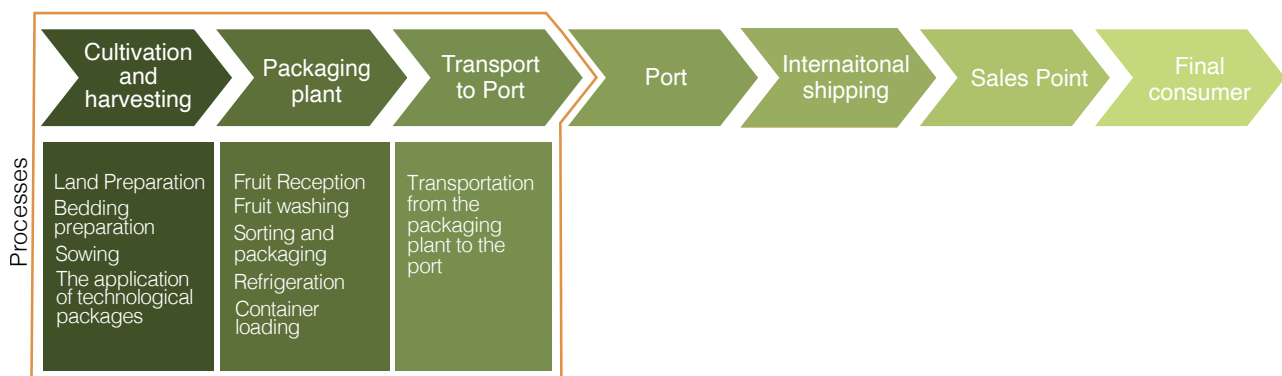
This guide is focused on the management of GHG emissions of a company whose scope depends on the limits established according to steps 1 and 2 shown in Figure 1. It considers those emissions that can be generated from the cultivation area (planting and harvesting), packing process (packing plant), and the land transportation of the fruit to the ports for export (Figure 2).

Figure 1. Emission inventory measurement and reporting process



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://openknowledge.fao.org/handle/20.500.14283/i8333en>

Figure 2. Stages of the pineapple value chain considered in the guide



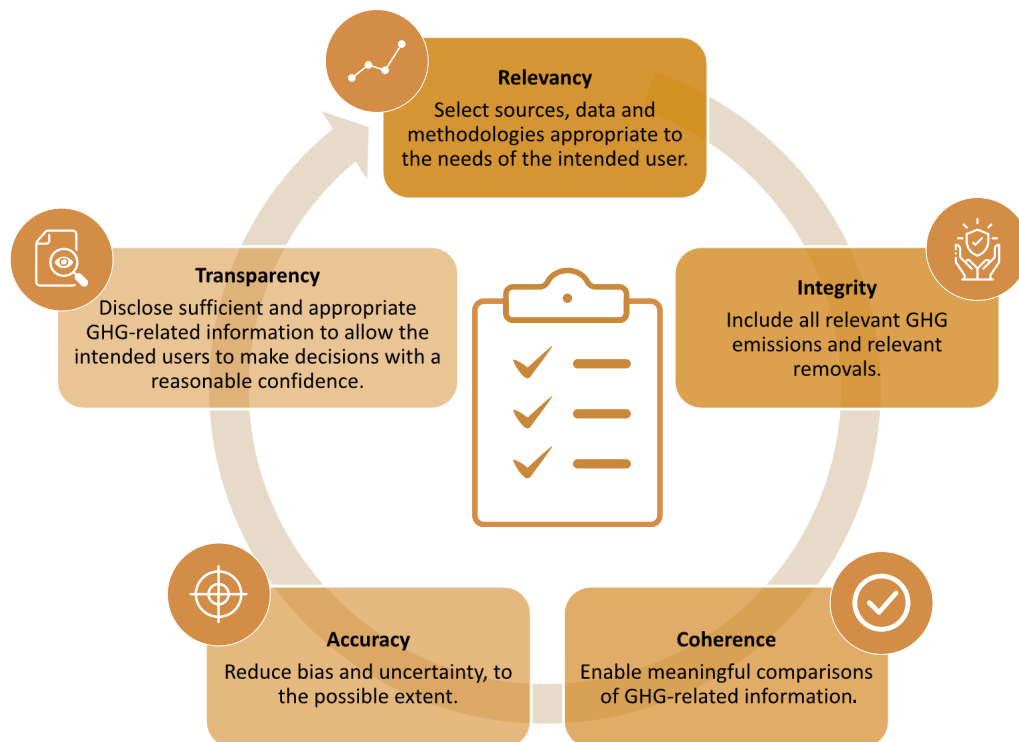
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2.1 Principles for accounting and reporting emissions

There are five fundamental principles to ensure that information and calculations related to GHG are true and reasonable. The principles are

defined in Figure 3 as set out in the international standard ISO 14064-1 (INTECO, 2019).

Figure 3. GHG emissions accounting and reporting principles



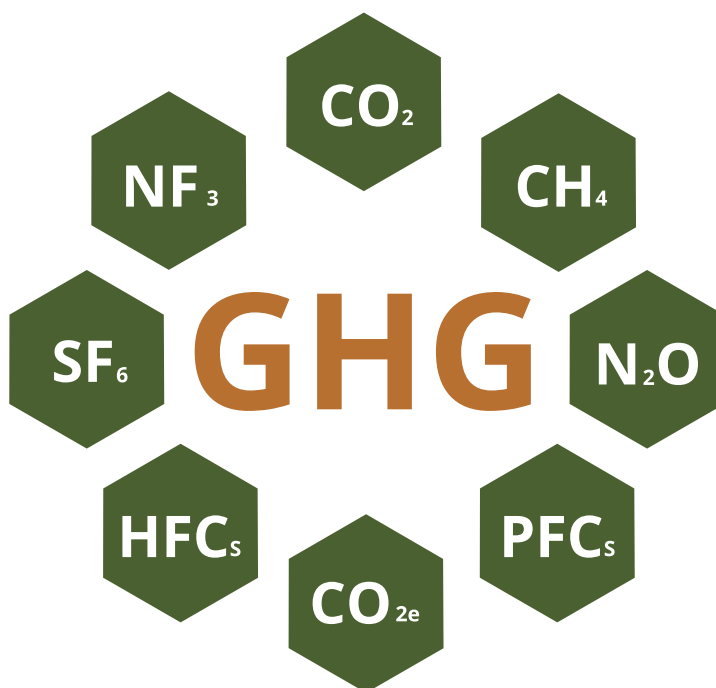
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2.2 What are the concepts I need to understand to properly manage my emissions?

- **Greenhouse gases (GHG):** are gaseous components present in the atmosphere, both of natural origin and as a result of human activities, that have the capacity to absorb and emit radiation (INTECO, 2019). These gases are considered to be responsible for the phenomenon of climate

change. When developing an emissions inventory, the following GHG are taken into account: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃). See Figure 4.

Figure 4. Greenhouse gases



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

Figure 4. General equation for calculating GHG emissions



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

- **GHG emission source:** any activity or process that causes GHG emissions into the atmosphere (INTECO, 2019).
- **GHG emissions:** the total amount of one or more GHG released into the atmosphere at a specific time. (INTECO, 2019). To determine the GHG generated by the identified sources in relation to the company’s activities or processes (for example, electricity consumption, fuel consumption, crop residue management, fertilizer application, etc.), a base formula detailed in Figure 5 will be employed.
- **Magnitude of the activity (activity data):** a specific quantitative measure of the activity/source that generates the emissions, which allows the calculation of the impact of the emissions (INTECO, 2019).
- **Carbon equivalent (CO₂e)⁴:** the unit that

⁴ To accumulate or sum emissions and allow comparisons, all emissions must be reported in the same unit of measurement, carbon dioxide equivalent.

allows comparison of the radiation force of a given GHG with carbon dioxide or CO₂. Carbon dioxide equivalent is calculated using the mass of a given GHG multiplied by its global warming potential (see below) (INTECO, 2019).

- **Emission factor (EF)⁵:** is a factor that relates the magnitude of the activity to the emission of a specific GHG (INTECO, 2019). There are differentiated emission factors to determine emissions by type of GHG and in some cases there are emission factors in CO₂e.
- **Global warming potential (GWP)⁶:** value that describes the greenhouse effect impact of a given GHG, with respect to CO₂, which allows reporting all emissions in terms of CO₂e (INTECO, 2019).
- **Direct GHG emissions:** GHG emissions from GHG sources owned or controlled by the company (INTECO, 2019).
- **Indirect GHG emission:** GHG emission resulting from the operations and activities of a company, but from sources that are not owned or controlled by the company (INTECO, 2019).
- **GHG sink:** any physical and/or chemical activity or process that, when carried out, results in the removal of GHGs from the atmosphere (INTECO, 2019).

- **GHG removal:** the total mass of any GHG that has been removed from the atmosphere at a given time (INTECO, 2019).
- **GHG emissions inventory:** a document that groups a company's sources, sinks, emissions and removals of GHG (INTECO, 2019). This is a benchmark tool for the company to understand its emissions and the risks associated with them, identify emission reduction opportunities, establish objectives and reduction targets, and communicate its performance to its stakeholders (Vallejo *et al.*, 2018).
- **Reduction Initiative:** an action that reduces the amount of GHG emitted or that increases its removal or capture (INTECO, 2019).
- **Adaptation measure:** an action that will allow the company to adapt to the expected consequences of climate change (DCC, 2014).
- **Offsetting:** the voluntary purchase of offsetting mechanisms in order to compensate for the emissions that have not been reduced internally (INTECO, 2021).

⁵ There are several recognized sources of information on emission factors, including the Intergovernmental Panel on Climate Change (IPCC) Guidelines, the United States Environmental Protection Agency (EPA), the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA), national publications such as Costa Rica's emission factors published by the National Meteorological Institute, among others. For the purposes of this guide, emission factors from the National Meteorological Institute of Costa Rica and the IPCC are used as reference. See Annex 1. Emission factors.

⁶ There are Global Warming Potentials published by different IPCC Reports. It is recommended to use the most recent ones, or when applicable, those requested by the GHG program. Each GHG has a global warming potential that allows emissions to be represented in a comparative unit (carbon dioxide equivalent). See Annex 2. Global Warming Potentials.

2.3 Defining the scope of the inventory

The company should be clear about the purpose for which it will quantify its emissions, which should also respond to the objectives of the target user. For instance, the trade association, the client, a carbon neutral country programme or a verification body. Once the purpose and reason of the study have been identified, the limits of the study can be defined, including organizational limits, reporting limits, types of GHG, and the timeframe to be covered. These boundaries define the scope of the inventory (Vallejo *et al.*, 2018).

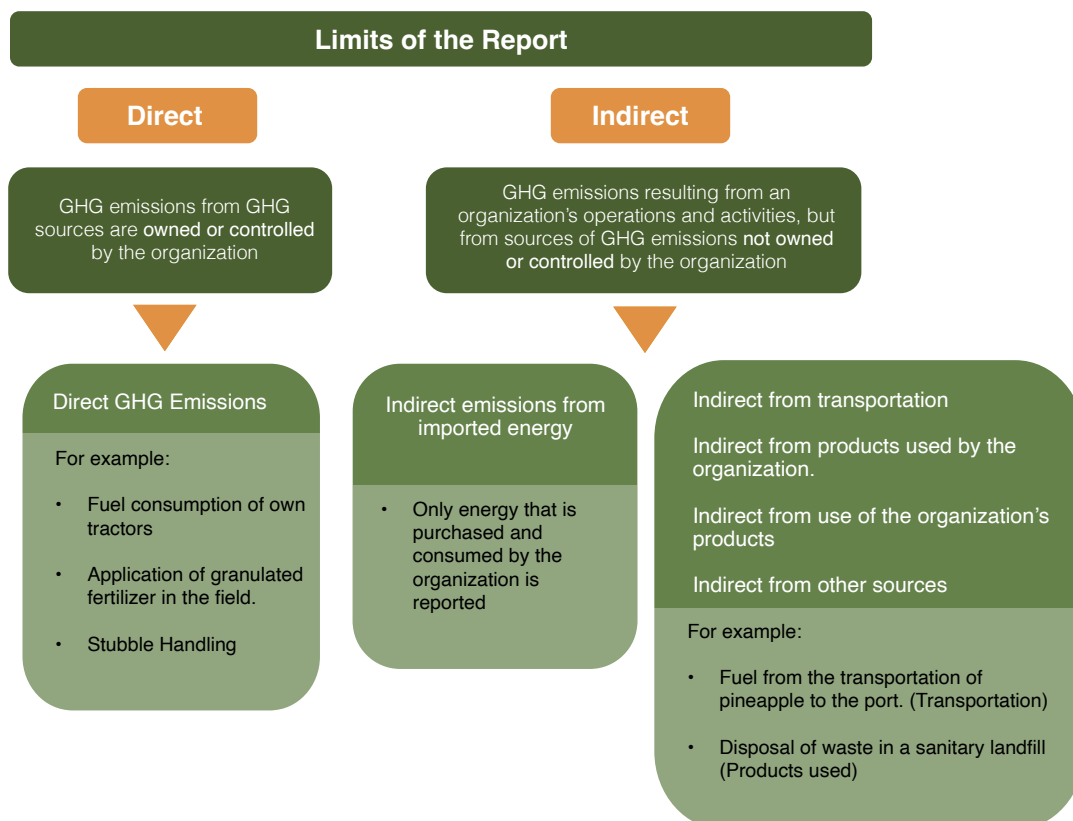
2.3.1 What should the organizational and reporting boundaries be when managing emissions?

The company should define the organizational and reporting boundaries that are envisaged in

the inventory development and reporting. The **organizational boundaries** refer to the areas of the company that will be considered: physical facilities, cultivation, processing, packaging and shipping areas, as well as the consolidation approach selected for inventory quantification. Of the options available, the control approach is recommended, which consists of selecting those activities, processes and facilities over which the company has operational control and decision-making power (Vallejo *et al.*, 2018).

Reporting boundaries refer to the identification of direct and indirect emissions and removals associated with the organization's operations. GHG emissions are classified by category, as defined in Figure 6.

Figure 6. Categorization of emissions in a company (INTE-ISO 14064-1)



Source: Authors' own elaboration.



Important

Although this guide provides methodological guidance for emission sources that may be categorized as direct or indirect emissions, it does not consider the identification of all indirect sources from the company's operations, nor the evaluation of such sources to determine the ones that are considered as significant. It is recommended that each company perform its analysis, identification, and evaluation of indirect sources to determine the significant ones, using INTE-ISO 14064-1 as a guideline.

Annex B of the INTE-ISO 14064-1 reference norm provides guidance on how to classify emission sources by categories and subcategories.

2.3.2 Selection and establishment of a base year

The company should establish a base year for GHG emissions and removals for comparison purposes that can help it meet GHG targets or comply with GHG program requirements or other intended uses of the GHG inventory.

The base year can be determined taking as a reference a specific period (for example, a year in which seasonal conditions are a feature of the company's activity) or averaged over several periods (e.g. several years). In the case of insufficient information on historical GHG emissions or removals, the company may use its first GHG inventory period as the base year (INTECO, 2019).

It is important that the base year has data that is representative of the company's current reporting

boundaries, and that the data is available, complete, supported, and verifiable. The period selected should cover all twelve months of a calendar year.

2.4 Emission sources in the pineapple sector

All activities that generate GHG emissions into the atmosphere represent an emission source. Emission sources that are within the proposed organizational and reporting boundaries should be identified. They should also be quantified in the emissions inventory by category, i.e. quantify direct emissions, indirect emissions from energy

and significant indirect emissions determined by the company. The following sections summarize the most important potential emission sources that may be found in the processes of planting, harvesting, packing and transport to port of pineapple for export. In Figure 7 some examples are shown (Vallejo *et al.*, 2018).

2.5 What data should be collected and how to estimate emissions?

It is essential that the company collects accurate data on each emission-generating activity from reliable sources. This ensures that the origin of the information is clearly identified and documented.

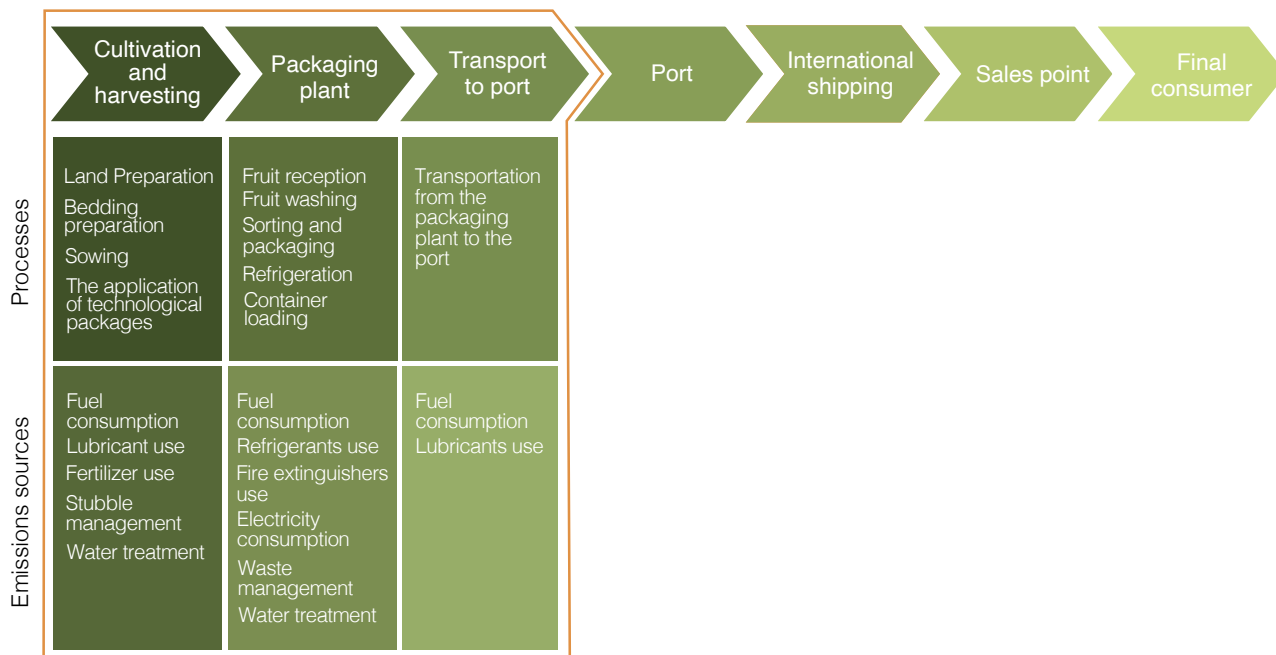
Examples of reliable and direct references for obtaining this data include invoices for services or product purchases, receipts, safety data sheets, records, reports and maintenance data.

These sources provide valid information that supports and ensures the quality and accuracy of the data collected (Vallejo *et al.*, 2018).

The following sections present the priority inventories for a company in the pineapple sector, and also additional or suggested inventories.

Each emission source is described in detail, including its calculation method, guidance on activity data collection, selection of emission factors, and applicable recommendations or exceptions. Example calculations are also provided for illustration and practical application purposes.

Figure 7. Examples of emission sources in the pineapple value chain



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>



For consideration:

In situations where data is missing or there is some limitation in the availability of information, it may be necessary to perform additional calculations or use theoretical data to complete the emissions assessment. This may involve the use of calculation models, theoretical data or references, as well as advice from subject matter experts to ensure the accuracy and completeness of the results obtained.

2.6 Most important emissions in the pineapple industry



Important

All emissions of the different GHG must be converted to CO₂e units, for which the GWP is used. The results of the inventory must be reported in tonnes of CO₂e.

Table 1 details the most significant emission sources in the various stages of pineapple production, which can be categorized as direct or indirect, depending on the control approach. Each source may be composed of several sub-sources that generate emissions, which may be associated with different types of GHG. In addition, the

same emission sources may be found in different emission categories, which will depend on the analysis, identification and evaluation of indirect sources carried out by the company. This process will determine which indirect emissions should be quantified.

Table 1. Main emission sources in pineapple companies

Source	Sub-source (examples)	GHG
Electricity consumption	Electricity consumption from the power grid	CO ₂ e
Use of lubricating oils	Use of engine lubricants in vehicles, tractors, or trucks Use of mixed lubricants in weed whackers	CO ₂ , CH ₄ , N ₂ O
Use of fire extinguishers	Use of CO ₂ fire extinguishers Use of clean agent fire extinguishers Use of halon fire extinguishers	CO ₂ , HFC, halons
Gas consumption for welding and oxyfuel (acetylene, propane)	Use of acetylene for welding Use of propane for oxyacetylene cutting	CO ₂ , CH ₄ , N ₂ O
Refrigerant gas leaks	Leaks of refrigerant gas from air conditioners Leaks of refrigerant gas from refrigerators Leaks of refrigerant gas from cold storage rooms	HFC, HCFC
Fossil fuel consumption (mobile and stationary sources)	Diesel consumption in field tractors Gasoline consumption in vehicles Diesel consumption in emergency power generator	CO ₂ , CH ₄ , N ₂ O
Use of nitrogen fertilizers	Use of granular fertilizers Use of fertigation	N ₂ O
Use of organic amendments	Use of organic fertilizers in the field Use of organic liquid fertilizer in the soil	N ₂ O
Soil correctors	Use of limestone Use of dolomite lime	CO ₂
Stubble management	Green management (incorporation of stubble residues into soil) Chemical drying of stubble with herbicide Chemical drying of stubble with herbicide and then burning	CO ₂ , CH ₄ , N ₂ O
Solid waste disposal	Disposal of waste in landfill Waste composting	CH ₄ , N ₂ O

Source	Sub-source (examples)	GHG
Wastewater treatment	Sewage disposal in septic tanks Use of latrines Aerobic treatment plant Oxidation lagoons	CH ₄ , N ₂ O

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. Methodological guide to reduce carbon and water footprints in banana plantations. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>

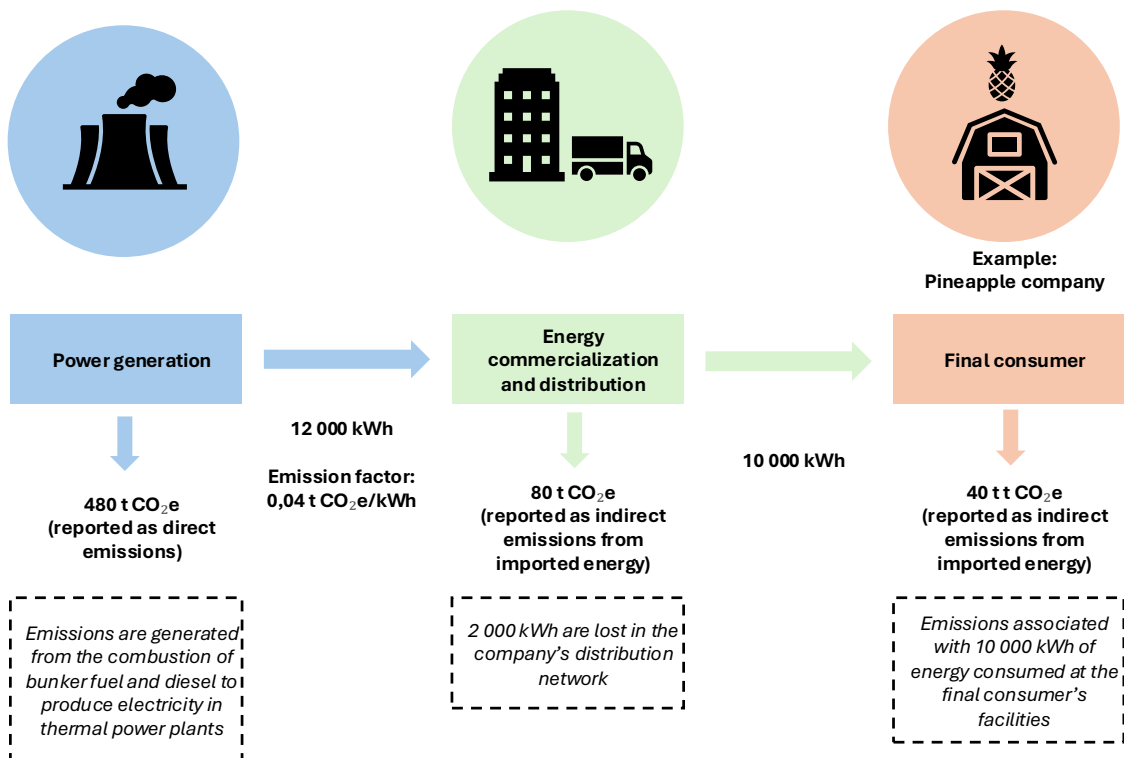
2.6.1 Electricity consumption

Category	Indirect from imported energy						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others
Electricity						✓	

Emissions from imported electricity correspond to those associated with the production of electricity consumed by the company. When a company purchases, acquires and consumes electricity from an electrical grid, it has associated indirect GHG emissions that must be accounted for.

For the purposes of this guide, the emission source indicated is considered only when the company consumes electricity produced by a third party. In Costa Rica, for example, third-party providers include the Costa Rican Institute of Electricity, Cooperative of Rural Electrification of San Carlos and National Power and

Figure 8. Example of GHG accounting of energy production, sales and consumption



Source: Authors' own elaboration



Exceptions:

- If the company has a distributed generation system (solar panels), and consumes energy from a third party's grid, the electricity consumption activity data to be considered in the calculations will be the net consumption billed by the service provider. This is obtained from the difference between the energy consumed from the grid, the energy generated by the company and the energy injected into the grid.
- If the company produces its own energy generation, this emission source should be reported as a direct category emission. For example, if energy production comes from fossil fuels, emissions associated with fuel consumption for electricity generation should be included as a direct emission source (Vallejo *et al.*, 2018).
- If 100 percent of the energy consumed comes from solar panels, this energy is exempt from the emission sources and therefore does not have an associated emission factor. Thus, it is considered as "zero" emissions. This energy consumption is not included in the quantification of the GHG emissions.

Light Company, among others). Such emissions should be reported in the category of indirect emissions from imported energy (Vallejo *et al.*, 2018).

Figure 8 provides an example of how to deal with emissions associated with electric power generation.

2.6.1.A Calculation method

Equation 2.6.1a

$$\text{Electricity emissions (t CO}_2\text{e): } AD \times EFE \times CF$$

Where:

tCO₂e: emissions from electricity in tonnes of carbon dioxide equivalent.

AD: activity data (kWh or MWh).

EF_e: electricity emission factor (kg CO₂ e/kWh or MWh).

CF: unit conversion factor (e.g. conversion from kg to tonnes).

2.6.1.B Collection of information

Activity data: The origin of the activity data depends on the characteristics of each company.

In most cases, the electricity activity data comes from monthly invoices for electricity consumption, provided by the electricity service provider. In some cases, the activity data may come from meters of internal energy consumption; mainly when energy meters are shared with other companies or facilities.

Emission factor: The emission factor for electricity consumption is usually expressed as kg CO₂ e/kWh or kg CO₂ e/MWh. For the calculation of emissions from this source, average emission factors of the local, regional or national grid can be used, depending on the information available and the characteristics of generation, sale and distribution of energy in each country. The emission factor used must correspond to the emissions of the year being reported or to be calculated, if available, otherwise, of the most recent year.

Below is an example of an emissions calculation for the electricity consumption, indirect category for imported energy.



Recommendation:

Tabulate the required information in an Excel database to simplify the processing of information and associated calculations.

Example: calculation of electricity emissions

Step 1. At a farm located in San Carlos, Costa Rica, 15 000 kWh of electricity were consumed during the year 2021 from the service provider's power grid. To calculate the associated emissions from electricity consumption, first identify the appropriate emission factor (EF) for this specific source, year and country.

FE_E	Reference
$0.0400 \frac{\text{Kg CO}_2\text{e}}{\text{kWh}}$	Specific value for Costa Rica for the year 2021

Step 2. Multiply the total amount of kWh consumed by the respective emission factor to obtain the CO₂

equivalent emissions (kg CO₂ e) and convert to tonnes with the CF. Emission factors for this source are usually given in CO₂ e, so it is not necessary to use the global warming potential (GWP).

Equation 2.6.1a

$$\text{Electricity emissions (t CO}_2\text{e)} = 15\,000 \text{ kWh} \times 0.0400 \text{ kgCO}_2\text{e/kWh} \times \frac{1\text{t}}{1000 \text{ Kg}} = \mathbf{0.6 \text{ t CO}_2\text{e}}$$

2.6.2 Use of lubricants

Category:	Direct/indirect by products used by the company						
	Source	Type of GHG to be evaluated					
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others
Lubricants/oils for four-stroke engines	✓						
Two-stroke engine mixed lubricants/oils	✓	✓	✓				

Lubricating oils are petroleum products widely used as non-energy agents in the lubrication of engines and various equipment in the pineapple industry (Vallejo *et al.*, 2018). Lubricating oils that are considered in the quantification of emissions are generally classified as **lubricants for four-stroke engines**, which are not burned, such as vehicle engine oil, machinery engine oil,

and emergency generator oil, among others; and oils or **lubricants for two-stroke engines**, which are mixed with fuel in equipment such as weed whackers, chainsaws, lawn mowers, and others.

In the case of **lubricants for four-stroke engines**, it is difficult to determine which fraction

of the lubricant consumed in machines and vehicles goes into combustion and produces CO₂ emissions and which fraction is not fully oxidized. Therefore, to calculate emissions from the total amount of lubricants lost during use, it is assumed that the lubricants are completely burned and emissions are reported as CO₂ emissions (IPCC, 2006).

The company has to declare emissions of CO₂, CH₄ and N₂O when it uses **lubricants for two-stroke engines**, as these use a mixture of oil and fuel, which are burned in the engine.

The emission source can be direct if the lubricant is used in equipment owned or operated by the company. For example, if the company has its own tractors for field work. The emission source would be indirect if the use of lubricants is in third-party tractors as part of a subcontracted service.

2.6.2.A Calculation Method

Equation 2.6.2a

Lubricant emissions (t CO₂e): $AD \times EF_{GHG} \times GWP \times CF$

Where:

t CO₂e: emissions from the use of lubricants in tonnes of carbon dioxide equivalent.

AD: activity data related to the volume of oil or lubricant (litres of lubricant).

EF_{GHG}: emission factor by type of GHG evaluated (e.g. kgCO₂/L of lubricant).

GWP: global warming potential by type of GHG evaluated.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.2.B Collection of information

Activity data: To obtain the number of litres of **lubricants for four-stroke engines**, which is not combusted, it is necessary to account for the volume of oil used per change or



Important

In the case of lubricants for four-stroke engines, which do not combust, only CO₂ emissions are determined. On the other hand, in the case of lubricants for two-stroke engines, which are combusted, CO₂, CH₄ and N₂O emissions are determined.

consumption in various cargo and transport vehicles related to production activities. It is also necessary to account for the volume of oil used in other vehicles and machinery (e.g. tractors) and equipment with four-stroke engines (e.g. pumps or generators) owned by the company. The volume of oil can be obtained from maintenance reports, internal records of oil changes per vehicle or equipment, or purchase invoices.

To determine the number of litres of **lubricants for two-stroke engines** that is combusted, it is necessary to consider the volume of oil that is mixed with the fuel in equipment with two-stroke engines, such as weed whackers, motorcycles and chainsaws, among others. The volume of oil used can be obtained from internal oil consumption records, purchase invoices, among others.



Important

Depending on the country or data source, the volume of oil may be expressed in different units, such as quarts, gallons or millilitres. However, since most of the available emission factors are given in kilograms of GHG per litre, it is necessary to convert the selected units to litres.



Recommendation:

- If data on the volume of lubricants for four-stroke engines used is not available, it can be estimated from the oil storage capacity of the engines and the frequency of oil changes. As last resort, theoretical oil usage data for each engine can be used, obtained from the technical data sheets of the equipment or from literature review (Vallejo *et al.*, 2018).
- If data on the volume of lubricants for two-stroke engines used is not available, the amount of oil can be estimated using the data for fuel used in two-stroke engine equipment and a reference of the ratio of blended oil to gasoline.
- For both cases indicated above, it is recommended to keep evidence of the references used.
- Tabulate the required information in an Excel database to simplify the processing of information and associated calculations.

Emission factor: The emission factor for use of lubricants for four-stroke engines is usually expressed as Kg CO₂/L. In the case of lubricants for two-stroke engines, the emission factors are usually expressed in Kg CO₂ and grams of CH₄

and N₂O per litre, (i.e., Kg CO₂/L, g CH₄/L and g N₂O/L).

The following is an example of an emissions calculation for the source of lubricant use.

Example: calculation of lubricant emissions

Step 1. At a pineapple farm, a total of 1 000 litres of motor oil was accounted for by oil changes of the farm's own tractors during the year 2022, and a total of 25 quarts of two-stroke engine oil blend for the farm's own equipment. To proceed with the quantification of emissions, identify the appropriate emission factors (EF) for each type of oil and identify the units required from the activity data.

Type of lubricant/factor	EF _{UAL}	Reference
Lubricants for four-stroke engines	0.5184 $\frac{\text{Kg CO}_2}{\text{L}}$	Specific value for Costa Rica provided by the National Meteorological Institute (IMN).
Lubricants for two-stroke engines	2.549 $\frac{\text{Kg CO}_2}{\text{L}}$	Specific value for Costa Rica by the National Meteorological Institute (IMN).
Residential/agricultural - lubricants for two-stroke engines	0.348 $\frac{\text{g CH}_4}{\text{L}}$	
Residential/agricultural - lubricants for two-stroke engines	0.021 $\frac{\text{g N}_2\text{O}}{\text{L}}$	

It is preferable to use country specific EFs, but in case they are not available, the EFs given by the IPCC can be used ([Annex 1. Emission factors](#)).

Step 2. Note that the emission factors are given per unit of litres, so in the case of the two-stroke blend oil activity data, the conversion from quarts to litres must be made.

$$\text{Litres of blending oil (two-stroke engines)} = 25 \text{ quarts} \times \frac{0.946 \text{ L}}{1 \text{ quarter}} = 23.65 \text{ litre}$$

Step 3. Once both activity data in litres have been obtained, the emissions for each type of lubricant are calculated by multiplying the total amount of oil used by the respective emission factor (see [Annex 1](#)) and the respective global warming potential (see [Annex 2](#)), to obtain the equivalent CO₂ emissions of the lubricating oils.

Four-stroke engine lubricant

Equation 2.6.2a

$$\text{Lubricants emissions (t CO}_2\text{e) (CO}_2\text{)} = 1\,000 \text{ L} \times 0.5184 \frac{\text{kg CO}_2}{\text{L}} \times 1 \times \frac{1\text{t}}{1000 \text{ Kg}} = 0.5184 \text{ t CO}_2\text{e}$$

Two-stroke engine lubricant

Equation 2.6.2a

$$\text{Lubricant emissions (t CO}_2\text{e) (CO}_2\text{)} = 23.65 \text{ L} \times 2.549 \frac{\text{kg CO}_2}{\text{L}} \times 1 \times \frac{1\text{t}}{1000 \text{ Kg}} = 0.060 \text{ t CO}_2\text{e}$$

$$\text{Lubricant emissions (t CO}_2\text{e) (CH}_4\text{)} = 23.65 \text{ L} \times 0.348 \frac{\text{g CH}_4}{\text{L}} \times 21 \times \frac{1\text{t}}{1000000 \text{ g}} = 0.000173 \text{ t CO}_2\text{e}$$

$$\text{Lubricant emissions (t CO}_2\text{e) (N}_2\text{O)} = 23.65 \text{ L} \times 0.021 \frac{\text{g N}_2\text{O}}{\text{L}} \times 310 \times \frac{1\text{t}}{1000000 \text{ Kg}} = 0.000154 \text{ t CO}_2\text{e}$$

Total emissions from two-stroke engine lubricant

$$0.060 \text{ t CO}_2\text{e} + 0.000173 \text{ t CO}_2\text{e} + 0.000154 \text{ t CO}_2\text{e} = 0.061 \text{ t CO}_2\text{e}$$

2.6.3 Use of fire extinguishers

Category:	Direct/indirect by products used by the company						
	Type of GHG to be evaluated						
Source	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
CO ₂ extinguishers	✓						
Halotron extinguishers				✓			
Clean agent extinguishers				✓	✓		✓

Fire extinguishers are safety devices designed for the purpose of controlling and extinguishing fire in a timely manner. Some extinguishers use extinguishing agents such as carbon dioxide

(CO₂), hydrofluorocarbons (HFCs) and, to a lesser extent, perfluorocarbons (PFCs), which are considered GHG. To ensure the effectiveness of a fire extinguisher, it is essential to guarantee the

quality of its extinguishing agent. Therefore, these devices require regular maintenance and, in some cases, must be recharged periodically. During the recharging process, the contents of the extinguisher may be released for subsequent recharging or, when used, there may be an intentional or accidental release, generating an emission into the environment. Table 2 lists some of the commonly used extinguishing agents, which represent a greenhouse gas.

Table 2. Commonly used extinguishing agents

Extinguishing agent
CO ₂ (dry ice)
HFC-23
HFC-125
HFC-227ea
HFC-236fa
Halon 1211
Halon 1301
PFC-143 (CF ₄)
PFC-31-10 (C ₄ F ₁₀)

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i83333en/i83333EN.pdf>



Important

There are fire extinguishers that do not represent a source of GHG emissions due to the type of extinguishing agent used, such as chemical powder, water or foam. Therefore, these should not be considered in the quantification of emissions.

Emissions from fire extinguishers are calculated based on the assumption that all the extinguishing agent is lost during recharge. Therefore, the total amount of agent recharged during the period under study will represent the total GHG emission (Vallejo et al., 2018).

2.6.3.A Calculation method

Equation 2.6.3a

$$\text{Extinguisher emissions (t CO}_2\text{e): } AD \times GWP \times CF$$

Where:

tCO₂e: emissions from the use of fire extinguishers in tonnes of carbon dioxide equivalent.



Recommendation:

- It is important to identify with the extinguisher maintenance service provider whether extinguishers are discharged and recharged every year during maintenance and to consider only the release and recharge of extinguishers in the period evaluated.
- Analyse with the supplier whether there is any recovery of the extinguishing agent during the maintenance of extinguishers, which should not be considered as an emission. Keep the evidence to support it.
- Take into account NFPA 10 portable fire extinguishers.
- Tabulate the required information in an Excel database to simplify the processing of information and associated calculations.



Important

In relation to the use of extinguishers, the gas contained in the extinguisher is released directly as a gas. Consequently, an emission factor is not required. However, to determine emissions in terms of carbon dioxide equivalent (CO₂ e), it is necessary to consider the global warming potential associated with the gas released.

Important

Depending on the country or data source, the required activity data may be given in pounds. However, since emissions are calculated in kilograms for reporting the final inventory in tonnes, it is necessary to convert the units from pounds to kilograms.

AD: activity data related to the quantity of extinguishing agent released or recharged (kg agent).

GWP: global warming potential by type of GHG evaluated.

CF: unit conversion factor (e.g. conversion from Kg to tonnes).

2.6.3.B Collection of information

Activity data: To obtain the activity data, the amount of extinguishing agent released is required. This can be obtained from the volume recharged if the company providing the maintenance service indicates it in the maintenance reports or service invoices. Otherwise, the capacity of each extinguisher indicated on the label of the device can be multiplied by the number of recharges during the year.

The following is an example of an emissions calculation for the source of fire extinguisher use.

Example: calculation of emissions from recharging fire extinguishers

Step 1. If the company has five CO₂ extinguishers in its facilities, which were recharged once during the study year, and their capacity is 10 pounds each, the total amount of CO₂ recharged is estimated as follows:

$$\text{Total recharge of fire extinguishers CO}_2 = 5 \text{ extinguishers} \times 1 \frac{\text{recharge}}{\text{extinguisher}} \times 10 \frac{\text{pounds}}{\text{recharge}} = 50 \text{ pounds CO}_2$$

Step 2. Conversion of units from pounds to kilograms is required.

$$\text{Kg CO}_2 = 50 \text{ pounds CO}_2 \times \frac{0.454 \text{ Kg}}{1 \text{ pound}} = 22.7 \text{ Kg CO}_2$$

Step 3. Multiply the total recharged amount of CO₂ in kilograms obtained in Step 2 by the global warming potential of CO₂ (See [Annex 2](#)), to obtain the CO₂e emissions.

Equation 2.6.3a

$$\text{Extinguishers emissions (t CO}_2 \text{ e)} = 22.7 \text{ Kg CO}_2 \times 1 \times \frac{1 \text{ t}}{1000 \text{ Kg}} = 0.023 \text{ t CO}_2 \text{ e}$$

2.6.4 Gas consumption (welding, oxyfuel, others)

Category:	Direct						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Acetylene	✓						
Propane	✓						
Carbon dioxide (CO ₂)	✓						

Oxy-acetylene (or oxy-fuel) is a thermal cutting process used to cut metals by combining oxygen and a fuel, usually acetylene, or other gases such as propane. The process involves the controlled combustion of fuel in the presence of oxygen.

For welding, acetylene is used in combination with oxygen to generate a high-temperature flame that melts the metals and joins the two parts. Acetylene, with the chemical formula C₂H₂, is a colourless and flammable gas that requires minimal amounts of oxygen to achieve complete combustion. Due to its properties, acetylene is widely used for welding and oxyacetylene cutting (Vallejo *et al.*, 2018).

Propane, with chemical formula C₃H₈, is a colourless and flammable gas, which unlike acetylene has a lower heating power, generating a flame of lower temperature and therefore the cut is slower.

When acetylene and propane undergo a combustion reaction, depending on the stoichiometry of the combustion, CO₂ emissions are produced that must be considered for the GHG inventory. For the calculations it is assumed that there is complete combustion forming CO₂ and water.

Additionally, in “other activities” where gases are consumed, other gases, such as CO₂ can be used. These activities also represent a CO₂ emission.

2.6.4.A Calculation method

Equation 2.6.4a

Emissions welding/flame cutting (t CO₂e): AD × EF × GWP × CF

Where:

t CO₂e: emissions from gas use in tonnes of carbon dioxide equivalent.

AD: activity data related to the amount of gas consumed/purchased (kg gas).

EF: emission factor according to type of gas (e.g. kg CO₂/kg gas).

GWP: global warming potential.

CF: unit conversion factor (e.g. conversion from kg to tonnes).

Note: If CO₂ gas is used, the emission factor (EF) should be omitted in the above formula.

2.6.4.B Collection of information

Activity data: To obtain the activity data, the amount of gas consumed or purchased is required. This can be obtained from purchase invoices, internal consumption records, and inventory movements, among others. To obtain the quantity of gas in kilograms, the quantity of cylinders consumed or purchased can be multiplied by the capacity of each cylinder.

An example of an emission calculation for the welding and oxyfuel gas source is offered below.

Example: calculation of acetylene emissions

Step 1. The Caribe 1 farm consumed three cylinders of acetylene weighing 7 kg each. Knowing the emission factor (EF), emissions are estimated by multiplying the total amount of acetylene consumed by the respective EF (see [Annex 1](#)), and the respective global warming potential (see [Annex 2](#)).

$$\text{Total acetylene consumption} = 3 \text{ cylinders} \times 7 \text{ Kg acetylene/cylinder} = 21 \text{ kg acetylene}$$

Equation 2.6.4a

$$\text{Acetylene emissions (t CO}_2\text{ e)} = 21 \text{ Kg C}_2\text{H}_2 \times 3.38 \frac{\text{Kg CO}_2}{\text{Kg C}_2\text{H}_2} \times 1 \times \frac{1\text{t}}{1000 \text{ Kg}} = 0.071 \text{ t CO}_2\text{e}$$

2.6.5 Refrigerant gas leaks

Category:	Direct/indirect due to transportation and indirect due to products used						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Refrigerant gases				✓	✓		✓

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are chemical compounds that are widely used in refrigeration systems. These systems include air conditioners in offices and vehicles, pineapple cooling and refrigeration chambers, refrigeration tunnels, as well as refrigerated containers used for transporting fruit to port, among others.

These gases play a key role in temperature regulation in different cooling systems. However, it is important to keep in mind that HFCs and

PFCs are considered GHG and most have high global warming potential.

Considering that any sealed system, whether through pipe and valve joints, pipe ruptures or component failures, can leak refrigerant, it is important to recognize this unplanned release as a fugitive emission. In other words, a leak that results in the release of refrigerant gas from equipment and systems constitutes a GHG emission (Vallejo *et al.*, 2018).



For consideration:

- The reference emission factors for acetylene and propane are constant values obtained from the mass balance in the complete combustion reaction of both gases.
- If the consumptions of both gases are given in pounds, the conversion to kilograms must be made for the calculation of emissions (Vallejo *et al.*, 2018).
- Tabulate the required information in an Excel database to simplify the processing of information and associated calculations.

The presence of leaks can have negative consequences, such as a decrease in the cooling capacity of the equipment. In some cases, it may be necessary to carry out maintenance work, including refrigerant gas recharging, which also represents GHG emissions.

Table 3 shows some types of refrigerants that can be found in different refrigeration systems.

Table 3. Different types of refrigerants

Refrigerants	
R-12	R-32
R-502	R-290 (propane)
R-507a	R-600a (isobutane)
R-404a	R-1270 (propylene)
R-407a	R-744 (CO ₂)
R-22	R-717 (ammonia)
R-407c	R-410
R-134a	-

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i83333en/i83333EN.pdf>



Important

- In relation to the calculation of refrigerant gas emissions, if the company knows the amount of refrigerant gas recharged, then an emission factor is not used because the refrigerant gas is released directly as a gas. However, to determine emissions in terms of carbon dioxide equivalent (CO₂e), it is necessary to consider the GWP associated with the gas released.
- When there is no data available for leaked or recharged refrigerant gas, a theoretical estimation can be performed, for which it is necessary to use an emission factor (percentage leakage of the initial load per year).

2.6.5.A Calculation method

Equation 2.6.5a

Refrigerant leakage emissions (t CO₂e): $AD \times GWP \times CF$



Recommendation:

- When there are no records of refrigerant recharges, percentages of annual refrigerant losses by equipment or system (Annex 1) can be used to make a theoretical estimate of emissions from refrigerant gas leaks. However, actions should be taken to initiate the control and recording of refrigerant gas recharges (Vallejo *et al.*, 2018).
- If refrigerant gas is recovered from equipment, the company must store such gas in cylinders in good condition; have the corresponding evidence of the amount and type of gas recovered; ensure proper storage to prevent the eventual loss of such gas; and seek options for final disposal and destruction to prevent emissions. The company needs to keep evidence, such as photographs, gas information, records, or certificates, among others.
- If refrigerant gas recharges are measured in pounds, the company must convert the units into kilograms for the calculation of emissions.
- Tabulate the required information in an Excel database to simplify the processing of information and associated calculations.



Important

Depending on the country or data source, the required activity data may be given in pounds. However, since emissions are calculated in kilograms for reporting the final inventory in tonnes, the company will need to convert the units from pounds to kilograms.

Where:

t CO₂e: emissions from refrigerant leakage in tonnes of carbon dioxide equivalent.

AD: activity data related to the amount of gas leaked or recharged (kg gas).

GWP: global warming potential by type of GHG.

CF: unit conversion factor (e.g. conversion from kg to tonnes).

2.6.5.B Collection of information

Activity data: The activity data can be obtained in one of the following ways:

- Amount of refrigerant gas leaked or recharged in the period evaluated, which can be obtained from internal maintenance reports or maintenance reports from service providers.
- If there are no records of refrigerant gas recharges, considering that the company purchases refrigerant gases for its own maintenance and recharges, the amount of gas purchased in the period evaluated could be used. The company can obtain the data either from purchase invoices or from the amount of the gas consumed. The

latter is possible if the company manages an inventory control where the information from the inventory outflows can be sourced.

- If none of the above is available, the annual loss of refrigerant gas from refrigeration systems can be estimated with a theoretical reference of annual leakage percentage by type of system.

Global warming potential: The global warming potential is selected according to the type of refrigerant gas evaluated (see [Annex 2](#)).

An example of a refrigerant gas leakage emission calculation is shown below.

Example: calculation of emissions due to refrigerant leakage

Part I. Calculation of emissions from refrigerant leakage when records are available

Step 1. Due to maintenance of the company's air conditioners, 300 pounds of R-410 refrigerant were recharged during the period under evaluation. To proceed with the emissions calculation, the conversion from pounds to kilograms of gas must first be made.

$$\text{Refrigerant recharge (kg gas)} = 300 \text{ lb} \times \frac{0.054 \text{ Kg}}{1 \text{ lb}} = 136.2 \text{ kg R410A}$$

Step 2. Multiply the total amount of refrigerant recharged in the period by the global warming potential of R-410A (see [Annex 2](#)), to obtain the emissions in carbon dioxide equivalent (CO₂e). Apply equation 2.6.5a.

Equation 2.6.5a

$$\text{Refrigerant leak emissions (t CO}_2\text{ e)} = 136.2 \text{ Kg R410A} \times 1725 \times \frac{1 \text{ t}}{1000 \text{ kg}} = 234.945 \text{ t CO}_2\text{ e}$$

Note: For the purposes of the exercise, the GWP of the IPCC II Report is selected.

Part II. Calculation of emissions from refrigerant leakage when there are no records

Step 1. A company decides to account for the emissions from annual leakage of refrigerant R-134a from the 76 containers where fruit was transported in the period evaluated. Not having records of refrigerant recharge and being a service offered by a third party, the company proceeds with the identification of the type of equipment, its load capacity and the percentage of annual leakage. See Table 17A.1 in [Annex 1](#). The following values are assumed:

Type of equipment	Refrigerant gas capacity or content in the system (kg)	Emission factor (% of capacity/year)
Refrigerated fruit transportation (containers)	8	50

Step 2. Multiply the total number of containers by the carrying capacity by the annual leakage rate or emission factor, and the global warming potential of R-134A ([Annex 2](#)), to obtain the carbon dioxide equivalent emissions (CO₂e). Apply Equation 2.6.5a.

Equation 2.6.5a (including annual percentage leakage)

$$\text{Refrigerant leak emissions (t CO}_2\text{e)} = 76 \text{ containers} \times 8 \text{ Kg} \frac{\text{gas}}{\text{containers}} \times 50\% \times 1\,300 \times \frac{1\text{t}}{1\,000 \text{ Kg}} = 395.2 \text{ t CO}_2\text{e}$$

Note 1: For the purposes of the exercise, the GWP of the IPCC II Report is selected.

IMPORTANT NOTE: Since the refrigerated fruit transport service is provided by a third party and this source of GHG emissions is reported as an indirect source, it is important to allocate emissions based on the service provided to the pineapple company. Furthermore, under the scenario that each of the 76 containers only made one trip to port in the reporting year, emissions can be allocated by dividing the annual tonnes by 365 days, to assume only the leakage per container for one day of transport. As shown below:

$$\text{Refrigerant leakage emissions allocation (t CO}_2\text{e)} = 395.2 \text{ t CO}_2\text{e}/365 = 1.08 \text{ t CO}_2\text{e}$$

2.6.6 Fossil fuel consumption

Category:	Direct/indirect through transportation and indirect through products used by the company						
	Type of GHG to be evaluated						
Source	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Fossil fuels	✓	✓	✓				

Fossil fuels are energy resources widely used in different activities related to pineapple production, harvesting, packing and marketing. They are used to operate a variety of equipment,

vehicles and machinery necessary to carry out the different activities of pineapple companies. The combustion of fossil fuels in engines leads to the emission of GHG, such as carbon dioxide

(CO₂), methane (CH₄) and nitrous oxide (N₂O). Therefore, it is essential to consider both mobile sources, such as the company's own vehicles for loading and transporting product, tractors and field machinery, and stationary or fixed sources, such as generators and pumps, among others, that are part of the activities carried out by the company.

2.6.6.A Calculation method

Equation 2.6.6a

$$\text{Fuel emissions (t CO}_2\text{e): } AD \times EF_{\text{GHG}} \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent.

AD: activity data related to fuel volume (litres of fuel).

EF_{GHG}: emission factor by type of GHG and type of fuel evaluated (e.g. kg CO₂/Litre fuel).

GWP: global warming potential by type of GHG evaluated.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

Once the tonnes of CO₂e from each GHG evaluated have been obtained, the total emissions are calculated by aggregating the results of tCO₂e from each GHG, as shown in equation 2.6.6b.

Equation 2.6.6b

$$\text{Total fuel emissions (t CO}_2\text{e): } t \text{ CO}_2\text{e (CO}_2\text{)} + t \text{ CO}_2\text{e (CH}_4\text{)} + t \text{ CO}_2\text{e (N}_2\text{O)}$$

Where:

Total t CO₂e: total tonnes of carbon dioxide equivalent of the emission source.

t CO₂e(CO₂): tonnes of carbon dioxide equivalent from CO₂.

t CO₂e(CH₄): tonnes of carbon dioxide equivalent from CH₄.

t CO₂e(N₂O): tonnes of carbon dioxide equivalent from N₂O.



Important

- For the different types of fuel, CO₂, CH₄ and N₂O emissions are generated during combustion. Therefore, equation 2.6.6a must be applied to determine the emissions of each GHG evaluated.
- Emission factors depend on the type of fuel and type of sector or equipment using fuel.

2.6.6.B Collection of information

Activity data: To obtain the number of litres of fuel, it is necessary to take into account the volume of fuel consumed and type of fuel used. For example, litres of diesel consumed in tractors, litres of gasoline consumed in vehicles, litres of diesel consumed in generators, etc. The volume of fuel can be obtained from fuel purchase invoices, internal fuel dispenser records, requisitions, and other sources.



Important

Depending on the country or data source, the fuel volume may be expressed in different units, such as gallons. Since most of the available emission factors are in kilograms of GHG per litre, it is necessary to either convert the units to litres or ensure that the units of the fuel volume are consistent with the units of the emission factors to be used.

Emission factor: The emission factor for fuel consumption depends on the type of fuel used or consumed. The emission factor must be selected by fuel type and by type of GHG evaluated. The emission factors for CO₂ are usually expressed as kg CO₂/L. The emission factors for CH₄ and

N₂O can be expressed in grams of each GHG per litre of fuel, i.e. g CH₄/L and g N₂O/L.

An example of an emissions calculation for fuel consumption source is shown below:

Example: calculation of fossil fuel emissions

Step 1. A company consumed 25 500 litres of diesel fuel for the use of tractors for land preparation in the period of one year. To calculate the emissions, the appropriate EF for this type of fuel and type of activity must be identified. Diesel combustion produces emissions of CO₂, N₂O and CH₄, so the EF is needed to determine the emissions of each gas.

GHG	Emission factor/Residential-Agricultural	Reference
EF _{CO2}	2.613 $\frac{\text{Kg CO}_2}{\text{L}}$	Specific value for Costa Rica, given by the National Meteorological Institute.
EF _{CO4}	0.382 $\frac{\text{g CH}_4}{\text{L}}$	
EF _{N2O}	0.02442 $\frac{\text{g N}_2\text{O}}{\text{L}}$	

It is preferable to use the EF specific to each country and fuel type, but if not available, EFs from recognized sources such as IPCC can be used.



Recommendation:

When there are no records of the volume of fuels consumed, there are possible estimation methods (Vallejo *et al.*, 2018):

- Take the mileage travelled by each of the vehicles as a reference. This parameter is divided by the average performance of each type of vehicle. To obtain the performance of the vehicles used by the company (direct) or subcontractors (indirect), you can consult vehicle suppliers' websites, technical data sheets or performance calculations by type of vehicle from recognized sources.
- Estimate fuel volume based on fuel cost. The historical fuel prices available at the relevant entity in each country (for example, the Costa Rican Petroleum Refinery known as RECOPE) must be identified. Then divide the fuel purchase cost by the price per litre of fuel, according to the date of purchase.
- Estimate fuel volume with hours of operation or use of equipment or machinery and relate working hours to the output (litres/hour) of the equipment or machinery.
- Tabulate the required information in an Excel database to simplify the processing of the information and the associated calculations.

Step 2. Multiply the total amount of fuel by the respective emission factor and the respective global warming potential ([Annex 2](#)) to obtain the emissions in tonnes of CO₂ equivalent. Apply equation 2.6.6a.

Equation 2.6.6a (CO₂)

$$\text{Fuel emissions (t CO}_2\text{ e) (CO}_2\text{)} = 25\,500\text{ L} \times 2.613 \frac{\text{Kg CO}_2}{\text{L}} \times 1 \times \frac{1\text{ ton}}{1000\text{ Kg}} =$$

$$\text{Fuel emissions (t CO}_2\text{ e) (CO}_2\text{)} = 66.63\text{ t CO}_2\text{e}$$

Equation 2.6.6a (CH₄)

$$\text{Fuel emissions (t CO}_2\text{ e) (CH}_4\text{)} = 25\,500\text{ L} \times 0.382 \frac{\text{g CH}_4}{\text{L}} \times 21 \times \frac{1\text{ ton}}{1000000\text{g}} =$$

$$\text{Fuel emissions (t CO}_2\text{ e) (CH}_4\text{)} = 0.205\text{ t CO}_2\text{e}$$

Equation 2.6.6a (N₂O)

$$\text{Fuel emissions (t CO}_2\text{ e) (N}_2\text{O)} = 25\,500\text{ L} \times 0.02442 \frac{\text{g N}_2\text{O}}{\text{L}} \times 310 \times \frac{1\text{ ton}}{1000000\text{g}} =$$

$$\text{Fuel emissions (t CO}_2\text{ e) (N}_2\text{O)} = 0.193\text{ t CO}_2\text{e}$$

Step 3. To obtain the total emissions, the amount of CO₂ equivalent emissions of each GHG evaluated must be added up.

Equation 2.6.6b

$$\text{Total fuel emissions (t CO}_2\text{ e): } 66.63\text{ t CO}_2\text{e} + 0.205\text{ t CO}_2\text{e} + 0.193\text{ t CO}_2\text{e} = 67.029\text{ t CO}_2\text{e}$$

2.6.7 Use of nitrogen fertilizers and organic amendments

A natural biological process of nitrification and denitrification reactions occurs in the soil, which plays a fundamental role in the nitrogen cycle and depends on the availability of nitrogen in the soil. As a result of both processes, nitrogen gases, including nitrous oxide (N₂O), are released into the atmosphere. By adding nitrogen fertilizers to the soil, an excess of nitrogen available in the soil can be generated, triggering nitrification and denitrification reactions, resulting in emissions of N₂O (IPCC, 2006).

The addition of nitrogen fertilizers to the soil is a common practice in the pineapple sector, in the early stages of pineapple crop development, to strengthen vegetative growth, promoting the development of leaves and roots.



Important

Kindly keep in mind that the CO₂ emission factor varies according to the type of fuel consumed, regardless of the use or type of equipment that consumes the fuel. However, the CH₄ and N₂O emission factors are selected according to the type of fuel and the use or type of equipment that uses the fuel. For example, if it is used in vehicles for land transportation, in tractors for agricultural activities, among others. See [Annex 1](#), where emission factors are indicated by type of fuel and according to the use or activity in which the fuel is used.

Category:	Direct/indirect by products used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Nitrogen fertilizers and organic amendments			✓				

Table 4 describes some common fertilizers and their average nitrogen content.

Table 4. Average nitrogen content in different synthetic fertilizers based on studies of the International Fertilizer Association

Fertilizer	% Nitrogen
Ammonium	82
Ammonium sulphate	21
Ammonium nitrate	33 – 34,5
Calcium ammonium nitrate	20,4 – 27
Urea	45 – 46
Diammonium phosphate	18
Monoammonium phosphate	11
NPK fertilizers	5 – 25
NP fertilizers	15 – 25
NK fertilizers	13 – 25

Source: Adapted from **International Fertilizer Association** (IFA). 2017. *Product Factsheets – Fertilizer Composition*. [Cited 5 June 2023]. <https://www.ifastat.org/factsheets/products>

2.6.7.A Calculation method

In the case of nitrogen additions to soil, the company needs to determine the direct emissions of N₂O and indirect emissions of N₂O by volatilization (nitrogen losses by volatilization) and by leaching or runoff (nitrogen washout or carryover by precipitation or irrigation). The description of the calculation methods for the three different emission processes due to fertilizer use is presented below.

a) Direct emissions from fertilizer use

Equation 2.6.7a

Direct fertilizer emissions (t CO₂e): $AD \times EFN_{2O} \times (44/28) \times GWP \times CF$



Important

Some considerations regarding the selection of fertilizers for emission quantification and reporting are described below:

- Synthetic nitrogen fertilizers applied directly to the soil, in granulated or liquid form by fertigation around the base of the plant are considered.
- Organic fertilizers incorporated into the soil, such as compost, sludge, vermicompost, agricultural residues, among others are considered.
- Foliar fertilizers are not considered since they are applied directly to the plant leaves and are not in direct contact with the soil where nitrification and denitrification processes occur. These fertilizers usually contain forms of nutrients that are more soluble and easily absorbed by the leaves, allowing rapid assimilation by plants without the intervention of nitrification and denitrification processes in the soil.

Where:

t CO₂e: tonnes of carbon dioxide equivalent.

AD: activity data related to the mass of nitrogen applied (kg of nitrogen).

EF_{N₂O}: N₂O emission factor (e.g. kg N₂O-N/kg N).

(44/28): the ratio of 44/28 is used to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).



Important

If synthetic or organic fertilizers are used in liquid form for fertigation, information on the density of the product must be collected in order to convert litres of nitrogen to kg.

In case of applying urea or other fertilizers with nitrogen derived from urea in soil, the company must estimate the CO₂ emissions from urea, described in module 2.6.8 CO₂ from Urea, in addition to estimating N₂O emissions described in this section.

b) Indirect emissions by volatilization

Equation 2.6.7a1

$$\text{Fertilizer volatile emissions (t CO}_2\text{e): } AD \times \text{Frac}_{\text{Volat}} \times EF_{\text{N}_2\text{O}} \times (44/28) \times \text{GWP} \times \text{CF}$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent from N volatilization.

AD: activity data related to the mass of nitrogen applied to the soil (kg of nitrogen).

Frac_{Volat}: fraction of N that volatilizes as NH₃ and NO_x ((kg NH₃-N + NO_x-N/kg N applied).

EF_{N₂O}: emission factor corresponding to emissions of N₂O by volatilization (e.g. kg N₂O-N/kg NH₃-N + NO_x-N volatilized.

(44/28): ratio of 44/28 to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or g to tonnes).

c) Indirect emissions by fertilizer leaching and runoff

Equation 2.6.7a2

$$\text{Fertilizer leakage emissions (tCO}_2\text{e): } AD \times \text{Frac}_{\text{Lix}} \times EF_{\text{N}_2\text{O}} \times (44/28) \times \text{GWP} \times \text{CF}$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent from N leaching.

AD: activity data related to the mass of nitrogen applied to the soil (kg of nitrogen).

Frac_{Lix}: fraction of N lost by leaching (kg N/kg N applied).

EF_{N₂O}: emission factor corresponding to N₂O emissions by leaching (e.g. kg N₂O-N/ kg N leached).

(44/28): ratio of 44/28 to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or g to tonnes).

d) Total emissions from fertilizer use

Once the tonnes of CO₂e from each type of emission have been obtained, the total emissions from fertilizer use are calculated by adding the results of t CO₂e from each formula, as shown in equation 2.6.7a3.

Equation 2.6.7a3

$$\text{Total fertilizer emissions (t CO}_2\text{e): } t \text{ CO}_2\text{e (direct)} + t \text{ CO}_2\text{e (volat.)} + t \text{ CO}_2\text{e (leach.)}$$

Where:

Total t CO₂e: total tonnes of carbon dioxide equivalent of the fertilizer emission source.

t CO₂e (direct): tonnes of direct carbon dioxide equivalent of N₂O.

t CO₂e (volat): tonnes of carbon dioxide equivalent from volatilization.

t CO₂e (leach): tonnes of carbon dioxide equivalent of leaching/runoff.

2.6.7.B Collection of information

Activity data: To determine the amount of nitrogen applied on soil in kilograms, the company needs to take into account the total amount of fertilizer applied on soil, the type of fertilizer (synthetic or organic), the fertilizer's form (solid or liquid) and the percentage of nitrogen

per type of fertilizer. The amount of fertilizer can be obtained from fertilizer purchase invoices, internal inventory records or requisitions, among others.

An example of the data collection needed to obtain the activity data is described below:

Fertilizer type	Fertilizer	Nitrogen (%)	Form	Presentation	Amount applied
Synthetic	NPK (8-20-5)	8%	Solid	50 kg per bag	25 bags

With the information collected as in the previous example, we proceed to obtain the activity data required in the calculation formulas as follows:

$$AD \text{ (kg N)} = \text{Quantity of bags applied} \times \text{presentation/bag} \times \% N$$

Example:

$$AD \text{ (kg N)} = 25 \text{ bags} \times 50 \text{ kg/bag} \times 8\% N = 100 \text{ kg N}$$

Emission factor and fractions: The selection of emission factors by emission type (direct, volatilization or leaching) and the selection of volatilization and leaching fractions may vary by fertilizer type (synthetic or organic). Therefore, it

is important to differentiate in the activity data collection the type of fertilizer applied. Emission factors can also be selected between default or average factors as aggregates or more specific emission factors by type of climate or type of nitrogen source, i.e. the emission factors can be disaggregated. For emission factor references, see [Annex 1](#).

An example of an emissions calculation for the source of nitrogen fertilizer use is shown below.



Recommendation:

- Differentiating the type of fertilizer between synthetic and organic is important to select the appropriate emission factors.
- Tabulate the required information in an Excel database to simplify data processing and associated calculations.
- Information on the percentage of nitrogen in synthetic fertilizers can be obtained from technical data sheets, safety data sheets or product labels.
- Information on the percentage of nitrogen in organic fertilizers or amendments can be obtained from laboratory analysis, theoretical references or technical data sheets.

Example: calculation of emissions from the use of nitrogen fertilizers

Part I. Calculation of synthetic fertilizer emissions

Step 1. As part of the technological package used for the early stages of plant development, a total of 10 800 kg of granular synthetic fertilizer was applied in 2022, as described below:

Type	Fertilizer	Nitrogen (%)	Form	Amount applied
Synthetic	NPK (8-20-5)	8%	Granulated	10 800 kg

Step 2. Estimate the total nitrogen applied, using the total amount of fertilizer applied and the nitrogen content:

$$\text{Kg N} = 10800 \text{ Kg}_{\text{fert total}} \times 8\% \text{ N} = 864 \text{ Kg N}$$

Step 3. Identify the EF for direct emissions of N₂O for synthetic fertilizers. It is preferable to use country specific EFs, but if not available, the IPCC recommended EF ([Annex 1](#)) can be used.

EF	Type	Reference
0.010 Kg N ₂ O - $\frac{\text{N}}{\text{Kg N}}$	FE for N additions from synthetic fertilizers, organic amendments and crop residues	Aggregate emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A.1.3.

Step 4. Obtain the direct emissions of N₂O in CO₂ equivalent by multiplying the total nitrogen, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28 to convert the N₂O-N emissions to N₂O. Apply Equation 2.6.7a.

Equation 2.6.7a

$$\text{Direct fertilizer emissions (t CO}_2\text{ e)} = 864 \text{ Kg N} \times 0.010 \frac{\text{Kg N}_2\text{O-N}}{\text{Kg N}} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} =$$

$$\text{Direct fertilizer emissions (t CO}_2\text{ e)} = 4.209 \text{ t CO}_2\text{ e}$$

Step 5. Identify emission factors and fractions to estimate N₂O emissions from volatilization and leaching/runoff from synthetic fertilizer application. It is preferable to use country specific EFs, but if not available, the company can use the IPCC recommended EFs ([Annex 1](#)).

Fraction of N/EF	Type	Reference
0.11 kg NH ₃ -N + NO _x -N /kg N applied	Frac _{volat} : volatilization fraction of synthetic fertilizers	Volatilization fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.
0.010 Kg N ₂ O-N / kg NH ₃ -N + NO _x - N volatilized	EF _{volat} : emission factor for N volatilization	Volatilization emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.

Fraction of N/EF	Type	Reference
0.24 kg N /kg N applied	Frac _{Lix} : fraction of N losses through leaching/runoff	Leaching/runoff fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.
0.011 Kg N ₂ O-N /Kg N	EF _{Lix} : emission factor for leaching/runoff	Leaching emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.

Step 6. Obtain the indirect emissions of N₂O by volatilization in CO₂ equivalent; for this, multiply the total nitrogen, the volatilization fraction, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28, to convert the emissions of N₂O-N to N₂O. Apply Equation 2.6.7a1.

Equation 2.6.7a1

$$\begin{aligned}
 & \text{Fertilizer volatil. emissions (t CO}_2\text{ e)} = \\
 & 864 \text{ kg N} \times 0.11 \text{ kg NH}_3\text{-N} + \text{NO}_x\text{-N/Kg N applied} \times 0.010 \text{ Kg N}_2\text{O-N/Kg NH}_3\text{-N} + \text{NO}_x\text{-N} \\
 & \text{volatilized} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} = \\
 & \text{Fertilizer volatil. emissions (t CO}_2\text{e)} = \mathbf{0.463 \text{ t CO}_2\text{ e}}
 \end{aligned}$$

Step 7. Obtain the indirect emissions of N₂O by leaching in CO₂ equivalent; for this, multiply the total nitrogen, the leaching fraction, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28, to convert the emissions of N₂O-N to N₂O. Apply Equation 2.6.7a2

Equation 2.6.7a2

$$\begin{aligned}
 & \text{Lixiv.fertilizer emission (t CO}_2\text{ e)} = \\
 & 864 \text{ Kg N} \times 0.24 \text{ kg N / Kg N applied} \times 0.011 \text{ Kg N}_2\text{O-N/Kg N} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} = \\
 & \text{Lixiv. fertilizer emission (t CO}_2\text{e)} = \mathbf{1.112 \text{ t CO}_2\text{e}}
 \end{aligned}$$

Step 8. To obtain the total tonnes of CO₂ e from the emission source for synthetic fertilizer use, add the direct emissions of N₂O, volatilization and leaching. Apply equation 2.6.7a3.

Equation 2.6.7a3

$$\text{Total fert. emissions (t CO}_2\text{ e)} = 4.209 \text{ t CO}_2\text{ e} + 0.463 \text{ t CO}_2\text{ e} + 1.112 \text{ t CO}_2\text{e} = \mathbf{5.783 \text{ t CO}_2\text{ e}}$$

Part II. Organic fertilizer emissions calculation

Step 1. As part of an on-farm improvement plan, a total of 1 500 kg of compost was applied as an organic amendment in 2022, as described below:

Type	Fertilizer	Nitrogen (%)	Form	Amount applied
Organic	Compost	2%	Solid	1 500 kg

Step 2. Estimate the total nitrogen applied, using the total amount of fertilizer applied and the nitrogen content:

$$kg\ N = 1\ 500\ Kg_{fert.total} \times 2\% N = 30\ Kg\ N$$

Step 3. Identify the emission factor for direct emissions of N₂O for fertilizers or organic amendments. It is preferable to use country specific EFs, but if not available, the IPCC recommended EF ([Annex 1](#)) can be used.

EF	Type	Reference
0.010 $\frac{Kg\ N_2O - N}{Kg\ N}$	EF for N additions from synthetic fertilizers, organic amendments and crop residues	Aggregate emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.3., in Annex 1.

Step 4. Obtain the direct emissions of N₂O in CO₂ equivalent by multiplying the total nitrogen, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28 to convert the N₂O-N emissions to N₂O. Apply Equation 2.6.7a.

Equation 2.6.7a

$$Direct\ fertilizer\ emissions(t\ CO_2\ e) = 30\ Kg\ N \times 0.010 \frac{Kg\ N_2O - N}{Kg\ N} \times \frac{44}{28} \times 310 \times \frac{1t}{1000\ Kg} =$$

$$Direct\ Fertilizer\ Emissions\ (t\ CO_2e) = 0.146\ t\ CO_2e$$

Step 5. Identify emission factors and fractions to estimate N₂O emissions from volatilization and leaching/runoff from organic fertilizer or amendment application. It is preferable to use country specific EFs, but if not available, the company can use the IPCC recommended EFs ([Annex 1](#)).

Fraction of nitrogen / EF	Type	Reference
0.21 Kg NH ₃ -N + NO _x -N /Kg N applied	Frac _{Volat} : volatilization fraction of nitrogen from organic fertilizers	Volatilization fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.
0.010 Kg N ₂ O-N/ kg NH ₃ -N + NO _x -N volatilized	EF _{Volat} : emission factor for N volatilization	Volatilization emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.
0.24 kg N /Kg N applied	Frac _{Lix} : fraction of N losses by leaching/runoff	Leaching/runoff fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.
0.011 kg N ₂ O-N /Kg N	EF _{Lix} : emission factor for leaching/runoff	Leaching emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, Table A1.4. in Annex 1.

Step 6. Obtain the indirect emissions of N₂O by volatilization in CO₂ equivalent. For this, multiply the total nitrogen, the volatilization fraction, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28, to convert the emissions of N₂O-N to N₂O. Use Equation 2.6.7a1

Equation 2.6.7a1

$$\begin{aligned} & \text{Volat. fertilizer emissions (t CO}_2\text{ e)} = \\ & 30 \text{ Kg N} \times 0.21 \text{ Kg NH}_3\text{-N} + \text{NO}_x\text{-N/Kg N applied} \times 0.010 \text{ Kg N}_2\text{O-N/Kg NH}_3\text{-N} + \text{NO}_x\text{-} \\ & \text{N volatilized} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} = \\ & \text{Volat. fertilizer emissions (t CO}_2\text{ e)} = \mathbf{0.031 \text{ tCO}_2\text{ e}} \end{aligned}$$

Step 7. Obtain the indirect emissions of N₂O by leaching in CO₂ equivalent; for this, multiply the total nitrogen, the leaching fraction, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28, to convert the emissions of N₂O-N to N₂O. Use Equation 2.6.7a2.

Equation 2.6.7a2

$$\begin{aligned} & \text{Lxiv.fertilizer emissions (t CO}_2\text{ e)} = \\ & 30 \text{ kg N} \times 0.24 \text{ Kg N /Kg N applied} \times 0.011 \text{ Kg N}_2\text{O-N /Kg N} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} = \\ & \text{Lxiv. fertilizer emissions (t CO}_2\text{ e)} = \mathbf{0.039 \text{ t CO}_2\text{ e}} \end{aligned}$$

Step 8. To obtain the total tonnes of CO₂e from the emission source for synthetic fertilizer use, add the direct emissions of N₂O, volatilization, and leaching. Use equation 2.6.7a3.

Equation 2.6.7a3

$$\text{Total fertilizer emissions (t CO}_2\text{ e)} = 0.146 \text{ t CO}_2\text{ e} + 0.031 \text{ t CO}_2\text{ e} + 0.039 \text{ t CO}_2\text{ e} = \mathbf{0.216 \text{ t CO}_2\text{ e}}$$

2.6.8 CO₂ from urea

Category:	Direct/indirect by products used by the company						
	Source	Type of GHG to be evaluated					
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Urea application (CO ₂)	✓		*				

Note: * While N₂O emissions are also estimated as a result of urea application due to the nitrogen input into the soil, in this section, only CO₂ emissions are estimated. N₂O emissions from urea are calculated following the guidance in section 2.6.7, Use of Nitrogen Fertilizers.

The addition of urea to soils during fertilization leads to a loss of CO₂ that was fixed in the industrial urea production process. Urea [CO(NH₂)₂] is converted to ammonium (NH₄⁺), hydroxyl ion (OH⁻), and bicarbonate (HCO₃⁻)

in the presence of water and urease enzymes. Similar to the soil reaction when lime is added, the bicarbonate formed is converted to CO₂ and water (IPCC, 2006).

In this context, this section provides guidance for calculating the CO₂ emissions produced by the application of urea. If applicable, these calculations should be done in addition to the calculations of N₂O emissions as presented in the previous section (2.6.7).

2.6.8.A Calculation method

The calculation method for estimating CO₂ emissions by urea is the following:

Equation 2.6.8a

$$\text{CO}_2 \text{ emissions from urea (t CO}_2\text{e): } AD \times EF_{\text{urea}} \times (44/12) \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent.

AD: activity data related to the mass of urea applied (kg of urea).

EF_{urea}: CO₂ emission factor (kg CO₂-C/kg urea).

(44/12): the ratio of 44/12 is used to convert CO₂-C to CO₂ emissions.

GWP: global warming potential of CO₂.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.8.B Collection of information

Activity data: It is necessary to obtain the total amount of urea in kilograms applied on the soil. The company can obtain this information from purchase invoices, internal inventory records, requisitions, among others.

An example of the data collection needed is described below:

Type	Presentation	Amount applied
Urea	45 kg/bag	60 bags

With the information gathered as in the previous example, the company proceeds to obtain the activity data required in the calculation formula as follows:

$$AD \text{ (kg urea)} = \text{Quantity of bags applied} \times \text{presentation}$$

Example:

$$AD \text{ (kg urea)} = 60 \text{ bags} \times 45 \text{ kg /bag} = 2700 \text{ kg urea}$$

Emission factor: There is a default emission factor given by the IPCC guidelines, which is equivalent to the carbon content of urea based on its atomic weight. For emission factor references see [Annex 1](#).

Following is an example of calculating CO₂ emissions from fertilization with urea.



Recommendation:

- Tabulate the required information in an Excel database to simplify data processing and associated calculations.

Example: calculation of CO₂ emissions from fertilization with urea

Step 1. During the period evaluated, 60 bags of urea, each weighing 45 kg, were applied on the farm. To estimate the associated emissions, the total kilograms of urea applied during the period must be calculated:

Type	Presentation	Amount applied
Urea	45 kg/bag	60 bags

$$\text{Total urea application (kg urea)} = 60 \text{ bags} \times 45 \frac{\text{Kg}}{\text{bag}} = 2\,700 \text{ Kg urea}$$

Step 2. Identify the most appropriate emission factor. It is preferable to use country specific EFs, but in case they are not available, the company can use the EF given by the IPCC ([Annex 1](#)).

EF	Value	Reference
EF of CO ₂ from urea	0.20	Emission factor recommended by IPCC, Refinement report 2019 (Volume 4, Chapter 11). See Table A1.1.

Step 3. Calculate CO₂ emissions by multiplying the total amount of urea applied, the urea emission factor, the ratio of 44/12 to convert CO₂-C emissions to CO₂ emissions, and the global warming potential of carbon dioxide ([Annex 1](#)). Apply equation 2.6.8a:

Equation 2.6.8a

$$\text{Urea emissions (t CO}_2\text{e)} = 2\,700 \text{ Kg urea} \times 0.20 \frac{\text{Kg CO}_2\text{-C}}{\text{kg urea}} \times \frac{44}{12} \times 1 \times \frac{1\text{t}}{1\,000 \text{ Kg}}$$

$$\text{Urea emissions (t CO}_2\text{e)} = 1.98 \text{ t CO}_2\text{e}$$

2.6.9 Soil correctors (liming)

Category:	Direct/indirect by products used by the company						
	Type of GHG to be evaluated						
Source	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Soil liming	✓						

Soil acidity (low pH), caused by the type of soil or by the characteristics of the components applied in fertilizers (acid salts), must be controlled to enhance soil productivity and fertility. This is done by applying lime treatments. Liming is used to reduce soil acidity and improve plant growth. The addition of carbonates onto the soil

in the form of lime, such as calcium limestone (CaCO₃) or dolomite [CaMg(CO₃)₂], causes CO₂ emissions. This occurs as the carbonates dissolve and release bicarbonate (HCO₃), which is later transformed into carbon dioxide (CO₂) and water (H₂O) (Vallejo *et al.*, 2018).

However, lime compounds containing oxides or hydroxides do not generate CO₂ emissions due to the absence of inorganic carbon in their structure. As such, these compounds should not be included in the emissions inventory (Vallejo *et al.*, 2018).

2.6.9.A Calculation method

The calculation method for estimating CO₂ emissions from liming is the following:

Equation 2.6.9a

$$\text{Lime emissions (t CO}_2\text{e): } AD \times EF_{\text{CO}_2} \times (44/12) \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent.

AD: activity data related to the mass of lime applied (kg of lime).

EF_{CO₂}: CO₂ emission factor (e.g. kg CO₂-C/kg Cal).

(44/12): the ratio of 44/12 is used to convert CO₂-C emissions to CO₂ emissions.

GWP: global warming potential of CO₂.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.9.B Collection of information

Activity data: It is necessary to obtain the total amount of lime in kilograms applied on the soil and the type of lime (dolomite or limestone). The company can obtain the quantity of lime from purchase invoices, internal inventory records, requisitions, among others.

An example of the data collection needed to obtain the activity data is described below:

Lime type	Presentation	Amount applied
Dolomite	45 kg/bag	50 bags

With the information collected as in the previous example, we proceed to obtain the activity data required in the calculation formula as follows:

$$AD \text{ (kg lime)} = \text{Quantity of bags applied} \times \text{presentation}$$

Example:

$$AD \text{ (kg lime)} = 50 \text{ bag} \times 45 \text{ kg/bag} = 2\,250 \text{ kg dolomite lime}$$

Emission factor: The selection of emission factors may vary according to the type of lime (dolomite or limestone). Therefore, it is important to differentiate the type of lime applied in the activity data collection. For emission factor references see [Annex 1](#).

Following is an example of an emissions calculation for soil improvers (liming):



Recommendation:

- Differentiating the type of lime between dolomite and limestone is important because it allows the selection of the appropriate emission factor for the emission calculation.
- Tabulate the required information in an Excel database to simplify data processing and associated calculations.

Example: calculation of emissions from liming of soils

Step 1. During the year 2022, 20 bags of 45 kg each of dolomite lime and 30 bags of 45 kg each of limestone were applied on the land. To estimate the associated emissions in this case, the total kilograms of each type of lime applied must be calculated.

Lime type	Presentation	Amount applied
Dolomite	45 kg/bag	20 bags
Limestone	45 kg/bag	30 bags

$$\text{Total application of dolomite lime (kg Cal}_D) = 20 \text{ bags} \times 45 \frac{\text{Kg}}{\text{bags}} = 900 \text{ Kg Cal}_D$$

$$\text{Total application of limestone (Kg Cal}_C) = 30 \text{ bags} \times 45 \frac{\text{Kg}}{\text{bags}} = 1\,350 \text{ Kg Cal}_C$$

Step 2. Identify the most appropriate emission factors for dolomite lime and limestone application. It is preferable to use the EF specific to each country and lime type, but in case it is not available, the company can use the EF recommended by the IPCC ([Annex 1](#)).

Type of lime	EF	Reference
Dolomite	0.13 $\frac{\text{Kg CO}_2\text{-C}}{\text{Kg Cal}_D}$	Emission factors recommended by the IPCC (Volume 4, Chapter 11). See Table A1.1.
Limestone	0.12 $\frac{\text{Kg CO}_2\text{-C}}{\text{Kg Cal}_C}$	

Step 3. Multiply the total amount of each type of lime applied by the respective lime emission factor, by the ratio of 44/12 to convert CO₂-C emissions to CO₂ emissions, and by the global warming potential of CO₂ ([Annex 2](#)). Use Equation 2.6.9a.

Equation 2.6.9a

$$\text{Dolomite lime use emissions (t CO}_2\text{e)} = 900 \text{ Kg Cal}_D \times 0.13 \frac{\text{Kg CO}_2\text{-C}}{\text{Kg Cal}_D} \times \frac{44}{12} \times 1 \times \frac{1\text{t}}{1\,000 \text{ Kg}}$$

$$\text{Emissions using dolomite limestone (t CO}_2\text{e)} = 0.429 \text{ t CO}_2\text{e}$$

$$\text{Emissions using limestone (t CO}_2\text{e)} = 1\,350 \text{ Kg Cal}_C \times 0.12 \frac{\text{Kg CO}_2\text{-C}}{\text{Kg Cal}_C} \times \frac{44}{12} \times 1 \times \frac{1\text{t}}{1\,000 \text{ Kg}}$$

$$\text{Emissions using limestone (t CO}_2\text{e)} = 0.594 \text{ t CO}_2\text{e}$$

Step 4. Add the emissions from limestone and dolomite to obtain the total emissions from liming.

$$\text{Liming emissions (t CO}_2\text{e)} = 0.429 \text{ t CO}_2\text{e} + 0.594 \text{ t CO}_2\text{e} = 1.023 \text{ t CO}_2\text{e}$$

2.6.10 Stubble management

Category:	Direct/indirect by products used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Stubble management	✓	✓	✓				

Stubble in pineapple cultivation refers to the plant residues left in the field after harvesting pineapple plants. This residue consists of leaves, stems and other unused parts of the plant. Although stubble generation depends on how the crop is managed on each farm, on average, pineapple plantations are renewed every two years to start a new production cycle, which results in a large amount of stubble that must be managed and that generates GHG emissions.

The most common forms of stubble management in the field are:

Green management: consists of cutting or shredding the plants after harvesting and reincorporating the residues into the soil.

Management with chemical drying: this involves the application of a chemical to

accelerate the decomposition of the stubble, which is later reincorporated into the soil.

Management with chemical drying plus burning: in this case, a chemical is first applied and then the stubble is burned.

Disposal pits: this consists of making a pit in the ground, disposing the green stubble in the pit, and covering it with soil. This method is not frequently used. It is mainly used when there are pineapple fruit fly outbreaks.

It is important to note that the four methods mentioned above generate GHG emissions. Some considerations in calculating emissions by stubble management method are described in Table 5.

Table 5. Calculation considerations according to pineapple stubble management method

Type of management	Comments
Green management	<ul style="list-style-type: none"> CO₂ and CH₄ are estimated using method-specific reference emission factors. N₂O is estimated by soil N input, according to IPCC methodology.
Management with chemical drying	<ul style="list-style-type: none"> CO₂ and CH₄ are estimated using method-specific reference emission factors. N₂O is estimated by soil N input, according to IPCC methodology.
Management with chemical drying plus burning	<ul style="list-style-type: none"> CO₂ and CH₄ are estimated using method-specific reference emission factors. N₂O is estimated by combustion of agricultural residues in the field according to IPCC methodology.
Disposal pits	<ul style="list-style-type: none"> CH₄ emissions are estimated under anaerobic conditions, following the IPCC first-order model for waste disposal sites and using default parameters.

2.6.10.A Calculation method

CO₂ and CH₄ emissions from green stubble management, chemical drying, and chemical drying plus burning

The following is a description of the calculation method to estimate CO₂ and CH₄ emissions from green stubble management, chemical drying, and chemical drying plus burning.

Equation 2.6.10a

$$\text{Stubble management emissions (t CO}_2\text{e): } AD \times EF \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per stubble management.

AD: activity data related to the number of hectares per management type (ha).

EF: emission factor by type of management (e.g. kg GHG/ha/year).

GWP: global warming potential by type of GHG evaluated.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

N₂O emissions from green management and chemical drying

To determine N₂O emissions from nitrogen additions to soil from green stubble management and chemical drying, the company needs to determine:

- the direct N₂O emissions;
- the indirect N₂O emissions from volatilization (nitrogen losses due to volatilization) and leaching (washing or dragging of nitrogen input by precipitation or irrigation); and
- the emissions from the use of nitrogen fertilizers.

The calculation methods for each are described in the following formulae.

Calculation of the activity data for the calculation of direct and indirect emissions

Equation 2.6.10b

$$AD \text{ (kg N/year): } Kg \text{ stubble/year} - (kg \text{ stubble/year} \times \% \text{ moisture}) \times \%N$$

Where:

AD: activity data related to the amount of nitrogen contributed to the soil by incorporation of stubble in the soil, in kilograms of nitrogen per year.

kg stubble/year: amount of stubble handled in the inventory period. See example, in step 1 of part II, within the example calculation at the end of this module.

% moisture: percentage of moisture in the stubble. The percentage of moisture is subtracted when the percentage of nitrogen is given on a dry basis. However, if the percentage of nitrogen is on a wet basis, then it is not necessary to subtract the moisture.

% N: percentage of nitrogen in the stubble.

Direct stubble emissions:

Equation 2.6.10b1

$$\text{Direct stubble emissions (t CO}_2\text{e): } AD \times EF_{N_2O} \times (44/28) \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent.

AD: activity data related to the mass of nitrogen incorporated (kg N/year). See equation 2.6.10b.

EF_{N₂O}: N₂O emission factor (e.g. kg N₂O-N/kg N).

(44/28): the ratio of 44/28 is used to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

Indirect N₂O emissions from volatilization

Equation 2.6.10b2

Indirect emissions from stubble volatil. (t CO₂e):
 $AD \times \text{Frac}_{\text{Volat}} \times EF_{\text{N}_2\text{O}} \times (44/28) \times GWP \times CF$

Where:

t CO₂e: tonnes of carbon dioxide equivalent from N volatilization.

AD: activity data related to the mass of nitrogen applied to the soil (kg N/year). See equation 2.6.10b.

Frac_{Volat}: fraction of N that volatilizes as NH₃ and NO_x (kg NH₃-N + NO_x-N/kg N applied).

EF_{N₂O}: emission factor corresponding to emissions of N₂O by volatilization (e.g. kg N₂O-N/kg NH₃-N + NO_x-N volatilized).

(44/28): ratio of 44/28 to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

Indirect N₂O emissions from leaching

Equation 2.6.10b3

Indirect emissions from stubble leaching (t CO₂e):
 $AD \times \text{Frac}_{\text{Lix}} \times EF_{\text{N}_2\text{O}} \times (44/28) \times GWP \times CF$

Where:

t CO₂e: tonnes of carbon dioxide equivalent by N leaching.

AD: activity data related to the mass of nitrogen incorporated in soil (kg N/year). See equation 2.6.10b.

Frac_{Lix}: fraction of N lost by leaching (kg N/kg N applied).

EF_{N₂O}: emission factor corresponding to N₂O emissions by leaching (e.g. kg N₂O-N/kg N leached).

(44/28): ratio of 44/28 to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

Once the company has calculated the tonnes of CO₂e from the contribution of nitrogen to the soil through stubble use, the total emissions are calculated by aggregating the results of tCO₂e of each equation, as shown in equation 2.6.10b4.

Equation 2.6.10b4

Total emissions of N₂O-Stubble (t CO₂e):
 $t \text{ CO}_2\text{e (direct)} + t \text{ CO}_2\text{e (volat)} + t \text{ CO}_2\text{e (leach)}$

Where:

Total emissions of N₂O-Stubble: total N₂O emissions from nitrogen input by stubble reincorporated in soil, in t CO₂e.

t CO₂e (direct): tonnes of direct carbon dioxide equivalent of N₂O.

t CO₂e (volat): tonnes of carbon dioxide equivalent from volatilization.

t CO₂e (leach): tonnes of carbon dioxide equivalent from leaching/runoff.

N₂O emissions from burning

To determine N₂O emissions from burning pineapple stubble with fire, the following methodology is used, based on IPCC references for agricultural residues (IPCC, 2006).

Equation 2.6.10c

Emissions from burning stubble (t CO₂e):
 $A \times M \times C \times EF_{\text{N}_2\text{O}} \times 10^{-3} \times GWP$

Where:

Emissions from burning stubble: emissions from burning pineapple stubble in t CO₂e.

A: burned area surface, in ha.

M: mass of fuel (biomass) available for combustion, in t/ha. Since the EF is given per kilogram of dry matter, the mass of dry matter available for combustion must be determined

using equation 2.6.10c1.

C: combustion factor, no unit. The combustion factor is a measure of the proportion of the fuel that is burned. A default value of 0.80 is proposed, which corresponds to the average of the reference value for agricultural residues of crops such as sugar cane, corn and rice, which are the only crops available in the IPCC reference.

EF_{N2O}: emission factor, grams N₂O/kg of dry matter burned from agricultural residues. See Table A1.6. in Annex 1.

GWP: global warming potential of N₂O.

Calculation of biomass available for combustion

Equation 2.6.10c1

$$M \text{ (t d.m./ha): } t \text{ stubble/ha} - (t \text{ stubble/ha} \times \% \text{ moisture})$$

Where:

M: Mass of fuel (biomass) available for combustion, expressed as tonnes of dry matter per hectare, t d.m./ha.

t stubble/ha: number of tonnes of green stubble generated per hectare.

% moisture: percentage of moisture in the stubble.

Emissions of CH₄ by pits in the field

The following is a description of the calculation method for estimating CH₄ emissions for stubble management in pits (IPCC, 2006).

Equation 2.6.10d

$$CH_4 \text{ emissions stubble pits (t CO}_2\text{e): } CH_{4 \text{ generated } t} \times (1 - OX) \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent from stubble handling in pits.

CH₄ generated^t: methane emitted during the inventory year, in kg.

OX: oxidation factor during the inventory year (fraction); 0.1 default for soil-covered managed pits.

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

Emissions of CH₄ from decomposing material

Equation 2.6.10d1

$$CH_{4 \text{ generated } t} \text{ (kg CH}_4\text{): } DDOC_{m \text{ decomp } t} \times F \times (16/12)$$

Where:

CH₄ generated^t: amount of CH₄ generated from decomposing material in the inventory year, in kg.

DDOC_{m decomp t}: amount of CH₄ decomposed during the year of the inventory, in kg.

F: volumetric fraction of CH₄ in the landfill gas generated (fraction). **Note:** Given that it is an uncontrolled disposal site and does not have gas disposal, this is not considered in the equation.

(16/12): quotient of molecular weights CH₄/C (ratio).

Amount of CH₄ decomposed

Equation 2.6.10d2

$$DDOC_{m \text{ decomp } t} \text{ (kg): } DDOC_{m t} \times (1 - e)^{-k}$$

Where:

DDOC_{m decomp t}: amount of CH₄ decomposed during the year of the inventory, in kg.

DDOC_{m t}: mass of dissolved degradable organic carbon (DDOC) deposited, in kg. See formula below.

k: reaction constant, k = 0.17. For the purposes of this guide, the value of k will be taken for humid tropical climates and for moderately degraded wastes, which includes organic wastes.



For consideration:

- To calculate N₂O emissions due to nitrogen input to the soil from stubble, only the reincorporation of green stubble and chemically dried stubble are considered.
- To calculate N₂O emissions from stubble that is burned, only the management of stubble with chemical drying plus burning is considered.
- Tabulate the required information in an Excel database to simplify data processing and associated calculations.
- The information on percentage of nitrogen in the stubble and percentage of moisture should preferably be obtained from a laboratory analysis. It is also recommended to differentiate whether the results are given on a dry or wet basis.
- In the absence of stubble nitrogen and moisture analysis, theoretical references can be used.

Amount of dissolved degradable organic carbon deposited

Equation 2.6.10d3

$$DDOC_m \text{ (kg)}: W \times DOC \times DOC_f \times MCF$$

Where:

DDOC_m: mass of dissolved degradable organic carbon deposited, in kg.

W: mass of waste deposited, in kg.

DOC: degradable organic carbon (DOC) during the year of deposition, a fraction expressed as kg C/kg waste. **Note:** For the purposes of this guide, a default value of 20 percent for the DOC content of wet waste will be used. This is the reference value for garden and park waste, which is the closest to stubble waste.

DOC_f: fraction of DDOC that can be decomposed,

with 0.5 as the recommended default value.

MCF: CH₄ correction factor for aerobic decomposition during the deposition year (a fraction). For the purposes of this guide a default value of “1” will be used, considering that disposal pits are managed and controlled.

2.6.10.B Collection of information

Activity data: It is necessary to obtain the total amount of ha per type of stubble management per year for the period evaluated. The company can get activity data through georeferencing, crop planning or internal farm management records.

Table 6 offers an example of the activity data collection.



Recommendation:

The proposed methodology to determine methane emissions from the disposal of stubble residues in pits is based on IPCC guidelines (Volume 5, Chapter 3) and assumes that the total deposited residues decompose in the inventory year.

Table 6. Example of stubble management data collection

Period	Type of stubble management	Ha or Kg
2022	Green management	250 ha
2022	Chemical drying	300 ha
2022	Chemical drying plus burning	100 ha
2022	Disposal pits	15 000 kg

To obtain the amount of nitrogen in kilograms incorporated into the soil from stubble, it is necessary to consider the total amount of stubble reincorporated in the field. The amount of stubble can be obtained from the company's records and internal controls of stubble management by lot or block, as well as through estimation according to crop density. Additionally, information on the nitrogen content of the stubble is required to obtain the total nitrogen incorporated in the field and the percentage of moisture.

Emission factors: The selection of emission

factors varies according to the type of stubble management, making it important to differentiate the number of hectares and number of residues by type of stubble management on the farm.

For the case of N₂O emissions from stubble put into the soil, the selection of emission factors by type of emission (direct and indirect through volatilization or leaching) and the selection of volatilization and leaching factors vary according to the source of nitrogen input into the soil. As such, it is important to differentiate the activity data associated with stubble reincorporation in the field from other nitrogen inputs.

Emission factors can also be selected from default or average factors such as aggregate factors or from more specific emission factors by type of climate or type of nitrogen source, i.e. disaggregated emission factors. See [Annex 1](#) for emission factor references.

Following is an example of an emissions calculation for the stubble management source.

Part I.

Example: calculation of CO₂ and CH₄ emissions from stubble harvesting

Step 1. During the year 2022, as part of the crop renewal in different sections of the farm, three types of stubble management were carried out on the following number of hectares:

Period	Type of stubble management	Ha
2022	Green management	250 ha
2022	Chemical drying	300 ha
2022	Chemical drying plus burning	100 ha

Step 2. Identify emission factors by stubble management type. It is preferable to use country specific EFs, but if no factors are available, the company can use the EFs recommended in Annex 1.

Type of stubble management	EF CH ₄ kg CH ₄ /ha/year	EF CO ₂ kg CO ₂ /ha/year
Green management	926.42	1541.76
Chemical drying	1592.30	2455.72
Chemical drying plus burning	1294.81	2175.96

Source: Fallas Rojas, T. M. 2019. *Greenhouse gas emission factors according to stubble management in pineapple cultivation*. Instituto Tecnológico de Costa Rica.

Step 3. Multiply the total number of hectares by the emission factor per type of management and by the global warming potential of CO₂ ([Annex 2](#)). Apply equation 2.6.10a. For example, for the case of green management:

Equation 2.6.10a

$$\text{Green management stubble emissions (t CO}_2\text{e) (CH}_4\text{)} = 250 \text{ ha} \times 926.42 \text{ Kg CH}_4\text{/ha/year} \times 21 \times \frac{1\text{t}}{1\,000 \text{ Kg}}$$

$$\text{Green management stubble emissions (t CO}_2\text{e) (CH}_4\text{)} = 4\,863.70 \text{ t CO}_2\text{e}$$

$$\begin{aligned} \text{Green management stubble emissions (t CO}_2\text{e) (CO}_2\text{)} &= 250 \text{ ha} \times 1\,541.76 \text{ Kg CO}_2\text{/ha/year} \\ &\times 1 \times \frac{1\text{t}}{1\,000 \text{ Kg}} \end{aligned}$$

$$\text{Green management stubble emissions (t CO}_2\text{e) (CO}_2\text{)} = 385.44 \text{ t CO}_2\text{e}$$

Step 4. Repeat the above equations for each type of stubble management and according to the emission factors by management type.

Part II. Calculation of N₂O emissions from pineapple stubble nitrogen input

Step 1. As part of stubble management after harvesting in 2022, the company reincorporated stubble in an area of 200 ha, with an average of 250 tonnes of stubble per hectare. The company carried out a characterization of several samples of stubble reincorporated with an average percentage of moisture and percentage total nitrogen obtained from the analyses. Based on this information, the company determined the total nitrogen incorporated in the field, as follows:

Type of waste	Area (ha)	t stubble/ha	Total stubble (t)	Total stubble (kg)	Moisture (%)	N (%)	N contribution (kg)
Organic residue (stubble)	200	250	50 000	50 000 000	83.75%	1.36%	110 500 kg (see the next formula)

Step 2. Estimate total nitrogen input, using the total amount of stubble incorporated in the field, percent moisture and nitrogen content:

Equation 2.6.10b

$$\text{kg N} = 50\,000\,000 \text{ Kg}_{\text{stubble}} - (50\,000\,000 \text{ Kg}_{\text{stubble}} \times 83.75\% \text{ moisture}) \times 1.36\% \text{ N} = 110\,500 \text{ Kg N}$$

Step 3. Identify the emission factor for direct emissions of N₂O for crop residues. It is preferable to use country specific EFs, but in case they are not available, the company can use the IPCC recommended EF ([Annex 1](#)).

EF	Type	Reference
0.010 KG N ₂ O - $\frac{N}{\text{Kg N}}$	EF for N additions from synthetic fertilizers, organic amendments, and crop residues	Aggregate emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, see Table A1.3. Annex 1.

Step 4. Obtain the direct emissions of N₂O in CO₂ equivalent. The company should multiply the total nitrogen, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28 to convert the N₂O-N emissions to N₂O. Use Equation 2.6.10b1.

Equation 2.6.10b1

$$\text{Direct stubble emissions (t CO}_2\text{e)} = 110\,500 \text{ Kg N} \times 0.010 \frac{\text{Kg N}_2\text{O-N}}{\text{kg N}} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1\,000 \text{ Kg}} =$$

$$\text{Direct stubble emissions (t CO}_2\text{e)} = 538.29 \text{ t CO}_2\text{e}$$

Step 5. Identify emission factors and fractions to estimate N₂O emissions by volatilization and leaching/runoff of nitrogen from stubble reincorporation in the field. It is preferable to use country specific EFs, but in case they are not available, the company can use the EFs recommended by the IPCC ([Annex 1](#)).

Frac/EF	Type	Reference
0.21 Kg kg NH ₃ -N + NO _x -N/Kg N applied	Frac _{Volat} : volatilization fraction of nitrogen from organic fertilizers	Volatilization fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, see Table A1.4., Annex 1.
0.010 kg N ₂ O-N/kg NH ₃ -N volatilized	EF _{Volat} : emission factor for N volatilization	Volatilization emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, see Table A1.4., Annex 1.
0.24 kg N/Kg N applied	Frac _{Lix} : fraction of N losses through leaching/runoff	Leaching/runoff fraction given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, see Table A1.4., Annex 1.
0.011 Kg N ₂ O-N/kg N	EF _{Lix} : emission factor for leaching/runoff	Leaching/runoff emission factor given by default by the IPCC 2019 Refinement in Volume 4, Chapter 11, see Table A1.4., Annex 1.

Step 6. Obtain the indirect emissions of N₂O by volatilization in CO₂ equivalent. For this, multiply the total nitrogen, the volatilization fraction, the emission factor, the global warming potential of nitrous oxide ([Annex 2](#)), and the ratio of 44/28, to convert the emissions of N₂O-N to N₂O. Use Equation 2.6.10b2.

Equation 2.6.10b2

$$\text{Indirect emissions from volat.stubble (t CO}_2\text{e)} =$$

$$110\,500 \text{ Kg N} \times 0.21 \text{ kg NH}_3\text{-N + NO}_x\text{-N/Kg N applied} \times 0.010 \text{ Kg N}_2\text{O - N/Kg NH}_3\text{-N + NO}_x\text{-N volatilization} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1\,000 \text{ Kg}} =$$

$$\text{Indirect emission from volat.stubble (t CO}_2\text{e)} = 113.04 \text{ t CO}_2\text{e}$$

Step 7. Obtain the indirect emissions of N₂O by leaching in CO₂ equivalent. For this, multiply the total nitrogen, the leaching fraction, the emission factor, the global warming potential of nitrous oxide (Annex 2), and the ratio of 44/28, to convert the emissions of N₂O-N to NO-N to N₂O. Use Equation 2.6.10b3.

Equation 2.6.10b3

$$\text{Indirect emissions from leach.stubble (t CO}_2\text{e)} =$$

$$110\,500 \text{ Kg N} \times 0.24 \text{ Kg N /Kg N aplicado} \times 0.011 \text{ Kg N}_2\text{O} - \text{N /Kg N} \times \frac{44}{28} \times 310 \times \frac{1\text{t}}{1000 \text{ Kg}} =$$

$$\text{Indirect emissions from leach.stubble (t CO}_2\text{e)} = 142.10 \text{ t CO}_2\text{e}$$

Step 8. To obtain the total tonnes of CO₂ e from the stubble-related emission, add the direct emissions of N₂O, and indirect emission from volatilization and leaching. Use equation 2.6.10b4.

Equation 2.6.10b4

$$\text{Total residual stubble emissions (t CO}_2\text{e)} =$$

$$538.29 \text{ t CO}_2\text{e} + 113.04 \text{ t CO}_2\text{e} + 142.10 \text{ t CO}_2\text{e} = 793.44 \text{ t CO}_2\text{e}$$

2.6.11 Solid waste disposal

Category:	Direct/indirect for products/services used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Ordinary municipal solid waste (sanitary landfill)		✓					
Organic waste composting		✓	✓				

2.6.11.1 Ordinary municipal solid waste (packaging, offices and dining room)

Municipal solid waste (MSW) includes ordinary domestic waste generated in offices, cafeterias and packing houses, among others. Emissions generated from this waste occur in the decomposition stages in anaerobic environments (the absence of oxygen). This section considers non-recoverable ordinary solid waste that is disposed in landfills (Vallejo *et. al.*, 2018).

2.6.11.1.A Calculation method

Methane emissions are estimated for non-recoverable ordinary waste sent to landfills, due to the decomposition of organic matter in anaerobic environments, using the following calculation method.

Equation 2.6.11.1a

$$\text{MSW emissions (t CO}_2\text{e): } AD \times EF_{\text{CH}_4} \times \text{GWP} \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per MSW disposal.

AD: activity data related to the mass of MSW sent to landfill (kg of waste).

EF_{CH₄}: CH₄ emission factor (e.g. kg CH₄/kg waste).

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.11.1.B Collection of information

Activity data: The activity data corresponds to kilograms of ordinary non-recoverable waste

sent to landfills. The amount of waste should preferably be obtained from internal waste weighing records and controls.

Emission factor: The emission factor for treatment and disposal of ordinary waste in landfills is used to determine emissions. This is given in CH₄ emissions per kilogram of waste generated. For emission factor references see [Annex 1](#).

An example of a calculation of emissions from the disposal of ordinary municipal waste is offered below.

Example: calculation of municipal solid waste emissions

Step 1. A pineapple farm located in the northern part of Costa Rica generated a total of 25 400 kg of MSW that was sent to a sanitary landfill during 2022, the year under study. The waste was generated in the administrative offices, the restrooms and the dining room. This waste was delivered to the municipal collection service for disposal in a sanitary landfill. As a first step, the company has to identify the appropriate emission factor for this type of waste treatment.

	Reference
0.0519 $\frac{\text{Kg CH}_4}{\text{KG waste}}$	Specific value for Costa Rica. IMN, 2022.

It is preferable to use country specific EF, but if not available, the company may use a recognize and cited EF.



Recommendation:

Keep controls and records on the generation of waste sent to landfills, and to keep this information in logs or other internal records.

Keep the evidence corresponding to the amount of waste used in the calculation of emissions.

Tabulate the required information in an Excel database to simplify data processing and associated calculations.

Step 2. Multiply the total amount of MSW generated, the respective emission factor and global warming potential ([Annex 2](#)) to obtain the CO₂ equivalent emissions. Apply equation 2.6.11.1a.

Equation 2.6.11.1a

$$MSW \text{ emissions (t CO}_2\text{e)} = 25\,400 \text{ kg waste} \times 0.0519 \frac{\text{Kg CH}_4}{\text{kg waste}} \times 21 \times \frac{1\text{t}}{1\,000 \text{ Kg}}$$

$$RSM \text{ Emissions (t CO}_2\text{e)} = 27.68 \text{ kg CO}_2\text{e}$$

2.6.11.2 Organic waste composting

Although it is not a common practice in the pineapple sector, the composting of organic waste generated in the company’s canteens, or the composting of crop residues may be incorporated as part of waste management. The waste composting process generates methane and nitrous oxide emissions. The calculation method is described below.

2.6.11.2.A Calculation method

In the case of organic waste treated by composting, CH₄ and N₂O emissions are estimated. The calculation method to determine emissions by type of GHG is described as follows.

Equation 2.6.11.2a

$$Emissions \text{ composting (t CO}_2\text{e)}: AD \times EF_{GHG} \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent by composting.

AD: activity data related to the mass of waste incorporated into a composting process (kg of waste).

EF_{GHG}: emission factor by type of GHG evaluated (e.g. kg CH₄/kg waste or kg N₂O/kg waste).

GWP: global warming potential according to the type of GHG evaluated.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.11.2.B Collection of information

Activity data: The activity data corresponds to the kilograms of organic waste incorporated into the composting process. The amount of waste should preferably be obtained from internal waste weighing records and controls.



Recommendation:

- Keep controls and records on the generation of waste incorporated into the composting process. This information should be saved in logs or other internal records.
- Keep evidence corresponding to the amount of waste used in the calculation of emissions.
- In case of incorporating any additional materials in the composting process for moisture control, for example, pellets, coconut chips, sawdust, among others, these should be considered as part of the total waste incorporated to the composting process.
- Tabulate the required information in an Excel database to simplify data processing and associated calculations.



Important

Emission factors are referenced on a wet and dry basis. As such, the selection depends on the activity data and whether the amount of waste is reported on a dry or wet basis.

Emission factor: To determine methane and nitrous oxide emissions, use is made of the emission factors for biological treatment of waste using compost, which are given in grams of GHG per kilogram of waste generated. For emission factor references see [Annex 1](#).

Following is an example of an emission calculation for waste treatment by composting.

Example: calculation of emissions from waste composting

Step 1. On a pineapple farm, composting organic waste from the canteens was incorporated as part of the internal waste management programme. During the study year 2022, 30 000 kg of waste were managed by composting. To estimate the related emissions, the emission factors corresponding to the type of treatment must be identified.

EF compost	Reference
0.004 $\frac{\text{Kg CH}_4}{\text{Kg waste}}$	EF published by IMN Costa Rica, see Table A1.1., Annex 1. Also available in the 2006 IPCC guidelines, chapter 4, volume 5. See Table A1.5., Annex 1.
0.24 $\frac{\text{g N}_2\text{O}}{\text{Kg waste}}$	EF published by IMN Costa Rica, see Table A1.1., Annex 1. Also available in the 2006 IPCC guidelines, chapter 4, volume 5. See Table A1.5., Annex 1.

It is preferable to use the specific EFs published for each country, but in case they are not available, the company can use the EF recommended by the IPCC ([Annex 1](#)).

It is important to note that, if the EF is given in grams, the value must be converted to kilograms by multiplying by 1/1000 in order to obtain the emissions data in the standard unit.

$$FE_{N_2O \text{ compost}} = 0.24 \frac{\text{g N}_2\text{O}}{\text{kg waste}} \times \frac{1 \text{ Kg}}{1\,000} = 0.00024 \frac{\text{Kg N}_2\text{O}}{\text{Kg waste}}$$

Step 2. Multiply the amount of waste by the composting emission factor per GHG type and the global warming potential per GHG type assessed ([Annex 2](#)) to obtain the carbon dioxide equivalent emissions. Use Equation 2.6.11.2a by GHG type.

Equation 2.6.11.2a

$$\text{Compost emissions (t CO}_2\text{e) (CH}_4\text{)} = 30\,000 \text{ kg waste} \times 0.004 \frac{\text{Kg CH}_4}{\text{kg waste}} \times 21 \times \frac{1 \text{ t}}{1\,000 \text{ Kg}}$$

$$\text{Compost emissions (t CO}_2\text{e) (CH}_4\text{)} = 2.52 \text{ t CO}_2\text{e}$$

Equation 2.6.11.2a

$$\text{Compost emissions (t CO}_2\text{e) (N}_2\text{O)} = 30\,000 \text{ Kg waste} \times 0.00024 \frac{\text{Kg N}_2\text{O}}{\text{Kg waste}} \times 310 \times 1\text{t} / \frac{1\text{ t}}{1\,000 \text{ Kg}}$$

$$\text{Compost emissions (t CO}_2\text{e) (N}_2\text{O)} = 2.23 \text{ t CO}_2\text{e}$$

Step 3. To obtain the total tonnes of CO₂e from the composting emission source, the emissions from methane and nitrous oxide are combined.

$$\text{Total compost emissions (t CO}_2\text{e)} = 2.52 \text{ t CO}_2\text{e} + 2.23 \text{ t CO}_2\text{e} = 4.75 \text{ t CO}_2\text{e}$$

2.6.12 Wastewater treatment

Category:	Direct/indirect by products or services used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Industrial wastewater from process: during treatment		✓	✓				
Industrial wastewater from process: discharge into receiving body		✓	✓				
Industrial wastewater from process: discharged on soil			✓				
Ordinary sewage: septic tank		✓					
Ordinary wastewater: latrines		✓					

2.6.12.1 Process wastewater (pack house)

Industrial wastewater (IWW) generated at the pack house, resulting from fruit washing and facility cleaning, can produce methane and nitrous oxide emissions during and after treatment depending on the treatment system used. To comply with legal requirements for wastewater discharge into a receiving body or its reuse, it is necessary to guarantee the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD) parameters after treatment. These parameters are necessary to calculate methane emissions. To calculate N₂O emissions, information on the total nitrogen content present in the wastewater is required.



Important

It is important to take into account that the generation of methane and nitrous oxide emissions during wastewater treatment depends on the type of treatment system (aerobic or anaerobic). This should be considered in the selection of the emission factor.



For consideration:

If the same flow is used at the inlet and outlet of the treatment system, the removed COD can be calculated by the difference in organic load between the inlet and outlet in concentration units (kg/L).

2.6.12.1.A-1 Calculation method

Methane emissions during treatment: The following equation is used to determine methane emissions during treatment.

Equation 2.6.12.1a

CH₄ IWW emissions during treatment (t CO₂e):
$$AD \times Q_{\text{Annual}} \times EF_{\text{CH}_4} \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent by wastewater treatment.

AD: activity data related to the organic load removed during treatment (kg COD/L).

Q_{Annual}: flow rate of treated wastewater (L/year)

EF_{CH₄}: CH₄ emission factor during treatment by type of treatment system (e.g. kg CH₄/kg COD).

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

The following equation is used to determine the organic load removed during treatment, when COD measurements of the wastewater at the inlet of the treatment system and COD at the outlet of the treatment system are available.

Equation 2.6.12.1a1

AD (Kg COD removed) = COD input - COD output

Where:

AD: Kg COD removed during treatment per year.

COD input: organic load entering the treatment

system (Kg COD/year).

COD output: organic load at system outlet, after treatment (Kg COD/year).

To determine the removal of the total mass of organic load in terms of COD (Kg) rather than COD concentration (Kg/L), consider potential variations in the inflow and outflow rates of the treatment system. Equation 2.6.12.1a1 is disaggregated as follows.

Equation 2.6.12.1a1 (disaggregated)

AD (kg COD removed) = (COD_{Input} × Q_{input}) - (COD_{output} × Q_{output})

Where:

AD: kg of COD removed during treatment per year.

COD_{Input}: organic load entering the treatment system, COD (kg/L).

Q_{input}: flow rate of wastewater entering the treatment system per year (L/year).

COD_{output}: organic load at the system outlet, after treatment, COD (kg/L).

Q_{output}: wastewater flow leaving the treatment system (L/year).

If a company does not have COD data at the inlet of the treatment system, but only has output data, the COD removed can be estimated using the following equation.

Equation 2.6.12.1a2

COD_{input} = (COD_{output} × 1/(1-TOW_{Rem}))



For consideration:

- Normally the COD parameters in laboratory analysis are given in mg/L. Since the units used for the emissions calculation are kg/L, the company should convert from mg to kg.
- When there is more than one analysis per year, it is recommended to use the average of the parameters obtained in the analyses conducted during the reporting period.
- Methane emissions are estimated for the discharge of treated wastewater into receiving bodies (e.g. river, canal, stream, lake). However, if treated wastewater is used for irrigation, methane emissions are not considered because there is no methodology for estimating this form of methane emissions at the time of drafting this guide.
- Tabulate the required information in an Excel database to simplify data processing and associated calculations.

Where:

COD_{input}: organic load in the wastewater entering the treatment system, COD (Kg/L).

COD_{output}: organic load in the wastewater at the outlet of the system, after treatment, COD (Kg/L).

TOW_{Rem}: fraction of organic load removal according to the type of treatment (see Table A1.7. in [Annex 1.](#))

Note: Values of 1 in the equation represent 100 percent.

Methane emission after treatment: The following equation is used to determine methane emissions after treatment, by discharge to a receiving body.

Equation 2.6.12.1b

$$CH_4 \text{ emissions IWW after treatment (t CO}_2\text{e):}$$

$$AD \times Q_{\text{discharge}} \times \frac{\text{Days}_{\text{discharged}}}{CF} \times FE_{CH_4} \times GWP \times$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per treated wastewater discharge.

AD: activity data related to the organic load in the discharge after treatment (kg COD/L).

Q_{Annual}: discharge wastewater flow (L/day).

Days_{discharged}: number of days in the year that

treated wastewater was discharged.

EF_{CH₄}: CH₄ emission factor after treatment by type of discharge (e.g. kg CH₄/kg COD).

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.12.1.B-1 Collection of information

Activity data: Activity data related to **organic load** in wastewater should be obtained from laboratory analyses performed for operational reporting and internal controls of the operation of treatment systems.

Activity data related to the **raw or untreated wastewater flow** can be obtained from packing plant water consumption data if differentiated consumption records are available. Otherwise, the company can make an estimate of this value using data on the capacity and frequency of changing the water in washing basins.

Discharge flow activity data can be obtained from sampling analyses performed for operational reports or internal discharge flow measurement records.

Emission factors: For the calculation of methane emissions from industrial wastewater

treatment, emission factors must be selected according to the type or treatment system used.

Table 7 presents the types of treatment systems considered in the methodological reference.

Table 7. CH₄ emission factor considerations by treatment system

Type of treatment system	Emission factor reference
Centralized aerobic treatment plant	The default emission factor is zero. See Annex 1, Table A1.8.
Shallow anaerobic lagoon or facultative lagoon (depth less than 2 meters)	There is a default emission factor, see Annex 1, Table A1.8.
Deep anaerobic lagoon (depth more than 2 meters)	There is a default emission factor, see Annex 1, Table A1.8.

Source: Adapted from IPCC. 2019. *Refinamiento 2019 de las Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero*. Volume 5, chapter 6. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html>

For the calculation of emissions after treatment by discharge into a receiving body, there are emission factors according to the type of

discharge. Table 8 provides a list of the types of discharges considered in the methodological reference.

Table 8. Considerations of CH₄ emission factors per discharge type

Type of treatment system	Emission factor reference
Discharge to aquatic environments	An emission factor for discharges into <i>any</i> aquatic environment, corresponding to an average emission factor. See Annex 1, Table A1.8.
Discharge to aquatic environments other than reservoirs, lakes and estuaries	Applies to most aquatic environments, including rivers. See Annex 1, Table A1.8. for the default emissions factor.
Discharge into reservoirs, lakes, and estuaries	See Annex 1, Table A1.8. for the default emissions factor.

Source: Adapted from IPCC. 2019. *Refinamiento 2019 de las Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero*. Volume 5, chapter 6. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html>

2.6.12.1.A-2 Calculation method

Nitrous oxide emissions during treatment:

The following equation is used to determine nitrous oxide emissions during treatment.

$$\text{Emissions of } N_2O \text{ by IWW during treatment (t } CO_2e): AD \times Q_{Annual} \times EF_{N_2O} \times (44/28) \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent by wastewater treatment.

AD: activity data related to total nitrogen in the wastewater to be treated (kg N/L).

Q_{Annual}: treated wastewater flow rate (L/year).

EF_{N₂O}: N₂O emission factor during treatment by type of treatment system (kg N₂O-N/kg N).

(44/28): the ratio of 44/28 is used to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).



For consideration:

- Normally the total nitrogen parameter in laboratory analysis is given in mg/L. Since the units used for the emissions calculation are kg/L, the company should convert from mg to kg.
- When there is more than one analysis per year, it is recommended to use the average of the parameters obtained in the analyses carried out during the reporting period.
- In the absence of laboratory analysis, a theoretical reference of nitrogen content in wastewater can be used for the type of activity being analysed. However, it is not common to find theoretical references for this activity.
- When only total nitrogen analysis of wastewater at the treatment system's inlet is available, a nitrogen removal fraction, based on the treatment type, can be used to estimate the total nitrogen in the effluent. Refer to Table A1.10. in Annex 1. Likewise, when only total nitrogen analysis of the effluent or post-treatment is available, the removal fraction can be used, according to the treatment type, to estimate the total nitrogen in the wastewater at the treatment system's inlet.
- Tabulate the required information in an Excel database to simplify the processing of the information and the associated calculations.

Nitrous oxide emissions after treatment:

The following equation is used to determine nitrous oxide emissions after treatment, either by discharge to a receiving body or by reuse (irrigation).

Equation 2.6.12.1d

Emissions of N₂O by IWW discharged (t CO₂e):

$$AD \times Q_{\text{discharged}} \times \text{Days}_{\text{discharged}} \times EF_{\text{N}_2\text{O}} \times (44/28) \\ \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per wastewater discharge.

AD: activity data related to total nitrogen in wastewater discharge/reuse (kg N/L).

Q_{discharged}: flow rate of wastewater discharged or reused (L/day)

Days_{discharged}: number of days in the year that treated wastewater was discharged/reused.

EF_{N₂O}: N₂O emission factor after treatment by type of discharge/reuse (kg N₂O-N/kg N).

(44/28): the ratio of 44/28 is used to convert N₂O-N emissions to N₂O emissions.

GWP: global warming potential of N₂O.

CF: unit conversion factor (e.g. conversion from kg or gr to tonnes).

2.6.12.1.B-2 Collection of information

Activity data: Activity data related to nitrogen content in wastewater should be obtained from laboratory analysis of untreated wastewater and after treatment for discharge to a receiving body or reuse for irrigation.

Activity data related to **raw or untreated wastewater flow** can be obtained from water consumption data of the packing house if differentiated consumption records are available, or the company can make an estimate of this value using data on the capacity and frequency of changing the water in washing basins.

Discharge flow activity data can be obtained from sampling analyses performed for operational reports or internal discharge flow measurement records.



For consideration:

When treated wastewater is discharged into the soil, in addition to direct emissions of N_2O , the company needs to calculate the indirect emissions due to volatilization and leaching as described in section 2.6.7 on nitrogen fertilizers (specifically equations 2.6.7a1 and 2.6.7a2).

Emission factors: For the calculation of nitrous oxide emissions from industrial wastewater treatment, emission factors must be selected

according to the type or treatment system used. Table 9 presents the types of treatment systems considered in the methodological reference.

Table 9. N_2O emission factor considerations by treatment system

Type of treatment system	Emission factor reference
Centralized aerobic treatment plant	See Annex 1, Table A1.9. for a default emission factor.
Anaerobic reactor	Emissions of N_2O are not considered to be significant, so there is no default emission factor. See Annex 1, Table A1.9.
Anaerobic lagoons	Emissions of N_2O are not considered to be significant, so there is no default emission factor. See Annex 1, Table A1.9.

Source: Adapted from IPCC. 2019. *Refinamiento 2019 de las Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero*. Volume 5, chapter 6. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html>

For the calculation of emissions after treatment by discharge into a receiving body or irrigation,

emission factors are determined according to the type of discharge as shown in Table 10.

Table 10. Considerations of N_2O emission factors per discharge type

Type of treatment system	Emission factor reference
Discharge into fresh, estuarine and marine waters	There is a default emission factor in Annex 1, Table A1.9.
Discharge to soil	In this case, the same emission factor is used for nitrogen inputs into the soil as used in section 2.2 on nitrogen fertilizer use. See Annex 1, Table A1.3.

Source: Adapted from IPCC. 2019. *Refinamiento 2019 de las Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero*. Volume 5, chapter 6. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html>

The following is an example of a wastewater treatment emissions calculation.

Example: calculation of emissions from packing house wastewater

Step 1. On a farm located in Costa Rica, wastewater is generated from a packing house. The packing house reuses the water for a week and then treats it in an anaerobic lagoon before discharging it into a river after treatment. First the information corresponding to the type of treatment must be collected to identify the emissions, activity data and applicable emission factors.

Emissions during treatment: treatment system type	CH ₄ emissions are applied during treatment	N ₂ O emissions are applied during treatment
Shallow anaerobic lagoon (less than 2 meters).	Yes	No
Emissions after treatment: type of discharge	CH ₄ applied emission per discharge	N ₂ O applied emissions per discharge
River discharge	Yes	Yes

Once the company has mapped out the type of treatment and discharge system, the activity data is compiled, which is obtained from annual laboratory analyses.

Activity data for emissions during processing	COD input wastewater to be treated	COD discharged wastewater outflow
Shallow anaerobic lagoon (less than 2 meters)	500 mg/L (0.0005 kg/L)	75 mg/L (0.000075 kg/L)
Activity data for emissions after processing	Total input N of the wastewater to be treated	N total discharged wastewater outflow
River discharge	Does not apply	14 mg/L (0.000014 kg/L)

In addition to the COD and total N concentrations in the wastewater, information is collected on the treatment plant's inflow and outflow, which should be similar. However, the inflow and outflow values may vary due to evaporation losses and rainfall. The data obtained are shown below.

Type of treatment and discharge system	Q (Flow rate)	Number of days per year with discharge
Shallow anaerobic lagoon, inflow	624 000 L/year	Does not apply
River discharge (outflow rate)	3 500 L/day (546 000 L/year)	156

Step 2. Identify appropriate emission factors. It is preferable to use country specific EFs, but if not available, the EFs recommended by the IPCC (Annex 1) can be used.

Emission	EF	Reference
CH ₄ during treatment	0.05	IPCC Refinement 2019, chapter 6, volume 5. See Table A1.8. in Annex 1.
CH ₄ at discharge	0.028	IPCC Refinement 2019, chapter 6, volume 5. See Table A1.8. in Annex 1.

N ₂ O during treatment	Not applicable	There is no default emission factor for anaerobic lagoons.
N ₂ O at discharge	0.005	IPCC Refinement 2019, chapter 6, volume 5. See Table A1.9. in Annex 1.

Step 3. Once the activity data and emission factors have been obtained, the emissions during and after treatment are calculated for each type of GHG.

Methane emissions during treatment:

Equation 2.6.12.1a1 (disaggregated)

$$AD \text{ (Kg COD removed)} = (0.0005 \text{ Kg COD/L} \times 624\,000 \text{ L/year}) - (0.000075 \text{ Kg COD/L} \times 546\,000 \text{ L/year}) =$$

$$AD \text{ (Kg COD removed)} = 312 \text{ Kg COD/year} - 40.95 \text{ Kg COD/year} = 271.05 \text{ Kg COD/year}$$

Equation 2.6.12.1a

$$\text{Emissions } CH_4 \text{ IWW during Treat. (t CO}_2\text{e):}$$

$$271.05 \text{ Kg COD/year} \times 0.05 \text{ kg } CH_4 / \text{Kg COD} \times 21 \times = 0.285 \text{ t CO}_2\text{e}$$

Methane emissions after treatment (discharge):

Equation 3.2.1.1b

$$CH_4 \text{ emissions by IWW after treatment (t CO}_2\text{e):}$$

$$0.000075 \text{ Kg COD/L} \times 3\,500 \text{ L/day} \times 156 \text{ days} \times 0.028 \text{ Kg } CH_4 / \text{Kg COD} \times 21 \times = 0.024 \text{ tCO}_2\text{e}$$

Nitrous oxide emissions after treatment (discharge):

Equation 3.2.1.1d

$$\text{Emissions of N}_2\text{O by IWW after treatment (t CO}_2\text{e):}$$

$$0.000014 \text{ kg N/L} \times 3\,500 \text{ L/day} \times 156 \text{ days} \times 0.005 \text{ kg N}_2\text{O-N/kg N} \times (44/28) \times 310 \times =$$

$$0.019 \text{ t CO}_2\text{e}$$

Total emissions from wastewater treatment at the packing house:

$$\text{Total wastewater treatment emissions at the packing house} =$$

$$0.285 \text{ t CO}_2\text{e} + 0.024 \text{ t CO}_2\text{e} + 0.019 \text{ t CO}_2\text{e} = 0.328 \text{ t CO}_2\text{e}$$

2.6.12.2 Ordinary wastewater

Ordinary wastewater (OWW) is generated as a result of domestic activities, such as the use of toilets, showers, sinks, etc. Ordinary wastewater is a source of methane emissions and depends

on the treatment system used (Vallejo *et al.*, 2018).

For the calculation of emissions from ordinary wastewater treatment, two disposal methods are proposed, which are described below.



For consideration:

- For the calculation of emissions, an annual average number of people applicable by type of wastewater treatment system can be used.
- In the calculation of emissions, in addition to considering the personnel days during the year, it is possible to include the emissions associated with visitors and internal personnel according to the fraction of a day they stay on site. This involves applying the proportion of hours spent in relation to the total hours of the day (24), i.e. hours spent/24. This methodology allows for a more accurate estimation of the emissions generated by visitors and internal staff.
- Tabulate the required information in an Excel database to simplify the processing of the information and the associated calculations.

a) Septic tank

This consists of an ordinary wastewater treatment unit, generally used to treat wastewater generated in administrative areas or packing houses. The calculation of emissions is directly related to the number of people who generate ordinary wastewater that is treated in this treatment system.

b) Latrines (located in the field)

Latrines are basic structures used as sanitary infrastructure that are installed in areas where there is no access to adequate sewerage systems or sanitation services. They consist of a sanitary slab over a pit that can be two meters or more deep, which uses little or no water for flushing. They are normally used in the field by personnel working in the area.

For both types of wastewater disposal and treatment, the following calculation method is used.

2.6.12.2.A Calculation method

Equation 2.6.12.2a

$$CH_4 \text{ emissions by OWW (t CO}_2\text{e): } AD \times EF_{CH_4} \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per OWW treatment.

AD: activity data related to the number of people who generate OWW in the septic tank/latrine (persons/year).

EF_{CH₄}: CH₄ emission factor for septic tank/Latrine (kg CH₄ per person/year).

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg to tonnes).

The above equation is used to estimate the CH₄ emissions per person per year (365 days). If the company wishes to estimate methane emissions according to the number of days worked, the following equation can be applied.

Equation 2.6.12.2a1

$$\text{Emissions CH}_4 \text{ OWW (t CO}_2\text{e): } AD \times \text{Frac}_D \times EF_{CH_4} \times GWP \times CF$$

Where:

t CO₂e: tonnes of carbon dioxide equivalent per OWW treatment.

AD: activity data related to the number of people that generate OWW to the septic tank or latrine (persons/year).

Frac_D: fraction of time in days worked (personnel days worked/365).

EF_{CH₄}: CH₄ emission factor for septic tank or latrine (kg CH₄ per person/year).



For consideration:

In the case of the latrine emission factor, this depends on the climate and characteristics of wastewater generation, see [Annex 1](#).

GWP: global warming potential of CH₄.

CF: unit conversion factor (e.g. conversion from kg to tonnes).

2.6.12.2.B Collection of Information

Activity data: Activity data is related to the average number of people staying in the facility and generating wastewater sent to the septic tank or latrine. Activity data can be obtained from

staff payroll, and logs of visitor and suppliers.

Emission factors: for the calculation of methane emissions from ordinary wastewater treatment, the emission factor must be selected according to the type or treatment system used, that is the septic tank or latrine.

The following is an example of a calculation of emissions from ordinary wastewater treatment.

Example: calculation of ordinary wastewater emissions in septic tank and latrine.

Step 1. The packing house and administrative offices have two septic tanks that receive and treat ordinary wastewater from toilets and sinks. There are also two latrines on the farm that use water for flushing. First, the information corresponding to the type of treatment must be compiled to identify the applicable emissions, activity data and applicable emission factors.

Location	Type of treatment and discharge system	Average number of people per year	Fraction of days per year worked	EF
Administrative offices	Septic tank	50	261/365	4.38 kg CH ₄ per person/year
Farm	Latrines (wet weather/discharge water use)	15	313/365	6.13 kg CH ₄ per person/year

Step 2. Once the activity data and emission factors have been obtained, the emissions by type of ordinary wastewater treatment system are calculated.

Emissions per septic tank:

Equation 2.6.12.2a1

$$CH_4 \text{ emissions by OWW (t CO}_2\text{e)} = 50 \text{ people/year} \times (261/365) \times 4.38 \text{ Kg CH}_4\text{/people/year} \times 21 \times \\ = 3.289 \text{ t CO}_2\text{e}$$



For consideration:

If the company intends to participate in a GHG programme in the country where its productive or packing activities take place, it is important to check if the programme has associated requirements or restrictions for reporting emissions from land use change or soil carbon stock changes.

Emissions per latrine:

Equation 2.6.12.2a1

$$CH_4 \text{ emissions by OWW (t CO}_2\text{e)} = 15 \text{ people/year} \times (313/365) \times 6.13 \text{ kg CH}_4\text{/people/year} \times 21 \times \\ = 1.656 \text{ t CO}_2\text{e}$$

2.6.13 Soil carbon stock change by tillage

Category:	Direct/indirect by products used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others: PFC
Tillage	✓						

The amount of carbon stored on permanent agricultural land, as well as the amount of carbon emitted by or absorbed in it, depends on the type of crop cultivated, soil and crop management practices, and soil and climate variables. Soil carbon stocks can be significant and are subject to variations in most management practices, particularly in relation to tillage, drainage, residue management and organic amendments (IPCC, 2005).

In this module, two methodologies are proposed: a theoretical methodology based on default ratios given by the IPCC, and a specific method based on farm soil analysis. Both methods are described below.

2.6.13.1 Soil carbon stock change – theoretical default method

2.6.13.1.A Calculation method

For areas of agricultural land that remain agricultural land, the change in carbon stocks can be calculated in two ways:

- by monitoring management changes and calculating the change in stocks on individual plots of land, or,
- by calculating total soil carbon stocks at the beginning and end of the period being assessed, using more general data on the surface distribution of agricultural land systems.

The overall results will be the same in either scenario. The main difference is that attributing the effects of management changes will require activity data that considers changes on particular land areas (IPCC, 2005).

The following is a description of the calculation formula to determine the variation of soil carbon.

Equation 2.6.13.1a

$$C \text{ variation in mineral soils} = \sum [(SOC_0 - SOC_{(0-t)}) \times S] / T$$

or

$$C \text{ variation in mineral soils} = [\sum (SOC_0 \times S) - \sum (SOC_{(0-t)} \times S)] / T$$

Where:

C variation in mineral soils: annual variation in carbon stocks in mineral soils, in tonnes C/year.

SOC₀: variation in soil organic carbon in the inventory year, in tonnes C/ha.

SOC_(0-t): soil organic carbon stock *t* years before the inventory, in tonnes C/ha.

T: reporting period, in years (default value: 20 years).

S: surface area of each plot, in ha.

To determine soil organic carbon (SOC) in the inventory year and before the inventory, the following equation is used.

Equation 2.6.13.1b

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I$$

Where:

SOC_{REF}: carbon stock reference value, in tonnes C/ha; see Table A1.11., in [Annex 1](#).

F_{LU}: stock change factor for a land use or land

use change, dimensionless; see Table A1.12. in [Annex 1](#).

F_{MG}: stock change factor for a management regime, dimensionless; see Table A1.12. in [Annex 1](#).

F_I: stock change factor for an input of organic matter, dimensionless; see Table A1.12. in [Annex 1](#).

Calculations to determine SOC₀ and SOC_(0-T) and the net change in soil C stocks per ha are performed through the following steps:

Step 1: select the reference carbon stock value (SOC_{REF}), based on climate and soil type, for each land area to be inventoried.

Step 2: select the type of agricultural land use (long-term crop) existing at the beginning of the inventory period, i.e. in period (0–t), together with the tillage (F_{MG}) and C input (F_I) levels. These factors, multiplied by the reference value of soil C stocks, provide the estimate of the “initial” soil C stocks (SOC_(0-t)), **equation 2.6.13.1b**.

Step 3: calculate the SOC value₀ by repeating step 2 and using the same carbon stock reference value (SOC_{REF}), but with land use, tillage and input factors that represent conditions existing in the current inventory year (0).

Step 4: calculate the average annual change in soil C stocks for the surface during the inventory period (C variation in mineral soils, **equation 2.6.13.1a**).

Step 5: represent the annual change in C in tonnes of CO₂. The final change of t C/year can be converted into units of CO₂ emissions by multiplying the change in carbon stock by –44/12. The change in sign (–) is due to the convention that increases in carbon stocks, i.e. positive (+) stock changes, represent an

absorption (or “negative” emission) from the atmosphere, while decreases in carbon stocks, i.e. negative (–) stock changes, represent a positive emission into the atmosphere. This conversion is represented as follows.

Equation 2.6.13.1c
C emission/absorption in t CO₂ =
C variation (t C/year) × (–44/12)

2.6.13.1.B Collection of information

Activity data: For activity data, information is required on the number of hectares per management block in the reporting year. It is necessary to know the areas where minimum tillage, conventional tillage or no-tillage were used during the reporting year.

Land management and use factors: The following management and use factors will be required for mineral soils:

1. reference carbon stock value (SOC_{REF});
2. factor of variation of reserves when there is a change in land use (F_{LU});

3. reserves variation factor for a soil management regime (F_{MG}); and
4. factor of variation of reserves in case of organic matter input (F_i).

These can be selected according to the conditions of the area under analysis and the type of soil management practices employed. See [Annex 1](#).

To select the reference carbon stock value (SOC_{REF}), as indicated in step 1, according to climate type and soil type, the following guidance is provided.

- a. **Climate type:** climate zones are classified by temperature zones that are defined according to mean annual temperature (MAT) and humidity regimes. Considering that the pineapple plant is typical of tropical climate zones and requires temperatures between 23 °C and 30 °C, this guide only considers humidity regimes for tropical zones. These are classified according to mean annual precipitation (MAP) (IPCC,2005).
- b. **Soil type:** Table 12 offers a description of the different types of soil by classification.

Table 11. Guidance on climate types

Mean annual temperature (MAT)	Humidity regimes Tropical zones		
Tropical	MAT >20 °C	Dry	MAP <1 000 mm
		Moist	MAP 1 000 – 2 000 mm
		Wet	MAP >2 000 mm

Table 12. Guidance on soil types

Classification	Description
HAC soils	Soils with high activity clay minerals (HAC) are soils with a mild to moderate level of weathering, dominated by silicate clay minerals 2:1 (in the World Reference Base for Soil Resources classification - WRB). This group includes leptosols, vertisols, kastanozems, chernozems, phaeozems, luvisols, alisols, albeluvisols, solonetz, calcisols, gypsisols, umbrisols, cambisols, regosols. The United States Department of Agriculture (USDA) classification also includes mollisols, vertisols, very alkaline alfisols, aridisols and inceptisols.
LAC soils	Soils with low activity clay minerals (LAC) are heavily weathered soils dominated by 1:1 clay minerals and amorphous iron, as well as aluminium oxides (WRB classification includes acrisols, lixisols, nitisols, ferralsols, durisols. The USDA classification includes ultisols, oxisols and acid alfisols).
Sandy soils (SAN)	Includes all types of soils (regardless of taxonomic classification) containing more than 70% sand and less than 8% clay based on typed texture analysis. The WRB classification includes arenosols; the USDA classification includes psammens.
Spodic soils (POD)	Heavily podzolized soils. The WRB classification includes podzols; the USDA classification includes spodosols.
Volcanic soils (VOL)	Soils derived from volcanic ash with allophanic mineralogy. The WRB classification includes andosols; the USDA classification includes andisols.
Wetland soils (WET)	Soils with restricted drainage resulting in periodic flooding and anaerobic conditions. The BMR classification includes gleysols; the USDA classification includes the aquaica suborders.

Source: Adapted from IPCC. 2006. *Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero*. Volume 4, chapter 2. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html>



For consideration:

- In the methodological guidance used (IPCC Guidelines), carbon stocks are measured to a default depth of 30 cm and do not include carbon from surface residues (i.e. dead organic matter) or changes in inorganic carbon (i.e. carbonate minerals). In most soils where pineapple is grown there are no surface residues as a result of incorporation through tillage.
- This IPCC guidance assumes that the variations of carbon in dead organic matter and inorganic carbon are zero.
- The IPCC Guidelines assume a linear change in soil carbon stocks over a 20-year period following a soil management change. In this scenario, soil carbon stocks move from an equilibrium position at time t_0 (year of the soil management change) to another equilibrium position at time t_{20} (20 years after the soil management change). Therefore, it is assumed that the rate of change of carbon stocks remains constant for the first 20 years following a management change and then the rate equals zero when a new equilibrium has been reached.

An example of soil carbon stock change calculation is shown below.

Example: calculation of emissions from soil carbon stock changes due to tillage

Step 1. The company has maintained 1 200 ha of pineapple for more than 10 years. Although the land has been maintained as agricultural area, tillage is carried out every year as part of the company’s land management for crop renewal. As the company is in the process of preparing the emissions inventory for the 2022 period, it needs to calculate the variation in soil carbon stocks due to tillage activities. Therefore, the first step is to characterize the areas before and after tillage, considering the changes occurring in the evaluated period, in order to select the reference carbon stock and management types in the evaluated period. The characterization of the areas is shown below:

Before tillage (Year 0-t)							
Plot/farm	Ha	Type of climate	Type of soil	COS _{REF}	F _{LU}	F _{MG}	F _I
A-B	300	Very humid tropical (average annual temperature higher than 20 °C and average annual rainfall higher than 2 000 mm).	Ultisols (LAC Soil)	Tropical very humid, LAS soils	Long-term crop tropical, very humid	No tillage tropical very humid	Medium, tropical very humid
C	900	Very humid tropical (average annual temperature higher than 20°C and average annual rainfall higher than 2 000 mm).	Ultisols (LAC Soil)	Tropical Very Humid, LAC soils	Long-term crop tropical, very humid	Full tillage, tropical very humid	High input-no manure, tropical very humid
After tillage (Year 0)							
Plot/farm	Ha	Type of climate	Type of soil	COS _{REF}	F _{LU}	F _{MG}	F _I
A-B	300	Very humid tropical (average annual temperature higher than 20°C and average annual rainfall higher than 2 000 mm).	Ultisols (LAC Soil)	Tropical very humid, LAC soils	Long-term crop tropical, very humid	Full tillage, tropical very humid	High input-no manure, very humid tropical
C	900	Very humid tropical (average annual temperature higher than 20°C and average annual rainfall higher than 2 000 mm).	Ultisols (LAC Soil)	Tropical very humid, LAC soils	Long-term crop tropical, very humid	No tillage tropical very humid	Medium., tropical very humid

Step 2. Once the areas have been characterized before the inventory year and during the inventory year, the corresponding values are assigned, according to Tables A1.11. and A1.12. of [Annex 1](#). The values corresponding to each managed area are shown below.

Before tillage (Year 0-t)							
Plot/farm	Ha	Type of climate	Type of soil	COS_{REF} t C/ha	F_{LU}	F_{MG}	F_I
A-B	300	Very humid tropical	LAC	52	0.83	1.10	1
C	900	Very humid tropical	LAC	52	0.83	1	1.11
After tillage (Year 0)							
Plot/farm	Ha	Type of climate	Type of soil	COS_{REF} t C/ha	F_{LU}	F_{MG}	F_I
A-B	300	Very humid tropical	LAC	52	0.83	1	1.11
C	900	Very humid tropical	LAC	52	0.83	1.10	1

Step 3. Once the activity data and emission factors have been obtained, the soil organic carbon stocks per plot before the inventory year and during the inventory year are calculated.

Before management change (Year 0-t)

Equation 2.6.13.1b

$$SOC \text{ Block A-B} = 52 \times 0.83 \times 1.10 \times 1 = 47.48 \text{ t C/ha}$$

$$SOC \text{ Block C} = 52 \times 0.83 \times 1 \times 1.11 = 47.91 \text{ t C/ha}$$

After management change (Year 0)

Equation 2.6.13.1b

$$SOC \text{ Block A-B} = 52 \times 0.83 \times 1 \times 1.11 = 47.91 \text{ t C/ha}$$

$$SOC \text{ Block C} = 52 \times 0.83 \times 1.10 \times 1 = 47.48 \text{ t C/ha}$$

Step 4. Once the organic carbon stocks (SOC) are obtained, the variation of soil organic carbon stocks by area managed is calculated.

Equation 2.6.13.1a

Soil C change =

$$\frac{[(SOC \text{ Block A-B}(0) - SOC \text{ Block A-B}(0-t)) \times \text{ha Block A-B}]}{T} + \frac{[(SOC \text{ Block C}(0) - SOC \text{ Block C}(0-t)) \times \text{ha Block C}]}{T}$$

Soil C change/year =

$$\frac{[(47.91 \text{ t C/ha} - 47.48 \text{ t C/ha}) \times 300 \text{ ha}]}{20 \text{ years}} + \frac{[(47.48 \text{ t C/ha} - 47.91 \text{ t C/ha}) \times 900 \text{ ha}]}{20 \text{ years}}$$

$$Soil \text{ C change/year} = 6.45 \text{ t C/year} + (-19.35 \text{ t C/year}) = -12.95 \text{ t C/year}$$

In the above equation the carbon change is negative, as it represents an emission. It would be a positive change if it represented a removal. However, to calculate the company's total carbon emissions, it is necessary to switch the sign and use a positive (+) for emissions and a negative (-) for removals. This will allow the correct aggregation of all emission values in the inventory. Therefore, in soil C change, the value resulting from the above equation is multiplied by the ratio of -44/12 to prepare the value that will be used in the inventory.

Step 5. Represent the variations of C in soil (emission or removal) in t CO₂e.

Equation 2.6.13.1c

$$C \text{ emission/absorption in t CO}_2 = -12.95 \text{ t C/year} \times (-44/12)$$

$$C \text{ emissions in t CO}_2 = 47.48 \text{ t CO}_2 \text{ /year}$$

2.6.13.2 Soil carbon stock change: soil analysis method

2.6.13.2A Calculation method

This methodology for estimating the stock and variation of soil organic carbon (SOC) is based on direct measurements from field sampling. The measurements are performed for the area under analysis before and after soil management such as tillage. The company should take into account the following considerations when carrying out its own analysis (FAO, 2020):

1. A large amount of the organic carbon in the soil is stored in the 0 to 5 cm and 0 to 10 cm-deep layers, as this is where the differences generated by soil management are often found. An acceptable criterion for soil analysis sampling is to go to a depth of 30 cm, separating layers of different bulk densities. At a minimum, samples should be obtained to determine the SOC concentration of the 0–10 cm and 10–30 cm layers. Then the soil organic carbon stocks of each layer are summed to report the total organic carbon stock for the 0–30 cm layer (that is, the sum of the 0–10 cm SOC and 10–30 cm SOC) to comply with IPCC recommendations.
2. Changes in SOC stocks are affected by changes in soil bulk density due to changes in soil compaction. This results in different masses for the same volume of soil. Soil carbon stocks are commonly quantified at fixed depths as the product of soil bulk density, depth and SOC concentration. However, this method systematically overestimates SOC stocks in treatments with higher bulk densities, such as minimum

tillage, overstating its benefits. Therefore, it is essential to report SOC stocks as a function of an equivalent soil mass, which should also be reported to normalize the effects of management on bulk density.

3. To determine the variation of SOC, soil analysis should be performed before and after the soil intervention.

A description of the calculation formula to determine the variation of carbon in soil by means of the company's own analysis follows (FAO, 2020).

T1 (before tillage)

Equation 2.6.13.2a (T1)

$$\text{Total soil mass T1 (t)} = \sum D_1 (A_1 \times B_1 \times C_1) + D_2 (A_2 \times B_2 \times C_2)$$

Where:

T1: date of first sampling before management or intervention.

D: soil mass layer per analysed soil layer (D₁: 0–10 cm; D₂: 10–30 cm).

A: hectares under analysis (m²).

B: bulk density (t/m³).

C: thickness of the analysed soil layer (m).

Equation 2.6.13.2b (T1)

$$\text{SOC stock T1 (t)} = \sum G_1 (D_1 \times F_1) + G_2 (D_2 \times F_2)$$

Where:

T1: date of first sampling before management/ intervention.

G: SOC stock per analysed soil layer (t/ha)
(G₁: 0–10 cm; G₂: 10–30 cm).
F: Percentage of SOC of the soil layer analysed (%) (G₁: 0–10 cm; G₂: 10–30 cm).

T2 (after management/intervention)

Equation 2.6.13.2a (T2)

$$\text{Total soil mass T2 (t)} = \sum D_1 (A_1 \times B_1 \times C_1) + D_2 (A_2 \times B_2 \times C_2)$$

Where:

T2: date of second sampling after management/intervention.
D: soil mass layer per analysed soil layer (D₁: 0–10 cm; D₂: 10–30 cm).
A: hectares under analysis (m²).
B: bulk density (t/m³).
C: thickness of the soil layer analysed (m).

Equation 2.6.13.2b (T2)

$$\text{SOC Stock T2 (t)} = \sum G_1 (D_1 \times F_1) + G_2 (D_2 \times F_2)$$

Where:

T2: date of second sampling after management/intervention.
G: stock of SOC per analysed soil layer (t/ha) (G₁: 0–10 cm; G₂: 10–30 cm).
F: percentage of SOC per analysed soil layer (%) (G₁: 0–10 cm; G₂: 10–30 cm).

Soil carbon stock change (emission or absorption) per year

Equation 2.6.13.2c

Variation of SOC reserves (t C/year) =

$$\frac{(\text{SOC stock in equivalent soil mass}_{T1} - \text{SOC stock in equivalent soil mass}_{T2})}{(T2 - T1) \times 365}$$

Variation of SOC reserves (t C/year)=

$$\frac{(\text{SOC Stock T2} \times \text{Total soil mass T2}) - (\text{SOC Stock T1} \times \text{Total soil mass T1})}{\text{Total soil mass T2} - \text{Total soil mass T1}} \times 365 \text{ days}$$

The final change in t C/year must be converted to CO₂ emission units by multiplying the carbon stock change by –44/12. The change in sign (–)



For consideration:

- Each company should establish its soil sampling design and plan, which defines the number of samples representative of the area under analysis.
- Each company must characterize and document the conditions of the areas under analysis before and after the intervention, management or tillage.
- When analyses provide only the percentage of organic matter and not the percentage of organic carbon, a conversion factor of 0.58 can be used to obtain the carbon content of soil organic matter (IPCC, 2005).
- There are references that provide guidance on soil sampling protocols, such as a protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes – GSOC-MRV Protocol (FAO, 2020)

is due to the convention that increases in carbon stocks, i.e. positive (+) stock changes, represent a removal (or “negative” emission) from the atmosphere, while decreases in carbon stocks, i.e. negative (-) stock changes, represent a positive emission to the atmosphere. This conversion is represented as follows.

$$\text{Equation 2.6.13.2d}$$

$$C \text{ emission/absorption in } t \text{ CO}_2/\text{year} = C \text{ variation (t C/year)} \times (-44/12)$$

The following is an example of a calculation of soil carbon stock change using analysis of soil samples from the farm.

Example: calculation of emissions from soil carbon stock changes due to tillage

Step 1. The company has maintained 500 ha of pineapple crops for more than 10 years. Although they have been maintained as agricultural areas, every year tillage is carried out as part of land management for crop renewal. The company is in the process of preparing the emissions inventory for the 2022 period and needs to calculate the variation in soil carbon stocks due to tillage activities. For this purpose, a sampling plan has been established to analyse the area before and after intervention. The characterization of the areas is shown below.

	Date	Profiles analysed	Area (m ²)	Bulk density (t/m ³)	Depth (m)	Percentage of SOC (%)
T1	4/1/2022	D1 (0–10 cm)	5 000 000	1,3	0,1	1,8
	4/1/2022	D2 (10–30 cm)	5 000 000	1,4	0,2	1,7
T2	4/1/2023	D1 (0–10 cm)	5 000 000	1,2	0,1	1,6
	4/1/2023	D2 (10–30 cm)	5 000 000	1,4	0,2	1,6

Step 2. Calculate the total soil mass and SOC stock before management/intervention (T1) and after management/intervention (T2).

Equation 2.6.13.2a (T1)

$$\text{Total soil mass T1 (t)} = (5\,000\,000 \text{ m}^2 \times 1.3 \text{ t/m}^3 \times 0.1 \text{ m}) + (5\,000\,000 \text{ m}^2 \times 1.4 \text{ t/m}^3 \times 0.2 \text{ m})$$

$$\text{Total soil mass T1 (t)} = 650\,000 \text{ t} + 1\,400\,000 \text{ t} = 2\,050\,000 \text{ t}$$

Equation 2.6.13.2b (T1)

$$\text{Stock of SOC T1 (t)} = (650\,000 \text{ t} \times 1.8\%) + (1\,400\,000 \text{ t} \times 1.7\%) =$$

$$\text{SOC stock T1 (t)} = 11\,700 \text{ t} + 23\,800 \text{ t} = 35\,500 \text{ t}$$

Equation 2.6.13.2a (T2)

$$\text{Total soil mass T2 (t)} = (5\,000\,000 \text{ m}^2 \times 1.2 \text{ t/m}^3 \times 0.1 \text{ m}) + (5\,000\,000 \text{ m}^2 \times 1.4 \text{ t/m}^3 \times 0.2 \text{ m})$$

$$\text{Total soil mass T2 (t)} = 600\,000 \text{ t} + 1\,400\,000 \text{ t} = 2\,000\,000 \text{ t}$$

Equation 2.6.13.2b (T2)

$$\text{Stock of SOC T2 (t)} = (600\,000 \text{ t} \times 1.6\%) + (1\,400\,000 \text{ t} \times 1.6\%) =$$

$$\text{SOC stock T2 (t)} = 9\,600 \text{ t} + 22\,400 \text{ t} = 32\,000 \text{ t}$$

Step 3. Calculate the change in soil carbon stocks per year.

Equation 2.6.13.2c

Variation of SOC stocks (t C/year) =

$$\left(\frac{(32\,000\,t \times 2\,000\,000\,t)}{2\,000\,000\,t} - \frac{(35\,000\,t \times 2\,000\,000\,t)}{2\,050\,000\,t} \right) / (04/01/2023 - 04/01/2022) \times 365\,days =$$

$$((32\,000\,t - 34\,634.15\,t) / (365)) \times 365\,days = -2\,634.15\,t\,C/day$$

Step 4. Represent the variations of C in soil (emission/absorption) in t CO₂ /year.

Equation 2.6.13.2d

$$C\,emission/absorption\,in\,t\,CO_2/year = -2\,634.15\,t\,C/year \times (-44/12)$$

$$C\,emission\,in\,t\,CO_2 = 9\,658.54\,t\,CO_2/year$$

2.6.14 Variation in carbon stock due to land use change

Category:	Direct/indirect by products used by the company						
Source	Type of GHG to be evaluated						
	CO ₂	CH ₄	N ₂ O	HFC	HCFC	CO ₂ e	Others PFC
Land use changes	✓						

The use and management of land have an influence on a variety of ecosystem processes that affect greenhouse gas fluxes, such as photosynthesis, respiration, and decomposition, among others. These processes involve carbon transformations driven by biological processes. CO₂ fluxes between the atmosphere and ecosystems are fundamentally controlled by uptake through plant photosynthesis and by release through respiration, decomposition and the combustion of organic matter. This guide proposes to assess net changes in carbon stocks in aboveground live biomass by estimating carbon stocks in live biomass before and after land use conversion (IPCC, 2006).

This module proposes methodological guidelines to determine carbon changes in three scenarios

of land conversion and use, which are described below.

Initial land use	Final land use
Cropland	Forest land
Forest land	Cropland
Forest land	Forest land

a. Conversion from cropland to forest land

This scenario corresponds to cropland that is converted to forest land through afforestation and reforestation, through natural or artificial regeneration methods (including plantations). This guidance to estimate carbon emissions and absorption from land conversion to forestry only considers the change in carbon stocks in living biomass (IPCC, 2005).



For consideration:

- The company has to select the appropriate variables and conditions according to the type of conversion.
- If the company intends to participate in a GHG programme in the country where the operations take place, it is important to check if the program has associated requirements or restrictions for reporting emissions from land use changes or soil carbon stock changes.
- Although the theoretical methodology allows estimating carbon stocks on forest lands that remain as forest lands, it is advisable to determine such stocks through an inventory of absorption in the field, using permanent monitoring plots. However, this is beyond the scope of this guide. The use of the Costa Rican national standard INTE/DN 03:2016 (Methodology for the quantification and reporting of greenhouse gas absorption from forestry activities and provisions) or requirements defined by the GHG program is recommended, when applicable.
- Biomass variation is estimated only for perennial woody crops. Biomass related to herbaceous annual and perennial (i.e., non-woody) plants is relatively ephemeral; that is, it decays and regenerates annually or every few years. Therefore, emissions from decomposition are offset by removals due to regeneration, making net carbon stocks generally quite stable over the long term. This is why the method focuses on biomass stock changes related to woody cover, in which large amounts of carbon can accumulate during its lifetime (IPCC, 2006).
- Given the above statement and considering that the pineapple crop is renewed every two years on average, it is assumed that the biomass gains in that period will be equal to the losses at the time of harvesting and stubble management.

The annual change in carbon stocks in living biomass on land converted to forest land will assume a difference between growth and loss of living biomass in the year assessed. Where the following considerations are assumed:

- Living biomass growth will be related to the growth of woody cover on converted lands.
- The carbon change due to the effect of conversion (elimination of the pineapple crop) is considered to be zero since pineapple is a perennial herbaceous crop, i.e. not a woody crop.

b. Conversion from forest land to cropland

The losses of carbon stock will be significant and will be represented by the carbon stock change when the forest area is removed.

c. Maintenance of forest land as forest land (no conversion)

The carbon stock will depend on the management and losses during the period analysed. Live biomass losses will be related to tree felling, fuelwood collection and other losses due to disturbances such as windstorms, fires or pests.

2.6.14.1.A Calculation method

A description of the calculation formula to determine the change in carbon stocks in live biomass (LB) of different land uses is offered the following formula.

$$\text{Equation 2.6.14.1a}$$
$$\Delta C_{LB} = \Delta C_{growth} - \Delta C_{loss}$$

Where:

ΔC_{LB} : annual change in carbon stocks in living biomass, in tonnes of C/year.

ΔC_{growth} : annual increase in carbon stocks in living biomass due to growth, in tonnes C/year.

ΔC_{loss} : annual decrease in carbon stocks in living biomass due to losses from harvesting, logging, fuelwood collection and disturbances such as fire, windstorms or pests; in tonnes of C/year.

To determine the annual change, first estimate the annual increase in carbon due to growth (carbon gains) and the annual decrease in carbon (carbon losses), as follows.

Annual increase in carbon (gains)

Since the growth rate of a forest is highly dependent on the management regime, a distinction is made between intensively managed forests (e.g. plantation forestry with intensive site preparation and fertilization) and extensively managed forests (e.g. naturally regenerated forests with minimal human intervention) (IPCC, 2005). Therefore, for land converted to forest land, calculations are made using the following equation.

Equation 2.6.14.1b

$$\Delta C_{Growth} = (\sum S_{INT_MNGMT} \times C_{total\ INT_MNGMT} + \sum S_{EXT_MNGMT} \times C_{total\ EXT_MNGMT}) \times CF$$

Where:

ΔC_{Growth} : annual increase in carbon stocks in living biomass due to growth, in tonnes of C/year.

S_{INT_MNGMT} : area of land converted to intensively managed forest (including plantations), in ha.

$C_{total\ INT_MNGMT}$: annual biomass growth rate in intensively managed forests (including plantations), in tonnes d.m./ha/year (where d.m. is dry matter).

S_{EXT_MNGMT} : area of land converted to extensively managed forest, in ha.

$C_{total\ EXT_MNGMT}$: annual growth rate of biomass in extensively managed forests, in tonnes d.m./ha/

year (includes natural regeneration).

CF: carbon fraction of dry matter (default value: 0.5), in tonnes C/ton d.m.

When estimating the annual growth of carbon stocks in living biomass on land remaining as forest land, the equation is summarized as follows.

Equation 2.6.14.1b2

$$\Delta C_{growth} = \sum (S \times C_{TOTAL}) \times CF$$

Where:

ΔC_{growth} : annual increase in carbon stocks due to biomass increase on forest land remaining forest land by forest type and climate zone, in tonnes C/year.

S: area of forest land remaining as forest land, by forest type in ha .

C_{TOTAL} : average annual increment rate of total biomass, in dry matter units, by forest type and climatic zone, in tonnes d.m./ha/year.

CF: carbon fraction of dry matter (default value = 0.5), in tonnes C/tonnes d.m.

The annual biomass growth rate in both intensively ($C_{total\ INT_MNGMT}$) and extensively ($C_{total\ EXT_MNGMT}$) managed forests and forest land remaining as forest land is calculated using the following equation.

Equation 2.6.14.1c

$$C_{TOTAL} = CW \times (1 + R)$$

Where:

C_{TOTAL} : average annual increment of above- and below-ground biomass, in tonnes d.m./ha/yr.

CW: average annual increment of aboveground biomass, in tonnes d.m./ha/year. See Tables A1.13. (natural regeneration ≤ 20 years and >20 years) and A1.14. (plantations) in [Annex 1](#).

R: root–stem ratio appropriate for increments, dimensionless. See Table A1.15. in [Annex 1](#).

Annual carbon reduction (losses)

Calculations are made using the following equation.

$$\Delta C_{\text{loss}} = P_{\text{logging}} + P_{\text{wood}} + P_{\text{other losses}}$$

Where:

ΔC_{loss} : annual decrease in carbon stocks in living biomass due to losses on forest land and land converted to forest land, in tonnes C/year.

P_{logging} : biomass loss from harvesting of industrial wood and sawlogs on forest land and land converted to forest land, in tonnes C/year.

P_{wood} : biomass loss due to fuelwood harvesting on forest land and on land converted to forest land, in tonnes C/year.

$P_{\text{other losses}}$: biomass loss due to fire and other disturbances on forest land and land converted to forest land, in tonnes C/year.

$$P_{\text{logging}} = R \times D \times BEF_2 \times (1 - f_{BD}) \times CF$$

Where:

P_{logging} : annual carbon loss due to commercial logging, in tonnes of C/year.

R: volume extracted annually, round logs, in m³/year.

D: basic wood density, in tonnes d.m./m³. See Table A1.16., in [Annex 1](#).

BEF₂: biomass expansion factor to convert harvested roundwood volumes into total aboveground biomass (including bark), dimensionless; see table A1.17., in [Annex 1](#).

f_{BD}: fraction of biomass that remains in the forest and decomposes (transferred to dead organic matter). By default, it is assumed that the total biomass associated with the volume of roundwood removed is an immediate emission, which implies that the f_{BD} should be set to 0.

CF: carbon fraction of dry matter (default value equals 0.5), in tonnes C/ton d.m.

The following equation will be used to estimate carbon loss due to fuelwood collection.

$$P_{\text{wood}} = FWC \times D \times BEF_2 \times CF$$

Where:

P_{wood} : annual loss of carbon due to fuelwood collection, in tonnes of C/year.

FWC: annual volume of firewood collected, m³/year.

D: basic wood density, in tonnes d.m./m³; see Table A1.14., in [Annex 1](#).

BEF₂: biomass expansion factor to convert harvested log volumes into total aboveground biomass (including bark), without unit. See Table A1.14., in [Annex 1](#).

CF: carbon fraction of dry matter (default value = 0.5), in tonnes C/ton d.m.

Other carbon losses on managed forest land are those caused by disturbances such as wildfires, windstorms, pests, and other disturbances, whether or not they are the result of human activities. Biomass losses accounted for as commercial harvesting or fuelwood will not be considered as losses due to other disturbances. This method assumes complete destruction of forest biomass in the event of disturbance, which is why the default methodology deals only with disturbances involving “stand replacement” (IPCC, 2005).

The following equation will be used to estimate carbon loss due to other losses:

$$P_{\text{other losses}} = S_{\text{alteration}} \times B_W \times (1 - f_{BD}) \times CF$$

Where:

$P_{\text{other losses}}$: other annual carbon losses, in tonnes of C/year.

$S_{\text{alteration}}$: forest areas affected by disturbances, in ha/year.



For consideration:

The basic density of the wood depends on the tree species present in the reforested area or in the regeneration area. When there are several species, the company may use an average density.

B_w: average value of biomass stocks in forest areas, in tonnes d.m./ha. See Tables A1.18. (natural regeneration), A1.19. (plantations), and A1.20. (forests) in [Annex 1](#).

f_{BD}: fraction of biomass remaining in the forest that decomposes (transferred to dead organic matter). It is assumed that all aboveground biomass carbon is lost with a given disturbance. Thus, f_{BD} is equal to 0.

CF: carbon fraction of dry matter (default value = 0.5), in tonnes C/tonnes d.m.

Carbon emission/absorption in t CO₂

The final change in t C/year can be converted to CO₂ emission units by multiplying the carbon stock change by -44/12. The change in sign (-) is due to the convention that increases in carbon stocks, i.e. positive (+) stock changes, represent an absorption (or “negative” emission) from the atmosphere, while decreases in carbon stocks,



Important

Equation variables should be selected according to climate type, forest type, region or country.

i.e. negative (-) stock changes, represent a positive emission into the atmosphere (IPCC, 2005). This conversion is represented as follows.

Equation 2.6.14.1h

$$C \text{ emission/absorption in t CO}_2 \text{ /year} = \Delta C_{LB} \text{ (t C/year)} \times (-44/12)$$

The following is an example of a calculation of carbon stock change due to land use change.

Example: Calculation of emissions from carbon change on cropland converted to forest land

Step 1. The company has decided to convert 15 ha of cropland with very poor-quality soils and low yields to forest by reforesting 10 ha with different species (intensive management) and 5 ha with natural regeneration (extensive management). To determine the carbon change in such land conversion we must estimate the carbon gains and losses in the converted area.

Area	Ha	Type of climate	Age class
Intensive management (reforestation with different broadleaf species)	10	Tropical moist	≤20 years
Extensive management (natural regeneration)	5	Tropical moist	≤20 years

Step 2. Calculate the carbon gains in the converted area, using equations 2.6.14.1b and 2.6.14.1c and the references of the corresponding variables taken from the applicable tables in [Annex 1](#).

Average annual increase of intensively managed area (plantation)

Equation 2.6.14.1c

$$C_{TOTAL} = 17 \text{ t d.m./ha/year} \times (1 + 0.48 \text{ t d.m./t d.m.}) = 25.16 \text{ t d.m./ha/year}$$

Average annual increase in extensively managed area (natural regeneration)

Equation 2.6.14.1c

$$C_{TOTAL} = 10 \text{ t d.m./ha/year} \times (1 + 0.42 \text{ t d.m./t d.m.}) = 14.2 \text{ t d.m./ha/year}$$

Carbon gains in the converted area

Equation 2.6.14.1b

$$\Delta C_{Growth} = ((10 \text{ ha} \times 25.16 \text{ t d.m./ha/year}) + (5 \text{ ha} \times 14.2 \text{ t d.m./ha/year})) \times 0.5 \text{ t C/t d.m.}$$

$$\Delta C_{Growth} = (251.6 \text{ t d.m./year} + 71 \text{ t d.m./year}) \times 0.5 = 161.3 \text{ t C/year}$$

Step 3. The carbon losses in the converted area are estimated using equations 2.6.14.1d, 2.6.14.1e, 2.6.14.1f and 2.6.14.1g and the references of the corresponding variables taken from the applicable tables in Annex 1.

Note: Given that this is the first year of land use conversion, it is considered that there are no losses associated with live biomass. Likewise, due to the type of crop, it is assumed that the variations attributed to the conversion are null.

Step 4. The change in carbon in living biomass resulting from the conversion of cropland to forest land is determined.

Equation 2.6.14.1a

$$\Delta C_{LB} = 161.3 \text{ t C/year} - 0 = 161.3 \text{ t C/year}$$

Note: A negative carbon stock change represents an emission, while a positive change represents an absorption. For the purpose of reporting the soil carbon stock change as tonnes of CO₂, the result is multiplied by the ratio of -44/12. The ratio uses the negative sign to report emissions (positive value) or absorptions in the inventory (negative value).

Step 5. Represent the variations of soil carbon (emission/absorption) in t CO₂e.

Equation 2.6.14.1h

$$\text{C emission/absorption in t CO}_2 = 161.3 \text{ t C/year} \times (-44/12)$$

$$\text{Absorption in t CO}_2 = 591,43 \text{ t CO}_2/\text{year}$$

2.7 Inventory consolidation and results reporting

Once the company has evaluated the emissions of all the sources identified, the results are then consolidated by source category and by type of GHG in tonnes of equivalent carbon dioxide (CO₂e). This will allow the company to analyse

the emissions of the period evaluated and make comparisons in the future, as well as to assess performance improvements. **Figure 9** offers an example of how a company can consolidate the results of the GHG emissions inventory.

Figure 9. Example of consolidation of emissions inventory results

Category	Emission source	CO ₂ (t CO ₂ e)	CH ₄ (t CO ₂ e)	N ₂ O (t CO ₂ e)	HFCs (t CO ₂ e)	HCFCs (t CO ₂ e)	Other Gases (t CO ₂ e)	Total (t CO ₂ e)
Direct	Source 1							
	Source 2							
Indirect by imported energy	Source 3							
Indirect by transport	Source 4							
	Source 5							
Indirect by products used by the company	Source 6							
	Source 7							
Indirect by use of company products	Source 8							
	Source 9							
Indirect from other sources	Source 10							
	Source 11							
Total emissions t CO ₂ e								

Source: Authors' own elaboration.

Anthropogenic biogenic emissions and removals can be found within emission inventories. These are due to emissions or removals from biogenic material, i.e. carbon from biomass, as a result of human activities. Such emissions and removals should be treated as follows (INTECO, 2021):

a. Anthropogenic biogenic GHG emissions and absorptions are the result of human activity. Anthropogenic biogenic GHG emissions (e.g. CO₂, CH₄ and N₂O) can result from biomass combustion, as well as other processes (e.g. aerobic and anaerobic decomposition of biomass and soil organic matter).

b. Non-anthropogenic biogenic GHG emissions and absorptions should be quantified and reported separately from anthropogenic emissions. Biogenic emissions and absorptions of other GHG (for example, CH₄ and N₂O) can be caused by natural disasters (such as uncontrolled fires or insect infestations) or natural evolution (plant growth, decomposition). These emissions should be quantified and reported along with the other emissions.



For consideration:

- When reliable historical data is not available to allow a historical base year to be declared, the company can declare the same reporting year as the base year. However, the company has to justify the selection in the results report.
- The company can exclude sources of low relevance from the quantification of emissions; however, their exclusion must be justified and reported. To proceed with the exclusion of any source of emission, the company is required to carry out a theoretical calculation of the emissions in order to justify its exclusion with criteria established in the reference standards.

The company can consolidate and present the results of anthropogenic biogenic CO₂ emissions from land use change (soil carbon change, cropland converted to forest land, forest land converted to cropland and land remaining forest land) as shown in Figure 10.

Figure 10. Example of consolidation of emissions/absorptions by land use

Land use change/land and soil management	CO ₂ (t CO ₂)
Soil carbon change by tillage	
Cropland converted to forest land	
Forest land converted to farmland	
Forest land remaining forest land	
Stubble management	
Total emissions t CO ₂ e	

Source: Authors' own elaboration.

The company can decide whether or not to report the results of its emissions inventory to different stakeholders, such as state entities or ministries, verification bodies, or customers, among others. However, whenever the company wants to inform a specific audience, they must ensure compliance with the principles for emissions accounting and reporting (**Figure 3**).

The results of the emissions inventory are generally presented in a results report, which is a document designed for interested parties with minimum content requirements, according to the INTE-ISO 14064-1 reference standard. The company should consider the following when planning the results report (INTE-ISO 14064-1:2019):

- purpose and objectives of the report in the context of the company's GHG policies, strategies or programs and applicable GHG programmes;
- intended use and intended users of the GHG inventory;
- general and specific responsibilities in the preparation and realization of the report;
- frequency of reporting;
- structure and format of the report;
- data and information to be included in the report; and
- policy on report availability and report dissemination methods.

Figure 11 shows the minimum content that the results report must have, according to the INTE-ISO 14064-1:2019 standard.

Figure 11. Minimum content of the results report

Minimum content in relation to the report findings

- Description of the company;
- person or entity responsible for the report;
- reporting period;
- documentation of the company's boundaries;
- documentation of reporting boundaries, including criteria established to define significant emissions;
- direct emissions quantified separately by type of GHG in t CO₂e;
- description of how biogenic emissions and removals are considered in the inventory, quantified separately in t CO₂e;
- whether direct removals are quantified in t CO₂e;
- explanation of the exclusion of any significant sources or sinks from the quantification;
- indirect emissions quantified separately by category in t CO₂e;
- the selected historical base year and the year of the GHG inventory;
- explanation of any changes to the base year or other historical GHG data, or categorization and any recalculation of the base year or other historical GHG inventory, and documentation of any limitations to comparability resulting from such recalculation;
- reference or description of quantification approaches, including the rationale for their selection;
- explanation of any changes to previously used quantification approaches;
- reference to or documentation of the GHG emission or removal factors used;
- description of the impact of uncertainties on the accuracy of GHG emissions and removals data by category;
- description and results of the uncertainty assessment;
- a statement that the GHG report has been prepared in accordance with the standard;
- disclosure describing whether the GHG inventory, report or statement has been verified, including the type of verification and the level of assurance achieved; and
- the GWP values used in the calculation, as well as their source.

Source: Adapted from INTECO. 2019. *INTE/ISO 14064-1:2019 Gases de Efecto Invernadero* — Parte 1: Especificación con orientación, a nivel de las organizaciones, para la cuantificación y el informe de las emisiones y remociones de gases de efecto invernadero. Costa Rica.



For consideration:

For the inventory it is also advisable to include carbon reserves or sinks, especially through forest resources (plantations and agroforestry systems). However, this aspect is outside the scope of this guide. The use of the Costa Rican national standard INTE/DN 03:2016 (Methodology for the quantification and reporting of greenhouse gas absorption from forestry activities and provisions) is recommended; as well as consulting the IPCC guidelines and the GHG protocol guidelines.

2.7.1 Relating emissions to pineapple production

The emissions results must be presented as the total sum of the tonnes of CO₂e. However, the company can also establish an internal performance indicator to evaluate its progress over time (Vallejo *et al.*, 2018).

Considering the emissions results and

information on the sales and production of the company, this indicator can be established to allow the comparison of emissions from different years. For this, it is recommended to gather the information on the number of boxes sold, kilograms or units produced or sold, and proceed to divide the emissions results between the productive unit, as exemplified below (Vallejo *et al.*, 2018).

Example: calculation of emissions per productive unit

In a pineapple farm, the total carbon emissions resulted in 5 000 kg CO₂e for the study year. In this same year, 600 000 boxes of pineapple were sold, equivalent to 9 600 000 kg of pineapple. To obtain the performance indicators, the data must be related as shown:

$$\text{Indicator per box} = 5\,000 \text{ Kg CO}_2\text{e} \div 600\,000 \text{ boxes} = 0.0083 \frac{\text{Kg CO}_2\text{e}}{\text{box}}$$

$$\text{Indicator per kilogram} = 5\,000 \text{ Kg CO}_2\text{e} \div 9\,600\,000 \text{ Kg} = 0.00052 \frac{\text{Kg CO}_2\text{e}}{\text{box}}$$

2.7.2 What next after developing my company's inventory?

Once the company has developed its inventory, it will be able to establish its mitigation measures. These may include actions to reduce the sources of GHG emissions, or actions to increase the absorption or removal of GHG (Vallejo *et al.* 2018).

To carry out reduction actions, the company must identify its main emission sources, and set its reduction objectives in relation to these sources. Generally, these actions may involve adjustments in production processes, such as changes to more efficient technologies, use of renewable energy or replacement of inputs. Sometimes these actions will focus on correcting process inefficiencies. This information is



For consideration:

Each country's verification body will assess compliance with the voluntary INTE/ISO 14064-1 standard for inventory declaration; and when applicable, the voluntary INTE B5 standard for demonstrating carbon neutrality and GHG program requirements, e.g. Costa Rica's Carbon Neutral Country Program..

expanded in the chapter on reductions, where emission reduction measures for the pineapple sector are proposed (Vallejo *et al.*, 2018).

Regarding actions to increase absorption (removal), these are mainly related to promoting the conservation of forest areas and/or expanding protection zones (Vallejo *et al.*, 2018).

Removals also imply a principle of environmental responsibility on the part of the pineapple company. For these removal projects, the company's own forests and forest plantations can be used. In addition, at the soil level, carbon removal capacity can be increased through less invasive management practices that promote soil conservation and soil carbon storage (Vallejo *et al.*, 2018).

To implement the areas and plots for measuring and monitoring tree growth and yield (in terms of carbon sequestration) in any of these options, the company requires the support of forestry professionals for the corresponding studies (Vallejo *et al.*, 2018).

2.7.3 Verification of the emissions inventory and declaration of carbon neutrality

When the company is required to make its results public, it is recommended to submit the study to a verification process. This process includes a detailed review by an accredited verification body,

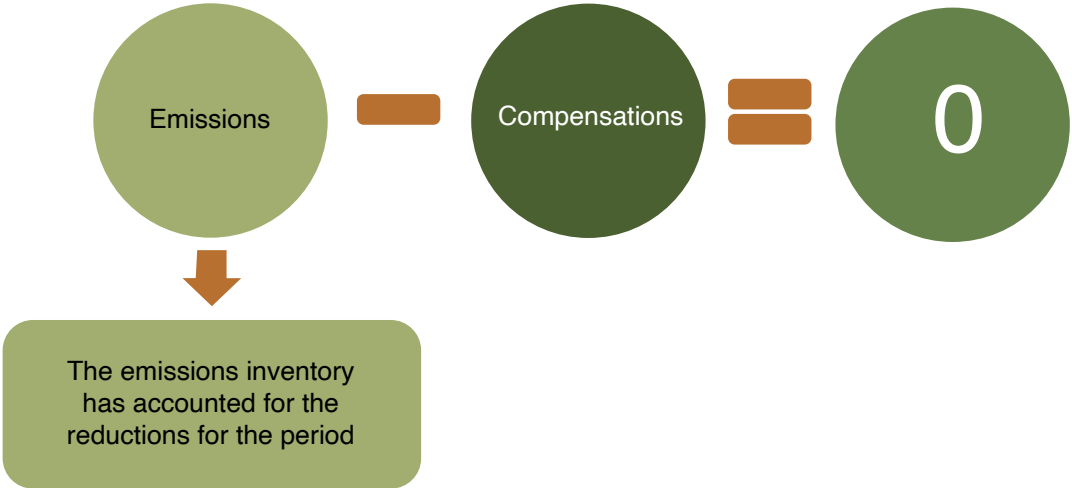
which increases transparency and credibility among the company's stakeholders. The report selection of the verification entity will depend on the objective for which the study was developed and the intended users identified (Vallejo *et al.* 2018).

To claim carbon neutrality, the company must offset the emissions that it failed to reduce or remove internally, in order to meet the equation shown in Figure 12.

The compensation mechanisms available are (INTECO, 2021):

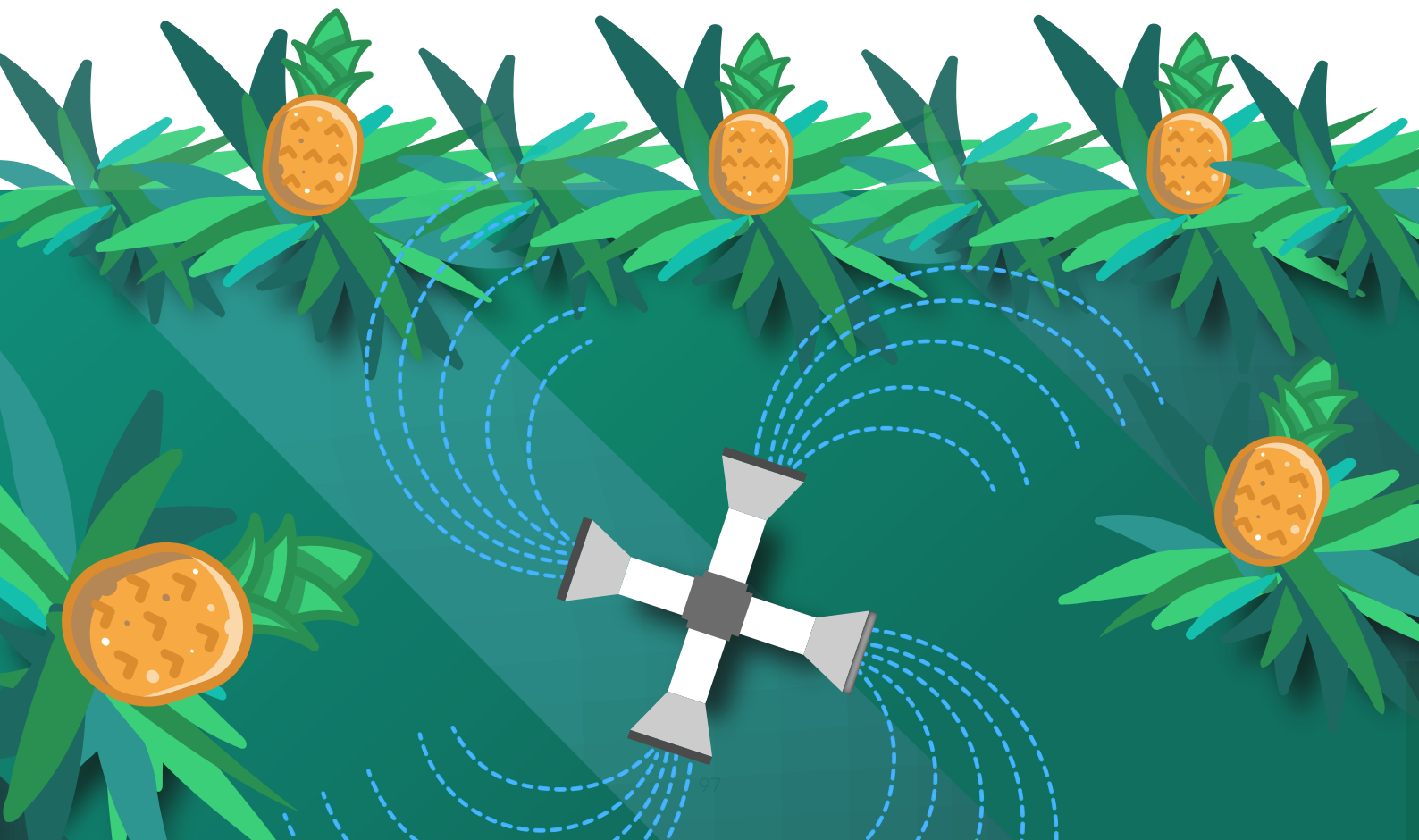
- **CERs:** Certified Emission Reductions, among which the Clean Development Mechanisms at the international level stand out;
- **VERs:** Voluntary Emission Reduction, among which the Gold Standard stands out internationally; and
- **UNC:** National Compensation Units of each country. In the case of Costa Rica, these are managed through the National Forest Financing Fund and are known as Costa Rican Compensation Units or UCCs.

Figure 12. Formula to demonstrate carbon neutrality



Source: Adapted from INTECO. 2021. INTE B5::2021 Norma para demostrar la Carbono Neutralidad. Requisitos. Costa Rica.

3. WATER FOOTPRINT OF A COMPANY'S DIRECT WATER USE



When a pineapple company uses water resources or conducts activities that directly or indirectly affect the characteristics of water, they should be aware that these actions impact both the **quantity** and the **quality of water**. In addition, these impacts are caused **regionally** where water availability varies depending on the types of soils and climatic characteristics of the area.

For this reason, if the company is going to analyse water resource management, it should be done under a comprehensive water footprint approach (ISO 14046 standard), which is proposed in this section.

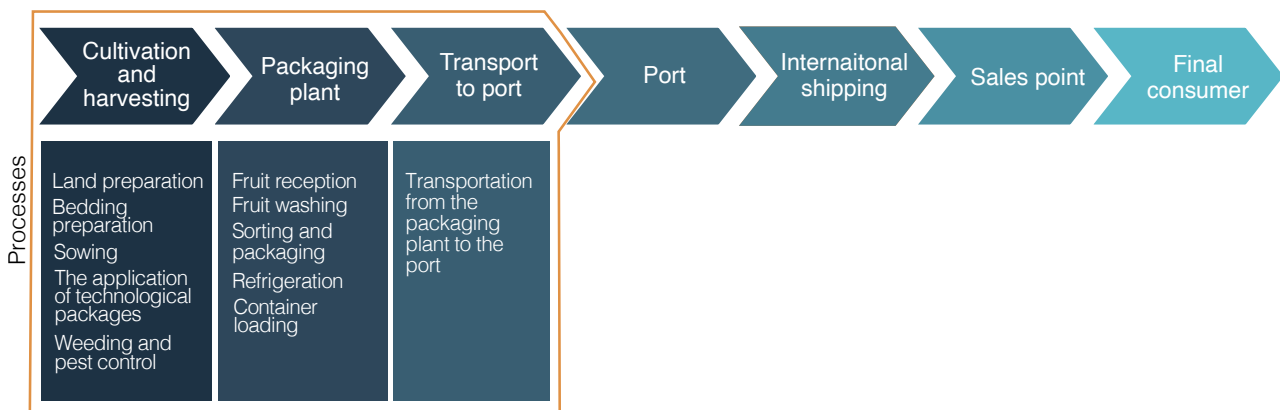
3.1. Scope of the guide

This guide will provide guidance for estimating the water footprint at the field stage (from pineapple pre-production to harvest) and packing house (washing, post-harvest handling system until the product leaves the plant), as shown in **Figure 13**.

the calculations to estimate the **water footprint from direct use of the resource, with an organizational approach (Figure 14)**. It does not contemplate a complete life cycle analysis, as it does not include the analysis of impacts on water involved in the production of inputs and energy.

For the purposes of practicality and considerations of data accessibility, this guide only considers

Figure 13. Stages of the pineapple export production process and scope of the guide



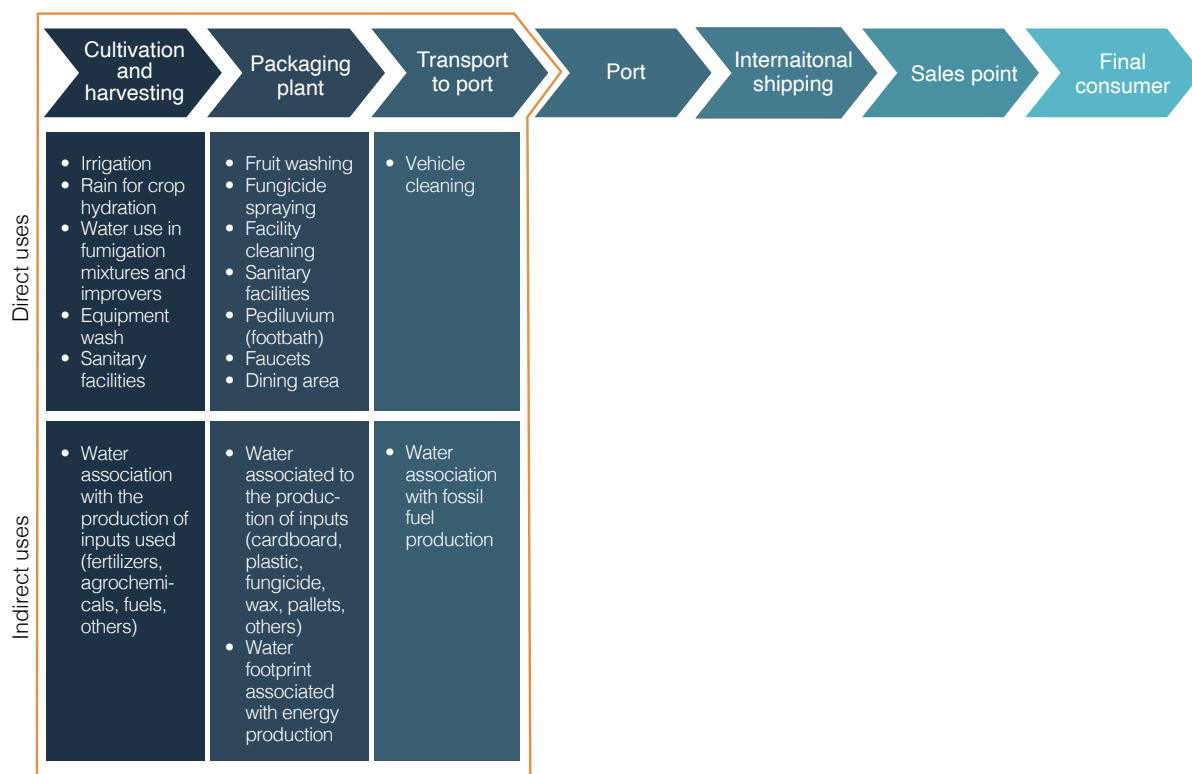
Source: Authors' own elaboration.

As indicated by ISO 14046, the objective of calculating the water footprint is to estimate the potential impacts of using water in the company's activities and to manage such impacts (SDC and CADIS, 2017). Therefore, the result to be obtained by applying these guidelines will be given in terms of **potential environmental**

impacts on water from pineapple production on the farm and packing.

The evaluation process proposed by ISO 14046 will be used as the basis for this guide. Likewise, as indicated previously, the effects that production will have on the quantity (**consumption or**

Figure 14. Direct and indirect uses of water in the production of pineapple for export



Source: Authors' own elaboration.

consumptive use)⁷ and **quality of the resource (degradative use)**⁸ must be considered (ISO, 2014; Vallejo, 2015). To this end, the guide explains the most recommended methods used in the literature to estimate potential impacts.

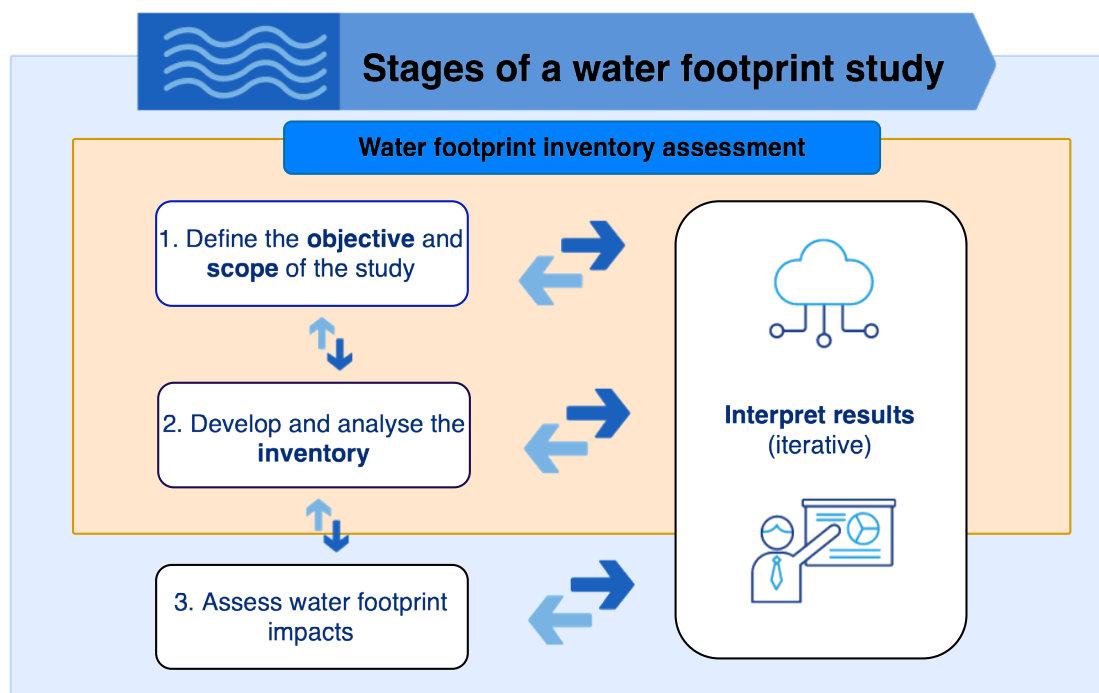
Impacts will be obtained at a level called “midpoint”, which considers the effects that may occur in the water between the time of the release of a substance into the water or when water is consumed, and prior to its final harmful effect (Vallejo, 2015; Vallejo *et al.*, 2018). This level of impact is supported scientifically and is the most common for reporting results (SDC and CADIS, 2017; Vallejo *et al.*, 2018).

⁷ Consumptive use of water refers to those activities that cause a certain volume of water to be lost from the watershed from which it was withdrawn. In other words, the amount of water available for other users is affected. Water losses can occur through evaporation, crop evapotranspiration, incorporation of water into the product, or discharges of water into a basin other than the one from which it was originally withdrawn.

⁸ Degradative water use refers to those activities that cause the original quality of the water used to be affected. It can occur, for example, when substances such as agrochemicals, fertilizers or organic matter are incorporated into the water.

Figure 15 illustrates the water footprint measurement process, which starts with the delimitation of an objective and scope for the study, followed by the development of the inventory, and then the evaluation of impacts. This is a recurrent and iterative process of interpretation and review of the results, to allow the company to verify compliance with the proposed objectives with the greatest possible clarity and certainty (FCH and Agualimpia, 2016; Vallejo *et al.*, 2018).

Figure 15. Stages of the water footprint study



Source: Adapted from International Organization for Standardization (ISO). 2014. *International standard ISO 14046:2014(E): Environmental management – Water footprint – Principles, requirements and guidelines*.

3.2. General concepts to understand the water footprint

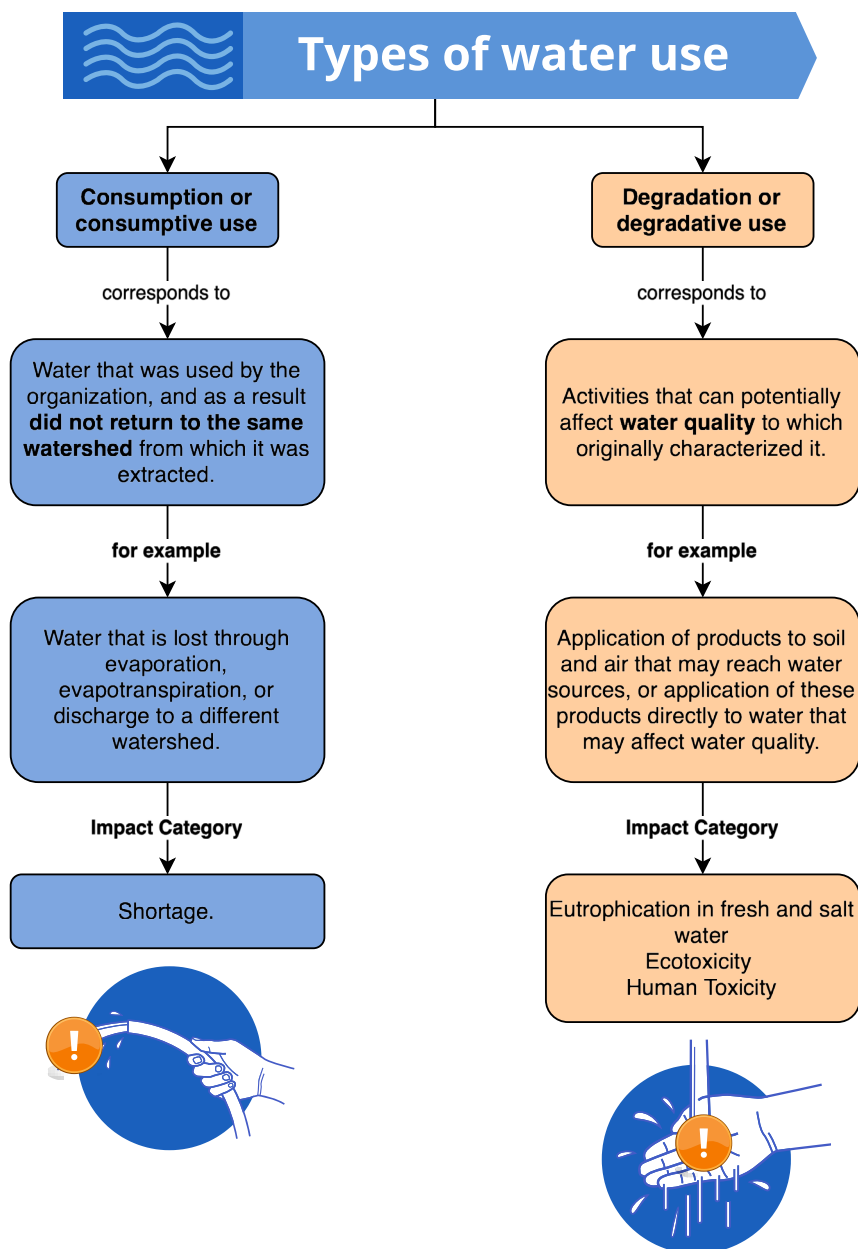
- **Water footprint:** metric(s) that quantifies potential water-related environmental impacts (ISO, 2014; Vallejo *et al.*, 2018).
- **Direct water uses:** uses that take place in the company's facilities for its operations (Vallejo, 2015; FCH and Agualimpia, 2016; Vallejo *et al.*, 2018).
- **Indirect water uses:** water consumption during the production of raw materials or in the generation of energy, which are related to the company's activities, but which have not been carried out inside the company itself (Vallejo, 2015; FCH and Agualimpia, 2016; Vallejo *et al.*, 2018).
- **Watershed:** areas where rainwater that runs on the surface drains by gravity into a river, lake, lagoon, etc. (ISO, 2014; Vallejo *et al.*, 2018). Watersheds are generally defined by the major rivers in a given region and country (Vallejo *et al.*, 2018).
- **Water use by human activities:** any withdrawal or release of water, or its use within the same watershed, that affects water quantity and/or quality (ISO, 2014; Vallejo *et al.*, 2018). It is important to differentiate between two types of water use (Figure 16): water consumption (volume lost from the watershed) and water degradation (affecting quality).
- **Water quality:** physical, chemical and biological water characteristics required for human or ecosystem consumption (ISO, 2014; Vallejo *et al.*, 2018).
- **Impact category:** classification that represents an environmental aspect of importance related to water use in the

productive activities of the sector (Vallejo, 2015; Vallejo *et al.*, 2018). The most important impact categories for the pineapple sector are summarized in Figure 17 and are explained in detail in later sections of this guide.

- **Impact category indicator:** corresponds to the numerical value of each impact (ISO,

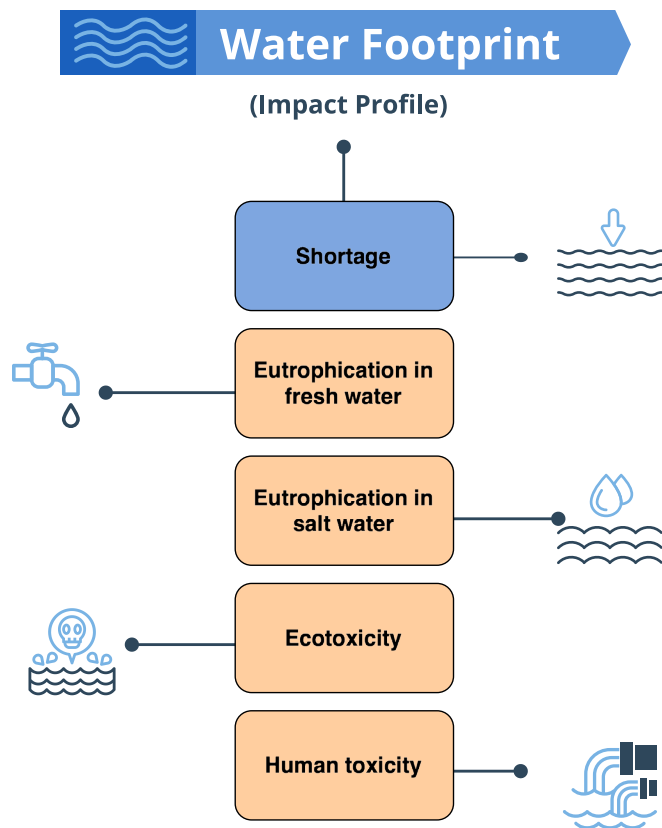
2014; Vallejo *et al.*, 2018), estimated by multiplying the water consumption or amount of a substance emitted, as appropriate, and a value known as the characterization factor (CF) (Vallejo, 2015; Suppen, 2014; Vallejo *et al.*, 2018), as shown in Figure 18.

Figure 16. Types of water use



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

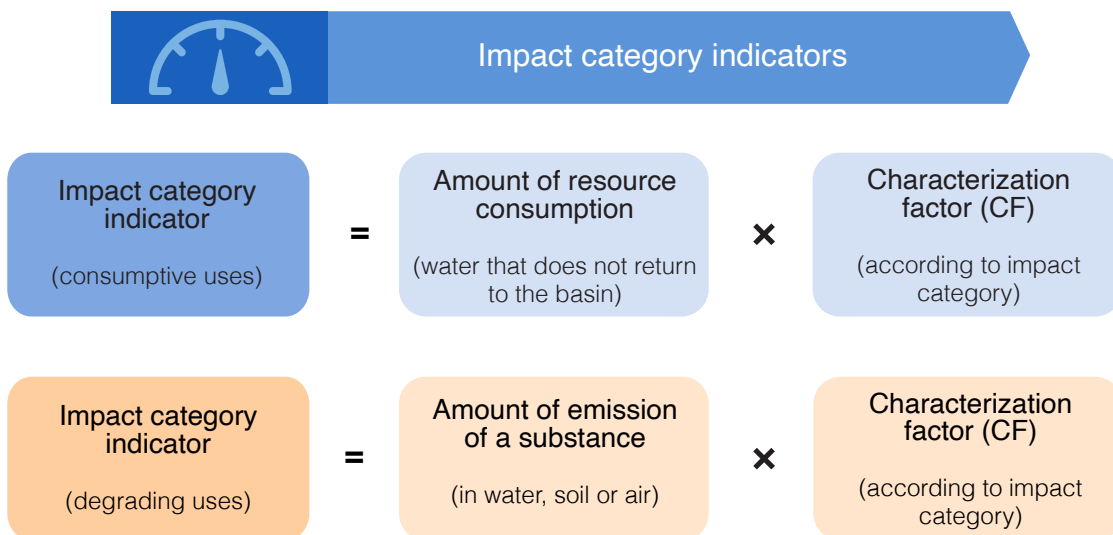
Figure 17. Potential impact categories for reporting water footprint



Note: Categories related to water consumption are highlighted in blue. Categories related to water degradation are highlighted in orange.

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

Figure 18. Quantification of impact category indicators



Source: Adapted from International Organization for Standardization (ISO). 2014. *International standard ISO 14046:2014(E): Environmental management – Water footprint – Principles, requirements and guidelines*.

3.3. Step 1: Define the objective and scope of the study

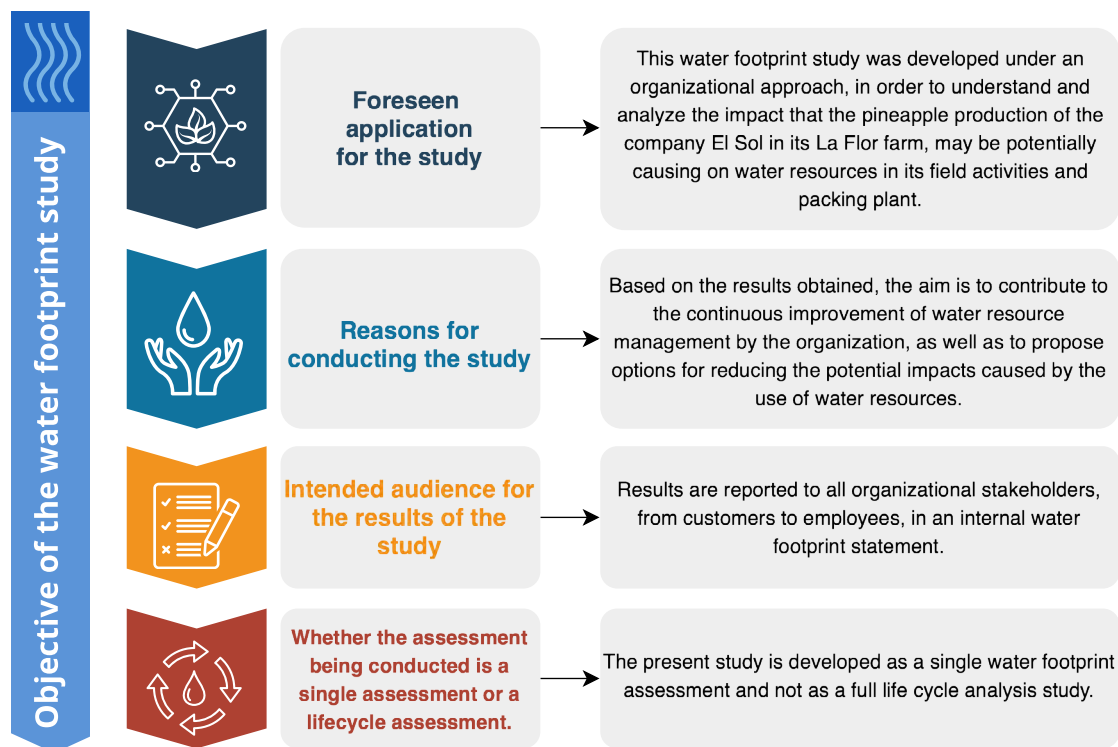
The first step that the company must take is to answer four basic questions to define the objective and scope of the study (Vallejo, 2015; FCH and Agualimpia, 2016; Vallejo *et al.*, 2018). These are:

- Why will the study be conducted?
- What does your company expect to obtain?
- How will the results be used?
- Who are the results for?

3.3.1. Objective

The **objective** of the study is a statement that should include at least the aspects listed in Figure 19. The figure also presents an example of how a company may define the objective of the study.

Figure 19. Components for the definition of a water footprint study's objective



Note: A complete life cycle assessment includes the estimation of the potential impacts of an activity, process, product or organization, including those not related to water resource management. For the purposes of this guide, only the estimate of the impacts associated with water management is shown, which will give the organization's water footprint profile.

Source: Adapted from Vallejo, A. L. 2015. *Metodología práctica para la cuantificación de la huella de agua en Plantas Empacadoras de piña en Costa Rica*. Instituto Tecnológico de Costa Rica. <http://repositoriotec.tec.ac.cr/handle/2238/6305> and Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

The definition of the objective is an iterative process throughout the development of the study, meaning it must be constantly reviewed and adjusted (see Figure 15). In addition, the

procedures, data, calculations and assumptions made must correspond to the proposed objective (FCH and Agualimpia, 2016; Vallejo *et al.*, 2018).

3.3.2. Scope

The **scope** will be a broader description of the water footprint study with respect to the defined objective and should include at least the aspects

shown in Figure 20. The figure also shows an example of how a company may define the scope of the study. Like the objective, the process of defining the scope is iterative, and should be adjusted and updated as the study progresses.

Figure 20. Conformation of the scope of the water footprint study



Source: Adapted from Vallejo, A. L. 2015. *Metodología práctica para la cuantificación de la huella de agua en Plantas Empacadoras de piña en Costa Rica*. Instituto Tecnológico de Costa Rica. <http://repositoriotec.tec.ac.cr/handle/2238/6305> and Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

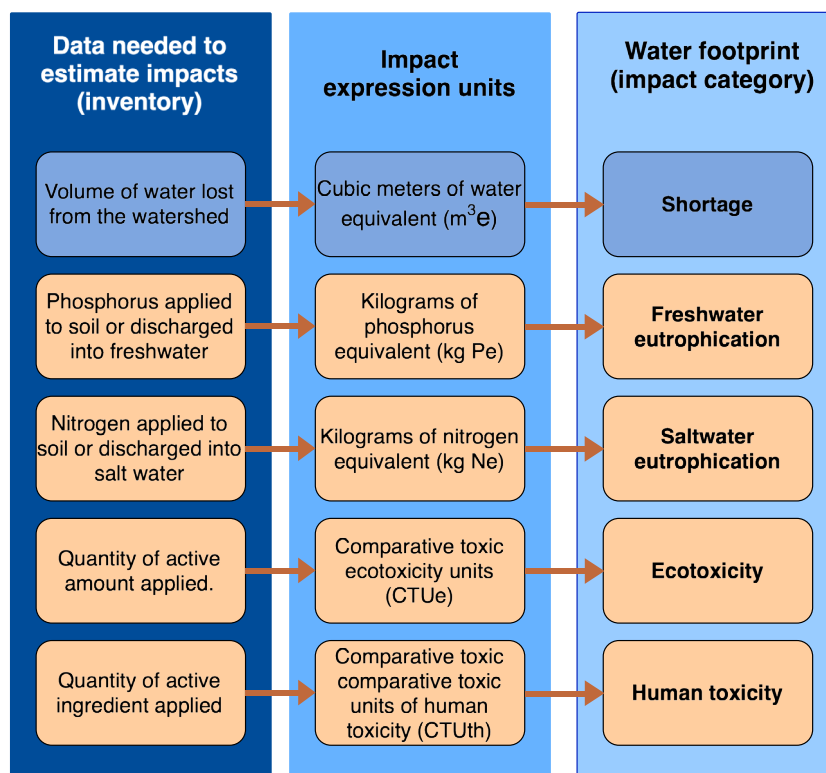
3.4. Step 2: Develop the water footprint inventory

The second step corresponds to the collection of information and preparing the water footprint inventory, which is a document containing organized information, data and calculations for the study (ISO, 2014; Vallejo, 2015; Vallejo *et al.*, 2018). It is the most critical phase in terms of the time required and the quality of the data needed to obtain reliable and traceable results (SDC and CADIS, 2017; FCH and Agualimpia, 2016).

3.4.1. Data collection

The information collected should correspond to the study year as defined in the scope. The impacts to be estimated will define the data requirements. Figure 21 provides a guide of the information needed to calculate the potential impacts, which, when combined will make up the water footprint profile.

Figure 21. Data required in the inventory, by impact category



Source: Authors' own elaboration.



Recommendation:

It is recommended that the data be arranged in a spreadsheet (e.g. Excel) for ease of use.

The quality of the data to be obtained and used must be considered, with the following order of priority:

1. Direct measurements or calculations (**primary data**) (INTECO, 2015), for example, data directly recorded from a water meter.
2. Secondary sources of information such as robust literature resources or databases (**secondary data**) (INTECO, 2015). For example, FAOSTAT information developed by FAO for climate data (Vallejo *et al.*, 2018) or studies available for the pineapple sector.

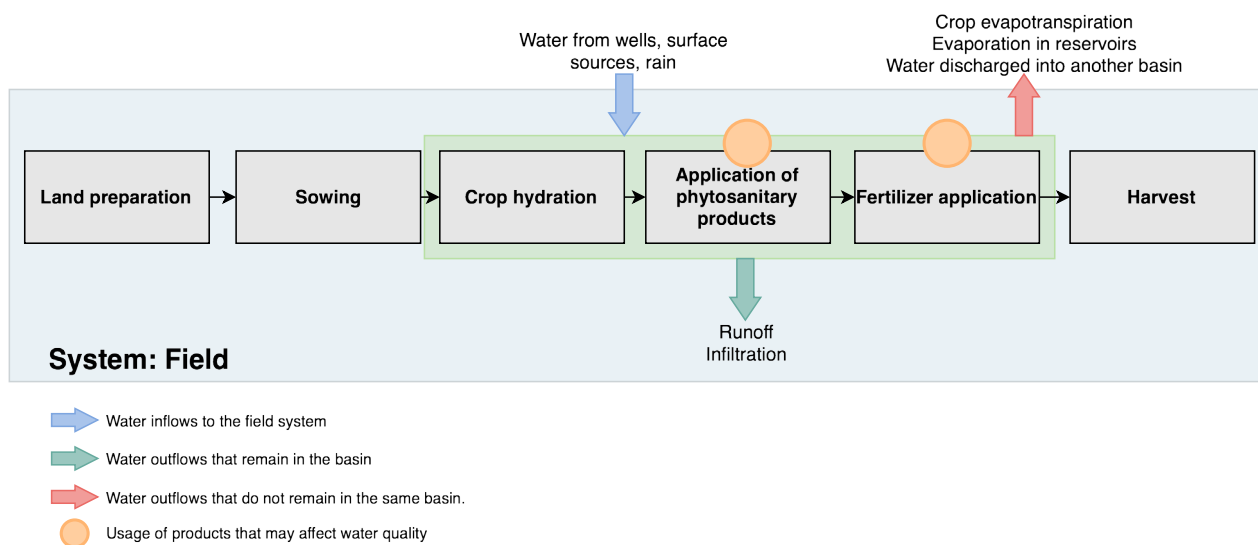
3.4.1.1. Field stage

As shown in Figure 21, it is necessary to determine the volume of water that does not return to the same watershed from which the

water was extracted. It is necessary to determine the amount of different active ingredients of the products applied. In addition, it is necessary to determine the amount of phosphorus and nitrogen applied that may have reached water bodies through the inputs of these nutrients to the soil, the air or directly through wastewater. To do so, as a first step, it is recommended to **draw up a diagram** showing the water inputs and outputs in the processes carried out in the field. Those activities that can potentially affect water quality should be indicated (see example in Figure 22).

Based on the initial identification, we proceed to collect data on water inputs and outputs, as well as the use of products. Table 13 offers some guidelines to carry this out.

Figure 22. Water balance and product use identification diagram



Source: Authors' own elaboration.

Table 13. Baseline information to collect in the inventory of the direct water footprint in the field system

General information	Detailed information	Possible sources of information
Farm data	<ul style="list-style-type: none"> • Total cultivated areas (ha) • Hydrographic basin in which it belongs • Water body from which the water is extracted • Water body where the farm discharges the water 	<ul style="list-style-type: none"> • Records • Geospatial information • Watershed maps of the country • Geographic maps

General information	Detailed information	Possible sources of information
Supply of water sources for cultivation (wells, rivers, etc.)	<ul style="list-style-type: none"> • Volume and frequency of irrigation • Volume of water incorporated in the product mixtures (phytosanitary and fertilizer) • Geographical location and basin from which water is extracted 	<ul style="list-style-type: none"> • Records • Meters • Reports, logbooks or receipts • Information provided by the company that provides the water service • Geospatial information
Natural water supply for cultivation (rainwater)	<ul style="list-style-type: none"> • Climatic conditions of the area: <ul style="list-style-type: none"> • monthly precipitation (mm/month) • monthly average minimum and maximum temperatures (°C) • monthly average humidity (%) • insolation (hours) • monthly average wind speed (m/s) 	<ul style="list-style-type: none"> • Own or nearby meteorological stations • National meteorological institute • Specialized programs for the sector (e.g. FAO's CLIMWAT) • Climate reports of the years under study
Crop evapotranspiration	<ul style="list-style-type: none"> • Total crop evapotranspiration (m³/year)* 	<ul style="list-style-type: none"> • Direct measurements with evaporimeter or lysimeter tank • Own or nearby meteorological stations • CROPWAT program developed by FAO (Annex 4) • National meteorological institute • Publications of the sector in the respective country • References in the literature (e.g. Allen <i>et al.</i>, 2006)
Evaporation of water reservoirs	<ul style="list-style-type: none"> • Evaporation (m³/year) 	<ul style="list-style-type: none"> • Direct measurements with evaporimeter or lysimeter tank • Own or nearby meteorological stations • Meteorological Institute of the country • Literature references
Quantity of fertilizers added	<ul style="list-style-type: none"> • Amount of phosphorus in fertilizer application and its presentation (kg) • Amount of nitrogen in fertilizer application and its presentation (kg) (in case of being close to saltwater sources) 	<ul style="list-style-type: none"> • Fertilization programs • Application records • Reports, logbooks or receipts
Quantity of phytosanitary products added	<ul style="list-style-type: none"> • Types of phytosanitary products used (formulation, concentration, active ingredient) • Amount of active ingredient applied 	<ul style="list-style-type: none"> • Fumigation programs • Application records • Reports, logbooks or receipts • Chemical Material Safety Data Sheets (MSDS) • Chemical laboratory tests • Scientific research

Note: The cells marked in light blue will be used to estimate water consumption, or use, and those with green shading will be related to impacts from water degradation. * Evapotranspiration (ET) is the combination of two separate processes whereby water is lost through the soil surface by evaporation and on the other hand through transpiration of the crop. (...) Evaporation and transpiration occur simultaneously and there is no simple way to distinguish between these two processes. (...) In the early stages of cultivation, water is lost mainly by direct evaporation from the soil, but with crop development and eventually when the crop completely covers the soil, transpiration becomes the main process. (...) Evapotranspiration is normally expressed in millimeters (mm) per unit of time. This unit expresses the amount of water lost from a cultivated area in units of water height." (Allen *et al.*, 2006)

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>

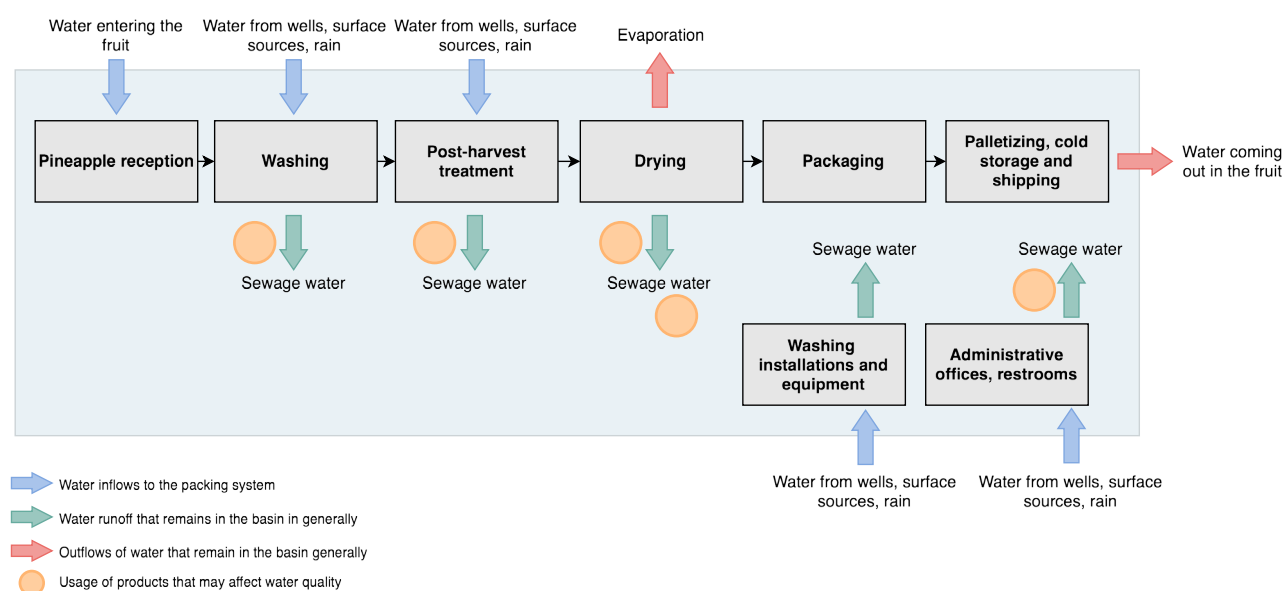
3.4.1.2. Packing house stage

As shown in Figure 22, and similar to the process in the field stage, it is necessary to determine the volume of water that does not return to the same watershed from which the water used in the processes is extracted. It will also be necessary to calculate the applied amounts of active ingredients contained in the products used, as well as the amount of phosphorus and nitrogen that may have reached bodies of water through inputs of these nutrients to the soil, the air or directly through wastewater.

As a first step, it is advisable to **draw up a diagram** to understand the balance between water inputs and outputs in the processes carried out in the packing house, and to identify those processes that may have a potential impact on the quality of the water resource (see example in Figure 23).

Table 14 lists the suggested information to be collected for the packing house stage. The collected information should be adjusted according to each company.

Figure 23. Diagram of water balance identification and product use in the packing stage



Source: Authors' own elaboration.

Table 14. Baseline information to collect in the inventory of the direct water footprint in the packing house system

General Information	Detailed information	Possible sources of information
Water supply (entries)	<ul style="list-style-type: none"> Total volume of water input to processes (ideally per process) Basin from which the water was extracted 	<ul style="list-style-type: none"> Records, logs Meters or meters Gauging and estimation of these calculations

General Information	Detailed information	Possible sources of information
Wastewater (dumped, reused, infiltrated)	<ul style="list-style-type: none"> Volume of water discharged from washing processes and which watershed it is discharged into Volume of water that infiltrates Volume of water reused and frequency of change 	<ul style="list-style-type: none"> Records, logs Meters or meters Discharge flow rate, gauging Estimate from measurement of tank volume and frequency of water change
Evaporation	<ul style="list-style-type: none"> Volume of water evaporating from drying processes Volume of water evaporating from reservoirs 	<ul style="list-style-type: none"> Estimates of primary data such as evaporation measurements Estimates based on literature references
Water in fruit	<ul style="list-style-type: none"> Volume of water leaving the basin with total pineapple production 	<ul style="list-style-type: none"> Production data Studies conducted by the organization on pineapple composition Literature references on moisture in pineapple
Organic matter in discharged water	<ul style="list-style-type: none"> Biological Oxygen Demand (BOD) contained in the outlet water from the packing house 	Laboratory tests and operational reports Literature references or reports on wastewater from other pineapple plants
Application of products in post-harvest treatment	<ul style="list-style-type: none"> Amount of active ingredient of fungicide applied Quantity of other products applied 	<ul style="list-style-type: none"> Application logs or records Pineapple sector literature references

Note: The data marked in light blue will be used to estimate water consumption or use. The data marked in green will be used to obtain the impacts of water degradation. Water discharge will be used to determine both types of impacts.

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>

3.5. Step 3: Assess the impacts of the water footprint

Following the development of the inventory, the potential water footprint impacts will be estimated. For this, it is recommended to follow the calculation process based on commonly used methodologies to obtain the characterization factor (CF) and its respective impact category indicator (SDC and CADIS, 2017; Vallejo, 2015; Suppen, 2014) (see Figure 18).

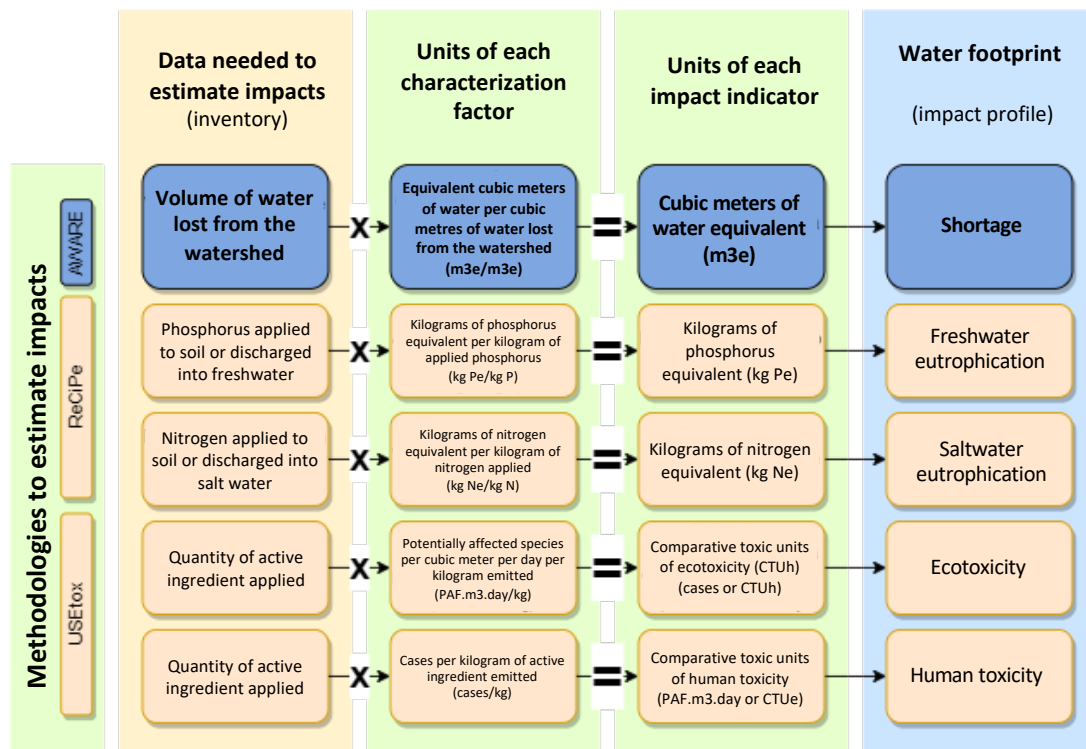
This step results in a **water footprint profile**, which is composed of the set of impact indicators by category (INTECO, 2015). **Figure 24** illustrates the required data, the CF units, the methodologies to be used and the expression of the indicator for each impact classification.



Important

If the company decides to estimate only some impacts or a single impact, the result cannot be called a water footprint profile. In this case, the result should be labelled as a water footprint indicator (e.g. eutrophication water footprint indicator) (INTECO, 2015).

Figure 24. Relationship between inventory data and impact assessment



Note: Blue shows the indicator related to consumptive use and orange shows those associated with degradative uses. AWARE=Available Water Remaining.

Source: Authors' own elaboration.

3.5.1. Impacts due to consumptive uses of water or water consumption

3.5.1.1. Scarcity

A potential scarcity impact is generated when a volume of water does not return to the same basin from which it was extracted due to the company's activity. As such, other potential users would no longer be able to consume it to meet their needs (UNEP, 2012). Water is lost in the following way (Vallejo, 2015; Vallejo *et al.*, 2018):

- **field system:** crop evapotranspiration, evaporation, or discharges to a different watershed; and
- **packing house system:** evaporation, discharge to a different basin, or water incorporated into the fruit.

The summary worksheet for water scarcity can be consulted in [Annex 3](#). The calculation method is described below.

3.5.1.1.A Calculation method

For the estimation of the impact indicator, the AWARE methodology ("Available Water REmaining") is used. The estimation is done by multiplying the total volume lost from the basin by a CF according to the geographic location, as shown in the following equation. The result will be given in terms of equivalent cubic meters of water (m^3e) (WULCA, 2017; Vallejo *et al.*, 2018).

Equation 3.5.1.1a

$$WF_{scarcity} (m^3e) = Bv_t \times CF_{regional}$$

Where:

WF scarcity: scarcity impact value in equivalent cubic meters (m^3e).

BVt: total volume of water withdrawn from the basin (m^3).

CFregional: characterization factor given by AWARE (m^3e/m^3).

3.5.1.1.B Collection of information

Required inventory data (BVt): The data corresponds to the volume of water in cubic meters (m^3) that does not return to the same basin from which it was extracted due to crop evapotranspiration, evaporation, discharges into a different basin or water incorporated into the fruit.

Characterization factor (CF regional): expressed in equivalent cubic meters of water per cubic meters of water withdrawn from the basin (m^3e/m^3), this factor depends on the geographic location and time of year. Its value can range from 0.1 to 100 and reflects the number of times that water in the region is not available with respect to the global average.

The characterization factor is downloaded from the official website of the **Water Use in Life Cycle Assessment (WULCA)** organization and



Important

More information on where to access the characterization factors (CF) can be found in [Annex 5](#). The company should download and install the Google Earth application to identify the CF that corresponds to the geographic location of the operations.

installed in the Google Earth application for use. The following is an example of a scarcity impact calculation.



Recommendation:

- weather station;
- evaporimeter tank to measure evaporation and evapotranspiration;
- lysimeters to determine evapotranspiration;
- water balance based on moisture measurement (TDR), inputs and outputs, and soil characteristics; and
- indirect estimates through tools such as CROPWAT (see [Annex 4](#) for more details on the use of the CROPWAT tool).

Example: water scarcity footprint

Step 1. On a 15-hectare pineapple farm (latitude 10°35'31.50 "N and longitude 84°29'23.67 "W), a total water volume (BV) was lost by evapotranspiration from the watershed during the study year as described below.

Month	Evapotranspiration of pineapple (m ³)	Month	Evapotranspiration of pineapple (m ³)
January	5 250	July	10 200
February	5 025	August	9 720
March	6 060	September	8 355
April	5 985	October	7 185
May	6 000	November	5 655
June	9 585	December	5 130
Total		84 150	

Step 2. To identify the monthly scarcity characterization factor, find the geographic location according to the Google Earth application and use the indicated coordinates.

Month	CF (m ³ e/m ³)	Month	CF (m ³ e/m ³)
January	0.3	July	0.2
February	0.7	August	0.2
March	1.0	September	0.2
April	1.1	October	0.2
May	0.6	November	0.2
June	0.3	December	0.2

Step 3. Calculate the potential impact on scarcity ($WF_{scarcity}$) per month, according to the characterization factor and the total volume lost from the basin. Each monthly data is estimated as follows.

$$WF_{scarcity\ month} = BV_{month} \times CF_{regional, month}$$

$$WF_{scarcity\ january} = 5\ 250\ m^3 \times 0.3 \frac{m^3e}{m^3}$$

$$WF_{scarcity\ january} = 1\ 575.0\ m^3e$$

The same procedure is performed for each month and the annual total is added up. The result will be:

Month	$WF_{scarcity}$ (m ³ e)	Month	$WF_{scarcity}$ (m ³ e)
January	1 575.0	July	2 040.0
February	3 517.5	August	1 944.0
March	6 060.0	September	1 671.0
April	6 583.5	October	1 437.0

May	3 600.0	November	1 131.0
June	2 875.5	December	1 026.0
Total	33 460.5		

3.5.2. Impacts from degradative water use

The indicators of potential water footprint impacts relate to freshwater eutrophication, saltwater eutrophication, ecotoxicity and human toxicity, as applicable to the company. Each indicator is explained below.

3.5.2.1. Eutrophication in freshwater and saltwater

The phenomenon of eutrophication occurs when excess nutrients are added to a body of water due to natural conditions or human consequence. This results into an exponential growth of algae, leading to a decrease in oxygen and affecting other species (Vallejo, 2015; Vallejo *et al.*, 2018). This can occur in freshwater or saltwater bodies, as follows:

- **Field system:** application of nitrogen or phosphorus fertilizers (to soil, air or water).
- **Packing house system:** discharge of wastewater with high organic loads.

The summary worksheets for eutrophication in freshwater and saltwater are in [Annex 3](#). The calculation methods are described below.

3.5.2.1.A1 Calculation method for freshwater eutrophication

The value of the impact indicator is estimated with the ReCiPe methodology, which assumes that the main factor causing eutrophication in freshwater is phosphorus. The results are expressed in units of kilograms of phosphorus equivalent (kg Pe), as shown in the following equation (Goedkoop *et al.*, 2013).

Equation 3.5.2.1a

$$WF_{eutrof-d} = m_{P_t} \times CF$$



Recommendation:

To determine the amount of phosphorus in wastewater, based on what Vallejo *et al.* (2018) and Soya (1998) proposed, a ratio of BOD5 to phosphorus (P) of 100:1 has been accepted. Therefore, the following equation is suggested to estimate the amount of phosphorus in wastewater.

$$m_{P_{total}} = BOD \times \frac{1}{100} \times Vd$$

$m_{P_{total}}$ = amount of total phosphorus discharged by wastewater (kg P total)

BOD = biological oxygen demand ($\frac{Kg}{m^3}$)

Vd=volume of wastewater discharge (m³)

Where:

WF_{eutrof-d}: value of impact on freshwater eutrophication (kg Pe).

m_{Pt}: amount of total phosphorus leached/discharged in soil or water (kg total P).

CF: characterization factor given by ReCiPe (kg Pe/kg total P).

3.5.2.1.B1 Collection of information:

Required inventory data (mPt): amount of phosphorus that was used in the soil (e.g. through fertilizers) or discharged into freshwater (e.g. wastewater or nutrient leaching) in kilograms of total phosphorus (kg total P).

Characterization factor (CF): expressed in

kilograms of phosphorus equivalent per kilogram of total phosphorus poured into the water or soil (kg Pe/kg total P), this factor depends on whether the phosphorus was used on agricultural soil (e.g. through fertilization) or poured into freshwater directly. In addition, it depends on the type of molecule in which the applied phosphorus was found (phosphorus, phosphate, phosphoric acid or phosphorus pentoxide).

The characterization factors are downloaded in Excel from the [official ReCiPe methodology website](#) and can be consulted in [Annex 5](#) of this guide.

Example calculations of the impact of eutrophication in fresh water are offered below.

Example: water footprint due to freshwater eutrophication

Activity: fertilizer use

Step 1. Through the fertilizer application record, it was determined that the following amounts of fertilizer were applied on a 15-hectare farm for the year under study.

Phosphorus origin	Fertilizer application (kg/ha/year)	Amount of phosphorus in the fertilizer (%)
Phosphate fertilizers	125	40
Phosphorus fertilizers	3	20

The first thing to do is to determine the amount of phosphorus (i.e. the phosphorus mass, PM) applied for each type of fertilizer.

$$\text{Phosphorus mass (PM)} = \text{hectares (ha)} \times \text{application (Kg/ha)} \times \frac{\text{phosphorus quantity (\%)}}{100}$$

$$\text{Phosphorus mass (PM}_{\text{phosphate}}) = 15 \text{ ha} \times 125 \frac{\text{Kg}}{\text{ha}} \times \frac{40}{100}$$

$$\text{PM}_{\text{phosphate}} = 750 \text{ kg}$$

$$\text{Phosphorus mass (PM}_{\text{phosphate}}) = 15 \text{ ha} \times 3 \frac{\text{Kg}}{\text{ha}} \times \frac{20}{100}$$

$$\text{PM}_{\text{phosphorus}} = 9 \text{ kg}$$

Step 2. Next, it is necessary to identify the characterization factors that correspond to the natural environment where the fertilizer was used, and the name of the substance that was present.

Natural environment where the fertilizer was released	Substance name	CF (kg Pe/ kg P)
Agricultural soil	Phosphate	0.033
Agricultural soil	Phosphorus	0.1

Step 3. Estimate the potential impacts of freshwater eutrophication:

$$\text{Eutrophication impact due to phosphate } (I_{Eut,phosphate}) = 750 \text{ kg} \times 0.033 \frac{\text{Kg Pe}}{\text{Kg P}}$$

$$I_{Eut,phosphate} = 24.75 \text{ kg Pe}$$

$$\text{Eutrophication impact due to phosphorus } (I_{Eut,phosphate}) = 9 \text{ kg} \times 0.1 \frac{\text{Kg Pe}}{\text{Kg P}}$$

$$I_{Eut,phosphate} = 0.9 \text{ kg Pe}$$

Step 4. Aggregate the total potential impact of freshwater eutrophication by fertilization ($I_{Eut, freshwater, fert}$):

$$\text{Freshwater eutrophication impact } (I_{Eut,freshwater}) = 24.75 \text{ kg Pe} + 0.9 \text{ Kg Pe}$$

$$I_{Eut,freshwater} = 25.65 \text{ kg Pe}$$

Activity: Discharge of wastewater from fruit washing processes

Step 1. Based on the operational reports and records of the wastewater treatment plant, the following biological oxygen demand (BOD) data were identified:

Report	BOD (kg/m ³)
First report	250
Second report	315
Third report	245

The average BOD of the wastewater (BOD_p) should be estimated by summing all values obtained and dividing the result by the number of reports.

Average BOD (BOD_p)

$$\text{Average BOD } (BOD_p) = (250 + 315 + 245) \div 3 = 270 \text{ Kg/m}^3$$

Step 2. Then, the amount of phosphorus (M_{Ptotal}) that was leached into the water should be estimated according to the BOD_p value. For this example, it is assumed that the total value of water discharged in that period was 3 615 m³ (Vd) according to the company's registries. The calculation is done as follows.

$$\text{Phosphorus mass in water } (M_{Ptotal}) = BOD_p \times \frac{1}{100} \times Vd$$

$$M_{Ptotal} = 270 \times \frac{1}{100} \times 3\,615 = 9\,760.5 \text{ Kg P}$$

Step 3. Next, it is necessary to identify the characterization factors that correspond to the natural environment that the fertilizer leached into, and the name of the substance in which the phosphorus was present (in this case it is assumed as total phosphorus).

Natural environment where the fertilizer was released	Substance name	CF (kg Pe/ kg P)
Fresh water	Total phosphorus	1

Step 4. Estimate the potential impact on freshwater eutrophication.

$$Eutrof.feshwater\ impact\ (I_{Eut,freshwater}) = 9\ 760.5\ Kg\ P \times 1\ \frac{Kg\ Pe}{Kg\ P}$$

$$I_{Eut,freshwater} = 9\ 760.5\ kg\ Pe$$

3.5.2.1.A2 Calculation method for saltwater eutrophication

The value of the impact indicator is estimated with the ReCiPe methodology, which assumes that the main factor causing eutrophication in saltwater is nitrogen. The results are given in units of kilograms of nitrogen equivalent (kg Ne), as shown in the following equation (Goedkoop *et al.*, 2013).

Equation 3.5.2.1b
 $WF_{eutrof-S} = m_{Nt} \times CF$

Where:

WF_{eutrof-S}: value of impact on saltwater eutrophication (kg Ne).

m_{Nt}: amount of total nitrogen used or discharged in soil or water (kg total N).

CF: characterization factor given by ReCiPe (kg Ne/kg total N).

3.5.2.1.B2 Collection of information

Inventory data required (m_{Nt}): the amount of nitrogen that was applied on the soil or discharged to fresh or salt water, expressed in kilograms of total nitrogen (kg total N).



Recommendation:

- To determine the amount of nitrogen in wastewater, based on what is proposed by Vallejo *et al.* (2018) and Soya (1998), it is indicated that a ratio of BOD5 to nitrogen (N) of 100:5 has been accepted. For this reason, use of the equation below is suggested to estimate the amount of nitrogen in wastewater.

$$m_{Ntotal} = BOD \times \frac{5}{100} \times Vd$$

m_{Ntotal} = amount of total nitrogen discharged by the wastewater (kg total N)

BOD=biological oxygen demand ($\frac{Kg}{m^3}$)

Vd=volume of wastewater discharge (m³)

Characterization factor (CF): expressed in kilograms of nitrogen equivalent per kilogram of total nitrogen applied to soil, freshwater or saltwater (kg Ne/kg total N), this factor depends on whether the nitrogen was applied to agricultural soil or to fresh or salt water directly. It also depends on the type of molecule in which the applied nitrogen was found (nitrogen, ammonium, ammonia, nitrogen oxides).

The characterization factors are downloaded in Excel from the [official ReCiPe methodology website](#) and can be consulted in [Annex 5](#) of this guide.

Following are examples of calculations of the impact of eutrophication in salt water.

Example: water footprint due to saltwater eutrophication

Activity: Fertilizer use

Step 1. Through the company's fertilizer application record, it was determined that the following amounts of fertilizer were applied on a 15-hectare farm for the year under study.

Nitrogen origin	Fertilizer application (kg/ha/year)	Amount of nitrogen in the fertilizer (%)
Nitrogen fertilizers	125	20
Ammonium fertilizers	4	50

First, the company needs to determine the amount of nitrogen (NM) applied by each type of fertilizer, that is:

$$\text{Nitrogen mass (NM)} = \text{hectares (ha)} \times \text{application (Kg/ha)} \times \frac{\text{Nitrogen quantity (\%)}}{100}$$

$$\text{Nitrogen mass (NM}_N) = 15 \text{ ha} \times 125 \text{ Kg/ha} \times \frac{20}{100}$$

$$\text{NM}_N = 375 \text{ kg N}$$

$$\text{Ammonium mass (NM}_{\text{ammonium}}) = 15 \text{ ha} \times 4 \text{ Kg / ha} \times \frac{50}{100}$$

$$\text{NM}_{\text{ammonium}} = 30 \text{ kg NH}_4$$

Step 2. Next, it is necessary to identify the characterization factors that correspond to the natural environment where the fertilizer was used, and the name of the substance in which the nitrogen was present.

Natural environment where the fertilizer was used	Substance name	CF (kg Ne/ kg used)
Agricultural soil	Nitrogen	0.13
Agricultural soil	Ammonium	0.10

Step 3. To sum up the total potential impact of saltwater eutrophication due to fertilization:

$$\text{Impact of nitrogen eutrophication } (I_{\text{Eut,nitrogen}}) = 375 \text{ Kg} \times 0.13 \frac{\text{Kg Ne}}{\text{Kg N}}$$

$$I_{\text{Eut,nitrogen}} = 48,75 \text{ kg Ne}$$

$$\text{Impact of eutrophication by ammonium } (I_{\text{Eut,nitrogen}}) = 30 \text{ Kg} \times 0.10 \frac{\text{Kg Ne}}{\text{Kg NH}_4}$$

$$I_{\text{Eut,nitrogen}} = 3 \text{ kg Ne}$$

Step 4. To sum up the total potential impact of saltwater eutrophication due to fertilization:

$$\text{Impact on eutrophication of salt water } (I_{\text{Eut,saltwater}}) = 48.75 \text{ Kg Ne} + 3 \text{ Kg Ne}$$

$$I_{\text{Eut,saltwater}} = 51.75 \text{ kg Ne}$$

Activity: Discharge of wastewater from fruit washing processes

Step 1. Based on the company's operational reports and records of the wastewater treatment plant, the following biological oxygen demand (BOD) data were identified:

Report	BOD (kg/m ³)
First report	250
Second report	315
Third report	245

The average BOD of the wastewater (BOD_p) should be estimated by summing all values and dividing by the number of reports.

$$\text{Average BOD } (BOD_p) = (250 + 315 + 245) \div 3 = 270 \text{ kg/m}^3$$

Step 2. Now the amount of nitrogen (M_{Ntotal}) that was discharged into the water should be estimated according to the BOD_p value according to the following equation. For this example, it is assumed that the total volume of water discharged in that period was 3 615 m³ (Vd).

$$\text{Nitrogen mass in the water } (M_{\text{Ntotal}}) = BOD_p \times \frac{5}{100} \times Vd$$

$$M_{\text{Ntotal}} = 270 \times \frac{5}{100} \times 3\,615 = 48\,802.5 \text{ Kg}$$

Step 3. Next, it is necessary to identify the characterization factors that correspond to the natural environment where the fertilizer was discharged (e.g. via leaching or wastewater), and the form in which the nitrogen was present in it (in this case it is assumed as total nitrogen).

Natural environment where the fertilizer was discharged	Substance name	FC (kg Ne/kg N _{discharged})
Freshwater	Nitrogen (N)	0.30

Step 4. Estimate the potential impact on saltwater eutrophication as follows.

$$Eutrof.\text{saltwater impact } (I_{Eut,saltwater}) = 48\,802.5 \text{ Kg N} \times 0.30 \frac{\text{Kg Ne}}{\text{Kg N emitted}}$$

$$I_{Eut,saltwater} = 14\,640.75 \text{ kg Ne}$$

3.5.2.2. Ecotoxicity and human toxicity

The use of organic or inorganic chemicals can lead to potential impacts on ecosystems and human health. This can occur in the following ways:

- **field system:** through the application of phytosanitary products that are discharged into the soil, air or water; and
- **packing house system:** by applying phytosanitary products for post-harvest treatment that are discharged into the air or water.

The summary sheets for the ecotoxicity and human toxicity water footprint can be consulted in [Annex 3](#). The calculation methods are described below.

3.5.2.2.A1 Ecotoxicity calculation method

The USEtox methodology (Fantke *et al.*, 2015) is used for these impact categories. This methodology obtains a result for ecotoxicity expressed as the decrease of aquatic species or comparative toxic units in the ecosystem (CTU_e) (ibid.). It is expressed in the following equation.

Equation 3.5.2.2a

$$WF_{ecotox} = m_x t \times CF_x$$



Important

- Usually, product application records report the total mixture of the commercial product used, however, to calculate the ecotoxicity impact, only the amount of the active ingredient should be determined.
- Likewise, if the product is in liquid form, the company should convert from litres to kilograms. This could be done by using the density of the product, whose value is recorded in the product data sheets. To do so, the calculation below is suggested:

Active ingredient mass (M_x) =

$$\text{application (l)} \times \frac{\text{active ingredient (\%)}}{100} \times \text{density} \frac{\text{Kg}}{\text{l}}$$

Where:

WF_{ecotox}: ecotoxicity impact value in water (CTU_e).

m_xt: total amount of a given substance (“x”) emitted to air, soil or water (kg x)

CF_x: characterization factor for a given substance (“x”), provided by USEtox (CTU_e/kg x)

3.5.2.2.B1 Collection of information:

Inventory data required (m_xt): Quantity of a given substance (“x”) that was discharged into the air, soil or water. Generally, the active

ingredients of the products used are used as reference. However, the most relevant ones can be selected for the inventory, as long as the justification criteria are adequately described in the scope of the study.

Characterization factor (CF_x): factor expressed as the fraction of potentially affected species (PAF) per cubic meter per day, per kilogram emitted of substance “x” (PAF.m³.day/kg x). The units of PAF.m³.day are also referred to as comparative toxic units for ecotoxicity (CTU_e).

The CTU_e is a factor that depends on the substance emitted and the natural environment where it is discharged, that is to say, whether the substance was released into the indoor air of a home, indoor air of an industrial building, urban air, rural air, a freshwater body, a saltwater body,



Important

Characterization factors have not been developed for all products. However, this does not mean that they do not have an impact on ecotoxicity levels. As such, the exclusion of any product should be described in the scope of the study.

natural soil or agricultural soil.

The characterization factors are downloaded in Excel from the [official USEtox® methodology website](#) and can be consulted in [Annex 5](#) of this guide.

An example of an ecotoxicity impact calculation in fresh water is shown below.

Example: water footprint due to ecotoxicity of fresh water

Step 1. Based on the company’s product application record for the study year, it was determined that the following active ingredients were used in the quantities indicated below.

Active ingredient	Applied (kg)	Natural environment where it was released
Glyphosate	400	Agricultural land
Ethephon (ethylene)	1 500	Agricultural land

Step 2. The corresponding characterization factors (CF) should be identified for each active ingredient. If not available, justification should be provided in the scope.

Active ingredient	CF (CTU _e or PAF.m ³ .day/kg _{emitted})
Glyphosate	71.8334829
Ethephon (ethylene)	101.8373734

Step 3. Calculate the ecotoxicity water footprint impact (I_{Ecotox}) by multiplying the respective CF and the applied amount of the active ingredient.

$$Ecotox.glyphosate\ impact\ (I_{Ecotox,Glyph}) = 400\ Kg \times 71.8334829\ PAF.\ m^3.\ day/Kg$$

$$I_{Ecotox, Glyph} = 28\,733.39 \text{ PAF} \cdot m^3 \cdot \text{day or CTUe}$$

$$Ecotox.ethylene \text{ impact } (I_{Ecotox, Ethylene}) = 1\,500 \text{ Kg} \times 101.8373734 \text{ PAF} \cdot m^3 \cdot \text{day/Kg}$$

$$I_{Ecotox, Ethylene} = 152\,756.06 \text{ PAF} \cdot m^3 \cdot \text{day or CTUe}$$

Step 4. Add up the total potential impact:

$$I_{Ecotox.} = 28\,733.39 \text{ CTUe} + 152\,756.06 \text{ CTUe}$$

$$I_{Ecotox.} = 181\,489.45 \text{ CTUe}$$

3.5.2.3.A2 Calculation method for human toxicity

The USEtox methodology (Fantke *et al.*, 2015) is used for these impact categories. This allows obtaining a result for human toxicity, expressed as cases of disease that can potentially occur due to the use of substances. These categories are also known as comparative toxic units in human health (CTU_h) (*ibid.*) and are calculated through the following equation.

Equation 3.5.2.3a

$$WF_{toxh} = m_x t \times CFx$$

Where:

WF_{toxh}: human toxicity impact value (CTU_h).

m_x t: total amount of a given substance (“x”) emitted to air, soil or water (kg x).

CFx: characterization factor for a given substance (“x”), provided by USEtox (CTU_h/kgx).

3.5.2.1.B2 Collection of information

Inventory data required (m_x t): Quantity of substance “x” that was applied in air, soil or water. Generally, the active ingredients of the products used are used as a reference. However, the most relevant ones can be selected for the inventory, as long as the justification criteria are adequately described in the scope of the study.



Important

- Usually, product application records report the total mixture of the commercial product used; however, to calculate the impact on human toxicity, only the amount of the active ingredient that applies should be determined.
- Likewise, if the product is in a liquid form, the company should convert from litres to kilograms. This can be done by using the product density, whose value is recorded in the product data sheets. To do so, it is recommended to follow the calculation below:

Active ingredient mass (M_x) =

$$\text{application (l)} \times \frac{\text{active ingredient (\%)}}{100} \times \text{density} \frac{\text{Kg}}{\text{l}}$$

Characterization factor (CFx): Factor expressed as the number of cases of disease per kilogram of substance “x” emitted (cases/kg x). The units of cases are also called comparative toxic units for human toxicity (CTU_h). It is a factor that depends on the substance emitted and the natural environment where it is discharged,

that is to say, whether the substance was released into the indoor air of a home, indoor air of an industrial building, urban air, rural air, a freshwater body, a saltwater body, natural soil or agricultural soil.

The characterization factors are downloaded in Excel from the [official USEtox@ methodology website](#) and can be consulted in [Annex 5](#) of this guide.

The following is an example of a calculation of the impact of saltwater eutrophication on human toxicity.



Important

Characterization factors are not developed for all the products used. However, this does not mean that they do not have an impact on human toxicity. As such, the exclusion of any product must be described in the scope of the study.

Example: water footprint due to human toxicity

Step 1. Based on the company's product application record for the study year, it was determined that the following active ingredients were used in the quantities indicated below.

Active ingredient	Applied (kg)	Natural environment where it was released
Glyphosate	400	Agricultural land
Ethephon (ethylene)	1 500	Agricultural land

Step 2. The corresponding characterization factors (CF) should be identified for each active ingredient. If not available, justification should be provided in the scope.

Active ingredient	CF (CTU _h or cases/kg _{emitted})
Glyphosate	1.15932E-07
Ethephon (ethylene)	9.38854E-07

Step 3. Calculate the human toxicity water footprint impact (I_{TH}) by multiplying the respective CF and the applied amount of the active ingredient.

$$\text{Glyphosate TH.impact } (I_{TH, \text{Glyph}}) = 400 \text{ Kg} \times 1.15932 \times 10^{-7} \text{ cases/Kg}$$

$$I_{TH, \text{Glyph}} = 0.000046 \text{ cases or CTUh}$$

$$\text{Ethylene TH.impact } (I_{TH, \text{Ethylene}}) = 1\ 500 \text{ Kg} \times 9.38854 \times 10^{-7} \text{ cases/Kg}$$

$$I_{TH, \text{Ethylene}} = 0.0014 \text{ cases or CTUh}$$

Step 4. Add up the total potential impact.

$$I_{TH} = 0.000046 \text{ CTUh} + 0,0014 \text{ CTUh}$$

$$I_{TH} = 0.001446 \text{ CTUh}$$

3.5.3. Interpretation of the water footprint

The results will be reported in regards to what is known as the “functional unit”, which is the reference unit of the footprint performance (INTECO, 2015); that is, the unit used to compare the variation of the impact from year to year and determine whether it is increasing or decreasing. For the purposes of this guide, this “functional unit” or “reporting unit” will be the organization as a whole, according to the delimitation of activities, processes and geographical location defined in the scope (INTECO, 2015).

Once the company has elaborated the footprint profile, it needs to update the scope of the study according to assumptions, the process or activity exclusion criteria, the data and its quality, as well as any other relevant aspect influencing the interpretation of the results.

The company also needs to conduct an analysis of the impact indicators obtained based on the defined scope, time coverage, regional



Important

The water footprint results obtained through the use of this guide should be reported and understood as the impact profile for the quantified activities of the company as a whole. However, each impact indicator can be divided by the pineapple production data for each corresponding period in order to obtain the water footprint profile per unit produced (e.g. per pineapple or per kilogram produced). This production-based data can facilitate understanding and analysis of results, but it should not be interpreted as the product’s water footprint.

characteristics and any limitations identified. Table 15 provides a guide to support the understanding of the impact profile.

Table 15. Summary of impact indicators and their interpretation

Impact category	Impact indicator	Interpretation
Scarcity (consumption)	m ³ e	The result will refer to the total water lost from the basin in the study year resulting from the activities directly associated with the company’s operations. This water can no longer be consumed by other users. When analysing the characterization factor (CF) following the AWARE method, the factor varies from 0.1 to 100, and is interpreted as the number of times water in the region is unavailable relative to the global average (e.g. a CF of 10, will refer to the water available in a region that is 10 times less than the global average) (SDC and CADIS, 2017). This varies from site to site, depending on the scarcity of each area.

Impact category	Impact indicator	Interpretation
Eutrophication in freshwater (degradation)	kg Pe	The results correspond to the amount of phosphorus discharged directly into the water, or that reaches water bodies through its interactions with soil or air, and that can potentially cause exponential and harmful growth of organisms in the nearest freshwater receiving body (Goedkoop <i>et al.</i> , 2013).
Eutrophication in saltwater (degradation)	kg Ne	The results correspond to the amount of nitrogen discharged directly into the water, or that reaches water bodies through its interactions with soil or air, and that can potentially cause exponential and harmful growth of organisms in the nearest saltwater receiving body (Goedkoop <i>et al.</i> , 2013).
Ecotoxicity (degradation)	CTU _e	The results refer to the fraction of potentially affected species (PAF) per cubic meter of water per day (PAF.m ³ .day), due to the discharge of chemicals during the production process (Fantke <i>et al.</i> , 2015). These units of measurement are also known as comparative toxic units of ecotoxicity (CTU _e).
Human toxicity (degradation)	CTU _h	The results will be interpreted as the number of cases of associated diseases (carcinogenic and/or non-carcinogenic effects), which could potentially occur due to the discharge of chemicals during the production process (Fantke <i>et al.</i> , 2015). These units of measurement are also known as comparative toxic units of human toxicity (CTU _h).

Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>

The analysis of the results of the inventory and the water footprint profile should lead to the identification of relevant and key areas that require attention in the company's activities and processes. This will help the company to prioritize actions to improve the management of water consumption and prevent and mitigate the degradation of the resource (Vallejo *et al.*, 2018). The more exhaustive the study is, the more efficient and the greater the impact it will have.

The water footprint impact profile will be the baseline for the company to compare its performance over the years and will contribute to decision making on the protection of water resources. It is not advisable to make a comparison between the results of different studies outside the company, as their scope may be very different.



Important

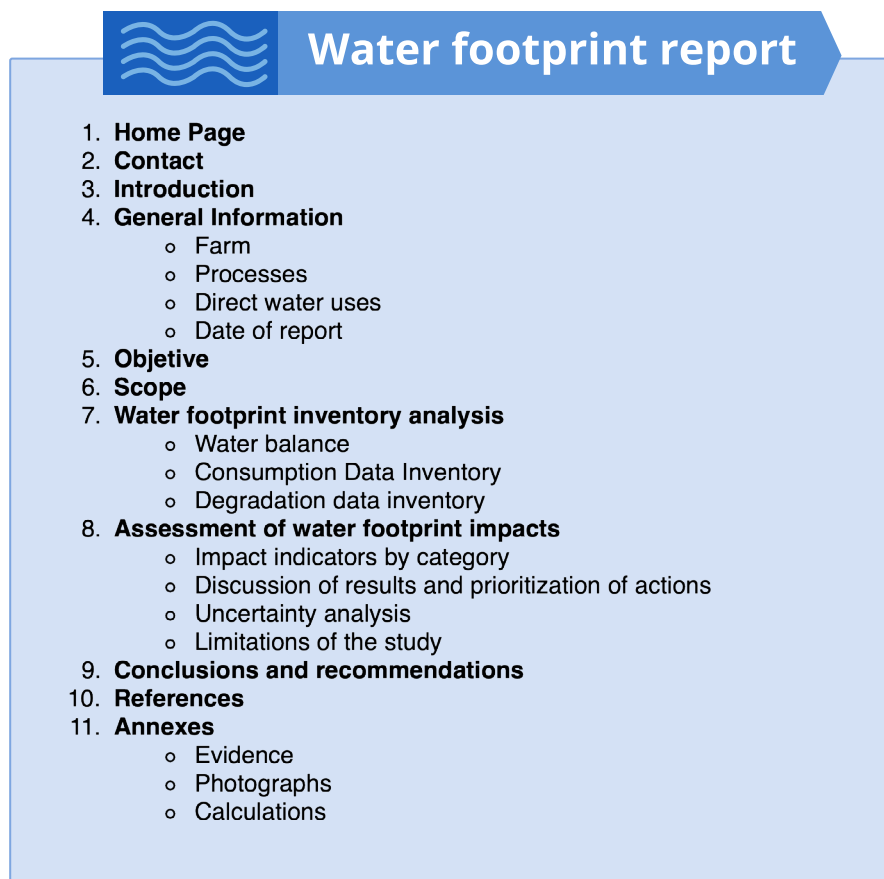
The water footprint results can be estimated in terms of impacts on human health, ecosystem quality and resource. These calculations are known as endpoint impacts or final impacts, and their estimation process is different from what is explained in this guide. In addition, a weighting may be performed to report a single value, which must be done in accordance with ISO 14044 (INTECO, 2015). It should be noted that both aspects are excluded from the scope of this guide.

3.6. Water footprint report

It is recommended that the results be reported according to the structure shown in Figure 25. It should be as detailed and transparent as

possible to allow for a good understanding of the full scope of the study.

Figure 25. Reporting structure



Source: Adapted from Vallejo, A. L. 2015. *Metodología práctica para la cuantificación de la huella de agua en Plantas Empacadoras de piña en Costa Rica*. Instituto Tecnológico de Costa Rica. <http://repositoriotec.tec.ac.cr/handle/2238/6305> and Swiss Agency for Development and Cooperation (SDC) and Centro de Análisis de Ciclo de Vida y Diseño Sustentable (CADIS). 2017. *Water Footprint (ISO 14046:2014) in Latin America and the Caribbean, analysis and recommendations for regional consistency*. Centro de Análisis de Ciclo de Vida y Diseño Sustentable. <http://centroacv.mx/archivos/HuellaAgualSO14046AmericaLatina.pdf> and Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>

3.7. Critical review of a water footprint study

The water footprint study can undergo a verification process, which is known as a critical review, that will contribute to the credibility and endorsement of the study. The guidance on how to do this will depend on the objective and scope defined by the company in the study, as it can be performed by a panel of stakeholders, by an expert or according to ISO 14044⁹ (INTECO, 2015).

For the critical review, the company should:

- make the study report available to the required stakeholders;

- allow site visits by experts to verify the information provided in the report; and
- submit the study to a committee approval process, with the review conducted through a verification and validation body (Vallejo *et al.*, 2018).

On the other hand, if the company is not going to do a critical review, it can elaborate a statement report, making the results and associated details of the study available to the target audience (Vallejo *et al.*, 2018; SDC and CADIS, 2017).

3.8. Concluding remarks on the water footprint

A water footprint assessment has a scientific approach (INTECO, 2015), making it necessary to verify the use of updated data, with reasonable accuracy and precision, and traceable in origin. In addition, the company should conduct the most comprehensive and exhaustive study possible, contemplating all its systems, activities and processes for decision-making at micro and macro scales for the management of water resource.

Additionally, it is important to note that the indicator values by category reflect impacts that may **potentially** be occurring but are not necessarily happening at that magnitude (Vallejo *et al.*, 2018). The results should be analysed and

interpreted with care, paying special attention to the opportunities that each impact category provides to improve water management to safeguard ecosystems and human health.

⁹ ISO 14044: Life cycle assessment of products and services. It focuses on the assessment of the life cycle of products and services, based on a systematic approach that covers the extraction of natural resources, production, use and final disposal.

4. RECOMMENDATIONS FOR THE REDUCTION OF CARBON EMISSIONS AND WATER IMPACTS ON PINEAPPLE FARMS



4.1. Reduction of carbon emissions

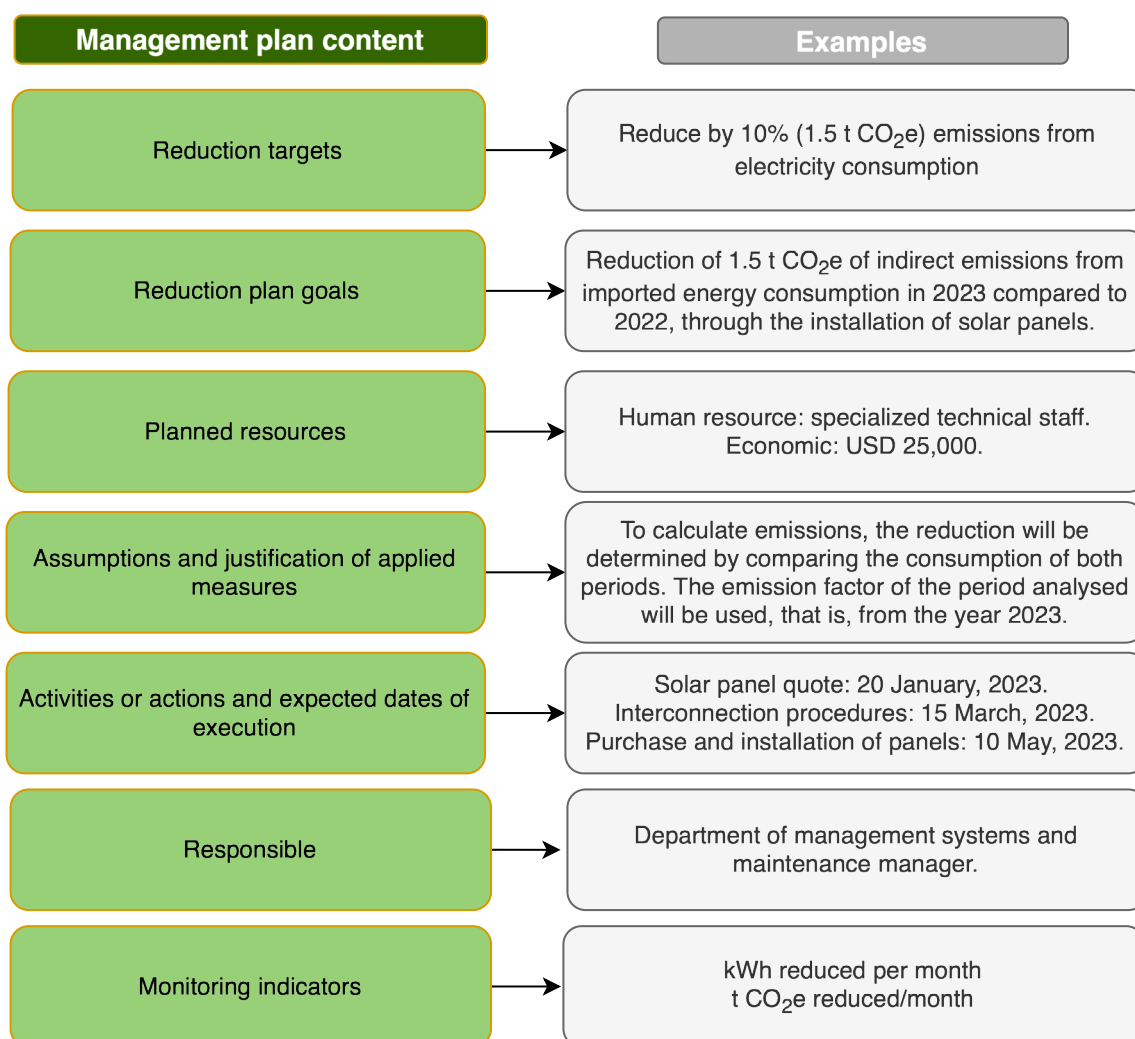
The reduction of GHG emissions is the fundamental basis of the management of an emissions inventory and occurs through the implementation of planned actions by the company.

Determining the carbon footprint makes it possible to identify potential opportunities to reduce emissions and contribute to mitigating the effects of climate change. Therefore, once the sources and amount of GHG have been identified and accounted for in the company, reduction strategies must be established to manage such

sources and reduce GHG emissions.

Based on ISO 14064-1 and INTE B5 standards, it is recommended to establish a **reduction management plan** as a tool to achieve emission reduction targets. A reduction management plan includes, but is not limited to, reduction targets, designation of responsibilities to achieve the targets, the means and/or resources needed and a timeline of activities. Figure 26 provides guidance on the content of a reduction management plan.

Figure 26. Guidance on the content of an emissions management plan.



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

Establishing reduction strategies leads to benefits for companies, including:

- contributions to the sustainability of the business. Working on mitigating emissions contributes to reducing the effects of climate change in the agricultural sector;
- identification of opportunities for improvement in processes and their efficiency, by establishing registration and accounting systems;
- cost reduction through innovation in processes and efficient use of resources, which may increase the business profitability;
- promotion of awareness among employees regarding the risks and opportunities associated with climate change; and
- a differentiating factor for the product and the company in international markets, thus contributing to their competitiveness (Vallejo *et al.*, 2018).



Important

It is essential that the process of developing the inventory and establishing the reduction management plan has the commitment of the company's senior management.

It is important to consider that, depending on the objective and scope of the carbon footprint as defined by the company, there are requirements linked to the reduction management plan and the documentation of reductions established in reference standards. Such standards include ISO 14064-1, INTE B5 or the country's GHG programme, when applicable.

Some good practices, technologies and options that can be considered for the establishment of reduction strategies for some emission sources in the pineapple sector are described in Figure 27.

Figure 27. Examples of emissions reduction actions

Emission source	Reduction alternatives
<p style="text-align: center;">Electricity</p>	On-site power generation from renewable sources, e.g. solar panels
	Replacement of artificial lighting with natural lighting
	Replacement of fluorescent or sodium lighting with LED lighting
	Improvements or renovation of electrical installation
	Replacement of obsolete or old equipment with more efficient equipment, for example, air conditioners, refrigerators, computers, printers, etc.
<p style="text-align: center;">Use of fuels</p>	Substitution of combustion vehicles for other technologies, such as electric or hybrid
	Replacement of old or obsolete vehicles with more efficient vehicles
	Utilization of fuel-saving devices
	Route optimization
	Application of efficient driving techniques or habits
	Replacement of combustion engines with electric motors
	Equipment and vehicle preventive management programmes

Emission source	Reduction alternatives
Fertilizer use	<ul style="list-style-type: none"> Reincorporation of organic matter into the soil and use of organic amendments Utilization of fertilizers with less volatilized nitrogen sources Utilization of fertilizers with volatilization inhibitors
Refrigerant gases and use of fire extinguishers	<ul style="list-style-type: none"> Substitution of refrigerant gases with high global warming potentials for gases with lower warming potential Preventive and periodic maintenance programmes for leak detection Gas recovery and destruction practices with authorized managers Evaluation of the frequency of fire extinguisher replacement or recharging
Solid waste and wastewater disposal	<ul style="list-style-type: none"> Reduction of the organic matter load in wastewater Implementation of practices that reduce the generation of packing plant wastewater, such as water reuse or recirculation Reduction of wastewater generation by changing consumption habits Implementation of waste management programmes for waste separation and recycling
Stubble management and tillage	<ul style="list-style-type: none"> Selection of tillage management practices with a lower emission factor Change conventional tillage practices to reduced tillage or minimum tillage Reincorporation of organic matter in soil

Source: Authors' own elaboration.

4.2. Carbon removals

Companies could also consider implementing strategies that allow them to remove emissions, through:

- reforestation of underutilized or unsuitable areas for pineapple cultivation;
- forest protection in own areas or conservation of regenerating areas; and
- agroforestry systems in productive and unproductive areas of the farms, in areas protecting water bodies, and areas bordering housing, packing houses or roads. (Vallejo *et al.*, 2018).

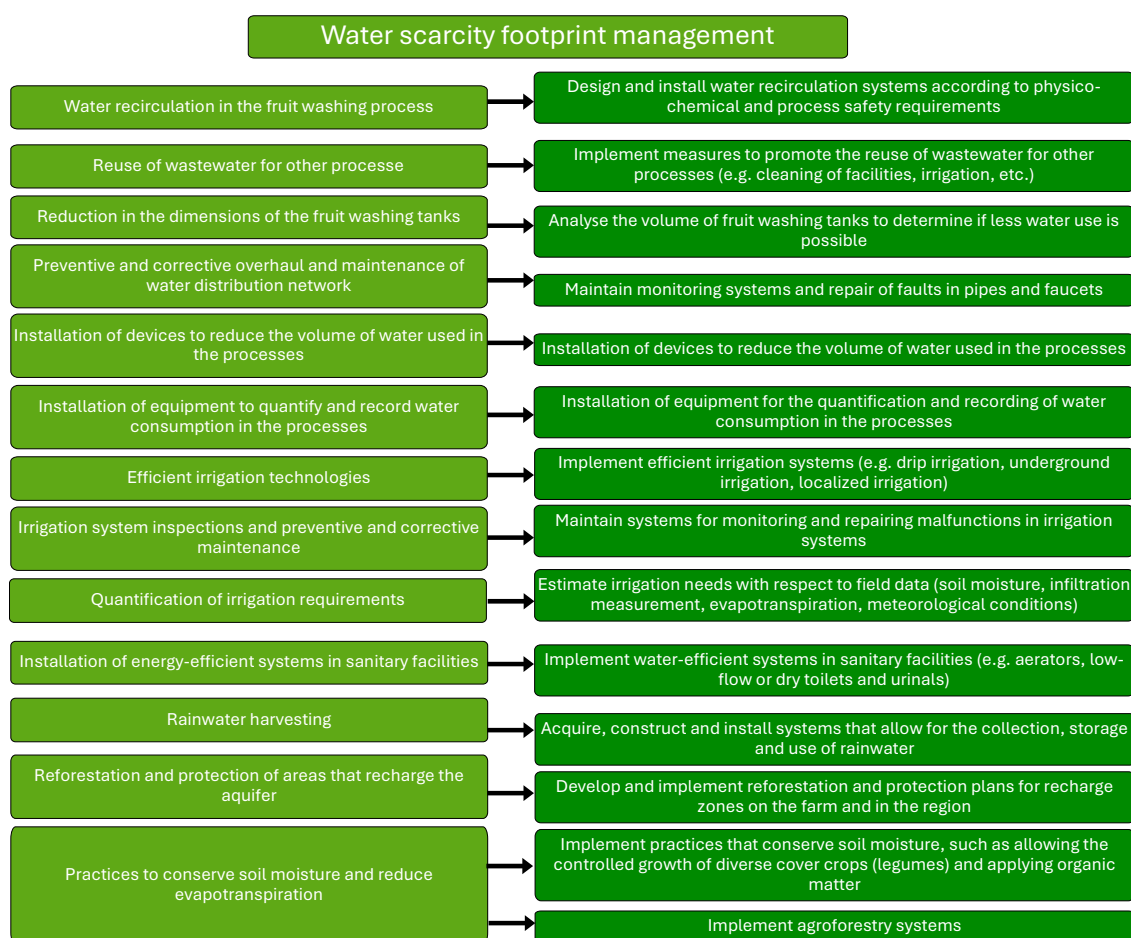
4.3 Water footprint

The water footprint indicator, having a life cycle analysis approach, is expressed by a set of potential impacts on different aspects associated with water resources. Therefore, when thinking about options to reduce the footprint, the company needs to consider all good practices available in the sector to make a more efficient

use of water and reduce the use of substances or activities that affect water quality.

Figure 28 summarizes a list of recommendations to guide producers towards a focus on reducing impacts related to consumptive water use (scarcity).

Figure 28. Water footprint reduction measures due to scarcity



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i8333EN.pdf>

In turn, Figure 29 shows the measures associated with the **management of impacts due to the degradative use of water (eutrophication in freshwater and saltwater, ecotoxicity and human toxicity)**. It should be noted that the measures are not limited to those indicated in the figure. Creativity and research by each producer and company is fundamental to achieve adequate management and reduction of the water footprint.

In addition, it is advisable to focus on the development of initiatives and projects that allow for comprehensive work at the level of the selected basin or sub-basin, since it represents a single and interrelated living system. Activities carried out in a fragmented manner in parts of the basin or sub-basin will not have the same

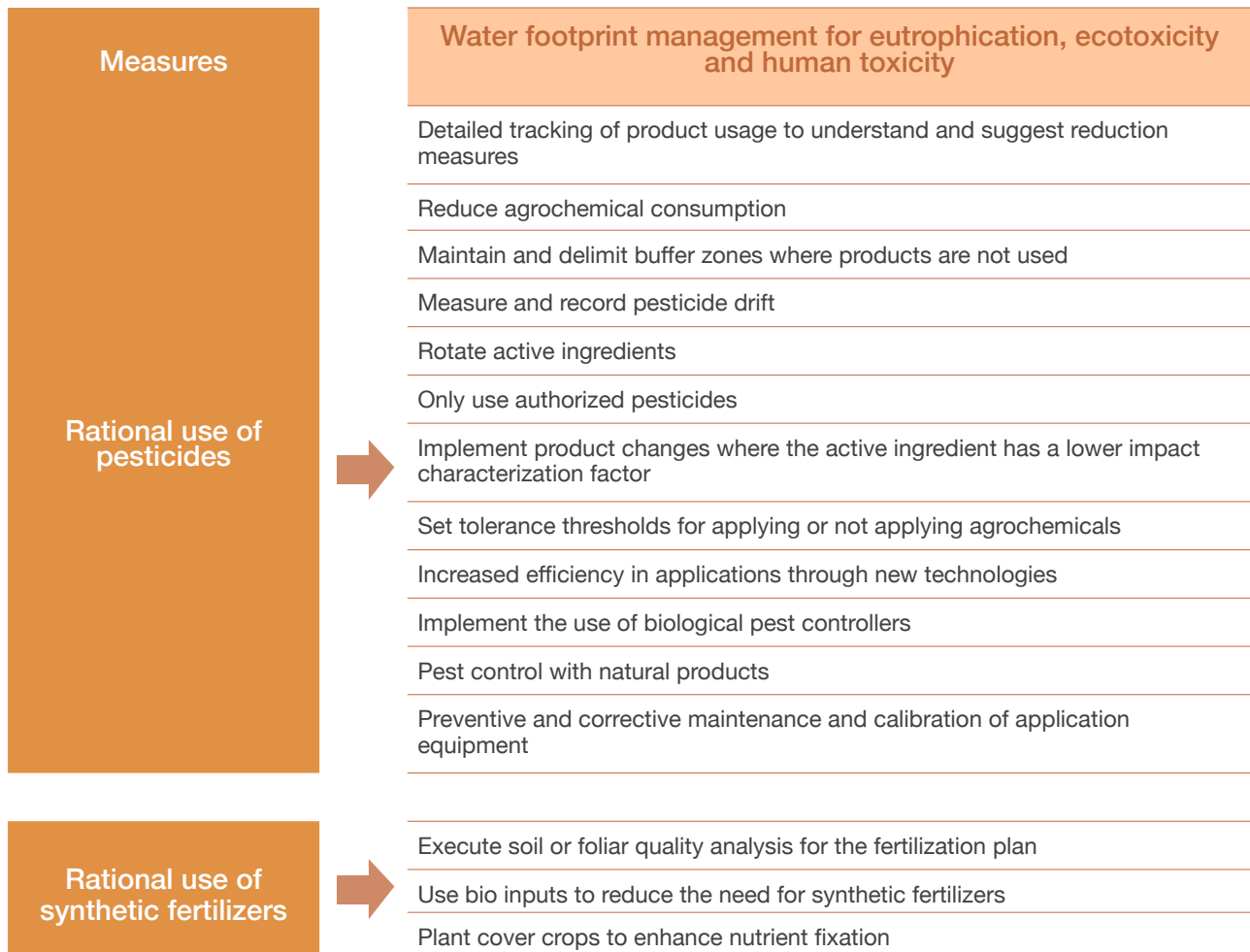


Important

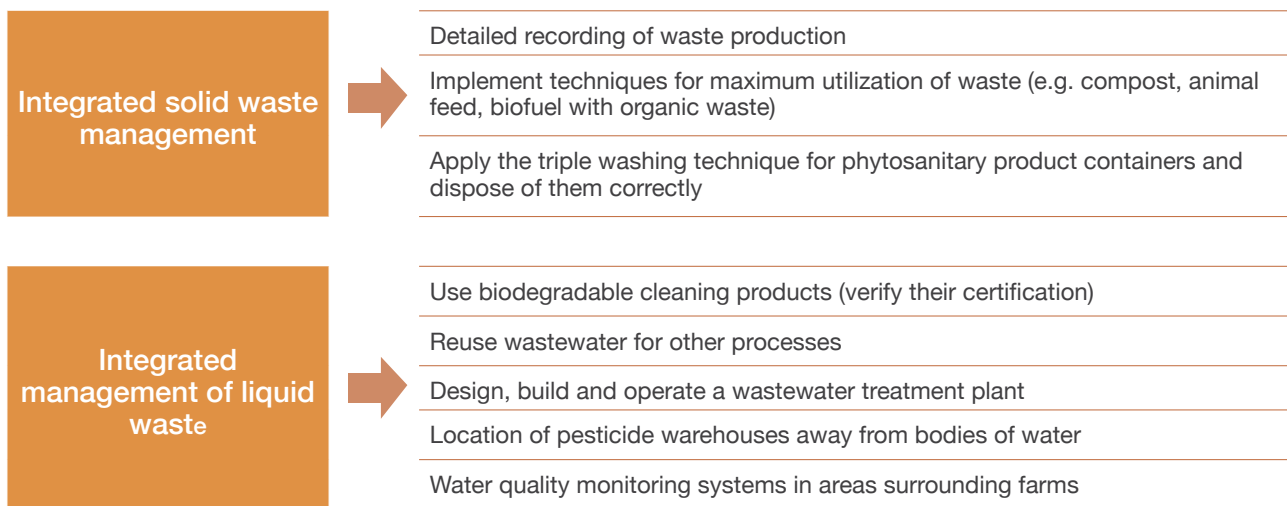
There is no consensus on “zero” water footprint declarations, since any human activity will undoubtedly generate some alteration in quantity or quality of the resource. Moreover, there is no justification for offsetting an impact – whether potential or tangible – if there are not sufficient, exhaustive and responsible measures in the company’s integrated management of water resources.

magnitude of positive impact as those carried out collaboratively, jointly and comprehensively in the region.

Figure 29. Water footprint reduction measures for human toxicity, ecotoxicity and eutrophication



<p>Protection of employees and residents of surrounding areas</p>	<p>Train and verify the use of personal protective equipment</p> <p>Maintain buffer zones</p> <p>Involve the community in biodiversity awareness and protection activities</p>
<p>Soil protection</p>	<p>Train and sensitize employees to the importance of soil microorganisms</p> <p>Plant vegetative covers to prevent erosion</p> <p>Implement practices that allow the conservation of soil moisture, such as allowing the controlled growth of various plant covers (legumes) and applying organic matter</p> <p>Implement agroforestry systems</p> <p>Apply crop rotation</p> <p>Apply organic fertilizer to the soil</p>
<p>Biodiversity protection measures</p>	<p>Design and implement management, restoration and protection plans for forest fragments and ecosystems on the farm</p> <p>Reforestation and maintenance of living barriers adjacent to the forest</p> <p>Map and define protection and restoration zones</p> <p>Inventory of species on the farms to be monitored (flora and fauna)</p> <p>Implement activities that promote colonization of pollinators and beneficial organisms</p> <p>Enable biological corridors to interconnect forested areas and allow the passage of wildlife</p> <p>Execute microbiological soil analysis</p> <p>Provide spaces on the farm for natural controllers (birds of prey, reptiles, etc.)</p> <p>Installation of signage to promote awareness and conservation of biodiversity</p> <p>Promote and implement actions for the conservation of native species</p> <p>Create and raise awareness among users of biodiversity policies</p> <p>Development and implementation of a monitoring plan for ecosystem health indicator species</p> <p>Record and improve impacts on biodiversity (+/-)</p>
<p>Organic production</p>	<p>Opt for zero pesticide residue certifications</p> <p>Cultivate and apply efficient microorganisms for soil regeneration and complement fertilization (use of bioinputs)</p>



Source: Adapted from Vallejo, A. L., Vallejo, M. A., Nájera, J. and Garnier, L. A. 2018. *Methodological guide to reduce carbon and water footprints in banana plantations*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and FAO. <https://www.fao.org/3/i8333en/i83333EN.pdf>.

5. EMISSION INVENTORY UNCERTAINTY ASSESSMENT



Uncertainty analysis is an important element of an inventory of emissions and removals as a means to prioritize efforts to reduce uncertainty in future inventories and to guide decisions on the selection of methodologies. This section is intended to be a practical guide, providing a general orientation to uncertainty analysis and tools applicable to all emission categories and sources (IPCC,2006).

Uncertainty is defined as the lack of knowledge of the true value of a variable. There are several types of uncertainty. In this section we will refer only to parameter uncertainty, which is derived from estimation uncertainty and that arises whenever GHG emissions are quantified (IPCC,2006).

Parameter uncertainty refers to the uncertainty associated with the quantification of the parameters used as inputs (activity data or emission factors) in the quantification models.

There are some recognized methodologies for uncertainty assessment of GHG emission inventories, for example:

- GHG Protocol guidance on the assessment of uncertainty in GHG inventories and the calculation of uncertainty in statistical parameters, and its calculation tool;
- Chapter 3: uncertainties, from Volume 1 of the IPCC Guidelines (2006) and Refinement (2019) and the IPCC Tool for Uncertainty Analysis of Approach 1;
- IPCC good practices guidance and uncertainty management in national greenhouse gas inventories;
- Guide for the expression of measurement uncertainty (GUM); and
- Methodological guide for the estimation and analysis of the uncertainty of greenhouse gas emissions and absorptions of the Carbon Neutral Country Programme 2.0 (CNCP 2.0) of Costa Rica.

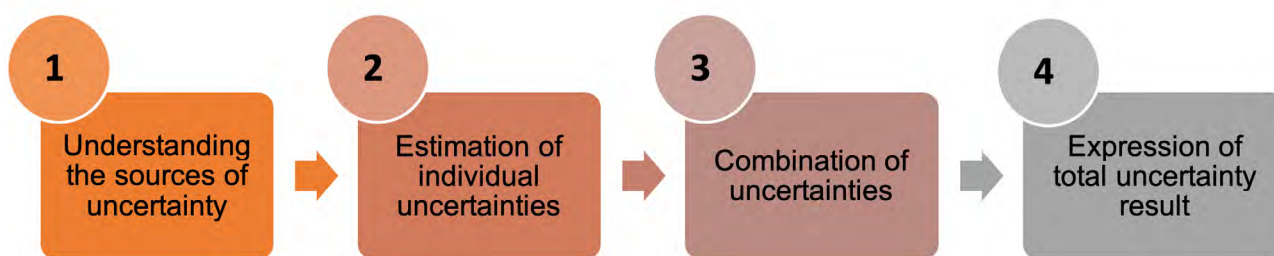


Important

- Cause-effect diagrams can be used to determine all sources of uncertainty in the emission estimation.
- For further details, please refer to the *Guía metodológica para la estimación y análisis de la incertidumbre de emisiones y remociones de gases de efecto invernadero (GEI) – Programa País de Carbono Neutralidad 2.0.* [Methodological Guide for the Estimation and Analysis of Uncertainty in Greenhouse Gas (GHG) Emissions and Removals – National Carbon Neutrality Programme 2.0.] (DCC, PMR and LCM, 2020.)

For the purposes of this guide, the guidance given by the Methodological guide for uncertainty estimation and analysis of Costa Rica's Carbon neutral country programme are used. These are summarized in the following steps for uncertainty assessment.

Figure 30. General steps for uncertainty assessment



Source: Authors' own elaboration.

Guidance on how to approach each step is provided below.

5.1 Understanding sources of uncertainty

Identify the contributions to the inventory by emission source and the possible sources of uncertainty in the result obtained for each emission source. Some considerations in understanding and identifying possible sources of uncertainty are:

- the measurements or estimates that are made;
- measuring equipment used, specifications, calibrations or verifications;
- if sampling and sampling errors are used; and
- variation in data; among others.

5.2 Estimation of individual uncertainties

The estimation of individual uncertainties depends on the quantification method used, direct or indirect. The **direct method** is when emissions or absorptions are quantified using measurement instruments that directly measure the amount of gases at the time of emission. The sources of uncertainty in this method are usually associated with the characteristics of the measuring instrument. The **indirect method** is when emissions or absorptions are estimated using an emission factor and activity data. In this method, the activity data usually originate from measurements, so the sources of uncertainty are also related to the characteristics of the measuring instruments of the activity data (DCC, 2021).

Once the information on the method used and the sources of uncertainty in each emission source

analysed is clear, the methodological guide for uncertainty estimation suggests performing the evaluation and quantification of the sources of uncertainty. This should be done by using a type A or B evaluation, as applicable (DCC,2021). The two types of uncertainty evaluation are described in Figure 31 below.

According to the methodological reference guide used, uncertainties shall be calculated and used as standard uncertainties (standard deviations) and not as expanded uncertainties (ranges) and shall be used in a relative percentage form.

Figure 31. Types of uncertainty assessment

Type A evaluation	Type B evaluation
<p>Applicability: Applicable when there are replicated measurements that are summarized by an average or some similar statistic.</p> <p>Process: It consists of quantifying the uncertainty associated with the calculation of the average (or similar statistic), based on the standard deviation of the data used to compute the average (or statistic used) and the amount of data.</p>	<p>Applicability: Applicable for all other cases that do not correspond to replicated measurements and that are evaluated by other methods, such as historical values, equipment manuals, calibration certificates, test reports, expert judgment, literature reference, equipment and process tolerance, among others.</p> <p>Process: To quantify these uncertainties, it is necessary to assign or assume an appropriate probability distribution to each uncertainty component.</p>

Source: Authors' own elaboration with information taken from **Dirección de Cambio Climático (DCC), Partnership for Market Readiness (PMR) del Banco Mundial y el Laboratorio Costarricense de Metrología (LCM)**. 2020. Guía metodológica para la estimación y análisis de la incertidumbre de emisiones y remociones de gases de efecto invernadero (GEI) – Programa País de Carbono Neutralidad 2.0. Costa Rica, Dirección de Cambio Climático. <https://cambioclimatico.go.cr/wp-content/uploads/2019/11/PPCN-GuiaIncertidumbre.pdf>

Once the individual standard uncertainties of each identified uncertainty component have been determined, the uncertainties are combined.

5.3 Combination of uncertainties

Combine the individual uncertainties determined in the previous step, using the mathematical models that make up the inventory calculation as a basis, i.e. the sum of emissions of the same gas or in CO₂ e, the multiplication of activity data and the emission factors, among others. In this way, the calculation of emissions or absorptions and the combination of uncertainties can be performed in parallel and the uncertainty can be determined for the total inventory or for each category of emissions separately (i.e., direct, indirect by imported energy and for significant indirect) (DCC,2021). According to the methodological guide for uncertainty estimation and analysis, the IPCC guidelines establish two rules for combining uncertainties of independent components (DCC,2021):



Important

For more details on the calculation formulas by type of assessment and selection of probability distributions in type B assessment, please refer to the Methodological Guide for the Estimation and Analysis of Uncertainty in Greenhouse Gas (GHG) Emissions and Removals – National Carbon Neutrality Programme 2.0.

- 1. Additions and subtractions:** when the components are to be combined by means of an operation containing only additions and subtractions to obtain the result, the relative standard uncertainty of such result is estimated through the equation below.

$$u_y = \frac{\sqrt{(u_1 * x_1)^2 + (u_2 * x_2)^2 + \dots + (u_n * x_n)^2}}{Y}$$



For consideration:

- The selection of the coverage factor k will depend on the level of confidence required. For a normal distribution, the value $k = 2$ produces a confidence interval of approximately 95 percent. On the other hand, the value $k = 3$ produces an interval with a confidence level of approximately 99 percent. These correspond to the values in general use and are recommended by the reference guide.
- It is recommended to express the expanded uncertainty result, U , with a maximum of two significant figures.

Where:

u_y : relative standard uncertainty of the result (e.g. the relative standard uncertainty of the total emissions inventory)

y : is the sum of the result of the emissions to be combined (e.g. the total emissions of the inventory)

u : standard uncertainty of each component (e.g. the combined uncertainty by source)

x : is the component to be combined (e.g. total emissions per source).

2. Multiplications and divisions: when the components are to be combined by means of an operation containing only multiplications

and divisions to obtain the result, the relative standard uncertainty of such result is estimated through the equation below.

$$u_y = \sqrt{(u_1^2 + u_2^2 + \dots + u_n^2)}$$

Where:

u_y : relative standard uncertainty of the result (e.g. the relative standard uncertainty of the emission of each GHG).

$u_{1,2,\dots,n}$: standard uncertainty of each component (e.g. standard uncertainty of the EF and standard uncertainty of the activity data).

5.4 Expression of total uncertainty result of the inventory

Once the combined standard uncertainties by emission category (direct, indirect by imported energy and significant indirect) and the total combined uncertainty of the inventory have been obtained, the final uncertainty result obtained. The result is reported as an interval, i.e. to express a measure of dispersion and to make it more understandable to information users.

For this purpose, a normal probability distribution will be assumed for the result and the expanded uncertainty U is estimated from a coverage factor k , using the equation below (DCC,2021).

$$U = k \times U_y$$

Where:

U : total expanded uncertainty.

k : coverage factor.

u_y : combined standard uncertainty of result.

From the above, the final result will be expressed as $y \pm U$.

An example of total uncertainty calculation is shown below.

Example: total inventory uncertainty calculation

Step 1. A company wants to assess the uncertainty associated with its 2021 emissions inventory, for which it needs to identify the sources of uncertainty of the emission sources under analysis.

Category	Emission source	Sources of uncertainty	
Direct	Truck diesel fuel consumption	Fuel dispenser	Emission factors (CO ₂ , CH ₄ and N ₂ O)
Direct	Gasoline fuel consumption green areas maintenance equipment	Fuel dispenser	Emission factors (CO ₂ , CH ₄ and N ₂ O)
Indirect - imported energy	Electricity consumption	Electric meter	Emission factor (CO ₂ e)

Step 2. Once the sources of uncertainty of the emission sources have been identified, the individual uncertainties must be estimated. For the purposes of the example, some references and assumptions will be used for the analysis, using as reference the calculation formulas given by the Methodological guide for uncertainty estimation and analysis of the Costa Rica Country Programme.

Category	Emission source	Source of uncertainty	or standard	Source of uncertainty	or standard
Direct	Diesel fuel consumption for trucks	Fuel dispenser	Tolerance established by Regulation for fuel dispensers (±0.5%) A rectangular distribution is assumed, so the following equation is applied to determine the standard u $u = \frac{0.5\%}{\sqrt{3}} = 0.289\%$	Emission factor (CO ₂)	Recommended standard uncertainty of emission factors for Costa Rica 1.66%
				Emission factor (CH ₄)	Recommended standard uncertainty of emission factors for Costa Rica 50%
				Emission factor (N ₂ O)	Recommended standard uncertainty of emission factors for Costa Rica 65.58%
Direct	Fuel consumption gasoline green areas	Fuel dispenser	Tolerance established by Regulation for fuel dispensers (±0.5%) A rectangular distribution is assumed, and the following equation is applied to determine the standard u $u = \frac{0.5\%}{\sqrt{3}} = 0.289\%$	Emission factor (CO ₂)	Recommended standard uncertainty of emission factors for Costa Rica 2.76%
				Emission factor (CH ₄)	Recommended standard uncertainty of emission factors for Costa Rica 67.17%
				Emission factor (N ₂ O)	Recommended standard uncertainty of emission factors for Costa Rica 70.10%

Indirect - Imported energy	Electricity consumption	Electric meter	<p>Maximum power meter tolerance ($\pm 0.5\%$)</p> <p>A rectangular distribution is assumed, and the following equation is applied to determine the standard u</p> $u = \frac{0.5\%}{\sqrt{3}} = 0.289\%$	Emission factor ($\text{CO}_2 \text{ e}$)	<p>Recommended standard uncertainty of emission factors for Costa Rica</p> <p>6.5 %</p>
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Step 3. Once the individual uncertainties have been estimated, the uncertainties by gas type, by emission source, by category and total inventory are combined.

Category	Emission source	u standard (Activity data)	u standard (Emission factor)	u combined standard (Per GHG)	u combined standard (Per source)
Direct	Diesel fuel consumption for trucks (73.42 t $\text{CO}_2 \text{ e}$)	0.289%	CO_2 : 1.66% (73.35 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 1.66^2}$ = 1.68%	$u = \frac{\sqrt{(1.68 \cdot 73.35)^2 + (50 \cdot 0.026)^2 + (65.58 \cdot 0.039)^2}}{73.42}$ = 1.68%
			CH_4 : 50% (0.026 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 50^2}$ = 50%	
			N_2O : 65.58% (0.039 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 1.66^2}$ = 65.58%	
Direct	Fuel consumption gasoline green areas (85 t $\text{CO}_2 \text{ e}$)	0.289%	CO_2 : 2.76% (83.98 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 2.76^2}$ = 2.78%	$u = \frac{\sqrt{(2.78 \cdot 83.98)^2 + (67.17 \cdot 0.085)^2 + (70.10 \cdot 0.935)^2}}{85}$ = 2.85%
			CH_4 : 67.17% (0.085 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 50^2}$ = 67,17%	
			N_2O : 70.10% (0.935 t $\text{CO}_2 \text{ e}$)	$u = \sqrt{0.289^2 + 1.66^2}$ = 70,10%	
Indirect - imported energy	Electricity consumption (150 t $\text{CO}_2 \text{ e}$)	0.289%	$\text{CO}_2 \text{ e}$: 6.5%	$u = \sqrt{0.289^2 + 6.5^2}$ = 6.51%	6.51%

Category	Emission source	u combined standard (Per source)	u combined standard (By category)
Direct	Diesel fuel consumption for trucks (73.42 t CO ₂ e)	1.68%	$u = \frac{\sqrt{(1.68 \cdot 73.42)^2 + (2.85 \cdot 85)^2}}{73.42 + 85} = 1.72\%$
Direct	Fuel consumption gasoline green areas (85 t CO ₂ e)	2.85%	
Indirect - imported energy	Electricity consumption (150 t CO ₂ e)	6.51%	6.51%
u total standard			$u = \frac{\sqrt{(1.72 \cdot 158.42)^2 + (6.51 \cdot 150)^2}}{158.42 + 150} = 3.29\%$

Step 4. Once the total uncertainty of the inventory has been estimated, the total uncertainty is expressed as a range, assuming a normal probability distribution, with a confidence interval of 95 % and a k=2, in order to express it as an expanded U.

$$\text{Expanded } U = 2 \times 3.29\% = \pm 6.58\%$$

The final result can be expressed as: 308.42 t CO₂e ± 6.58%

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ANNEXES



Annex 1. Carbon footprint emission factors

Table A1.1. Reference Emission Factors

Emission source/type	GHG	Emission factor	Units	Reference
Electricity consumption (imported)	CO ₂	0.0400	kg CO ₂ e/kWh	(IMN, 2022)
Use of lubricating oil (four-stroke engine)	CO ₂	0.5184	kg CO ₂ /l	(IMN, 2022)
Lubricant combustion (two-stroke engine)	CO ₂	2.549	kg CO ₂ /l	(IMN, 2022)
Lubricant combustion (two-stroke engine) residential/agriculture	CH ₄	0.348	g CH ₄ /l	(IMN, 2022)
Lubricant combustion (two-stroke engine) residential/agriculture	N ₂ O	0.021	g N ₂ O/l	(IMN, 2022)
Use of acetylene (C ₂ H ₂)	CO ₂	3.38	kg CO ₂ /kg C ₂ H ₂	Stoichiometric calculation
Use of propane (C ₃ H ₈)	CO ₂	3.00	kg CO ₂ /kg C ₃ H ₈	Stoichiometric calculation
Gasoline consumption, transportation with catalytic converter	CO ₂	2.231	kg CO ₂ /l	(IMN, 2022)
Gasoline consumption, transportation with catalytic converter	CH ₄	0.000907	kg CH ₄ /l	(IMN, 2022)
Gasoline consumption, transportation with catalytic converter	N ₂ O	0.000283	kg N ₂ O/l	(IMN, 2022)
Gasoline consumption, transportation with catalytic converter	CO ₂	2.272	kg CO ₂ /l	(IPCC, 2006)
Gasoline consumption, transportation with catalytic converter	CH ₄	0.00082	kg CH ₄ /l	(IPCC, 2006)
Gasoline consumption, transportation with catalytic converter	N ₂ O	0.00026	kg N ₂ O/l	(IPCC, 2006)
Gasoline consumption, transportation without catalytic converter	CO ₂	2.231	kg CO ₂ /l	(IMN, 2022)
Gasoline consumption, transportation without catalytic converter	CH ₄	0.001176	kg CH ₄ /l	(IMN, 2022)
Gasoline consumption, transportation without catalytic converter	N ₂ O	0.000116	kg N ₂ O/l	(IMN, 2022)
Gasoline consumption, transportation without catalytic converter	CO ₂	2.272	kg CO ₂ /l	(IPCC, 2006)
Gasoline consumption, transportation without catalytic converter	CH ₄	0.00108	kg CH ₄ /l	(IPCC, 2006)
Gasoline consumption, transportation without catalytic converter	N ₂ O	0.00010	kg N ₂ O /l	(IPCC, 2006)

Diesel consumption, transportation without catalytic converters	CO ₂	2.613	kg CO ₂ /l	(IMN, 2022)
Diesel consumption, transportation without catalytic converter	CH ₄	0.000149	kg CH ₄ /l	(IMN, 2022)
Diesel consumption, transportation without catalytic converter	N ₂ O	0.000154	kg N ₂ O /l	(IMN, 2022)
Diesel consumption, transportation without catalytic converter	CO ₂	2.613	kg CO ₂ /l	(IPCC, 2006)
Diesel consumption, transportation without catalytic converter	CH ₄	0.000138	kg CH ₄ /l	(IPCC, 2006)
Diesel consumption, transportation without catalytic converter	N ₂ O	0.000138	kg N ₂ O/l	(IPCC, 2006)
LPG consumption land transportation	CO ₂	1.611	kg CO ₂ /l	(IMN, 2022)
LPG consumption land transportation	CH ₄	0.0015835	kg CH ₄ /l	(IMN, 2022)
LPG consumption land transportation	N ₂ O	0.0000051	kg N ₂ O/l	(IMN, 2022)
Diesel electric generator	CO ₂	2.613	kg CO ₂ /l	(IMN, 2022)
Diesel electric generator	CH ₄	0.000122	kg CH ₄ /l	(IMN, 2022)
Diesel electric generator	N ₂ O	0.00002442	kg N ₂ O/l	(IMN, 2022)
Gasoline consumption, residential and agricultural	CO ₂	2.231	kg CO ₂ /l	(IMN, 2022)
Gasoline consumption, residential and agricultural	CH ₄	0.000346	kg CH ₄ /l	(IMN, 2022)
Gasoline consumption, residential and agricultural	N ₂ O	0.00002211	kg N ₂ O/l	(IMN, 2022)
Residential and agricultural diesel consumption	CO ₂	2.613	kg CO ₂ /l	(IMN, 2022)
Residential and agricultural diesel consumption	CH ₄	0.000382	kg CH ₄ /l	(IMN, 2022)
Residential and agricultural diesel consumption	N ₂ O	0.00002442	kg N ₂ O/l	(IMN, 2022)
LPG consumption, residential and agricultural	CO ₂	1.611	kg CO ₂ /l	(IMN, 2022)
LPG consumption, residential and agricultural	CH ₄	0.000139	kg CH ₄ /l	(IMN, 2022)
LPG consumption, residential and agricultural	N ₂ O	0.000002745	kg N ₂ O/l	(IMN, 2022)
Limestone-based liming	CO ₂	0.12	kg CO ₂ -C/kg	(IPCC, 2006)
Liming based on dolomite stone	CO ₂	0.13	kg CO ₂ -C/kg	(IPCC, 2006)
EF of CO ₂ from urea	CO ₂	0.2	kg CO ₂ -C/kg urea	(IPCC, 2006)
Stubble incorporated in green (RV)	CH ₄	926	kg CH ₄ /ha/year	Fallas Rojas, T. M. 2019
Stubble incorporated in green (RV)	CO ₂	1 541.76	kg CO ₂ /ha/year	Fallas Rojas, T. M. 2019
Stubble burned with chemical herbicide (RH)	CH ₄	1 592.3	kg CH ₄ /ha/year	Fallas Rojas, T. M. 2019
Stubble burned with chemical herbicide (RH)	CO ₂	2 455.72	kg CO ₂ /ha/year	Fallas Rojas, T. M. 2019
Stubble burned with chemical herbicide plus fire (RH+Q)	CH ₄	1 297.81	kg CH ₄ /ha/year	Fallas Rojas, T. M. 2019

Stubble burned with chemical herbicide plus fire (RH+Q)	CO ₂	2 175.96	kg CO ₂ /ha/year	Fallas Rojas, T. M. 2019
Landfill	CH ₄	0.0519	kg CH ₄ /kg waste	(IMN, 2022)
Compost-CH ₄	CH ₄	0.004	kg CH ₄ /kg waste	(IMN, 2022)
Compost-N ₂ O	N ₂ O	0.24	g N ₂ O/kg waste	(IMN, 2022)
Septic Tank (ARO)	CH ₄	4.38	kg CH ₄ /person/year	(IMN, 2022)/(IPCC, 2019)
Latrine 1 (dry climate, water table lower than the latrine, for use by 3 to 5 persons)	CH ₄	0.88	kg CH ₄ / person/year	(IPCC, 2019)
Latrine 2 (dry climate, water table lower than latrine, many users)	CH ₄	4.38	kg CH ₄ / person/year	(IPCC, 2019)
Latrine 3 (humid climate/discharge water use, water table higher than latrine)	CH ₄	6.13	kg CH ₄ / person/year	(IPCC, 2019)

Sources: Fallas Rojas, T. M. & Ramírez Vargas, C. 2019. Factores de emisión de CH₄ y CO₂ en rastrojo de piña (*Ananas comosus* (L.) Merr. var. *comosus*), en San Carlos, Costa Rica. <https://revistas.tec.ac.cr/index.php/agroinn/article/view/4687/4440>, Instituto Meteorológico Nacional. 2022. Factores de Emisión GEI. Costa Rica. <http://cglobal.imn.ac.cr/index.php/publications/factores-de-emision-2022/>, and IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3. Industrial processes and product use. Chapter 7. Emissions from fluorinated substitutes for ozone-depleting substances. Table 7.9. [Cited 12 May 2023]. HYPERLINK "http://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/3_Volume3/19R_V3_Ch07_ODS_Substitutes.pdf"www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/3_Volume3/19R_V3_Ch07_ODS_Substitutes.pdf.

Table A1.2. Default Estimates for charge, lifetime, and emission factors for refrigeration and conditioning systems.

air-

TABLE 7.9 (UPDATED) DEFAULT ESTIMATES ¹ FOR CHARGE, LIFETIME AND EMISSION FACTORS FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS						
Sub-application	Charge (kg)	Lifetimes (years) ²	Emission Factors (% of initial charge/year) ³		End-of-Life Emission (%)	
Factor in Equation	(M)	(d)	(k)	(x)	($\eta_{rec,d}$)	(p)
			At Time of Charge	Annual loss, Operating Lifetime	Recovery Efficiency ⁴	Initial Charge Remaining
Domestic Refrigeration	$0.05 \leq M \leq 0.5$	$12 \leq d \leq 20$	$0.2 \leq k \leq 1$	$0.1 \leq x \leq 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$0.2 \leq M \leq 6$	$10 \leq d \leq 15$	$0.5 \leq k \leq 3$	$1 \leq x \leq 15$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$50 \leq M \leq 2000$	$7 \leq d \leq 15$	$0.5 \leq k \leq 3$	$10 \leq x \leq 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Transport Refrigeration	$3 \leq M \leq 8$	$6 \leq d \leq 9$	$0.2 \leq k \leq 1$	$15 \leq x \leq 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Industrial Refrigeration including Food Processing and Cold Storage	$10 \leq M \leq 10,000$	$15 \leq d \leq 30$	$0.5 \leq k \leq 3$	$7 \leq x \leq 25$	$0 < \eta_{rec,d} < 90$	$50 < p < 100$
Chillers	$10 \leq M \leq 2000$	$15 \leq d \leq 30$	$0.2 \leq k \leq 1$	$2 \leq x \leq 15$	$0 < \eta_{rec,d} < 95$	$80 < p < 100$
Residential and Commercial A/C, including Heat Pumps	$0.5 \leq M \leq 100$	$10 \leq d \leq 20$	$0.2 \leq k \leq 1$	$1 \leq x \leq 10$	$0 < \eta_{rec,d} < 80$	$0 < p < 80$
Mobile A/C	$5 \leq M \leq 6500$ (maritime) $10 \leq M \leq 30$ (railway) $4 \leq M \leq 18$ (busses) $0.5 \leq M \leq 2$ (other MAC)	$9 \leq d \leq 16$	$0.2 \leq k \leq 0.5$	$20 \leq x \leq 40$ (maritime) $5 \leq x \leq 20$ (railway) $10 \leq x \leq 20$ (other MAC)	$0 < \eta_{rec,d} < 50$	$0 < p < 50$

Source:

¹ UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003), Japan Refrigeration and Air Conditioning Industry Association (2009), Gallagher et al (2014), Umweltbundesamt (2015). For information on mobile A/C charge and mobile A/C emission factors for annual loss during operating lifetime: Schwarz and Rhiemeier (2007) and Gallagher et al (2014).

^{2,3} Lower value for developed countries and higher value for developing countries

⁴ The lower threshold (0%) highlights that there is no recovery in some countries.

Source: IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3. Industrial processes and product use. Chapter 7. Emissions from fluorinated substitutes for ozone-depleting substances. Table 7.9. [Cited 12 May 2023]. www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/3_Volume3/19R_V3_Ch07_ODS_Substitutes.pdf

Table A1.3. Default Emission Factors to Estimate Direct N₂O Emissions from managed soils

TABLE 11.1 (UPDATED)					
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N₂O EMISSIONS FROM MANAGED SOILS					
Emission factor	Aggregated		Disaggregated		
	Default value	Uncertainty range	Disaggregation ⁴	Default value	Uncertainty range
EF ₁ for N additions from synthetic fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon ¹ [kg N ₂ O–N (kg N) ⁻¹]	0.010	0.002 – 0.018	Synthetic fertiliser inputs ⁵ in wet climates	0.016	0.013 – 0.019
			Other N inputs ⁶ in wet climates	0.006	0.001 – 0.011
			All N inputs in dry climates	0.005	0.000 – 0.011
EF _{1FR} for flooded rice fields ^{2,7} [kg N ₂ O–N (kg N) ⁻¹]	0.004	0.000 – 0.029	Continuous flooding	0.003	0.000 – 0.010
			Single and multiple drainage	0.005	0.000 – 0.016
EF _{3PRP, CPP} for cattle (dairy, non-dairy and buffalo), poultry and pigs ³ [kg N ₂ O–N (kg N) ⁻¹]	0.004	0.000– 0.014	Wet climates	0.006	0.000 – 0.027
			Dry climates	0.002	0.000 – 0.007
EF _{3PRP, SO} for sheep and other animals ^{3,3} [kg N ₂ O–N (kg N) ⁻¹]	0.003	0.000 – 0.010	-	-	-

Sources:

¹ Stehfest & Bouwman 2006; van Lent *et al.* 2015; Grace *et al.* 2016; van der Weerden *et al.* 2016; Albanito *et al.* 2017; Cayuela *et al.* 2017; Liu *et al.* 2017; Rochette *et al.* 2018.

² Akiyama *et al.* 2005; Albanito *et al.* 2017; Cayuela *et al.* 2017.

³ Yamulki *et al.* 1998; Galbally *et al.* 2000; Liebig *et al.* 2008; Cai & Akiyama 2016; Cardenas *et al.* 2016; Di *et al.* 2016; Hoogendoorn *et al.* 2016; Hyde *et al.* 2016; Krol *et al.* 2016; Li *et al.* 2016; Luo *et al.* 2016; Marsden *et al.* 2016; Misselbrook *et al.* 2016; Nichols *et al.* 2016; O'Connor *et al.* 2016; Owens *et al.* 2016; Pelster *et al.* 2016; Ward *et al.* 2016; Balvert *et al.* 2017; Byrnes *et al.* 2017; Forrestal *et al.* 2017; Marsden *et al.* 2017; Owens *et al.* 2017; Thomas *et al.* 2017a, b; Tully *et al.* 2017; van der Weerden *et al.* 2017; Cardoso *et al.* 2018; Chadwick *et al.* 2018; Nichols *et al.* 2018.

⁴ Disaggregation of EF₁ and EF_{3PRP, CPP} by climate (based on long-term averages): Wet climates occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm (cf. Figure 3A.5.1 in Chapter 3 of Vol. 4 provides a map subdividing wet and dry climates based on these criteria). In wet climates, the EF₁ is further disaggregated by synthetic fertiliser N inputs and other N inputs.

⁵ This emission factor should be used for synthetic fertiliser applications, and fertiliser mixtures that include both synthetic and organic forms of N.

⁶ Other N input refers to organic amendments, animal manures (e.g. slurries, digested manures), N in crop residues and mineralised N from soil organic matter decomposition.

⁷ Disaggregation of EF_{1FR}: Single and multiple drainage also include alternate wetting and drying. Disaggregated EF_{1FR} for rain-fed and deep-water systems not provided due to lack of data. The EF₁ should be used for upland rice.

Notes:

EF₁: Uncertainty range of disaggregated EF₁ based on the 95% confidence interval of fitted values. Uncertainty range of aggregated EF₁ is based on the 2.5th to 97.5th percentile of the dataset (See methods, data and results in Annex 11A.2).

EF_{1FR}: Uncertainty range is based on the 2.5th to 97.5th percentile (See methods and data in Annex 11A.3).

EF_{3PRP, CPP} and EF_{3PRP, SO}: Uncertainty range is based on the 2.5th to 97.5th percentile (See methods and data in Annex 11A.4).

For EF₂, see guidance in 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Chapter 2, Table 2.5.

Source: IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land use. Chapter 11. N₂O emissions from managed soils and CO₂ emissions from lime and urea application. Table 11.1. [Cited 22 May 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

Table A1.4. Default emissions, volatilization and leaching factors for indirect soil N₂O emissions.

TABLE 11.3 (UPDATED) DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N ₂ O EMISSIONS					
Factor	Aggregated		Disaggregated		
	Default value	Uncertainty range	Disaggregation	Default value	Uncertainty range
EF ₄ [N volatilisation and re-deposition] ¹ , kg N ₂ O–N (kg NH ₃ –N + NO _x –N volatilised) ⁻¹	0.010	0.002 - 0.018	Wet climate	0.014	0.011 – 0.017
			Dry climate	0.005	0.000 – 0.011
EF ₅ [leaching/runoff] ² , kg N ₂ O–N (kg N leaching/runoff) ⁻¹	0.011	0.000 - 0.020	-	-	-
Frac _{GASF} [Volatilisation from synthetic fertiliser] ³ , (kg NH ₃ –N + NO _x –N) (kg N applied) ⁻¹	0.11	0.02 - 0.33	Urea	0.15	0.03 – 0.43
			Ammonium-based	0.08	0.02 – 0.30
			Nitrate-based	0.01	0.00 – 0.02
			Ammonium-nitrate-based	0.05	0.00 – 0.20
Frac _{GASM} [Volatilisation from all organic N fertilisers applied, and dung and urine deposited by grazing animals] ⁴ , (kg NH ₃ –N + NO _x –N) (kg N applied or deposited) ⁻¹	0.21	0.00 - 0.31	-	-	-
Frac _{LEACH(H)} [N losses by leaching/runoff in wet climates] ⁵ , kg N (kg N additions or deposition by grazing animals) ⁻¹	0.24	0.01 – 0.73	-	-	-

Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land use.* Chapter 11. N₂O emissions from managed soils and CO₂ emissions from lime and urea application. Table 11.3. [Cited 22 May 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

Table A1.5. Default emissions factors for CH₄ and N₂O emissions from biological treatment of waste

TABLE 4.1 DEFAULT EMISSION FACTORS FOR CH ₄ AND N ₂ O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE					
Type of biological treatment	CH ₄ Emission Factors (g CH ₄ /kg waste treated)		N ₂ O Emission Factors (g N ₂ O/kg waste treated)		Remarks
	on a dry weight basis	on a wet weight basis	on a dry weight basis	on a wet weight basis	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.24 (0.06 - 0.6)	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
Anaerobic digestion at biogas facilities	2 (0 - 20)	0.8 (0 - 8)	Assumed negligible	Assumed negligible	
Sources: Arnold, M.(2005) Personal communication; Beck-Friis (2002); Detzel <i>et al.</i> (2003); Petersen <i>et al.</i> 1998; Hellebrand 1998; Hogg, D. (2002); Vesterinen (1996). Note: Default emission factors for CH ₄ for anaerobic digestion already account for CH ₄ recovery.					

Source: IPCC. 2006. *IPCC 2006 Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* Chapter 4. Biological treatment of solid waste. Table 4.1. [Cited 22 May 2023]. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

Table A1.6. Emission factors (g kg⁻¹ of dry matter burned) for different types of burning

TABLE 2.5 EMISSION FACTORS (g kg⁻¹ DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING. VALUES ARE MEANS ± SD AND ARE BASED ON THE COMPREHENSIVE REVIEW BY ANDREA AND MERLET (2001) (To be used as quantity 'G _{ef} ' in Equation 2.27)					
Category	CO ₂	CO	CH ₄	N ₂ O	NO _x
Savanna and grassland	1613 ± 95	65 ± 20	2.3 ± 0.9	0.21 ± 0.10	3.9 ± 2.4
Agricultural residues	1515 ± 177	92 ± 84	2.7	0.07	2.5 ± 1.0
Tropical forest	1580 ± 90	104 ± 20	6.8 ± 2.0	0.20	1.6 ± 0.7
Extra tropical forest	1569 ± 131	107 ± 37	4.7 ± 1.9	0.26 ± 0.07	3.0 ± 1.4
Biofuel burning	1550 ± 95	78 ± 31	6.1 ± 2.2	0.06	1.1 ± 0.6

Note: The "extra tropical forest" category includes all other forest types.
Note: For combustion of non-woody biomass in Grassland and Cropland, CO₂ emissions do not need to be estimated and reported, because it is assumed that annual CO₂ removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.

Source: IPCC. 2019. *Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry, and Other Land Uses.* Chapter 2. Generic methodologies applicable to multiple land use categories. Table 2.5. [Cited 4 August 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch02_Generic%20Methods.pdf

Table A1.7. Wastewater treatment organic removal fractions (TOWREM) according to treatment type

TABLE 6.6B (NEW) WASTEWATER TREATMENT ORGANICS REMOVAL FRACTIONS (TOW_{REM}) ACCORDING TO TREATMENT TYPE		
Treatment Type	Default	Range
Untreated systems	0	0 – 0.1
Primary (mechanical treatment plants)	0.40	0.25 – 0.50
Primary + Secondary (biological treatment plants)	0.85	0.80 – 0.90
Primary + Secondary + Tertiary (advanced biological treatment plants)	0.90	0.80 – 0.95
Septic tank/septic system	0.625	0.50 – 0.60
Latrines – Dry climate, groundwater table lower than latrine, small family (3–5 persons)	0.1	0.05 – 0.15
Latrines – Dry climate, groundwater table lower than latrine, communal (many users)	0.5	0.4 – 0.6
Latrines – Wet climate/flush water use, groundwater table higher than latrine	0.7	0.7 – 1.0

Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* Chapter 6. Wastewater treatment and disposal. Table 6.6B. [Cited 12 June 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table A1.8. Default MCF values and resultant EFs (CH₄) for industrial wastewater

TABLE 6.8 (UPDATED)				
DEFAULT MCF VALUES AND RESULTANT EFs FOR INDUSTRIAL WASTEWATER				
Type of treatment and discharge pathway or system	Comments	MCF¹ (Range)	EF² (kg CH₄/kg BOD)	EF² (kg CH₄/kg COD)
Discharge from treated or untreated system				
Discharge to aquatic environments (Tier 1)	Most aquatic environments including rivers are supersaturated in CH ₄ . Nutrient oversupply will increase CH ₄ emissions. Environments where carbon accumulates in sediments have higher potential for methane generation.	0.11 (0.004 – 0.27)	0.068	0.028
Discharge to aquatic environments other than reservoirs, lakes, and estuaries (Tier 2)	Most aquatic environments including rivers are supersaturated in CH ₄ . Nutrient oversupply will increase CH ₄ emissions.	0.035 ³ (0.004 – 0.06)	0.021	0.009
Discharge to reservoirs, lakes, and estuaries (Tier 2)	Environments where carbon accumulates in sediments have higher potential for methane generation.	0.19 ³ (0.08 – 0.27)	0.114	0.048
Discharge to soil	Sludge and/or wastewater discharge to soil may be a source of CH ₄ for fertilisation	Emissions reported in Volume 4		
Wastewater treatment system				
Centralised, aerobic treatment plant	Some CH ₄ can be emitted from settling basins and other anaerobic pockets. For treatment plants that are receiving wastewater beyond the design capacity, inventory compilers should judge the amount of organic material removed in sludge accordingly.	0 (0 – 0.1)	0	0
Anaerobic reactor (e.g., upflow anaerobic sludge blanket digestion (UASB))	CH ₄ recovery is not considered here.	0.8 (0.8 – 1.0)	0.48	0.2
Anaerobic shallow lagoon and facultative lagoons	Depth less than 2 metres, use expert judgment.	0.2 (0 – 0.3)	0.12	0.05
Anaerobic deep lagoon	Depth more than 2 metres.	0.8 (0.8 – 1.0)	0.48	0.2

Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* Chapter 6. Wastewater treatment and disposal. Table 6.8. [Cited 12 June 2023]. <https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol5.html>

Table A1.9. Default EF (N₂O) Values for domestic and industrial wastewater

TABLE 6.8A (NEW) DEFAULT EF VALUES FOR DOMESTIC AND INDUSTRIAL WASTEWATER			
Type of treatment and discharge pathway or system	Comments	EF¹ (kg N₂O-N/kg N)	Range
Discharge from treated or untreated system, EF_{EFFLUENT}			
Freshwater, estuarine, and marine discharge (Tier 1)	Based on limited field data and on specific assumptions regarding the occurrence of nitrification and denitrification in rivers and in estuaries	0.005 ²	0.0005 – 0.075
Nutrient-impacted and/or hypoxic freshwater, estuarine, and marine environments (Tier 3, if needed)	Higher emissions are associated with nutrient-impacted/hypoxic water such as eutrophic lakes, estuaries and rivers, or locations where stagnant conditions occur. See section 6.3.1.2 for more information.	0.019 ²	0.0041 – 0.091
Discharge to soil	Emissions reported in Volume 4		
Wastewater treatment system, EF_{plants}			
Centralised, aerobic treatment plant	N ₂ O is variable and can be significant	0.016 ¹	0.00016 – 0.045
Anaerobic reactor	N ₂ O is not significant	0	0 – 0.001
Anaerobic lagoons	N ₂ O is not significant	0	0 – 0.001
Constructed wetlands	<i>See 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC 2014)</i>		
Septic tank	N ₂ O is not significant	0	0 – 0.001
Septic tank + land dispersal field	N ₂ O is emitted by the soil dispersal system	0.0045	0 – 0.005
Latrine	N ₂ O is not significant	0	0 – 0.001
Sludge treatment system			
Anaerobic digester for sludge	N ₂ O is not significant	0	0
Composting	See Chapter 4 for emissions methodology	See Chapter 4, Table 4.1	
Incineration and open burning	See Chapter 5 for emissions methodology	See Chapter 5	
Sources: Based on scientific literature and expert judgment by Lead Authors of this section.			
¹ See Annex 6A.5.			
² See Annex 6A.6.			

Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* Chapter 6. Wastewater treatment and disposal. Table 6.8A. [Cited 12 June 2023]. <https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol5.html>

Table A1.10. Wastewater Treatment Nitrogen Removal Fractions (N_{REM}) According to the treatment type

TABLE 6.10C (NEW) WASTEWATER TREATMENT NITROGEN REMOVAL FRACTIONS (N_{REM}) ACCORDING TO TREATMENT TYPE		
Treatment Type	Default	Range
No treatment	0 ¹⁻³	0 ¹⁻³
Primary (mechanical)	0.10 ¹⁻³	0.05 – 0.20 ¹⁻³
Secondary (biological)	0.40 ¹⁻³	0.35 – 0.55 ¹⁻³
Tertiary (advanced biological)	0.80 ¹⁻⁴	0.45 – 0.85 ¹⁻⁴
Septic tank	0.15 ¹⁻³	0.10 – 0.25 ¹⁻³
Septic tank + land dispersal field	0.68 ⁵	0.62 – 0.73 ⁵
Latrine	0.12 ⁶	0.07 – 0.21 ⁶
Sources: ¹ Kristensen <i>et al.</i> (2004) ² Van Drecht <i>et al.</i> (2009) ³ Based on expert judgment by Lead Authors of this section. ⁴ Ekama and Wentzel (2008) ⁵ Andreoli <i>et al.</i> (1979) ⁶ EMEP/EAA (2016)		

Source: IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* Chapter 6. Wastewater treatment and disposal. Table 6.10C. [Cited 12 June 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table A1.11. Default Reference Condition Soil Organic Carbon Stock (SOC_{REF}) for mineral soils (tonnes of carbon per hectare in 0-30 cm of depth)

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

Note: Data are derived from Batjes (2010) and Batjes (2011) unless otherwise noted through the use of superscripts.

¹ NA denotes that soil categories the soil category may occur in a climate zone, but no data was available. NO denotes that the soil type does not normally occur within a climate zone. ² All values are presented in the format of the mean for the soil by climate combination ± the 95% confidence limit expressed as a percentage of the mean (that is ± 1.96 * standard error /mean *100). Values in parentheses are the number of soils included in the derivation of mean and standard error values for each combination of soil and climate types. ³ Indicates where no data were available from Batjes (2011) but values were derived for the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and have been used in the table. No values of n were available. A nominal error estimate of ±90% of the mean was assigned as per the 2006 IPCC Guidelines. ⁴ Indicates where no data were available either from Batjes (2011) or in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Mean values present the default values used in the 1996 IPCC Guidelines. No values of n were available. A nominal error estimate of ±90% of the mean was assigned as per the 2006 IPCC Guidelines. ⁵ Climate classes are defined according to (IPCC 2006, p. 3.39) using elevation, mean annual temperature, mean annual precipitation, mean annual precipitation to potential evapotranspiration ratio and frost occurrence. ⁶ Soil classes are inferred from the FAO-1990/WRB-2006 classification in accordance with IPCC (2006, p. 3.40 - 3.41). ⁷ Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification: Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification: Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols). ⁸ Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification: Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification: Ultisols, Oxisols, acidic Alfisols). ⁹ Soils (regardless of taxonomic classification) having > 70% sand and < 8% clay (in WRB classification: Arenosols; in USDA classification: Psamments). ¹⁰ Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols). ¹¹ Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols). ¹² Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders). ¹³ The Boreal dry and Boreal moist zones and the Polar dry and Polar moist zones were not differentiated. Results presented represent the SOC₃₀ stocks for the undifferentiated (undiff.) Boreal (Bx) and Polar (Px) classes.

Source: IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land use. Generic methodologies applicable to multiple land-use categories. Table 2.3. [Cited 3 July 2023]. <https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol5.html>

Table A1.12. Relative Carbon Stock Change Factors (F_{LU} , F_{MG} y F_I) (Over 20 years) for management activities on cropland

TABLE 5.5 (UPDATED)						
RELATIVE CARBON STOCK CHANGE FACTORS (F_{LU}, F_{MG}, AND F_I) (OVER 20 YEARS) FOR MANAGEMENT ACTIVITIES ON CROPLAND						
Factor value type	Level	Temperature regime	Moisture regime¹	IPCC defaults	Error^{2,3}	Description
Land use ⁵ (F_{LU})	Long-term cultivated	Cool Temperate/Boreal	Dry	0.77	±14%	Represents area that has been converted from native conditions and continuously managed for predominantly annual crops over 50 yrs. Land-use factor has been estimated under a baseline condition of full tillage and nominal (“medium”) carbon input levels. Input and tillage factors are also applied to estimate carbon stock changes, which includes changes from full tillage and medium input.
			Moist	0.70	±12%	
		Warm Temperate	Dry	0.76	±12%	
			Moist	0.69	±16%	
		Tropical	Dry	0.92	±13%	
			Moist/Wet	0.83	±11%	
Land use ⁶ (F_{LU})	Paddy rice	All	Dry and Moist/Wet	1.35	±4%	Long-term (> 20 year) annual cropping of wetlands (paddy rice). Can include double-cropping with non-flooded crops. For paddy rice, tillage and input factors are not used.
Land use ⁵ (F_{LU})	Perennial/Tree Crop	Temperate/Boreal	Dry and Moist	0.72	±22%	Long-term perennial tree crops such as fruit and nut trees, coffee and cacao.
		Tropical	Dry and Moist/Wet	1.01	±25%	
Land use (F_{LU})	Set aside (< 20 yrs)	Temperate/Boreal and Tropical	Dry	0.93	±11%	Represents temporary set aside of annually cropland (e.g., conservation reserves) or other idle cropland that has been revegetated with perennial grasses.
			Moist/Wet	0.82	±17%	
		Tropical montane ⁴⁴	n/a	0.88	±50%	
Tillage (F_{MG})	Full	All	Dry and Moist/Wet	1.00	n/a	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g., <30%) of the surface is covered by residues.
Tillage ⁷ (F_{MG})	Re-duced	Cool Temperate/Boreal	Dry	0.98	±5%	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30% coverage by residues at planting.
			Moist	1.04	±4%	
		Warm Temperate	Dry	0.99	±3%	
			Moist	1.05	±4%	
		Tropical	Dry	0.99	±7%	
			Moist/Wet	1.04	±7%	
Tillage ⁷ (F_{MG})	No-till	Cool Temperate/Boreal	Dry	1.03	±4%	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.
			Moist	1.09	±4%	
		Warm Temperate	Dry	1.04	±3%	
			Moist	1.10	±4%	
		Tropical	Dry	1.04	±7%	
			Moist/Wet	1.10	±5%	

TABLE 5.5 (UPDATED) (CONTINUED)
RELATIVE CARBON STOCK CHANGE FACTORS (FLU, FMG, AND FI) (OVER 20 YEARS) FOR MANAGEMENT ACTIVITIES ON CROPLAND

Factor value type	Level	Temperature regime	Moisture regime ¹	IPCC defaults	Error ^{2,3}	Description
Input (Fi)	Low	Temperate/Boreal	Dry	0.95	±13%	Low residue return occurs when there is removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g., vegetables, tobacco, cotton), no mineral fertilization or N-fixing crops.
			Moist	0.92	±14%	
		Tropical	Dry	0.95	±13%	
			Moist/ Wet	0.92	±14%	
Tropical montane ⁴	n/a	0.94	±50%			
Input (Fi)	Medium	All	Dry and Moist/ Wet	1.00	n/a	Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g., manure) is added. Also requires mineral fertilization or N-fixing crop in rotation.
Input (Fi)	High without manure	Temperate/Boreal and Tropical	Dry	1.04	±13%	Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see row below).
			Moist/ Wet	1.11	±10%	
		Tropical montane ⁴	n/a	1.08	±50%	
Input (Fi)	High – with manure	Temperate/Boreal and Tropical	Dry	1.37	±12%	Represents significantly higher C input over medium C input cropping systems due to an additional practice of regular addition of animal manure.
			Moist/ Wet	1.44	±13%	
		Tropical montane ⁴	n/a	1.41	±50%	

Notes: Long-term cultivation, perennial crops paddy rice and tillage management factors were derived using methods provided in Annex 5A1.

¹Where data were sufficient, separate values were determined for temperate and tropical temperature regimes; and dry, moist, and wet moisture regimes. Temperate and tropical zones correspond to those defined in Chapter 3; wet moisture regime corresponds to the combined moist and wet zones in the tropics and moist zone in temperate regions.

²± two standard deviations, expressed as a percent of the mean; where sufficient studies were not available for a statistical analysis to derive a default, uncertainty was assumed to be ± 50% based on expert opinion. NA denotes ‘Not Applicable’, where factor values constitute defined reference values, and the uncertainties are reflected in the reference C stocks and stock change factors for land use.

³ This error range does not include potential systematic error due to small sample sizes that may not be representative of the true impact for all regions of the world.

⁴There were not enough studies to estimate some of the stock change factors for mineral soils in the tropical montane climate region. As an approximation, the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical montane climate.

Sources:

⁵ The following references used for land-use factors (other than paddy rice): Aborisade and Aweto 1990; Adachi *et al.* 2006; Agbenin and Goladi 1997; Aina 1979; Alcantara *et al.* 2004; Allen 1985; An *et al.* 2003; Ashagrie *et al.* 2005; Assad *et al.* 2013; Aweto 1981; Aweto and Ayuba 1988; Aweto and Ayuba 1993; Aweto and Ishola 1994; Ayanaba *et al.* 1976; Banaticla and Lasco 2006; Bashkin and Binkley 1998; Battle-Bayer *et al.* 2010; Bautista-Cruz and del Castillo 2005; Berhongaray *et al.* 2013; Bernardi *et al.* 2007; Bernhardreversat 1988; Berthrong *et al.* 2012; Bertol and Santos 1995; Beyer 1994; Binkley *et al.* 2004; Binkley and Resh 1999; Bonde *et al.* 1992; Bowman and Anderson 2002; Brand and Pfund 1998; Brown and Lugo 1990; Bruun *et al.* 2006; Burke *et al.* 1995; Burke *et al.* 1995; Buschbacher *et al.* 1988; Buschiazzo *et al.* 1998; Buyanovksy *et al.* 1987; Cadisch *et al.* 1996; Cai *et al.* 2008; Cambardella and Elliott 1994; Cambardella and Elliott 1992; Campos *et al.* 2007; Cao *et al.* 2004; Carvalho *et al.* 2009; Carvalho *et al.* 2009; Cerri *et al.* 1991; Cerri *et al.* 2003; Cerri *et al.* 2007; Chan 1997; Chandran *et al.* 2009; Chen *et al.* 2007; Chen 2006; Chia *et al.* 2017; Chidumayo and Kwibisa 2003; Chiti *et al.* 2014; Chone *et al.* 1991; Cleveland *et al.* 2003; Collins *et al.* 1999; Conant *et al.* 2001; Conti *et al.* 2014; Cook *et al.* 2014; Corazza *et al.* 1999; D’Annunzio *et al.* 2008; da Silva-Junior *et al.* 2009; Dai *et al.* 2008a; Dai *et al.* 2008b; Dalal *et al.* 2005; Dalal and Mayer 1986; Dawoe *et al.* 2014; de Blecourt *et al.* 2013; de Camargo *et al.* 1999; de Freitas *et al.* 2000; de Koning *et al.* 2003; de Moraes *et al.* 2002; de Moraes *et al.* 1996; de Neergaard *et al.* 2008; Dechert *et al.* 2004; Delelegn *et al.* 2017; Denef *et al.* 2007; Desjardins *et al.* 1994; Desjardins *et al.* 2004; Detwiler 1986; Eaton and Lawrence 2009; Eclesia *et al.* 2012; Eden *et al.* 1990; Ekanade 1991; Elliott *et al.* 1991; Elmore and Asner 2006; England *et al.* 2016; Epron *et al.* 2009; Erickson *et al.* 2001; Fabrizzi *et al.* 2009; Farley *et al.* 2004; Feldpausch *et al.* 2004; Feller *et al.* 2001; Fernandes *et al.* 2002; Fernandez *et al.* 2012; Fisher *et al.* 1994; Follett *et al.* 1997; Freibauer 1996; Freixo *et al.* 2002; Fu *et al.* 2000; Fu *et al.* 2001; Han *et al.* 2004; Han *et al.* 2005; Harden *et al.* 1999; Hölscher *et al.* 1997; Hou *et al.* 2008;

Source: IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land use. Chapter 5. Cropland. Table 5.5. [Cited 3 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch02_Generic%20Methods.pdf

Table A1.13. Average annual increase in above-ground biomass in natural regeneration, by general category (tonnes of dry matter/ha/year)

TABLE 3A.1.5 AVERAGE ANNUAL INCREMENT IN ABOVEGROUND BIOMASS IN NATURAL REGENERATION BY BROAD CATEGORY (tonnes dry matter/ha/year) (To be used for G_W in Equation 3.2.5)						
Tropical and Sub-Tropical Forests						
Age Class	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
	R > 2000	2000>R>1000		R<1000	R>1000	R<1000
Africa						
≤20 years	10.0	5.3	2.4 (2.3 – 2.5)	1.2 (0.8 – 1.5)	5.0	2.0 (1.0 – 3.0)
>20 years	3.1 (2.3 -3.8)	1.3	1.8 (0.6 – 3.0)	0.9 (0.2 – 1.6)	1.0	1.5 (0.5 – 4.5)
Asia & Oceania						
Continental						
≤20 years	7.0 (3.0 – 11.0)	9.0	6.0	5.0	5.0	1.0
>20 years	2.2 (1.3 – 3.0)	2.0	1.5	1.3 (1.0 – 2.2)	1.0	0.5
Insular						
≤20 years	13.0	11.0	7.0	2.0	12.0	3.0
>20 years	3.4	3.0	2.0	1.0	3.0	1.0
America						
≤20 years	10.0	7.0	4.0	4.0	5.0	1.8
>20 years	1.9 (1.2 – 2.6)	2.0	1.0	1.0	1.4 (1.0 – 2.0)	0.4
Temperate Forests						
Age Class		Coniferous			Broadleaf	
≤20 years		3.0 (0.5 – 6.0)			4.0 (0.5 – 8.0)	
>20 years		3.0 (0.5 – 6.0)			4.0 (0.5 – 7.5)	
Boreal forests						
Age Class	Mixed Broadleaf-Coniferous	Coniferous	Forest-Tundra	Broadleaf		
Eurasia						
≤20 years	1.0	1.5	0.4 (0.2 – 0.5)	1.5 (1.0 – 2.0)		
>20 years	1.5	2.5	0.4 (0.2 – 0.5)	1.5		
America						
≤20 years	1.1 (0.7 – 1.5)	0.8 (0.5 – 1.0)	0.4 (0.2 – 0.5)	1.5 (1.0 – 2.0)		
>20 years	1.1 (0.7 – 1.5)	1.5 (0.5 – 2.5)	0.4 (0.2 – 0.5)	1.3 (1.0 – 1.5)		
Note: R= annual rainfall in mm/yr Note: Data are given as mean value and as the range of possible values.						

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Table 3A.1.5. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.14. Average annual increase in above-ground biomass in plantations, by general category (tonnes of dry matter/ha/year)

<p align="center">Table 3A.1.6 ANNUAL AVERAGE ABOVEGROUND BIOMASS INCREMENT IN PLANTATIONS BY BROAD CATEGORY (tonnes dry matter/ha/year) (To be used for G_w in Equation 3.2.5. In case of missing values it is preferred to use stemwood volume increment data I_v from Table 3A.1.7)</p>							
<p align="center">Tropical and sub-tropical Forests</p>							
	Age Class	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
		R >2000	2000 > R > 1000		R < 1000	R > 1000	R < 1000
Africa							
Eucalyptus spp	≤20 years	-	20.0	12.6	5.1 (3.0-7.0)	-	-
	>20 years	-	25.0	-	8.0 (4.9-13.6)	-	-
Pinus sp	≤20 years	18.0	12.0	8.0	3.3 (0.5-6.0)	-	-
	>20 years	-	15.0	11.0	2.5	-	-
others	≤20 years	6.5 (5.0-8.0)	9.0 (3.0-15.0)	10.0 (4.0-16.0)	15.0	11.0	-
	>20 years	-	-	-	11.0	-	-
Asia							
Eucalyptus spp	All	5.0 (3.6-8.0)	8.0	15.0 (5.0-25.0)	-	3.1	-
other species	-	5.2 (2.4-8.0)	7.8 (2.0-13.5)	7.1 (1.6-12.6)	6.45 (1.2-11.7)	5.0 (1.3-10.0)	-
America							
Pinus	-	18.0	14.5 (5.0 - 19.0)	7.0 (4.0 - 10.3)	5.0	14.0	-
Eucalyptus	-	21.0 (6.4 - 38.4)	16.0 (6.4 - 32.0)	16.0 (6.4 - 32.0)	16.0	13.0 (8.5 - 17.5)	-
Tectona	-	15.0	8.0 (3.8 - 11.5)	8.0 (3.8 - 11.5)	-	2.2	-
other broadleaved	-	17.0 (5.0 - 35.0)	18.0 (8.0 - 40.0)	10.5 (3.2 - 11.8)	-	4.0	-
<p>Note 1 : R= annual rainfall in mm/yr</p> <p>Note 2 : Data are given as mean value and as the range of possible values.</p> <p>Note 3 : Some Boreal data were calculated from original values in Zakharov <i>et al.</i> (1962), Zagreev <i>et al.</i> (1993), Isaev <i>et al.</i> (1993) using 0.23 as belowground/aboveground biomass ratio and assuming a linear increase in annual increment from 0 to 20 years.</p> <p>Note 4 : For plantations in temperate and boreal zones, it is good practice to use stemwood volume increment data (I_v in Equation 3.2.5) instead of above ground biomass increment as given in above table.</p>							

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Box 3A.1.6. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.15. Mean below-ground/above-ground biomass ratio (root-shoot ratio, R) in natural regeneration, by broad categories

Vegetation Type		Mean (t d.m./t d.m.)
Tropical/subtropical forest	Natural regeneration (≤ 20 years) /Secondary Forest (> 20 years)	0,42
Coniferous forest/ plantation	Pine forest plantation	0,32
Other	Eucalyptus plantation forest	0,48
	Teak plantation forest	0,48
	Forest plantation of other species	0,48

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Box 3A.1.8. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.16. Basic wood densities (D) of logs (tonnes of dry matter/m³ of freshly felled volume) for tropical tree species

TABLE 3A.1.9-2					
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m³ fresh volume) FOR TROPICAL TREE SPECIES					
(To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)					
TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
Acacia leucophloea	0.76	Albizia spp.	0.52	Afzelia spp.	0.67
Adina cordifolia	0.58, 0.59+	Alcornea spp.	0.34	Aidia ochroleuca	0.78*
Aegle marmelo	0.75	Alexa grandiflora	0.6	Albizia spp.	0.52
Agathis spp.	0.44	Alnus ferruginea	0.38	Allanblackia floribunda	0.63*
Aglaia llanosiana	0.89	Anacardium excelsum	0.41	Allophylus africanus f. acuminatus	0.45
Alangium longiflorum	0.65	Anadenanthera macrocarpa	0.86	Alstonia congensis	0.33
Albizzia amara	0.70*	Andira retusa	0.67	Amphimas pterocarpoides	0.63*
Albizzia falcata	0.25	Aniba riparia lduckeii	0.62	Anisophyllea obtusifolia	0.63*
Aleurites trisperma	0.43	Antiaris africana	0.38	Annonidium mannii	0.29*
Alnus japonica	0.43	Apeiba echinata	0.36	Anopyxis klaineana	0.74*
Alphitonia zizyphoides	0.5	Artocarpus comunis	0.7	Anthocleista keniensis	0.50*
Alphonsea arborea	0.69	Aspidosperma spp. (aracanga group)	0.75	Anthothona macrophylla	0.78*
Alseodaphne longipes	0.49	Astronium lecontei	0.73	Anthostemma aubryanum	0.32*
Alstonia spp.	0.37	Bagassa guianensis	0.68, 0.69+	Antiaris spp.	0.38
Amoora spp.	0.6	Banara guianensis	0.61	Antrocaryon klaineianum	0.50*
Anisophyllea zeylanica	0.46*	Basiloxylon exelsum	0.58	Aucoumea klaineana	0.37
Anisoptera spp.	0.54	Beilschmiedia sp.	0.61	Autranella congolensis	0.78
Anogeissus latifolia	0.78, 0.79+	Bertholletia excelsa	0.59, 0.63+	Baillonella toxisperma	0.71
Anthocephalus chinensis	0.36, 0.33+	Bixa arborea	0.32	Balanites aegyptiaca	0.63*
Antidesma pleuricum	0.59	Bombacopsis sepium	0.39	Baphia kirkii	0.93*
Aphanamiris perrottetiana	0.52	Borojoa patinoi	0.52	Beilschmiedia louisii	0.70*
Araucaria bidwillii	0.43	Bowdichia spp.	0.74	Beilschmiedia nitida	0.50*
Artocarpus spp.	0.58	Brosimum spp. (alicastrum group)	0.64, 0.66+	Berlinia spp.	0.58
Azadirachta spp.	0.52	Brosimum utile	0.41, 0.46+	Blighia welwitschii	0.74*
Balanocarpus spp.	0.76	Brysenia adenophylla	0.54	Bombax spp.	0.4
Barringtonia edulis *	0.48	Buchenauia capitata	0.61, 0.63+	Brachystegia spp.	0.52
Bauhinia spp.	0.67	Bucida buceras	0.93	Bridelia micrantha	0.47*
Beilschmiedia tawa	0.58	Bulnesia arborea	1	Calpocalyx klainei	0.63*
Berrya cordifolia	0.78*	Bursera simaruba	0.29, 0.34+	Canarium schweinfurthii	0.40*
Bischofia javanica	0.54, 0.58, 0.62+	Byrsonima coriacea	0.64	Canthium rubrocostratum	0.63*
Bleasdalea vitiensis	0.43	Cabralea cangerana	0.55	Carapa procera	0.59
Bombax ceiba	0.33	Caesalpinia spp.	1.05	Casearia battiscombei	0.5
Bombycidendron vidalianum	0.53	Calophyllum sp.	0.65	Cassipourea euryoides	0.70*
Boswellia serrata	0.5	Camposperma panamensis	0.33, 0.50+	Cassipourea malosana	0.59*
Bridelia squamosa	0.5	Carapa sp.	0.47	Ceiba pentandra	0.26
Buchanania latifolia	0.45	Caryocar spp.	0.69, 0.72+	Celtis spp.	0.59
Bursera serrata	0.59	Casearia sp.	0.62	Chlorophora ercelsa	0.55
Butea monosperma	0.48	Cassia moschata	0.71	Chrysophyllum albidum	0.56*
Calophyllum spp.	0.53	Casuarina equisetifolia	0.81	Cleistanthus mildbraedii	0.87*
Calycarpa arborea	0.53	Catostemma spp.	0.55	Cleistopholis patens	0.36*
Cananga odorata	0.29	Cecropia spp.	0.36	Coelocaryon preussii	0.56 ^o
Canarium spp.	0.44	Cedrela spp.	0.40, 0.46+	Cola sp.	0.70 ^o
Canthium monstrosus	0.42	Cedrelinga catenaeformis	0.41, 0.53+	Combretodendron macrocarpum	0.7
Carallia calycina	0.66*	Ceiba pentandra	0.23, 0.24, 0.25, 0.29+	Conopharyngia holstii	0.50*

+ The wood densities specified pertain to more than one bibliographic source.
* Wood density value is derived from the regression equation in Reyes *et al.* (1992).
Source: Reyes, Gisel; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

TABLE 3A.1.9-2 (CONTINUED)					
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m ³ fresh volume) FOR TROPICAL TREE SPECIES					
(To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)					
TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
Cassia javanica	0.69	Centrolobium spp.	0.65	Copaifera religiosa .	0.50**
Castanopsis philippensis	0.51	Cespedesia macrophylla	0.63	Cordia millenii	0.34
Casuarina equisetifolia	0.83	Chaetocarpus schomburgkianus	0.8	Cordia platythyrsa	0.36**
Casuarina nodiflora	0.85	Chlorophora tinctoria	0.71,0.75+	Corynanthe pachyceras	0.63**
Cedrela odorata	0.38	Clarisia racemosa	0.53,0.57+	Coda edulis	0.78*
Cedrela spp.	0.42	Clusia rosea	0.67	Croton megalocarpus	0.57
Cedrela toona	0.43	Cochlospermum orinocensis	0.26	Cryptosepalum staudtii	0.70*
Ceiba pentandra	0.23	Copaifera spp.	0.46, 0.55+	Ctenolophon englerianus	0.78*
Celtis luzonica	0.49	Cordia spp. (gerascanthus group)	0.74	Cylicodiscus gabonensis	0.8
Chisocheton pentandrus	0.52	Cordia spp. (alliodora group)	0.48	Cynometra alexandri	0.74
Chloroxylon swietenia	0.76, 0.79, 0.80+	Couepia sp.	0.7	Dacryodes spp.	0.61
Chukrassia tabularis	0.57	Couma macrocarpa	0.50,0.53+	Daniellia ogea	0.40*
Citrus grandis	0.59	Couratari spp.	0.5	Desbordesia pierreana	0.87**
Cleidion speciflorum	0.5	Croton xanthochloros	0.48	Detarium senegalensis	0.63*
Cleistanthus eollinus	0.88	Cupressus lusitanica	0.43, 0.44+	Dialium excelsum	0.78*
Cleistocalyx spp.	0.76	Cyrilla racemiflora	0.53	Didelotia africana	0.78**
Cochlospermum gossypium+religiosum	0.27	Dactyodes colombiana	0.51	Didelotia letouzeyi	0.5
Cocos nucifera	0.5	Dacryodes excelsa	0.52, 0.53+	Diospyros spp.	0.82
Colona serratifolia	0.33	Dalbergia retusa.	0.89	Discoglyprena caloneura	0.32*
Combretodendron quadrialatum	0.57	Dalbergia stevensonii	0.82	Distemonanthus benthamianus	0.58
Cordia spp.	0.53	Declinanona calycina	0.47	Drypetes sp.	0.63*
Cotylelobium spp.	0.69	Dialium guianensis	0.87	Ehretia acuminata	0.51*
Crataeva religiosa	0.53*	Dialyanthera spp.	0.36, 0.48+	Enantia chlorantha	0.42**
Cratoxylon arborescens	0.4	Dicorynia paraensis	0.6	Endodesmia calophylloides	0.66**
Cryptocarya spp.	0.59	Didymopanax sp.	0.74	Entandrophragma utile	0.53
Cubilia cubili	0.49	Dimorphandra mora	0.99*	Eribroma oblongum	0.60*
Cullenia excelsa	0.53	Diploporis purpurea	0.76, 0.77, 0.78+	Eriocoelum microspermum	0.50**
Cynometra spp.	0.8	Dipterix odorata	0.81,0.86,0.89+	Erismadelphus ensul	0.56*
Dacrycarpus imbricatus	0.45, 0.47+	Drypetes variabilis	0.69	Erythrina vogelii	0.25**
Dacrydium spp.	0.46	Dussia lehmannii	0.59	Erythrophleum ivorense	0.72
Dacryodes spp.	0.61	Ecclinusa guianensis	0.63	Erythroxyllum mannii	0.5
Dalbergia paniculata	0.64	Endlicheria cocvirey	0.39	Fagara macrophylla	0.69
Decussocarpus vitiensis	0.37	Enterolobium schomburgkii	0.82	Ficus iteophylla	0.40**
Degeneria vitiensis	0.35	Eperua spp.	0.78	Fumtumia latifolia	0.45*
Dehaasia triandra	0.64	Eriotheca sp.	0.4	Gambeya spp.	0.56*
Dialium spp.	0.8	Erismia uncinatum	0.42, 0.48+	Garcinia punctata	0.78**
Dillenia spp.	0.59	Erythrina sp.	0.23	Gilletiodendron mildbraedii	0.87**
Diospyros spp.	0.7	Eschweilera spp.	0.71,0.79,0.95+	Gossweilerodendron balsamiferum	0.4
Diplodiscus paniculatus	0.63	Eucalyptus robusta	0.51	Guarea thompsonii	0.55**
Dipterocarpus caudatus	0.61	Eugenia stahlia	0.73	Guibourtia spp.	0.72
Dipterocarpus eurynchus	0.56	Euxylophora paraensis	0.68,0.70+	Hannoa klaineana	0.28**
Dipterocarpus gracilis	0.61	Fagara spp.	0.69	Harungana madagascariensis	0.45**
Dipterocarpus grandiflorus	0.62	Ficus sp.	0.32	Hexalobus crispiflorus	0.48**
Dipterocarpus kerrii	0.56	Genipa spp.	0.75	Holoptelea grandis	0.59**

+ The wood densities specified pertain to more than one bibliographic source.

* Wood density value is derived from the regression equation in Reyes *et al.* (1992).

Source: Reyes, Gisel; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

TABLE 3A.1.9-2 (CONTINUED)					
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m ³ fresh volume) FOR TROPICAL TREE SPECIES					
(To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)					
TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
Dipterocarpus kunstlerii	0.57	Goupia glabra	0.67, 0.72+	Homalium spp.	0.7
Dipterocarpus spp.	0.61	Guarea chalde	0.52	Hylodendron gabonense.	0.78"
Dipterocarpus warburgii	0.52	Guarea spp.	0.52	Hymenostegia pellegrini	0.78"
Dracontomelon spp.	0.5	Guatteria spp.	0.36	Irvingia grandifolia	0.78"
Dryobalanops spp.	0.61	Guazuma ulmifolia	0.52, 0.50+	Julbernardia globiflora	0.78
Dtypetes bordenii	0.75	Guettarda scabra	0.65	Khaya ivorensis	0.44
Durio spp.	0.53	Guillielma gasipae	0.95, 1.25+	Klainedoxa gabonensis	0.87
Dyera costulata	0.36	Gwtavia sp.	0.56	Lannea welwitschii	0.45"
Dysoxylum quercifolium	0.49	Helicostylis tomentosa	0.68, 0.72+	Lecomtedoxa klainenna	0.78"
Elaeocarpus serratus	0.40*	Hernandia Sonora	0.29	Letestua durissima	0.87"
Emblica officinalis	0.8	Hevea brasiliense	0.49	Lophira alata	0.87"
Endiandra laxiflora	0.54	Himatanthus articulata	0.40,0.54+	Lovoa trichilioides	0.45"
Endospermum spp.	0.38	Hirtella davisii	0.74	Macaranga kilimandscharica	0.40*
Enterolobium cyclocarpum	0.35	Humiria balsamifera	0.66,0.67+	Maesopsis eminii	0.41
Epicharis cumingiana	0.73	Humirastrum procera	0.7	Malacantha sp. aff. alnifolia	0.45"
Erythrina subumbrans	0.24	Hura crepitans	0.36, 0.37, 0.38+	Mammea africana	0.62
Erythrophloeum densiflorum	0.65	Hyeronima alchorneoides	0.60,0.64+	Manilkara lacera	0.78"
Eucalyptus citriodora	0.64	Hyeronima laxiflora	0.59	Markhamia platycalyx	0.45*
Eucalyptus deglupta	0.34	Hymenaea davisii	0.67	Memecylon capitellatum	0.77"
Eugenia spp.	0.65	Hymenolobium sp.	0.64	Microberlinia brazzavillensis	0.7
Fagraea spp.	0.73	Inga sp.	0.49,0.52,0.58, 0.64+	Microcos coriaceus	0.42"
Ficus benjamina	0.65	Iryanthera spp.	0.46	Milletia spp.	0.72
Ficus spp.	0.39	Jacaranda sp.	0.55	Mitragyna stipulosa	0.47
Ganua obovatifolia	0.59	Joannesia heveoides	0.39	Monopetalanthus pellegrinii	0.47"
Garcinia myrtifolia	0.65	Lachmellea speciosa	0.73	Musanga cecropioides	0.23
Garcinia spp.	0.75	Laetia procera	0.68	Nauclea diderichii	0.63
Gardenia turgida	0.64	Lecythis spp.	0.77	Neopoutonia macrocalyx	0.32"
Garuga pinnata	0.51	Licania spp.	0.78	Nesogordonia papaverifera	0.65
Gluta spp.	0.63	Licaria spp.	0.82	Ochtocosmus africanus	0.78'
Gmelina arborea	0.41,0.45+	Lindackeria sp.	0.41	Odyndea spp.	0.32
Gmelina vitiensis	0.54	Linociera domingensis	0.81	Oldfieldia africana	0.78*
Gonocaryum calleryanum	0.64	Lonchocarpus spp.	0.69	Ongokea gore	0.72
Gonystylus punctatus	0.57	Loxopterygium sagotii	0.56	Oxystigma oxyphyllum	0.53
Grewia tiliacifolia	0.68	Lucuma spp.	0.79	Pachyelasma tessmannii	0.70"
Hardwickia binata	0.73	Luehea spp.	0.5	Pachypodanthium staudtii	0.58"
Harpullia arborea	0.62	Lueheopsis duckeana	0.64	Paraberlinia bifoliolata	0.56"
Heritiera spp.	0.56	Mabea piriri	0.59	Parinari glabra	0.87"
Hevea brasiliensis	0.53	Machaerium spp.	0.7	Parkia bicolor	0.36"
Hibiscus tiliaceus	0.57	Macoubea guianensis	0.40*	Pausinystalia brachythyrsa	0.56"
Homalanthus populneus	0.38	Magnolia spp.	0.52	Pausinystalia cf. talbotii	0.56"
Homalium spp.	0.76	Maguirea sclerophylla	0.57	Pentaclethra macrophylla	0.78"
Hopea acuminata	0.62	Mammea americana	0.62	Pentadesma butyracea	0.78"
Hopea spp.	0.64	Mangifera indica	0.55	Phyllanthus discoideus	0.76"
Intsia palembanica	0.68	Manilkara sp.	0.89	Pierreodendron africanum	0.70;"
Kayea garciae	0.53	Marila sp.	0.63	Piptadeniastrum africanum	0.56

+ The wood densities specified pertain to more than one bibliographic source.

* Wood density value is derived from the regression equation in Reyes *et al.* (1992).

Source: Reyes, Gisell; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

TABLE 3A.1.9-2 (CONTINUED)
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m³ fresh volume) FOR TROPICAL TREE SPECIES
 (To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)

TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
Kingiodendron alternifolium	0.48	Marmaroxylon racemosum	0.78*	Plagiostyles africana	0.70 ^o
Kleinhovia hospita	0.36	Matayba domingensis	0.7	Poga oleosa	0.36
Knema spp.	0.53	Matisia hirta	0.61	Polyalthia suaveolens	0.66 ^o
Koompassia excelsa	0.63	Maytenus spp.	0.71	Premna angolensis	0.63 ^o
Koordersiodendron pinnatum	0.65, 0.69+	Mezilaurus lindaviana	0.68	Pteleopsis hylodendron	0.63*
Kydia calycina	0.72	Michropholis spp.	0.61	Pterocarpus soyauxii	0.61
Lagerstroemia spp.	0.55	Minquartia guianensis	0.76,0.79+	Pterygota spp.	0.52
Lanea grandis	0.5	Mora sp.	0.71	Pycnanthus angolensis	0.4
Leucaena leucocephala	0.64	Mouriria sideroxylon	0.88	Randia cladantha	0.78*
Litchi chinensis ssp. philippinensis	0.88	Myrciaria floribunda	0.73	Rauwolfia macrophylla	0.47*
Lithocarpus soleriana	0.63	Myristica spp.	0.46	Ricinodendron heudelotii	0.2
Litsea spp.	0.4	Myroxylon balsamum	0.74, 0.76, 0.78+	Saccoglottis gabonensis	0.74 ^o
Lophopetalum spp.	0.46	Nectandra spp.	0.52	Santiria trimera	0.53*
Macaranga denticulata	0.53	O c o t e a spp.	0.51	Sapium ellipticum	0.50*
Madhuca oblongifolia	0.53	Onychopetalum amazonicum	0.64	Schrebera arborea	0.63*
Mallotus philippensis	0.64	Ormosia spp.	0.59	Sclorodophloeus zenkeri	0.68*
Mangifera spp.	0.52	Ouratea sp.	0.66	Scottellia coriacea	0.56
Maniltoa minor	0.76	Pachira acuatica	0.43	Scyphocephalum ochocoa	0.48
Mastixia philippinensis	0.47	Paratecoma peroba	0.6	Scytometalum tieghemii	0.56 ^o
Melanorrhea spp.	0.63	Parinari spp.	0.68	Sindoropsis letestui	0.56*
Melia dubia	0.4	Parkia spp.	0.39	Staudtia stipitata	0.75
Melicope triphylla	0.37	Peltogyne spp.	0.79	Stemonocoleus micranthus	0.56 ^o
Meliosma macrophylla	0.27	Pentaclethra macroloba	0.65,0.68+	Sterculia rhinopetala	0.64
Melochia umbellata	0.25	Peru glabrata	0.65	Strephonema pseudocola	0.56*
Me&a ferrea	0.83,0.85+	Peru schomburgkiana	0.59	Strombosiopsis tetrandra	0.63 ^o
Metrosideros collina	0.70,0.76+	Persea spp.	0.40, 0.47,0.52+	Swartzia fistuloides	0.82
Michelia spp.	0.43	Petitia domingensis	0.66	Symphonia globulifera	0.58 ^o
Microcos stylocarpa	0.4	Pinus caribaea	0.51	Syzygium cordatum	0.59*
Micromelum compressum	0.64	Pinus oocarpa	0.55	Terminalia superba	0.45
Milliusa velutina	0.63	Pinus patula	0.45	Tessmania africana	0.85 ^o
Mimusops elengi	0.72*	Piptadenia sp.	0.58	Testulea gabonensis	0.6
Mitragyna parviflora	0.56	Piranhea longepedunculata	0.9	Tetraberlinia tubmaniana	0.60 ^o
Myristica spp.	0.53	Piratinera guianensis	0.96	Tetrapleura tetraptera	0.50 ^o
Neesia spp.	0.53	Pithecellobium guachapele (syn. Pseudosamea)	0.56	Tieghemella heckelii	0.55 ^o
Neonauclea bernardoi	0.62	Platonia insignis	0.70 ^o	Trema sp.	0.40*
Neotrewia cumingii	0.55	Platymiscium spp.	0.71, 0.84+	Trichilia prieureana	0.63 ^o
Ochna foxworthyi	0.86	Podocarpus spp.	0.46	Trichoscypha arborea	0.59 ^o
Ochroma pyramidale	0.3	Pourouma aff. melinonii	0.32	Triplochiton scleroxylon.	0.32
Octomeles sumatrana	0.27, 0.32+	Pouteria spp.	0.64, 0.67+	Uapaca spp.	0.6
Oroxylon indicum	0.32	Prioria copaifera	0.40,0.41+	Vepris undulata	0.70 ^o
Ougenia dalbergioides	0.7	Protium spp.	0.53,0.64+	Vitex doniana	0.4
Palaquium spp.	0.55	Pseudolmedia laevigata	0.64	Xylopia staudtii	0.36*
Pangium edule	0.5	Pterocarpus spp.	0.44		
Parashorea malaanonan	0.51	Pterogyne nitens	0.66		
Parashorea stellata	0.59	Qualea albiflora	0.5		
Paratrophis glabra	0.77	Qualea cf. lancifolia	0.58		
Parinari spp.	0.68	Qualea dinizii	0.58		

+ The wood densities specified pertain to more than one bibliographic source.

* Wood density value is derived from the regression equation in Reyes *et al.* (1992).

Source: Reyes, Gisell; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

TABLE 3A.1.9-2 (CONTINUED)					
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m ³ fresh volume) FOR TROPICAL TREE SPECIES					
(To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)					
TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
<i>Parkia roxburghii</i>	0.34	<i>Qualea</i> spp.	0.55		
<i>Payena</i> spp.	0.55	<i>Quararibaea guianensis</i>	0.54		
<i>Peltophorum pterocarpum</i>	0.62	<i>Quercus alata</i>	0.71		
<i>Pentace</i> spp.	0.56	<i>Quercus costaricensis</i>	0.61		
<i>Phaeanthus ebracteolatus</i>	0.56	<i>Quercus eugeniaefolia</i>	0.67		
<i>Phyllocladus hypophyllus</i>	0.53	<i>Quercus</i> spp.	0.7		
<i>Pinus caribaea</i>	0.48	<i>Raputia</i> sp.	0.55		
<i>Pinus insularis</i>	0.47,0.48+	<i>Rheedia</i> spp.	0.72		
<i>Pinus merkusii</i>	0.54	<i>Rollinia</i> spp.	0.36		
<i>Pisonia umbellifera</i>	0.21	<i>Saccoglottis cydonioides</i>	0.72		
<i>Pittosporum pentandrum</i>	0.51	<i>Sapium</i> spp.	0.47,0.72+		
<i>Planchonia</i> spp.	0.59	<i>Schinopsis</i> spp.	1		
<i>Podocarpus</i> spp.	0.43	<i>Sclerobium</i> spp.	0.47		
<i>Polyalthia flava</i>	0.51	<i>Sickingia</i> spp.	0.52		
<i>Polyscias nodosa</i>	0.38	<i>Simaba multiflora</i>	0.51		
<i>Pometia</i> spp.	0.54	<i>Simarouba amara</i>	0.32, 0.34,0.38+		
<i>Pouteria villamilii</i>	0.47	<i>Sloanea guianensis</i>	0.79		
<i>Premna tomentosa</i>	0.96	<i>Spondias mombin</i>	0.30, 0.40,0.41+		
<i>Pterocarpus marsupium</i>	0.67	<i>Sterculia</i> spp.	0.55		
<i>Pterocymbium tinctorium</i>	0.28	<i>Stylogyne</i> spp.	0.69		
<i>Pygeum vulgare</i>	0.57	<i>Swartzia</i> spp.	0.95		
<i>Quercus</i> spp.	0.7	<i>Swietenia macrophylla</i>	0.42,0.45,0.46, 0.54+		
<i>Radermachera pinnata</i>	0.51	<i>Symphonia globulifera</i>	0.68		
<i>Salmalia malabarica</i>	0.32,0.33+	<i>Tabebuia</i> spp. (lapacho group)	0.91		
<i>Samanea saman</i>	0.45, 0.46+	<i>Tabebuia</i> spp. (roble)	0.52		
<i>Sandoricum vidalii</i>	0.43	<i>Tabebuia</i> spp. (white cedar)	0.57		
<i>Sapindus saponaria</i>	0.58	<i>Tabebuia stenocalyx</i>	0.55,0.57+		
<i>Sapium luzontcum</i>	0.4	<i>Tachigalia myrmecophylla</i>	0.56		
<i>Schleichera oleosa</i>	0.96	<i>Talisia</i> sp.	0.84		
<i>Schrebera swietenoides</i>	0.82	<i>Tapirira guianensis</i>	0.47*		
<i>Semicarpus anacardium</i>	0.64	<i>Terminalia</i> sp.	0.50, 0.51, 0.58+		
<i>Serialbizia acle</i>	0.57	<i>Tetragastris altissima</i>	0.61		
<i>Serianthes melanesica</i>	0.48	<i>Toluidifera balsamum</i>	0.74		
<i>Sesbania grandiflora</i>	0.4	<i>Torrubia</i> sp.	0.52		
<i>Shorea assamica forma philippinensis</i>	0.41	<i>Toulicia pulvinata</i>	0.63		
<i>Shorea astylosa</i>	0.73	<i>Tovomita guianensis</i>	0.6		
<i>Shorea ciliata</i>	0.75	<i>Trattinickia</i> sp.	0.38		
<i>Shorea contorta</i>	0.44	<i>Trichilia propingua</i>	0.58		
<i>Shorea gisok</i>	0.76	<i>Trichosperma mexicanum</i>	0.41		
<i>Shorea guiso</i>	0.68	<i>Triplaris</i> spp.	0.56		
<i>Shorea hopeifolia</i>	0.44	<i>Trophis</i> sp.	0.54		
<i>Shorea malibato</i>	0.78	<i>Vatairea</i> spp.	0.6		
<i>Shorea negrosensis</i>	0.44	<i>Virola</i> spp.	0.40, 0.44, 0.48+		
<i>Shorea palosapis</i>	0.39	<i>Vismia</i> spp.	0.41		
<i>Shorea plagata</i>	0.7	<i>Vitex</i> spp.	0.52,0.56, 0.57+		

+ The wood densities specified pertain to more than one bibliographic source.

* Wood density value is derived from the regression equation in Reyes *et al.* (1992).

Source: Reyes, Gisel; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

TABLE 3A.1.9-2 (CONTINUED)					
BASIC WOOD DENSITIES (D) OF STEMWOOD (tonnes dry matter/m ³ fresh volume) FOR TROPICAL TREE SPECIES					
(To be used for D in Equations 3.2.3., 3.2.5, 3.2.7, 3.2.8)					
TROPICAL ASIA	D	TROPICAL AMERICA	D	TROPICAL AFRICA	D
Shorea polita	0.47	Vitex stahelii	0.6		
Shorea polysperma	0.47	Vochysia spp.	0.40,0.47, 0.79+		
Shorea robusta	0.72	Vouacapoua americana	0.79		
Shorea spp. balau group	0.7	Warszewicia coccinea	0.56		
Shorea spp. dark red meranti	0.55	Xanthoxylum martinicensis	0.46		
Shorea spp. light red meranti	0.4	Xanthoxylum spp.	0.44		
Shorea spp. white meranti	0.48	Xylopiia frutescens	0.64*		
Shorea spp. yellow meranti	0.46				
Shorea virescens	0.42				
Sloanea javanica	0.53				
Soymida febrifuga	0.97				
Spathodea campanulata	0.25				
Stemonurus luzoniensis	0.37				
Sterculia vitiensis	0.31				
Stereospermum suaveolens	0.62				
Strombosia philippinensis	0.71				
Strychnos potatorum	0.88				
Swietenia macrophylla	0.49,0.53+				
Swintonia foxworthyi	0.62				
Swintonia spp.	0.61				
Sycopsis dunni	0.63				
Syzygium spp.	0.69, 0.76+				
Tamarindus indica	0.75				
Tectona grandis	0.50,0.55+				
Teijsmanniodendron ahernianum	0.9				
Terminalia citrina	0.71				
Terminalia copelandii	0.46				
Terminalia foetidissima	0.55				
Terminalia microcarpa	0.53				
Terminalia nitens	0.58				
Terminalia pterocarpa	0.48				
Terminalia tomentosa	0.73,0.76, 0.77+				
Termstroemia megacarpa	0.53				
Tetrameles nudiflora	0.3				
Tetramerista glabra	0.61				
Thespesia populnea	0.52				
Toona calantas	0.29				
Trema orientalis	0.31				

+ The wood densities specified pertain to more than one bibliographic source.
* Wood density value is derived from the regression equation in Reyes *et al.* (1992).
Source: Reyes, Gisel; Brown, Sandra; Chapman, Jonathan; Lugo, Ariel E. 1992. Wood densities of tropical tree species. Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15pp.

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Table 3A.1.9-2. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.17. Default values of biomass expansion factors (BEF)

<p align="center">TABLE 3A.1.10 DEFAULT VALUES OF BIOMASS EXPANSION FACTORS (BEFs) (BEF₂ to be used in connection with growing stock biomass data in Equation 3.2.3; and BEF₁ to be used in connection with increment data in Equation 3.2.5)</p>				
Climatic zone	Forest type	Minimum dbh (cm)	BEF₂ (overbark) to be used in connection to growing stock biomass data (Equation 3.2.3)	BEF₁ (overbark) to be used in connection to increment data (Equation 3.2.5)
Boreal	Conifers	0-8.0	1.35 (1.15-3.8)	1.15 (1-1.3)
	Broadleaf	0-8.0	1.3 (1.15-4.2)	1.1 (1-1.3)
Temperate	Conifers: Spruce-fir	0-12.5	1.3 (1.15-4.2)	1.15 (1-1.3)
	Pines	0-12.5	1.3 (1.15-3.4)	1.05 (1-1.2)
	Broadleaf	0-12.5	1.4 (1.15-3.2)	1.2 (1.1-1.3)
Tropical	Pines	10.0	1.3 (1.2-4.0)	1.2 (1.1-1.3)
	Broadleaf	10.0	3.4 (2.0-9.0)	1.5 (1.3-1.7)

Note: BEF₂s given here represent averages for average growing stock or age, the upper limit of the range represents young forests or forests with low growing stock; lower limits of the range approximate mature forests or those with high growing stock. The values apply to growing stock biomass (dry weight) including bark and for given minimum diameter at breast height; Minimum top diameters and treatment of branches is unspecified. Result is above-ground tree biomass.

Sources: Isaev *et al.*, 1993; Brown, 1997; Brown and Schroeder, 1999; Schoene, 1999; ECE/FAO TBFRA, 2000; Lowe *et al.*, 2000; please also refer to FRA Working Paper 68 and 69 for average values for developing countries (<http://www.fao.org/forestry/index.jsp>)

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Box 3A.1.10. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.18. Aboveground biomass stocks in naturally regenerated forests, by broad categories (tonnes of dry matter/ha)

TABLE 3A.1.2						
ABOVEGROUND BIOMASS STOCK IN NATURALLY REGENERATED FORESTS BY BROAD CATEGORY (tonnes dry matter/ha)						
(To be used for Bw in Equation 3.2.9, for $L_{conversion}$ in Equation 3.3.8 in Cropland section and for $L_{conversion}$ in Equation 3.4.13. in Grassland section, etc. Not to be applied for C_2 or C_1 in Forest section Equation 3.2.3)						
Tropical Forests ¹						
	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
Africa	310 (131 - 513)	260 (159 - 433)	123 (120 - 130)	72 (16 - 195)	191	40
Asia & Oceania:						
Continental	275 (123 - 683)	182 (10 - 562)	127 (100 - 155)	60	222 (81 - 310)	50
Insular	348 (280 - 520)	290	160	70	362 (330 - 505)	50
America	347 (118 - 860)	217 (212 - 278)	212 (202 - 406)	78 (45 - 90)	234 (48 - 348)	60
Temperate Forests						
Age Class	Coniferous		Broadleaf		Mixed Broadleaf-Coniferous	
Eurasia & Oceania						
≤20 years	100 (17 - 183)		17		40	
>20 years	134 (20 - 600)		122 (18 - 320)		128 (20-330)	
America						
≤20 years	52 (17-106)		58 (7-126)		49 (19-89)	
>20 years	126 (41-275)		132 (53-205)		140 (68-218)	
Boreal Forests						
Age Class	Mixed Broadleaf-Coniferous		Coniferous		Forest-Tundra	
Eurasia						
≤20 years	12		10		4	
>20 years	50		60 (12.3-131)		20 (21- 81)	
America						
≤20 years	15		7		3	
>20 years	40		46		15	
Note: Data are given in mean value and as range of possible values (in parentheses).						
¹ The definition of forest types and examples by region are illustrated in Box 2 and Tables 5-1, p 5.7-5.8 of the <i>IPCC Guidelines</i> (1996).						

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Table 3A.1.2. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_languages.html

Table A1.19. Aboveground biomass reserves in plantation forests, by general categories

TABLE 3A.1.3 ABOVEGROUND BIOMASS STOCK IN PLANTATION FORESTS BY BROAD CATEGORY (tonnes dry matter/ha) (To be used for B_w in Equation 3.2.9, for $L_{conversion}$ in equation in Equation 3.3.8 in Cropland section and for $L_{conversion}$ in Equation 3.4.13. in Grassland section, etc. Not to be applied for C_{t_2} or C_{t_1} in Forest section Equation 3.2.3)							
Tropical and sub-tropical Forests							
	Age Class	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
		R > 2000	2000>R>1000		R<1000	R>1000	R<1000
Africa							
Broadleaf spp	≤20 years	100	80	30	20	100	40
	>20 years	300	150	70	20	150	60
Pinus sp	≤20 years	60	40	20	15	40	10
	>20 years	200	120	60	20	100	30
Asia:							
Broadleaf	All	220	180	90	40	150	40
other species	All	130	100	60	30	80	25
America							
Pinus	All	300	270	110	60	170	60
Eucalyptus	All	200	140	110	60	120	30
Tectona	All	170	120	90	50	130	30
other broadleaved	All	150	100	60	30	80	30
Temperate Forests							
	Age class	Pine		Other coniferous	Broadleaf		
Eurasia							
Maritime	≤20 years	40		40	30		
	>20 years	150		250	200		
Continental	≤20 years	25		30	15		
	>20 years	150		200	200		
Mediterranean & steppe	≤20 years	17		20	10		
	>20 years	100		120	80		
S. America	All	100		120	90		
N America	All	175 (50–275)		300	–		
Boreal Forests							
	Age class	Pine		Other coniferous	Broadleaf		
Eurasia							
	≤20 years	5		5	5		
	>20 years	40		40	25		
N. America	All	50		40	25		

Source: IPCC, 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Table 3A.1.3. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_languages.html

Table A1.20. Volume of standing wood and aboveground biomass content (dry matter) in forests

TABLE 3A.1.4 (CONTINUED) AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)				TABLE 3A.1.4 (CONTINUED) AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)			
(1) To be used for V in Equation 3.2.3. (2) To be used for B _w in Equation 3.2.9, for L _{conversion} in Equation 3.3.8 in cropland section and for L _{conversion} in Equation 3.4.13. in grassland section, etc. Not to be applied for C _{t2} or C _{t1} in Forest section Equation 3.2.3.				(1) To be used for V in Equation 3.2.3. (2) To be used for B _w in Equation 3.2.9, for L _{conversion} in Equation 3.3.8 in cropland section and for L _{conversion} in Equation 3.4.13. in grassland section, etc. Not to be applied for C _{t2} or C _{t1} in Forest section Equation 3.2.3.			
e. NORTH AND CENTRAL AMERICA				e. NORTH AND CENTRAL AMERICA (Continued)			
Country	Volume (aboveground) m ³ / ha	Biomass (aboveground) t / ha	Information Source	Country	Volume (aboveground) m ³ / ha	Biomass (aboveground) t / ha	Information Source
Antigua and Barbuda	116	210	ES	Saint Vincent and Grenadines	166	173	NI
Bahamas	-	-	-	Trinidad and Tobago	71	129	ES
Barbados	-	-	-	United States	136	108	FAO
Belize	202	211	ES	US Virgin Islands	-	-	-
Bermuda	-	-	-				
British Virgin Islands	-	-	-				
Canada	120	83	FAO				
Cayman Islands	-	-	-				
Costa Rica	211	220	ES				
Cuba	71	114	NI				
Dominica	91	166	ES				
Dominican Republic	29	53	ES				
El Salvador	223	202	FAO				
Greenland	-	-	-				
Grenada	83	150	PI				
Guadeloupe	-	-	-				
Guatemala	355	371	ES				
Haiti	28	101	ES				
Honduras	58	105	ES				
Jamaica	82	171	ES				
Martinique	5	5	ES				
Mexico	52	54	NI				
Montserrat	-	-	-				
Netherlands Antilles	-	-	-				
Nicaragua	154	161	ES				
Panama	308	322	ES				
Puerto Rico	-	-	-				
Saint Kitts and Nevis	-	-	-				
Saint Lucia	190	198	ES				
Saint Pierre & Miquelon	-	-	-				
Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)				TABLE 3A.1.4 (CONTINUED) AVERAGE GROWING STOCK VOLUME (1) AND ABOVEGROUND BIOMASS CONTENT (2) (DRY MATTER) IN FOREST IN 2000. (SOURCE FRA 2000)			
				(1) To be used for V in Equation 3.2.3. (2) To be used for B _w in Equation 3.2.9, for L _{conversion} in Equation 3.3.8 in cropland section and for L _{conversion} in Equation 3.4.13. in grassland section, etc. Not to be applied for C _{t2} or C _{t1} in Forest section Equation 3.2.3.			
f. SOUTH AMERICA							
Country	Volume (aboveground) m ³ / ha	Biomass (aboveground) t / ha	Information Source	Country	Volume (aboveground) m ³ / ha	Biomass (aboveground) t / ha	Information Source
Argentina	25	68	ES	Argentina	25	68	ES
Bolivia	114	183	PI	Bolivia	114	183	PI
Brazil	131	209	ES	Brazil	131	209	ES
Chile	160	268	ES	Chile	160	268	ES
Colombia	108	196	NI	Colombia	108	196	NI
Ecuador	121	151	ES	Ecuador	121	151	ES
Falkland Islands	-	-	-	Falkland Islands	-	-	-
French Guiana	145	253	ES	French Guiana	145	253	ES
Guyana	145	253	ES	Guyana	145	253	ES
Paraguay	34	59	ES	Paraguay	34	59	ES
Peru	158	245	NI	Peru	158	245	NI
Suriname	145	253	ES	Suriname	145	253	ES
Uruguay	-	-	-	Uruguay	-	-	-
Venezuela	134	233	ES	Venezuela	134	233	ES
Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)				Information source: NI = National inventory; PI = Partial inventory; ES = Estimate; EX = External data (from other regions)			

Source: IPCC. 2005. *Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF)*. Chapter 3, Box 3A.1.4. [Cited 6 July 2023]. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_languages.html

Annex 2. Global warming potentials

Gas	IPCC second report	IPCC fourth report	IPCC fifth report	IPCC sixth report
	Global warming potential (horizon: 100 years)			
Carbon dioxide (CO ₂)	1	1	1	1
Methane (CH ₄)	21	25	28	27.9
Nitrous oxide (N ₂ O)	310	298	265	273
Halon 1211	-	1 890	1 750	1 930
Halon 1301	5 400	7 140	6 290	7 200
R-12 (CFC)	8 100	1 0900	10 200	12 500
R-125 (HFC)	2 800	3 500	3 170	3 740
R-152a (HFC)	140	124	138	164
R-123 (HCFC)	90	77	79	90,4
R-502 (HCFC-CFC)	-	4 657	4 786	5 872
R-507A (HFC)	3 300	3 985	3 985	4 775
R-404A (HCFC)	3 260	3 922	3 771	4 728
R-407A (HFC)	1 770	2 107	1 923	2 262
R-22 (HCFC)	1 500	1 810	1 760	1 960
R-407C (HFC)	1 526	1 774	1 638	1 908
R-134A (HFC)	1 300	1 430	1 300	1 530
R-32 (HFC)	650	675	677	771
R-290	-	3	-	0.02
R-600A	-	3	-	0.006
R-1270	-	2	-	-
R-410A (HFC)	1 725	2 088	1 924	2 256

Annex 3. Water footprint impact summary worksheets

Table A3.1. Scarcity summary worksheet

Water footprint due to scarcity ($WF_{scarcity}$)	
Type of impact	Consumptive or for consumption
Definition	Water is a finite resource and its availability to different users will vary according to supply and demand in the region. Moreover, its supply is impacted to the extent that its quality or quantity is affected. ¹⁰ To estimate the impact of scarcity, it is assumed that the less water available per unit area in a basin, the greater the potential deprivation of the resource to other users. ¹¹
Methodology	AWARE “Available WAter REmaining”.
Inventory data required (BV t)	Volume of water in cubic meters (m^3) that does not return to the same watershed from which it was withdrawn due to events such as: crop evapotranspiration, evaporation, discharges into a different watershed, water incorporated into the fruit.
Characterization factor (regional CF)	Factor expressed in equivalent cubic meters of water per cubic meters of water withdrawn from the basin (m^3e/m). It is a factor that depends on geographic location and time of year. Its value can range from 0.1 to 100 and is the number of times water in the region is not available compared to the world average. It is downloaded from the official website of the Water Use in Life Cycle Assessment (WULCA) organization , and installed in the Google Earth application for use.
Result (WF scarcity)	The water footprint due to scarcity will be the cubic meters of water equivalent ($m^3 e$) that, due to the activity in question, ceased to be available in the basin for other potential users.
Equation	$WF_{scarcity} = V_{Ct} \times CF_{regional}$ <p>WF scarcity: Scarcity impact value ($m^3 e$)</p> <p>BV t: Total volume of water withdrawn from the basin (m^3)</p> <p>CF regional: Characterization factor given by AWAR ($m^3 e/m^3$)</p>

Source: Authors' own elaboration.

¹⁰ United Nations (UN). 2023. Water Scarcity. <https://www.unwater.org/water-facts/water-scarcity>

¹¹ Water Use in Life Cycle Assessment (WULCA). 2023. What is AWARE? <https://wulca-waterlca.org/aware/what-is-aware/>

Table A3.2. Freshwater eutrophication summary worksheet

Eutrophication water footprint in freshwater ($WF_{\text{eutrof-d}}$)	
Type of impact	Degradative
Definition	Eutrophication is a phenomenon that occurs in freshwater bodies, due to the extraordinary increase of nutrients due to human causes, causing an imbalance in the aquatic ecosystem by the excessive growth of algae that deplete oxygen for other species. In freshwater this phenomenon is mainly caused by high phosphorus loads reaching the water bodies.
Methodology	ReCiPe
Inventory data required (m_{Pt})	Amount of phosphorus that was applied to the soil or discharged into freshwater in kilograms of total phosphorus (kg total P).
Characterization factor (CF)	Factor expressed in kilograms of phosphorus equivalent per kilogram of total phosphorus applied in water or soil (kg Pe/kg total P). It is a factor that depends on whether the phosphorus was applied to the agricultural soil or to freshwater directly. In addition, it depends on the type of molecule in which the applied phosphorus was found (phosphorus, phosphate, phosphoric acid, phosphorus pentoxide). It is downloaded in Excel from the official ReCiPe methodology page .
Result ($WF_{\text{eutrof-d}}$)	The water footprint due to eutrophication in fresh water will be the kilograms of phosphorus equivalent (kg Pe) that the activity in question could potentially have caused the eutrophication phenomenon in nearby water bodies.
Equation	$WF_{\text{eutrof-d}} = m_{\text{Pt}} \times CF$ <p style="text-align: center;"> $WF_{\text{eutrof-d}}$: freshwater eutrophication impact value(kg Pe) m_{Pt} : numbera of total phosphorus emitted in soil or water (kg P total) CF : Characterization factor given by ReCiPe (kg Pe/kg P total) </p>

Source: Authors' own elaboration.

Table A3.3. Eutrophication in salt water summary worksheet

Eutrophication water footprint in salt water (WF _{eutrof-s})	
Type of impact	Degradative
Definition	Eutrophication is a phenomenon that can occur in bodies of water, due to the extraordinary increase of nutrients due to human activities. This results in an imbalance in the aquatic ecosystem by the excessive growth of algae that deplete oxygen for other species. In salt water, this phenomenon is mainly caused by high nitrogen loads reaching the water bodies.
Methodology	ReCiPe
Inventory data required (m _{Nt})	Amount of nitrogen that was applied to the soil or poured into fresh or salt water in kilograms of total nitrogen (kg total N).
Characterization factor (CF)	Factor expressed in kilograms of nitrogen equivalent per kilogram of total nitrogen applied in soil, freshwater or saltwater (kg Ne/kg total N). It is a factor that depends on whether the nitrogen was applied to the agricultural soil or to fresh or salt water directly. It also depends on the type of molecule in which the applied nitrogen was found (nitrogen, ammonium, ammonia, nitrogen oxides). It is downloaded in Excel from the official ReCiPe methodology page .
Result (WF _{eutrof-s})	The water footprint due to eutrophication in salt water represents the kilograms of nitrogen equivalent (kg Ne) that a given activity could potentially have caused the eutrophication phenomenon in nearby bodies of salt water.
Equation	$WF_{\text{eutrof-s}} = m_{Nt} \times CF$ <p>WF_{eutrof-s} : value of impact on saltwater eutrophication(kg Ne) m_{Nt} : number of total nitrogen emitted in soil or water (kg N total) CF : Characterization factor given by ReCiPe (kg Ne/kg N total)</p>

Source: Authors' own elaboration.

Table A3.4. Ecotoxicity summary sheet

Ecotoxicity water footprint (WF _{ecotox})	
Type of impact	Degradative
Definition	Ecotoxicity is defined as the ability of a substance to cause damage to the environment and organisms, including microorganisms, plants, insects and any other animal. ¹²
Methodology	USEtox®
Inventory data required (m _{x,t})	Amount of a substance “x” that was applied in air, soil or water. Generally, the active ingredients of the products used are used as a reference. The most relevant ones can be selected for the inventory, as long as the justification criteria are adequately described in the scope of the study.
Characterization factor (CFx)	Factor expressed as the fraction of potentially affected species (PAF) per cubic meter per day, per kilogram emitted of substance “x” (PAF.m ³ .day/kg x). The units of PAF.m ³ .day are also referred to as comparative toxic units of ecotoxicity (CTUe) for short. It is a factor that depends on the substance emitted and the compartment where it is emitted, i.e. whether it was released into: indoor air of a home, indoor air of an industry, urban air, rural air, freshwater body, saltwater body, natural soil or agricultural soil. Downloaded in Excel from the official USEtox methodology website ®. Note: There might not be factors developed for all the products used, but this does not mean that they do not generate an impact. As such, their exclusion should be described in the scope of the study.
Result (WF _{ecotox})	The water footprint for ecotoxicity in water will result in the comparative toxic ecotoxicity units (CTUe) or the fraction of species potentially affected per cubic meter of water of degradative use per day. This fraction becomes relatively high, as it contemplates the affectation of microorganisms, plants, insects and any other animal. Based on the result of the potential impact, the characterization factors of each active ingredient, as well as the doses applied, an analysis can be made of the products used and alternatives that can be implemented to reduce the corresponding impact.
Equation	$WF_{ecotox} = m_{x,t} \times CFx$ <p>WF_{ecotox} : Value of the impact of ecotoxicity in water (CTUe)</p> <p>m_{x,t} : number of x total substance emitted to air,soil or water (kg x)</p> <p>CFx:Characterization factor x substance given by USEtox(CTUe/kg x)</p>

Source: Authors' own elaboration.

¹² Kuldeep, R., Nimeet, D., HariPriya, K., Muktika, T., Mukesh, C. S., Santosh, K. B. and Rakesh, K. T. 2022. *Pharmacokinetics and Toxicokinetic Considerations, Volume 2*. In *Advances in Pharmaceutical Product Development and Research*, Chapter 14 - In silico methods for the prediction of drug toxicity. 357-383 p. <https://doi.org/10.1016/B978-0-323-98367-9.00012-3>

Table A3.5. Human toxicity summary worksheet

Human Toxicity Water Footprint (WF_{toxh})	
Type of impact	Degradative
Definition	The potential human toxicity impact estimates potential harm to human health from the use of substances, with possible carcinogenic and non-carcinogenic impacts.
Methodology	USEtox®
Inventory data required (m_{xt})	Amount of a substance “x” that was applied in air, soil or water. Generally, the active ingredients of the products used are used as a reference. The most relevant ones can be selected for the inventory, as long as the justification criteria are adequately described in the scope of the study.
Characterization factor (CFx)	Factor expressed as the number of cases of disease per kilogram of substance “x” emitted (cases/kg x). Case units are also referred to as comparative toxic units of human toxicity (CTUh). It is a factor that depends on the substance emitted and the compartment where it is emitted, i.e. whether it was released into indoor air of a home, indoor air of an industry, air in urban areas, air in rural areas, freshwater body, saltwater body, natural soil or agricultural soil. Downloaded in Excel from the official USEtox methodology website® <i>Note:</i> There might not be factors developed for all the products used, but this does not mean that they do not generate an impact. As such, their exclusion should be described in the scope of the study.
Result (WF_{toxh})	The water footprint for human toxicity will result in the comparative toxic human toxicity units (CTUh) or the number of cases of carcinogenic and non-carcinogenic diseases that could potentially occur from the use of the products. Based on the result of the potential impact, the characterization factors of each active ingredient, as well as the doses applied, an analysis can be made of the products used and the alternatives that can be implemented to reduce the corresponding impact.
Equation	$WF_{toxh} = m_{xt} \times CFx$ <p>WF_{toxh} : human toxicity impact value (CTUh)</p> <p>m_{xt} : number of x total substance emitted to air,soil or water (kg x)</p> <p>CFx:Characterization factor x substance given by USEtox (CTUh/kg x)</p>

Source: Authors’ own elaboration.

Annex 4. CROPWAT Tool

The CROPWAT 8.0 software was developed by FAO and is freely available. Its step-by-step use is explained below:

Step 1. Go to the official CROPWAT 8.0 software download page at the following address: <https://www.fao.org/land-water/databases-and-software/cropwat/en/> In the right menu you can download the application and accept its installation.

Step 2. The first step is to enter the climate data by selecting “Climate/ETo” in the menu on the left. In the box that appears, you must fill in the data for monthly average minimum and maximum temperature (°C), monthly average humidity (%), wind (m/s) and sunshine (hours). Additional data such as country, altitude (m.a.s.l.), latitude and longitude of the farm, and the name of the weather station must also be filled in.

Notes:

- If insolation information is not available, the program makes an estimate based on the location provided using the latitude and longitude.
- Only the blank cells will be filled in, the yellow cells are estimated by the software.

Figure A4.1. Visualization of the CROPWAT program in its climate and reference evapotranspiration section

CROPWAT - Sesión: untitled - [ETo Penman-Monteith Mensual - untitled]

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Nuevo Abrir Guardar Cerrar Imprimir Gráfico Opciones

País Estación

Altitud m. Latitud °N Longitud °E

Mes	Temp Min	Temp Max	Humedad	Viento	Insolación	Rad	ETo
	°C	°C	%	m/s	horas	MJ/m ² /día	mm/día
Enero	19,7	32,1	86	1,8	8,0	19,1	3,97
Febrero	19,4	31,3	83	2,0	7,8	20,1	4,21
Marzo	19,7	31,9	81	2,0	8,1	21,7	4,64
Abril	20,3	32,3	83	2,0	8,2	22,2	4,74
Mayo	21,3	32,3	87	1,7	7,8	21,1	4,45
Junio	22,2	31,9	86	1,7	7,0	19,6	4,21
Julio	21,0	32,0	87	1,7	7,9	21,0	4,39
Agosto	21,7	32,5	86	1,7	7,7	21,1	4,50
Septiembre	21,4	32,6	85	1,9	7,8	21,2	4,55
Octubre	22,3	32,9	83	2,1	7,2	19,4	4,34
Noviembre	21,6	33,5	84	2,0	7,8	19,0	4,21
Diciembre	21,6	32,6	85	2,0	7,2	17,5	3,84
Promedio	21,0	32,3	85	1,9	7,7	20,2	4,34

Clima/ETo

Prec.

Cultivo

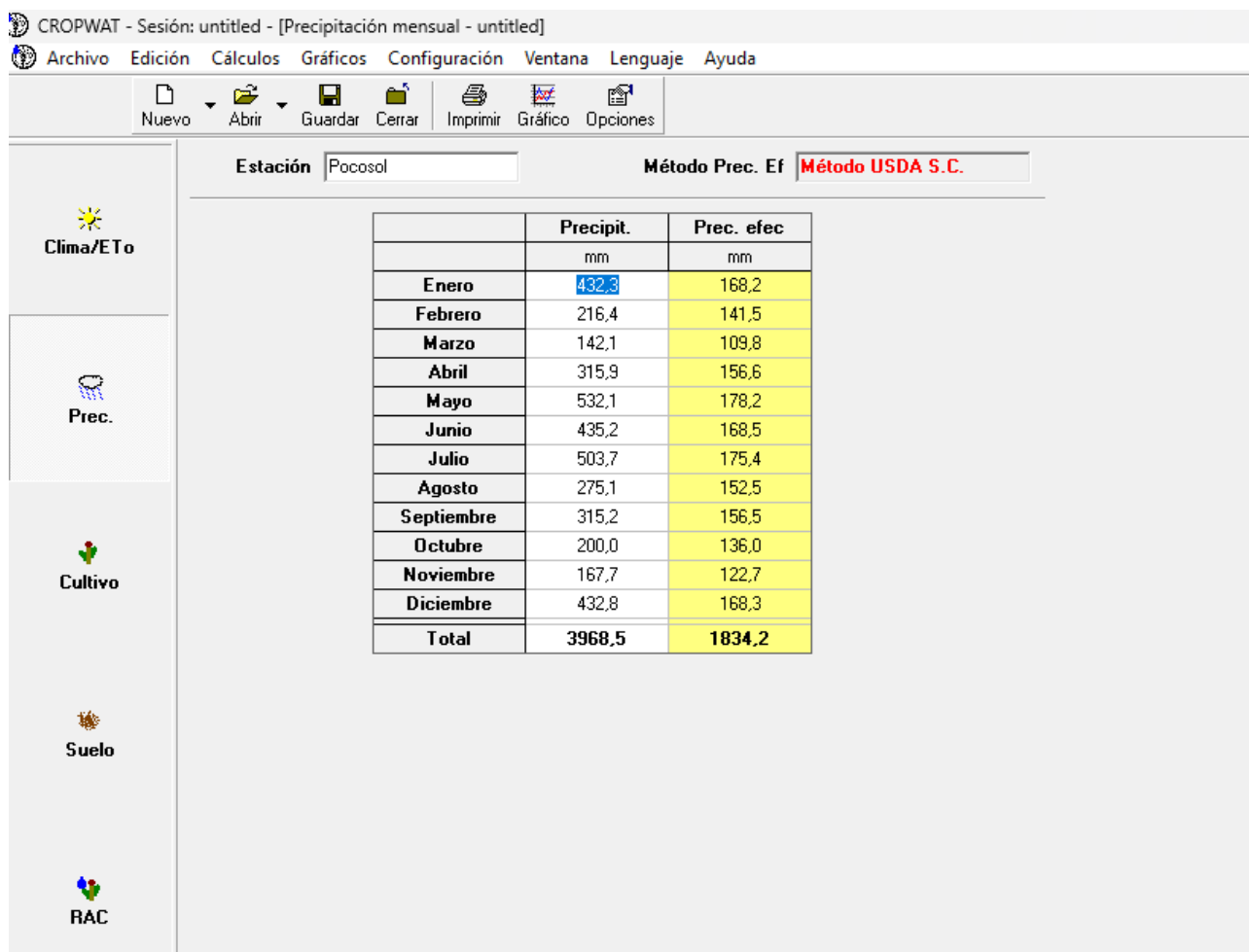
Suelo

RAC

Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Step 3. Next, you must enter the monthly precipitation data using the “Prec.” option in the left column of the screen (see Figure A4.2.).

Figure A4.2. CROPWAT program display in the precipitation section (Prec.)



Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Step 4. In the “Crop” option in the left column of the screen (see Figure A4.3.), enter data associated with the pineapple crop. These values could be determined in the field by the organization, or the theoretical information from Allen *et al.* (2006) is provided in the table below.

Table A4.1. Theoretical pineapple crop data for use in CROPWAT

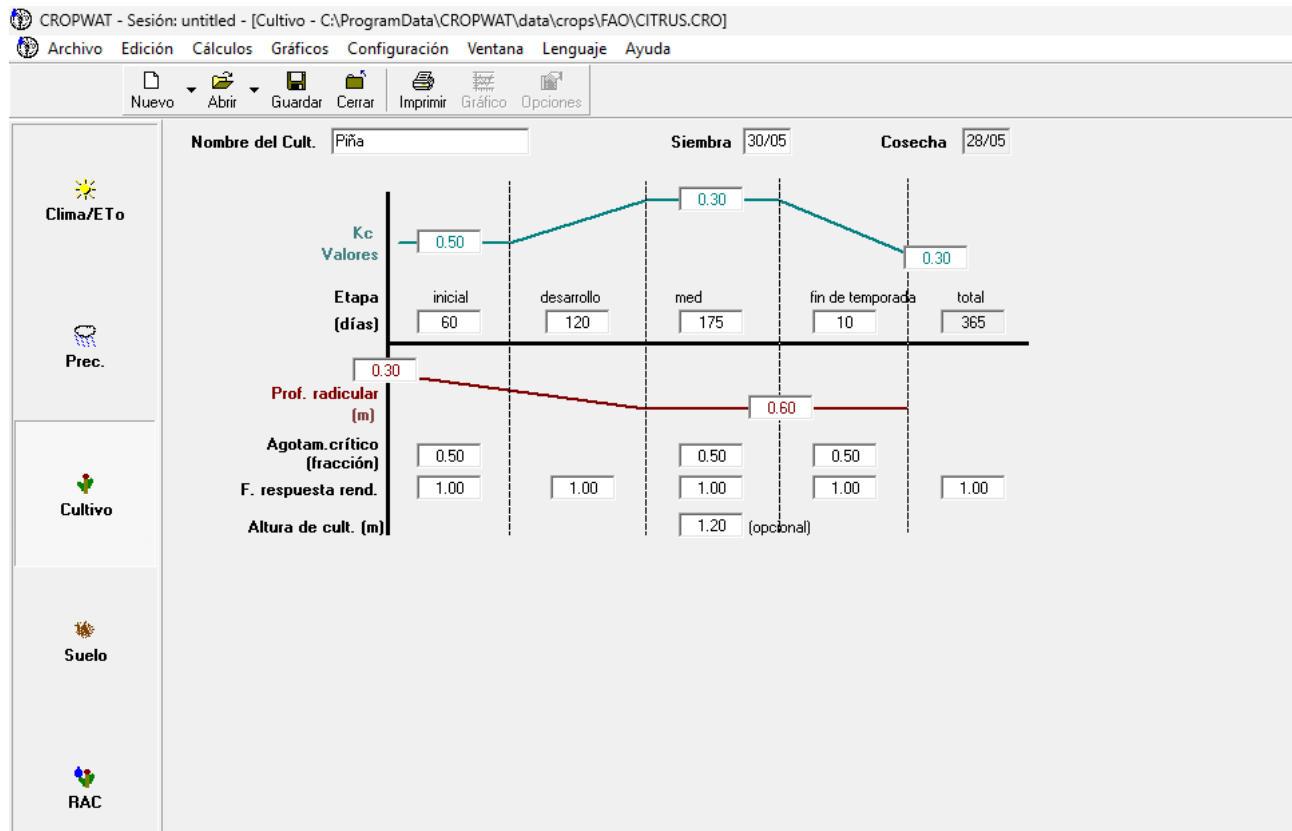
Stage	Initial	Development	Medium	Final	Source
Kc (uncovered soil)	0.50		0.30	0.30	Table 12, p. 112.
Kc (soil with grass cover)	0.50		0.50	0.50	
Days	60	120	600	10	Table 11, p. 107.
Root depth (m)	0.3-0.6		0.3-0.6		Table 22, p. 165.
Critical depletion (fraction)	0.5		0.5	0.5	Table 22, p. 165.
Performance response factor (Ky)	1	1	1	1	p. 177.
Crop height (m)			0.6-1.2		Table 12, p. 112.

Note: As indicated by **Allen et al.** (2006):

“The pineapple plant has a very low transpiration because it closes its stomata during the day and opens them at night. Therefore, most of the ETC in pineapple is constituted by evaporation occurring in the soil. The value of K_c med < K_c ini because K_c med occurs under conditions of complete soil cover, so evaporation in the soil will be less. The values given assume that 50% of the soil surface is covered by a black plastic cover and that the crop is irrigated through sprinkler irrigation. In the case of drip irrigation below the plastic cover, K_c values can be reduced to 0.10.” (p. 112)
 “For a large number of crops, the value of K_y is about 1. For crops where the value of K_y is unknown, the user can use $K_y = 1$ ” (p.177).

Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Figure A4.3. Visualization of the CROPWAT program in its cultivation section



Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Step 5. In the “Soil” option in the left column (see Figure A4.4.), the soil characteristics of the region should be noted, which in the first instance it is recommended that they be determined by the organization through a soil survey.

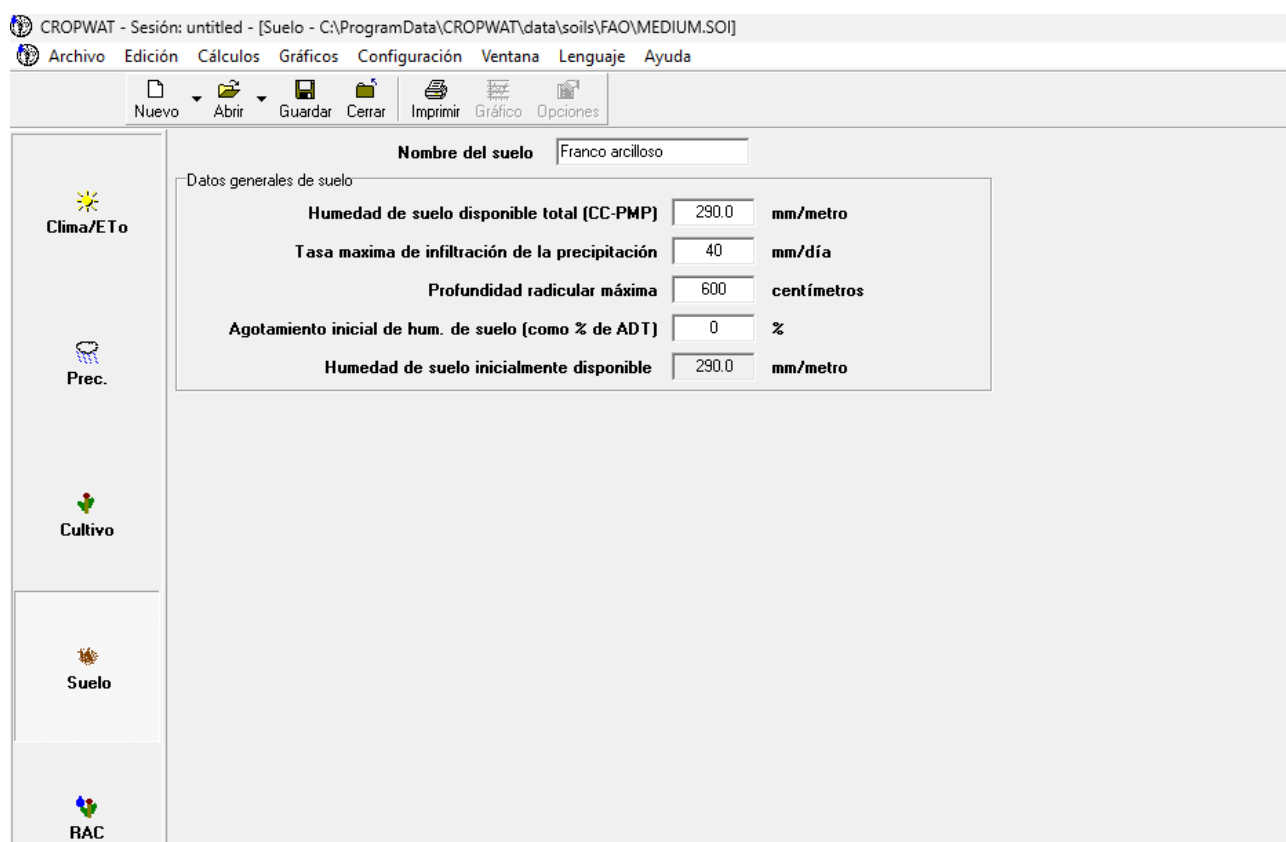
In case this is not possible, by means of adequately supported and justified literature references, the soil texture should be investigated, and based on this, the values could be approximated. Also, the software contains preset data of the values according to some soil types, for which it can be used as a reference by loading the information from the “Open” icon in the top menu.

Table A4.2. Soil-related parameters to enter in CROPWAT

Parameter	Description
Initial available soil moisture (usable moisture)	It is the soil moisture content at the beginning of the growing season; estimated as the product of the total available water by the initial soil moisture depletion, expressed in millimetres per meter of soil depth (mm/m). The total available water is the total amount of water available to the crop, which is estimated by subtracting the soil moisture content between the field capacity and the permanent wilt point.
Maximum precipitation infiltration rate	The maximum infiltration rate, expressed in mm per day, represents the amount of water that can infiltrate into the soil in a 24-hour period, depending on soil type, slope and intensity of precipitation or irrigation. The maximum infiltration rate has the same value as the hydraulic conductivity of the soil at saturation. For its measurement, laboratory results can be used, or the double cylinder method (Centro AGUA-UMSS, 2022), which can be useful on site to determine irrigation needs.
Initial soil moisture depletion	Initial soil moisture depletion indicates the dryness of the soil at the beginning of the growing season (planting). Initial soil moisture depletion is expressed as a percentage of total available water, in terms of field capacity depletion. The default value of 0 percent represents a wet soil profile at CC and 100 percent is a soil at permanent wilt point.

Source: Descriptions taken from CROPWAT 8.0, Help section. For more information on each parameter, it is recommended to review the Help section - Help Topics of CROPWAT 8.0.

Figure A4.4. Visualization of the CROPWAT program in its soil section



Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Step 6. In the “RAC” option, the results obtained for evapotranspiration (ET_c) can be observed, which are provided in millimetres per day per square meter (mm/day/m²), (see Figure A4.5.). Therefore, the equation shown below should be applied to obtain the total crop evapotranspiration per month (ET_M) (Vallejo *et al.*, 2017).

$$\text{Monthly evapotranspiration (ET}_M) = \text{ET}_c \times D \times 10 \times A$$

$$\text{ET}_M: \text{Monthly evapotranspiration (} \frac{\text{m}^3}{\text{month}} \text{)}$$

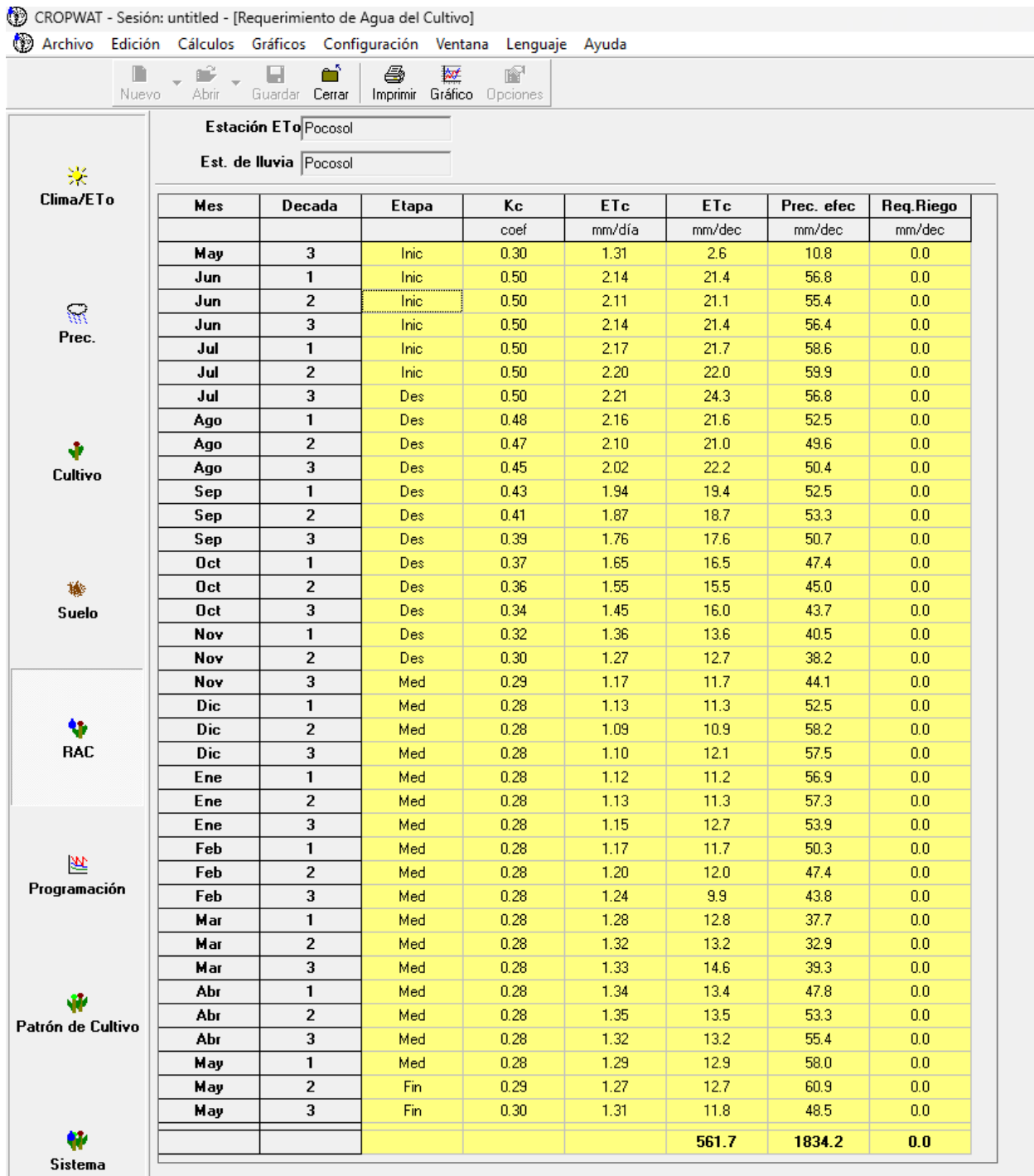
$$\text{ET}_C: \text{Daily crop evapotranspiration in the month (} \frac{\text{mm}^3}{\text{day}} \text{)}$$

D: Days of the month (days)

10: Conversion factor to cubic meters

A: Area sown in the hectare (ha)

Figure A4.5. Visualization of the CROPWAT program in its crop water requirement (CWR) section and evapotranspiration results.



Source: Allen, R., Pereira, S., Raes, D., and Smith, M. 2006. *Crop evapotranspiration: Guidelines for determining crop water requirements*. FAO Irrigation and Drainage Studies. Rome, Italy, FAO. <http://www.fao.org/docrep/009/x0490s/x0490s00.htm>

Annex 5. Water footprint impact characterization factors

1. Characterization factor for scarcity impact

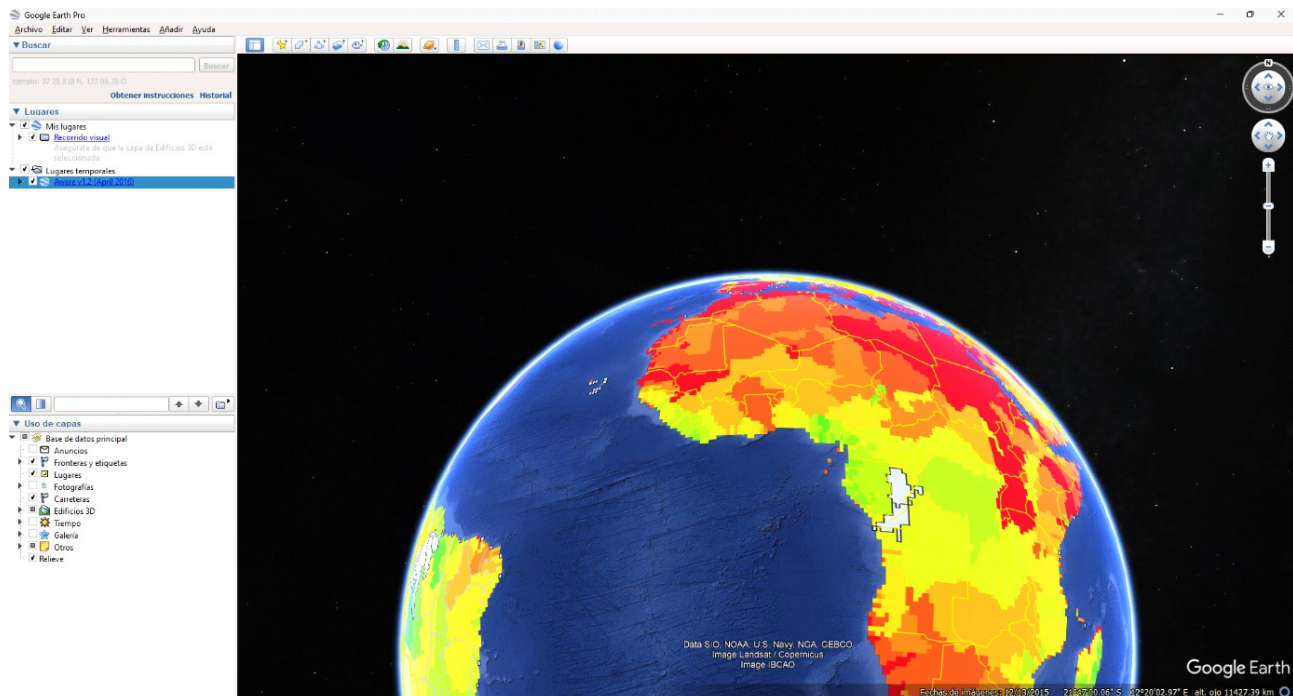
Step-by-step installation and determination of the characterization factor (regional CF) given by AWARE

Step 1. Download the Google Earth program to the computer by clicking on the following link: <https://www.google.com/intl/es/earth/versions/#earth-pro>, clicking on “Download Earth Pro for computers”, “Accept and download” and accept the installation.

Step 2. Go to the official WULCA website and download the AWARE characterization factors from the following link: <https://wulca-waterlca.org/aware/download-aware-factors/>, in the “Download (Sub) Watershed level values (annual and monthly)” section, click on “Download Google Earth Layer Document”.

Step 3. Double click on the downloaded file named “AWARE_v1_2April_7th.kmz”, and the layer will open directly in the Google Earth application (see Figure A5.1.). The grids marked in red are the regions of greatest scarcity, and those marked in green are the regions of least scarcity.

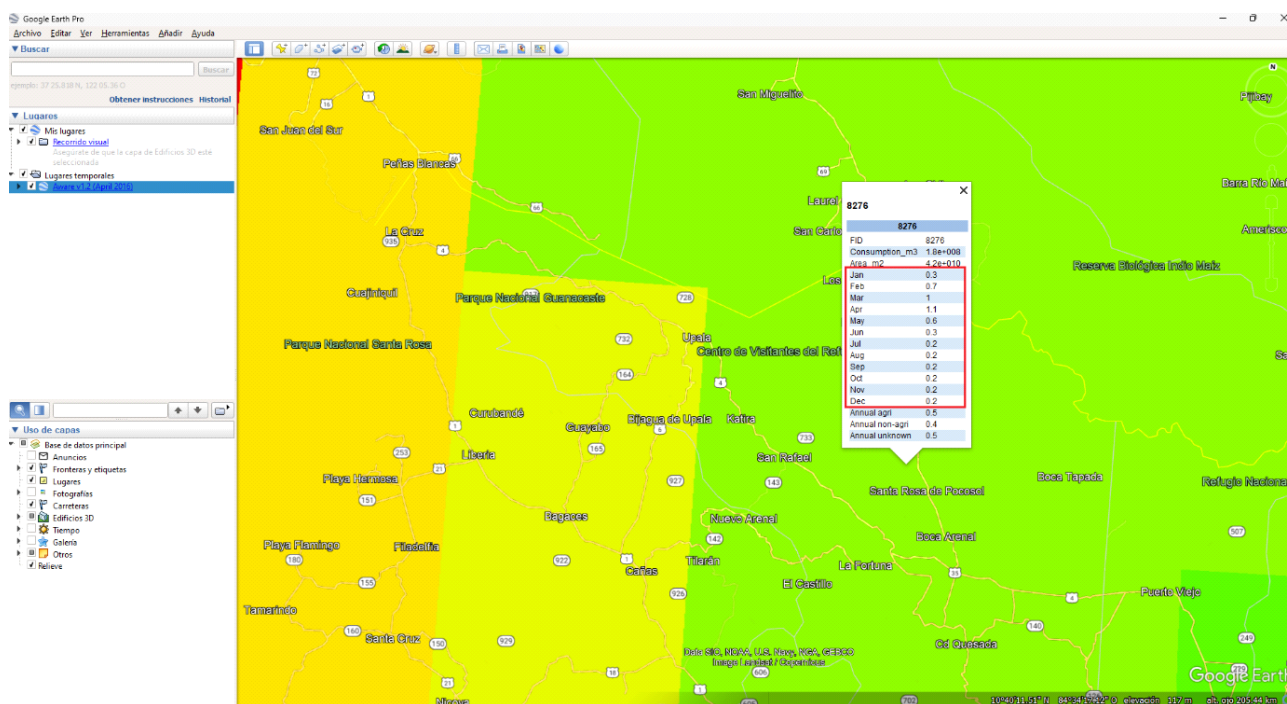
Figure A5.1. Initial visualization of Google Earth with the AWARE layer



Source: Google Earth. [Cited 29 May 2023]. <https://earth.google.com/>

Step 4. In order to identify the specific CFs for the region under study, find the location and click on it. A table will immediately appear with the monthly breakdown of the CFs for that area (see Figure A5.2.), as well as the option of an annual CF for agricultural and non-agricultural uses. It is recommended to use the monthly CFs, which are expressed in cubic meters equivalent per cubic meter lost from the basin.

Figure A5.2. CF information corresponding to the selected geographic location.



Source: Google Earth. [Cited 29 May 2023]. <https://earth.google.com/>

2. Determination of the characterization factor (CF) given by ReCiPe for freshwater eutrophication.

The CFs provided by ReCiPe are presented below according to the type of phosphorus presentation and the natural environment where it is emitted.

Table A5.1. Characterization factors for estimating the water footprint due to eutrophication in freshwater

Presentation of applied phosphorus	Natural means of emission	CF (kg Pe /kg P total)
Phosphorus (P)	Fresh water	1
Phosphate (PO ₄ ³⁻)	Fresh water	0.33
Phosphoric acid	Fresh water	0.32
Phosphorus pentoxide	Fresh water	0.22
Phosphorus (P)	Agricultural land	0.1
Phosphate (PO ₄ ³⁻)	Agricultural land	0.033
Phosphoric acid	Agricultural land	0.032
Phosphorus pentoxide	Agricultural land	0.022

Source: Adapted from Dutch National Institute of Public Health and Environment. 2016. *Excel characterization factors, eutrophication in freshwater tab, hierarchical modelling scenario*. [Cited 29 May 2023]. <https://www.rivm.nl/documenten/recipe2016cfsv1120180117>

3. Determination of the characterization factor (CF) given by ReCiPe for saltwater eutrophication.

The CFs provided by ReCiPe are presented below according to the type of nitrogen presentation and the natural environment where it is emitted.

Table A5.2. Characterization factors for estimating the water footprint due to eutrophication in saltwater

Presentation of applied nitrogen	Natural means of emission	CF (kg Ne /kg N total)
Nitrogen (N)	Fresh water	0.30
Ammonium (NH ₄ ⁺)	Fresh water	0.23
Ammonia (NH ₃)	Fresh water	0.24
NO	Fresh water	0.14
NO ₂	Fresh water	0.09
NO ₃	Fresh water	0.07
NO _x	Fresh water	0.09
Nitrogen (N)	Agricultural land	0.13
Ammonium (NH ₄ ⁺)	Agricultural land	0.10
Ammonia (NH ₃)	Agricultural land	0.10
NO	Agricultural land	0.06
NO ₂	Agricultural land	0.04
NO ₃	Agricultural land	0.03
NO _x	Agricultural land	0.04
Nitrogen (N)	Salt water	1
Ammonium (NH ₄ ⁺)	Salt water	0.78
Ammonia (NH ₃)	Salt water	0.82
NO	Salt water	0.47
NO ₂	Salt water	0.30
NO ₃	Salt water	0.23
NO _x	Salt water	0.30

Source: Adapted from **Dutch National Institute of Public Health and Environment**. 2016. *Excel characterization factors, eutrophication in freshwater tab, hierarchical modelling scenario*. [Cited 29 May 2023]. <https://www.rivm.nl/documenten/recipe2016cfsv1120180117>

4. Determination of the characterization factor (CF) given by USEtox® by Ecotoxicity

The ecotoxicity FCs provided by USEtox according to different substances commonly found in pineapple production are presented below.

Table A5.3. Midpoint characterization factors for freshwater ecotoxicity impact for active ingredients commonly found in pineapple production

		<i>Ecotoxicity midpoint characterization factor (CF) [PAF.m³.clay/kg emitted].</i>									
CAS Number	Name of active ingredient	Natural means of emission	Emission to indoor air housing	Industrial indoor air emission	Urban air emissions	Rural air emission	Freshwater emission	Saltwater emission	Natural soil emission	Agricultural soil emission	
		Use	Fresh water	Fresh water	Fresh water	Fresh water	Fresh water	Fresh water	Fresh water	Fresh water	
98886-44-3	Phosthiazate	Insecticide / nematocide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	
69327-76-0	Buprofezin	Insecticide / nematocide	10,17222456	14,11981921	16,75154898	3,592900129	894,4424472	0,039601486	4,183080454	4,979534052	
121-75-5	Malathion	Insecticide / nematocide	6979,448534	10423,17426	12718,9914	1239,905666	62163,05441	0,007426976	69,79832407	69,79796065	
52315-07-8	Cypermethrin	Insecticide	770038,7063	1004380,309	1160608,044	379469,3688	50264426,19	1040,338526	13442,80512	13442,71516	
108-94-1	Cyclohexanone	Insecticide	1,350384667	1,356442276	1,360480681	1,340288652	66,42535552	0,018940529	13,24326815	13,24326671	
1330-20-7	Xylene	Insecticide	0,010065682	0,010446432	0,010700265	0,009431099	77,42689879	0,000852843	0,862449519	0,862460306	
52918-63-5	Deltamethrin	Insecticide	23957,33771	30409,57691	34711,06971	13203,60572	3430135,176	197,4873177	795,9438513	795,9373957	
82560-54-1	Benfuracarb	Insecticide	17427,96761	25737,22716	31276,73352	3579,201692	210238,9723	0,18943943	140,8672743	140,8608272	
333-41-5	Diazinon	Insecticide	3745,43742	5433,510128	6558,891932	931,9829087	185211,2189	0,308912314	1612,544632	1566,111653	
2921-88-2	Chlorpyrifos	Insecticide	23836,2299	33103,11877	39281,04469	8391,415119	6230276,073	222,876553	7087,946472	7088,054959	
60-51-5	Dimethoate	Insecticide	3139,659894	4213,483112	4929,365257	1349,954532	17905,29326	0,000454024	1253,237448	1253,246468	
935545-74-7	Spinetoram	Insecticide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	
63-25-2	Carbaryl	Insecticide	6317,577841	9093,974505	10944,90561	1690,250067	45855,36751	0,018518106	731,11175	731,1687844	
68038-71-1	Bacillus thuringiensis	Insecticide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	

110488-70-5	Dimethomorph	Fungicide	450,8366947	621,8249385	735,8171011	165,8562882	2742,43128	0,000132897	147,525804	147,5258041
57837-19-1	Metalaxyl	Fungicide	209,8420557	242,7480398	264,6853625	154,9987489	955,8209987	0,001372589	168,7539613	168,7537276
77732-09-3	Oxadixil	Fungicide	52,03325428	51,85468765	51,73564324	52,33086533	158,5946632	4,19431E-07	59,48441786	59,48441786
17804-35-2	Benomyl	Fungicide	3511,741966	5001,272979	5994,293655	1029,190278	24072,71466	1,08447E-06	776,6166022	1060,226557
60207-90-1	Propiconazole	Fungicide	3339,657403	4766,707658	5718,074495	961,2403104	22239,62311	0,006906825	496,9268247	496,8909023
67747-09-5	Prochloraz	Fungicide	28525,52551	42189,41997	51298,68294	5752,368078	391374,2504	0,841721376	988,2570677	977,4887111
131341-86-1	Fludioxonil	Fungicide	13795,73395	20543,759	25042,44236	2549,025537	98718,0998	0,006280178	249,3685721	249,3664887
57966-95-7	Cymoxanil	Fungicide	1611,069205	2362,691533	2863,773085	358,3653248	10896,54867	5,73978E-05	76,6615977	81,56948469
12071-83-9	Propineb	Fungicide	755,024429	1110,383526	1347,289591	162,7592675	4945,389344	3,17463E-05	58,04146351	58,04146351
8018-01-7	Mancozeb	Fungicide	8040,154439	11308,86306	13488,00214	2592,306738	52647,33107	1,00527E-09	982,9896617	4128,636841
39148-24-8	Fosetyl aluminium	Fungicide	223,3260629	334,6138042	408,8056317	37,84649409	1490,552565	9,00067E-10	2,052606972	2,052606972
119446-68-3	Difenoconazole	Fungicide	8101,527309	10422,66212	11970,08533	4232,96929	128639,7566	0,000354436	1462,125529	1462,000442
43121-43-3	Triadimefon	Fungicide	911,437564	1329,684039	1608,515023	214,3601051	5785,838939	7,68807E-05	75,0756325	75,07523137
133-06-2	Captan	Fungicide	8609,831904	12772,90776	15548,29166	1671,372145	84839,16389	0,05094353	399,8088508	399,8094889
5234-68-4	Carboxin	Fungicide	3463,025257	5193,179163	6346,6151	579,4354143	24613,87962	0,000587619	81,20045228	81,1998791
10605-21-7	Carbendazim	Fungicide	107189,3872	156015,2784	188565,8726	25812,90179	739596,1398	0,001807334	18449,08061	17856,65735
84696-15-1	Ginger extract	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
131860-33-8	Azoxystrobin	Fungicide	14038,19787	14558,91765	14906,06418	13170,33157	77028,28406	3,91764E-06	15613,74014	15613,74014
81412-43-3	Tridemorph (technical)	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV

24602-86-6	Tridemorph	Fungicide	49,324,05686	67,984,95403	80,425,55214	18,222,56158	53119,03888	1,548,655149	54,959,93319	30,564,99174
23564-05-8	Thiophanate methyl	Fungicide	1019,654878	1528,173456	1867,185841	172,123,9159	7409,131722	6,534,36E-05	5,620,878826	11,835,57927
7558-80-7	Monobasic phosphite of Na and K		N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
7558-79-4	Dibasic phosphite of Na and K		N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
68647-73-4	Tea Tree Oil (melaleuca alternifolia)	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
1071-83-6	Glyphosate	Herbicide	78,499,76193	88,602,30014	95,337,32561	61,662,19825	320,785,2096	1,983,44E-07	71,724,23705	71,833,4829
834-12-8	Ametryn	Herbicide	11095,44344	15784,57111	18910,65622	3280,230661	75920,76885	0,0382,33775	1814,707026	1798,494328
330-54-1	Diuron	Herbicide	11331,78049	14822,87294	17150,26791	5513,293076	59976,6839	0,008900192	4643,010627	4642,988447
314-40-9	Bromacil	Herbicide	973,0047157	1105,812143	1194,350428	751,6590031	3903,812628	0,000171476	784,5913597	771,8091832
100646-51-3	Quizalofop - P- ethyl	Herbicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
69806-34-4	Haloxypop-r methyl ester	Herbicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
42874-03-3	Oxyfluorfen	Herbicide	948,7473539	1156,468856	1294,949857	602,5448507	63827,79542	4,323144549	18,269,93829	18,269,82766
1912-24-9	Atrazine	Herbicide	13496,05218	18680,54474	22136,87311	4855,231247	87360,96299	0,055944615	3427,168517	3426,709295
1910-42-5	Paraquat dichloride	Herbicide	821,3026937	1215,396686	1478,126015	164,4793724	5259,794096	2,463,98E-08	33,3461264	33,345,82563
16672-87-0	Ethephon (Ethylene)	Physiological regulator	262,1744611	344,3985733	399,214648	125,1342742	1359,828738	2,146,59E-14	102,0002077	101,837,3734
86-87-3	Alpha naphthylacetic acid	Physiological regulator	25,81781689	32,57494349	37,07969456	14,55593923	128,6196661	2,41074E-08	12,428,04447	15,715,45304
68157-60-8	Forchlorfenuron	Physiological regulator	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
133-32-4	Indolylbutyric acid	Physiological regulator	28,60417562	38,99217448	45,91750705	11,290,84419	181,074,9643	2,324,78E-08	9,330,30046	16,629,998
50-65-7	Niclosamide	Molluscicide	21244,75795	25374,74388	28128,06783	14361,44806	434951,6669	0,000165898	6073,671906	6353,257721
108-62-3	Metalddehyde	Molluscicide	3,891749332	4,385018627	4,713864823	3,069633842	245,9221306	0,003257538	25,266,22007	25,266,21151

39121-37-4	5- Hydroxy-5-methylheptan-3-one	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
21570-35-4	2-methyl-4-heptanol	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
154170-44-2	4-methyl-5-nonanol	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
32723-67-4	4-methoxy-3-methylbenzaldehyde	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
1405-41-0	Gentamicin sulfate	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
2058-46-0	Oxytetracycline hydrochloride	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
99129-21-2	Clethodim	490,3497048	739,0542477	904,8572763	75,84213337	3734,075794	4,8723E-06	1,91048443	7,085067594										
71626-11-4	Benalaxil	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
1897-45-6	Chlorothalonil	42742,77915	44743,64147	46077,54969	39408,00861	1143877,45	814,7741465	8259,067954	8259,01547										
51235-04-2	Hexazinone	23625,84055	28888,60981	32397,12265	14854,55846	118114,9574	0,000103887	6560,191197	26229,35444										
57764-08-6	Furalaxyl - M	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
24579-73-5	Propamocarb	24,06148012	36,23275607	44,34694005	3,776020188	165,4873463	2,2054E-06	0,012763654	0,012898493										
25606-41-1	Propamocarb HCL	17,69612673	25,71905599	31,0676755	4,32457797	111,6399835	1,19712E-09	1,817364422	1,817347665										
135410-20-7	Acetamiprid	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
116714-46-6	Novaluron	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
138261-41-3	Imidacloprid	891,4342613	898,5634912	903,3163112	879,5522114	3196,828241	6,81656E-09	1223,18985	1223,161488										
82657-04-3	Bifenthrin	115147,0887	147455,6963	168994,768	61299,40933	6578908,376	147,9796931	1378,994364	1379,142281										
12057-74-8	Magnesium phosphide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
53112-28-0	Pyrimethanil / Pyrimethanil	122,7646303	182,6326112	222,5445985	22,98466219	3406,790832	0,002772443	47,00057772	45,66154461										

76674-21-0	Flutriafol	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
946578-00-3	Sulfoxatlor	Insecticide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
77182-82-2	Glufosinate ammonium / Glufosinate ammonium	Herbicide	88,65740981	130,978146	159,1919701	18,12284956	577,8562139	4,59802E-14	4,103288242	4,10324982			
153719-23-4	Thiamethoxam	Insecticide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
91465-08-6	Lambda-cyhalothrin / Lambda-Cyhalothrin	Insecticide	1188545,518	1568289,94	1821452,889	555638,1466	138627257	3682,903272	9289,573091	9289,523534			
100646-51-3	Quizalofop-ethyl	Herbicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
7758-99-8	Copper sulfate pentahydrate	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
99129-21-2	Clethodim	Herbicide	490,3497048	739,0542477	904,8572763	75,84213337	3734,075794	4,8723E-06	1,91048443	7,085067594			
69806-40-2	Haloxypop-P-Methyl	Herbicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV
56073-10-0	Brodifacoum	Rodenticide	108,692184	130,2285614	144,5861463	72,79822156	3535,737457	6,36006E-14	0,99413839	5,060536691			
148-24-3	8-Hydroxyquinoline	Fungicide and Bactericide	6,684146642	9,827404564	11,92290985	1,445383437	1258,950085	0,001298924	0,456494255	0,789873862			
211867-47-9	Flumorph	Fungicide	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV	N/AV

Note: N/AV: Characterization factors not available; N/A: Characterization factors not applicable.

Source: Adapted from USEtox. Excel "USEtox Results organics," "Ecotox CF" tab, midpoint impacts. [Cited 7 March 2023]. <https://usetox.org/model/download>

5. Determination of the characterization factor (CF) given by USEtox® for human toxicity

The human toxicity CFs provided by USEtox according to different substances commonly found in pineapple production are presented below.

Table A5.4. Midpoint characterization factors for human toxicity impact for active ingredients commonly found in pineapple production

CAS number	Name of active ingredient	Natural means of emission	Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																							
			Indoor air emission			Industrial indoor air emission			Emissions to urban air			Emission to rural air			Emission to fresh water			Emission to seawater			Emission to natural soil			Emission to agricultural land		
			Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total	Cancer	Non-canc.	Total
98886-44-3	Fosthiazate	Insecticide/nematocide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
69327-76-0	Buprofezin	Insecticide/nematocide	N/A	0.000 6019	0.00 06019	N/A	2.095 E-05	2.095 E-05	N/A	4.6488 5E-06	4.648 85E-06	N/A	2.140 6E-06	2.140 6E-06	N/A	2.140 6E-06	N/A	1.142 E-05	1.142 E-05	N/A	1.011 3E-07	1.011 3E-07	N/A	5.6995 1E-08	5.6995 1E-08	5.2105 2E-06
121-75-5	Malathion	Insecticide/nematocide	0	1.86 2E-05	1.862 E-05	0	5.885 E-07	5.885 E-07	0	8.0476 8E-08	8.047 68E-08	0	1.2553 7E-08	1.2553 7E-08	0	2.144 E-07	2.144 E-07	2.144 E-07	2.144 E-07	0	1.08 37E-09	1.083 7E-09	0	2.4095 9E-10	2.4095 9E-10	1.8458 4E-09
52315-07-8	Cypermethrin	Insecticide	N/A	0.000 1089	0.000 1089	N/A	4.38 2E-06	4.382 E-06	N/A	1.4590 1E-06	1.4590 1E-06	N/A	9.4469 3E-07	9.4469 3E-07	N/A	4.108 E-06	4.10 8E-06	N/A	2.805 9E-07	2.805 9E-07	N/A	2.805 9E-07	2.805 9E-07	1.369 2E-09	1.369 2E-09	1.235 79E-07
108-94-1	Cyclohexanone	Insecticide	0	1.17E-06	1.17 E-06	0	3.879 E-08	3.879 E-08	0	7.3528 1E-09	7.3528 1E-09	0	8.5041 7E-10	8.5041 7E-10	0	7.383 E-09	7.383 E-09	0	1.471 8E-11	1.471 8E-11	0	1.6739 7E-09	1.6739 7E-09	7.0502 5E-09		
1330-20-7	Xylene	Insecticide	1.56 7E-06	3.64 7E-05	3.804 E-05	5.1137 2E-08	1.19 E-06	1.241 E-06	8.96 542E-09	2.085 2E-07	2.1748 5E-07	4.4521 3E-10	1.0223 5E-08	1.0668 8E-08	1.847 E-08	1.467 E-08	3. 8E-09	9.868 9E-10	7.5319 3E-11	1.062 2E-09	1.062 2E-09	3.626 16E-10	7.5246 6E-09	7.8872 8E-09	1.4587 4E-08	1.86 17E-08
52918-63-5	Deltamethrin	Insecticide	0	0.000 1953	0.000 1953	0	7.491 E-06	7.491 E-06	0	2.2426 3E-06	2.2426 3E-06	0	1.3110 6E-06	1.3110 6E-06	0	7.519 E-06	7.51 E-06	0	3.401 1E-07	3.40 11E-07	0	6.2097 2E-09	6.2097 2E-09	2.007 19E-07	2.0071 9E-07	
82560-54-1	Bentfuracarb	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
333-41-5	Diazinon	Insecticide	0	0.005 2862	0.005 2862	0	1.734 E-05	0.000 1734	0	3.0103 6E-05	3.0103 6E-05	0	7.004 1E-06	7.004 1E-06	0	0.000 1551	0.000 1551	0	1.526 3E-06	1.526 3E-06	0	1.3716 9E-06	1.3716 9E-06	3.1227 1E-05	3.1227 1E-05	
2921-88-2	Chlorpyrifos	Insecticide	0	0.001 3236	0.001 3236	0	4.584 E-05	4.584 E-05	0	1.0313 4E-05	1.0313 4E-05	0	3.031 9E-06	3.031 9E-06	0	0.000 4578	0.000 4578	0	2.537 8E-05	2.537 8E-05	0	5.4523 5E-07	5.4523 5E-07	7.809 19E-06	7.8091 9E-06	

Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																					
Natural means of emission	Indoor air emission			Industrial indoor air emission			Emissions to urban air			Emission to rural air			Emission to fresh water		Emission to seawater		Emission to natural soil		Emission to agricultural land		
60-51-5	0	0.00	0.000	0	1.409	1.409	0	1.6519	7.9568	7.9568	0	1.2624	1.262	2.9121	2.9121	0	1.2524	1.2524	0	1.2524	
935545-74-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
63-25-2	0.00	0.000	0.000	0.000	1.169	8.669	2.036	1.749	4.8078	4.8078	2.360	9.322	2.19	8.3002	1.9498	1.119	4.1047	9.6424	5.5377	4.1047	
68038-71-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
110488-70-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
57837-19-1	N/A	3.121	3.121	N/A	1.117	1.117	N/A	2.5221	2.2745	2.2745	N/A	2.621	2.621	1.0645	1.0645	N/A	3.7770	3.7770	N/A	3.7770	
77732-09-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17804-35-2	N/A	1.493	1.493	N/A	4.653	4.653	N/A	5.3160	2.3349	2.3349	N/A	1.8978	1.897	4.6210	4.6210	N/A	4.8702	4.8702	N/A	4.8702	
60207-90-1	N/A	0.000	0.000	N/A	7.544	7.544	N/A	4.3331	1.4779	1.4779	N/A	3.5625	3.562	3.434	3.4347	N/A	2.069	2.069	N/A	2.069	
67747-09-5	0.000	0.000	0.000	2.467	4.602	4.602	2.22	4.1527	5.8026	5.8026	7.09E-05	1.05	1.617	7.646	1.1747	4.1009	1.8984	2.9166	1.0181	1.8984	
131341-86-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
57966-95-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12071-83-9	N/A	0.000	0.000	N/A	2.433	2.433	N/A	4.642	8.6240	8.6240	N/A	1.175	1.175	1.6816	1.6816	N/A	6.7941	6.7941	N/A	6.7941	
8018-01-7	N/A	0.000	0.000	N/A	3.72	3.72	N/A	6.636	2.1844	2.1844	N/A	4.781	4.781	4.0325	4.0325	N/A	4.3703	4.3703	N/A	4.3703	
39148-24-8	1.33	7.771	2.11	4.425	2.581	7.007	8.338	4.86	8.8948	2.4148	81E-09	2.803	7.610	2.0502	5.566	3.5159	4.2463	1.1528	7.2820	4.2463	
119446-68-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
43121-43-3	N/A	0.000	0.00	N/A	8.218	8.218	N/A	2.571	5.5019	5.5019	N/A	7.79E-08	7.779	1.0787	1.0787	N/A	4.7648	4.7648	N/A	4.7648	
133-06-2	4.12	4.337	4.75	1.525	1.604	1.756	4.487	4.716	8.1267	8.8999	1.90	2.498	2.736	9.4516	1.035	8.9931	3.7950	4.0904	3.5538	3.7950	

Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																	
Natural means of emission	Indoor air emission		Industrial indoor air emission		Emissions to urban air		Emission to rural air		Emission to fresh water		Emission to seawater		Emission to natural soil		Emission to agricultural land		
	N/A	5.408 E-05	5.408 E-05	1.8E-06	3.389 03E-07	3.389 03E-07	8.0146 4E-08	8.0146 4E-08	1.082 E-06	1.082 E-06	1.554 3E-09	1.554 3E-09	N/A	3.5680 6E-09	3.5680 6E-09	1.9587 9E-08	1.9587 9E-08
5234-68-4	Fungi-cide	5.408 E-05	5.408 E-05	1.8E-06	N/A	3.389 03E-07	3.389 03E-07	8.0146 4E-08	8.0146 4E-08	1.082 E-06	1.082 E-06	N/A	3.5680 6E-09	3.5680 6E-09	N/A	1.9587 9E-08	1.9587 9E-08
10605-21-7	Fungi-cide	7.77 E-05	7.77 E-05	2.56 E-06	N/A	4.562 38E-07	4.562 38E-07	1.0435 7E-07	1.0435 7E-07	1.501 E-06	1.501 E-06	N/A	3.7432 6E-08	3.7432 6E-08	N/A	1.2384 2E-07	1.2384 2E-07
84696-15-1	Fungi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
131860-33-8	Fungi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
81412-43-3	Fungi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
24602-86-6	Fungi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23564-05-8	Fungi-cide	6.765 E-05	6.765E-05	2.333 E-06	N/A	5.30 186E-07	5.301 86E-07	8.8360 6E-08	8.836 06E-08	1.753 E-06	1.753 E-06	N/A	1.3304 2E-09	1.3304 2E-09	N/A	8.1073 4E-09	8.107 4E-09
7558-80-7	Monobasic phosphate of Na and K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7558-79-4	Dibasic phosphate of Na and K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
68647-73-4	Fungi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1071-83-6	Herbi-cide	1.744 E-05	1.744 E-05	5.559 E-07	N/A	6.85 077E-08	6.850 77E-08	6.5824 8E-08	6.5824 8E-08	2.727 3E-11	2.727 3E-11	N/A	3.5836 4E-08	3.5836 4E-08	N/A	1.1593 2E-07	1.1593 2E-07
834-12-8	Herbi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
330-54-1	Herbi-cide	0.000 3121	0.000 3121	1.12 E-05	0	2.534 33E-06	2.5343 3E-06	2.365 3E-06	2.365 3E-06	1.7575 E-08	1.757 5E-08	0	5.0769 9E-07	5.0769 9E-07	0	3.7662 6E-06	3.7662 6E-06
314-40-9	Herbi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100646-51-3	Herbi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
69806-34-4	Herbi-cide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																										
Nat- ural means of emis- sion	Indoor air emission			Industrial indoor air emission			Emissions to urban air			Emission to rural air			Emission to fresh water			Emission to seawater			Emission to natural soil			Emission to agricultural land				
42874-03-3	Oxyfluorfen	N/A	0.003 2256	0.003 2256	N/A	0.000 1292	0.000 1292	4.434 33E-05	4.434 33E-05	2.0488 9E-05	2.0488 9E-05	N/A	7.940 7E-05	7.940 7E-05	N/A	2.161 75E-07	2.161 75E-07	2.161 75E-07	2.161 75E-07	N/A	2.306 55E-06	2.306 55E-06	N/A	2.306 55E-06	2.306 55E-06	2.306 55E-06
1912-24-9	Atrazine	0.000 1338	0.000 155	0.0002 888	4.876 08E-06	5.653 E-06	1.053 E-05	1.259 84E-06	1.460 46E-06	2.720 3E-06	8.1126 3E-07	6.9981 9E-07	3.692 E-06	7.37 11E-09	6.3585 1E-09	1.4503 1E-07	1.6812 7E-07	3.1315 9E-07	1.6812 7E-07	8.0603 7E-07	9.3439 6E-07	1.7404 3E-06	9.3439 6E-07	1.7404 3E-06	9.3439 6E-07	
1910-42-5	Paraquat dichloride	N/A	0.000 4316	0.000 4316	N/A	1.403 E-05	1.403 E-05	2.285 97E-06	2.285 97E-06	6.128 6E-07	6.128 6E-07	N/A	N/A	3.284 6E-09	3.284 6E-09	N/A	4.119 3E-08	4.119 3E-08	4.119 3E-08	N/A	9.3687 2E-08	9.3687 2E-08	N/A	9.3687 2E-08	9.3687 2E-08	
16672-87-0	Ethephon (Ethylene)	N/A	0.000 2648	0.000 2648	N/A	9.049 E-06	9.049 E-06	1.819 77E-06	1.819 77E-06	9.8837 5E-07	9.8837 5E-07	N/A	N/A	9.891 7E-10	9.891 7E-10	N/A	3.7989 7E-07	3.7989 7E-07	3.7989 7E-07	N/A	9.3885 4E-07	9.3885 4E-07	N/A	9.3885 4E-07	9.3885 4E-07	
86-87-3	Alpha naphthyl- lactic acid	0	N/A	0	0	N/A	0	N/A	0	0	0	0	0	N/A	0	N/A	0	N/A	0	0	N/A	0	N/A	0	0	
68157-60-8	Forchlorfenuron	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
133-32-4	Indolylbutyric acid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
50-65-7	Niclosamide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
108-62-3	Metalddehyde	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
39121-37-4	5- Hy- droxy-5-methyl- heptan-3-one	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
21570-35-4	2-methyl-4-hep- tanol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
154170-44-2	4-meth- yl-5-nonanol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
32723-67-4	4-me- thoxy-3-methyl- benzaldehyde	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1405-41-0	Gentamicin sulfate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
2058-46-0	Oxytetracycline hydrochloride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																									
99129-21-2	Natural means of emission	Indoor air emission			Industrial indoor air emission			Emissions to urban air			Emission to rural air			Emission to fresh water			Emission to seawater			Emission to natural soil			Emission to agricultural land		
		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
71626-11-4	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1897-45-6	Fungicide	2.185E-06	6.587E-05	6.805E-05	1.08387E-07	3.267E-06	3.375E-06	5.06711E-08	1.52718E-06	1.57785E-06	3.86912E-08	1.16612E-06	1.20481E-06	3.312E-06	3.422E-06	2.50394E-09	7.5467E-08	7.7971E-08	1.84195E-09	5.55145E-08	5.73565E-08	4.37707E-09	1.31921E-07	1.36298E-07	N/A
51235-04-2	Herbicide	N/A	5.43E-05	5.43E-05	N/A	1.936E-06	1.936E-06	N/A	4.18314E-07	4.18314E-07	N/A	4.41927E-07	4.41927E-07	1.046E-06	1.046E-06	N/A	4.2601E-10	4.2601E-10	N/A	5.80773E-08	5.80773E-08	N/A	9.7369E-07	9.7369E-07	N/A
57764-08-6	Herbicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
24579-73-5	Fungicide	N/A	5.397E-05	5.397E-05	N/A	1.666E-06	1.666E-06	N/A	1.85549E-07	1.85549E-07	N/A	2.25072E-08	2.25072E-08	5.091E-07	5.091E-07	N/A	2.4645E-10	2.4645E-10	N/A	3.92654E-11	3.92654E-11	N/A	1.50057E-10	1.50057E-10	N/A
25606-41-1	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
135410-20-7	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
116714-46-6	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
138261-41-3	Insecticide	N/A	9.6E-05	9.6E-05	N/A	4.241E-06	4.241E-06	N/A	1.64865E-06	1.64865E-06	N/A	1.34268E-06	1.34268E-06	2.504E-06	2.504E-06	N/A	5.8378E-10	5.8378E-10	N/A	9.58071E-07	9.58071E-07	N/A	1.99156E-06	1.99156E-06	N/A
82657-04-3	Insecticide	0	0.0001332	0.0001332	0	8.564E-06	8.564E-06	0	5.45386E-06	5.45386E-06	0	2.88753E-06	2.88753E-06	0.0001246	0.0001246	0	2.094E-05	2.094E-05	0	2.68088E-08	2.68088E-08	0	1.28289E-07	1.28289E-07	N/A
12057-74-8	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
53112-28-0	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
76674-21-0	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
946578-00-3	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
77182-82-2	Herbicide	N/A	0.00027	0.00027	N/A	8.427E-06	8.427E-06	N/A	9.93248E-07	9.93248E-07	N/A	3.43327E-07	3.43327E-07	2.469E-06	2.469E-06	N/A	4.2263E-10	4.2263E-10	N/A	1.75332E-08	1.75332E-08	N/A	5.6828E-08	5.6828E-08	N/A
153719-23-4	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Characterization factor (CF) of midpoint in Human Toxicity [cases/kg issued]																										
Natural means of emission	Indoor air emission			Industrial indoor air emission			Emissions to urban air			Emission to rural air			Emission to freshwater			Emission to natural soil			Emission to agricultural land							
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
91465-08-6	Lambdacyhalothrin / Lambda-Cyhalothrin	Insecticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100646-51-3	Quinalofop-ethyl	Herbicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7758-99-8	Copper sulfate pentahydrate	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
99129-21-2	Clethodim	Herbicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
69806-40-2	Haloxyp-P-Methyl	Herbicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
56073-10-0	Brodifacoum	Rodenticide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
148-24-3	8-Hydroxyquinoline	Fungicide and Bactericide	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0
211867-47-9	Flumorph	Fungicide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: N/A: Characterization factors not available; N/A: Characterization factors not applicable.

Source: Adapted from **USEtox**. Excel "USEtox Results organics," "Ecotox CF" tab, midpoint impacts. [Cited 7 March 2023]. <https://usetox.org/model/download>

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