METHODOLOGICAL GUIDE TO REDUCE CARBON AND WATER FOOTPRINTS IN BANANA PLANTATIONS

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Contents

Acronyms

AWARE	Available WAter Remaining
BOD	Biological Oxygen Demand
CERs	Certified Emission Reductions
CF	Characterization Factor
CIBSA	Compañía Internacional de Banano S.A.
COD	Chemical Oxygen Demand
CORBANA	Corporación Bananera Nacional, Costa Rica
CSA	Climate Smart Agriculture
CTU	Comparative Toxic Units
DCC	Dirección de Cambio Climático (Climate Change Unit), Costa Rica
DWW	Domestic Wastewater
EF	Emission Factor
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FONAFIFO	Fondo Nacional de Financiamiento Forestal (National Forestry Financing Fund), Costa Rica
FU	Functional Unit
GHG	Greenhouse Gases
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IFA	International Fertilizer Association
IMN	National Meteorological Institute, Costa Rica
INTECO	Technical Standards Institute of Costa Rica
IPCC	Intergovernmental Panel on Climate Change
ISO	Internatioal Organization for Standardization
IWW	Industrial Wastewater
MINAE	Ministry of Environment and Energy, Costa Rica
MSW	Municipal Solid Wastes
PAF	Potentially Affected Fraction
PFCs	Perfluorocarbons
RA	Rain Forest Alliance
RECOPE	Costa Rican Oil Refinery
SAN	Sustainable Agriculture Network
SDGs	Sustainable Development Goals
UCC	Costa Rican Offset Unit (Unidad Costarricense de Compensación)
UN	United Nations
UNC	National Offset Units (Unidades Nacionales de Compensación)
VERs	Voluntary Emission Reductions
VVA	Verification and Validation Agency
WBF	World Banana Forum
WWF	World Wildlife Fund

1. Introduction

Banana is one of the world's most popular fruits.[1] The Food and Agriculture Organization of the United Nations (FAO) has identified it as the most exported fresh fruit in the world and an essential source of income for thousands of rural homes in developing countries.[2] But banana production requires the intensive use of agrochemicals, fertilizers and water. Therefore, its production must go hand in hand with strategies to safeguard the health and safety of workers, the community and the environment.

Banana plantation. Photo Miguel Vallejo

On the other hand, the growth of world population demands an increase in agricultural production to meet the needs and safeguard food security, which are being threatened by the climate phenomena the world is experiencing (greater frequency and intensity of floods, hurricanes, draughts, extreme temperatures, etc.), which will affect agriculture more and more significantly in the near future. In order to attain sustainable development and food security, the implementation of the concept of Climate Smart Agriculture, or CSA, has been promoted in recent years. This concept seeks the development of technical, political and investment conditions in order to attain sustainable agricultural production that will protect food security under climate change conditions.[3]

In compliance with its objectives for the sector, FAO created the World Banana Forum (WBF), with the aim of providing a joint work space for these interest groups. Its mission includes achieving consensus regarding good work practices, gender equality, environmental impact, sustainable production and economic issues.[2]

The initiative to develop this guide as a means for promoting CSA in the sector, through emission management and proper handling of water resources, arises as a result of the efforts of the WBF, with the support of the German International Cooperation Agency (GIZ) in Costa Rica.

The role of Costa Rica with respect to emission management must be highlighted as a frame of reference, as it is currently implementing the Country for Carbon Neutrality Program, officially adopted under Agreement-36-2012 of the Ministry of Environment and Energy (MINAE), and is backed by the National Standard for Carbon Neutrality INTE 12-01-06:2016 in its most recent version. This scenario promotes the issue in the region for the banana sector.

1.1. What does emission management and water resource management in an organization consist of?

The atmosphere is a fluid made up of different types of gases, among them some with good capacity to absorb solar radiation, known as greenhouse gases or GHG. These play an important role in warming the atmosphere and, therefore, are responsible for a proper temperature on Earth to harbor life. This process is known as the natural greenhouse effect.

However, human activity has been generating emissions that exceed the natural levels from GHG, as well as other GHG emissions of synthetic origin. A greater amount of GHG in the atmosphere increases the capture of radiation and causes a rise in the Earth's temperature. This phenomenon has led to an increase of the greenhouse effect and its main consequence is the change in average global temperature, known as Climate Change.

It is for this reason that organizations are encouraged, through voluntary regulations and various programs, to quantify, reduce and properly manage their GHG emissions. The objective is to create awareness regarding the impact of production activities on climate change, and reduce said impact to the extent that the organization is capable.

On the other hand, water is an essential resource for life of human beings and the ecosystem, and cannot be replaced by any other substance. Its availability worldwide varies depending on the region. In some regions this resource is scarce, resulting in a negative impact on human health and affecting the biodiversity of ecosystems. In other regions, scarcity problems are aggravated by overexploitation and contamination of water sources, particularly for industrial and agricultural uses.[4,5]

With the growth of the world's population, the demand for water is increasing, and availability of the resource is limited.[6] This scenario is compounded by the consequences of climate change, as it is anticipated that pressure on water sources will grow even further. Quantifying water use and pollution, and evaluating environmental impact under a life cycle approach, are fundamental steps in reducing impacts on the resource[5] and ensuring its quantity, quality and continuity for an organization.

1.2. What is the origin of the concepts of GHG emissions inventory and water footprint?


Packing plant. Photo Miguel Vallejo

The quantification of GHG emissions comes from years of research and was promoted in 1997 with the approval of the Kyoto Protocol, during the Third Session of the Conference of the Parties on Climate Change. There are different methodologies to estimate emissions, such as the Guidelines of the Intergovernmental Panel on Climate Change (IPCC), the guidelines published by the Greenhouse Gas Protocol (GHG Protocol), voluntary standards such as PAS 2050 and 2060, and the family of ISO 14064 voluntary standards, which cover the development of national, organizational or product inventories.

This guide is based on the GHG inventory development procedure in an organization, as set out in international ISO 14064 voluntary standard "Greenhouse gases-Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals". In addition, it follows the guidelines in the GHG Protocol and the IPCC Guidelines as emission estimation methodologies, with the aim of directing the efforts of the sector along a single path in the quantification of its emissions.

On the other hand, the water footprint concept has evolved from different methodologies such as the ecological footprint, virtual water, the water footprint (according to the International Water Footprint Network and Hoesktra et al., 2003), and the international voluntary standards for life cycle assessment (ISO 14044). Among these, the most widely accepted concept by the international community is currently that of the water footprint, whose development derives from the concepts mentioned above.

The purpose of this guide is to introduce the banana sector to the estimation of the environmental indicator known as the water footprint. The proposed structure was developed on the basis of the international ISO 14046 standard "Environmental Management - Water footprint - Principles, requirements and guidelines".

Compared to other methodologies, the water footprint has the advantage of being a more complete and significant indicator for a comprehensive assessment of water resource management in an organization or product. It enables a banana company to analyze and understand its impact, identify risks and opportunities related to water management, and monitor and report performance to the company's stakeholders.[70] Moreover, there is a global tendency of the markets to move toward the concept of life cycle analysis, which is the basis for the ISO 14046 standard.

1.3. What is the importance of properly measuring and managing carbon emissions as well as the impact of water use in a banana company?

Climate Change is having a direct impact on the agricultural sector, which contributes 13% of the total worldwide GHG emissions, and it is estimated that this contribution will increase with population growth and changes in consumer habits.[61]

Likewise, the negative effects of climate change will impact all components of the water cycle, affecting agriculture through the increase in evapotranspiration from crops, changes in the amount of rainwater, variations in river runoff and groundwater recharge. FAO underscores that the effect of climate change on water resources has a broad context, and must be assessed taking into consideration the increase in demand by all sectors, the degradation of water quality and the competition for water at various levels (community, rivers, drainage basins and aquifers)[3].

It is important to note that awareness of the impact of climate change has led companies to include sustainability as one of the criteria for evaluation of their clients and investors.[7] In addition, in 2015 the countries of the United Nations (UN) organization agreed to work toward various sustainable development goals (SDGs) over the next fifteen years. Implementing an emission and water management system will contribute to attain goals SDG 6 "Clean water and sanitation", SDG 12 "Responsible consumption and production" and SDG 13 "Climate action".[72,73]

The Paris Agreement, in which the signatory countries undertake, among other aspects, to reduce their GHG emissions, was signed in 2015 within the Framework Convention on Climate Change.[74]

For the above reasons, estimations of the carbon and water footprints are important methods for the banana sector to contribute to meet the goals and targets undertaken at the global and national levels, and this guide seeks to encourage the sector in this regard.

In addition, among the benefits of quantifying the carbon footprint, and the resulting quantification and reduction of emissions, are the reduction of operating costs, compliance with environmental requirements and response to the demand of the international markets, as well as image improvement.[7] Likewise, this contributes to sustainability of the business, makes it possible to identify processes that must be adjusted to improve efficiency, and is a differentiating factor in the markets, opening new business opportunities.[8]

On the other hand, quantifying the water footprint in the organization provides an opportunity for identifying where and how use and productivity can be optimized in relation to managing the resource and reducing environmental impacts. Furthermore, this indicator can serve as a verification mechanism for the responsible management of the resource. Among other advantages, there is the opportunity to report, based on reliable and scientifically backed evidence, on the potential environmental impact related to water (in terms of quantity and quality), to the companies' decision makers.[9]

It is important to highlight that quantification of the carbon and water footprints helps to comply with requirements of certification standards such as the Rainforest Alliance (RA) and Global GAP, which require planning and management systems, documentation of production inputs, water system management, as well as management and possible reduction in the use of energy and water.

CARBON FOOTPRINT

2. Calculating the carbon footprint of my organization

This chapter describes the process, the basic aspects and method of calculation for banana companies to quantify and report their carbon emissions into the atmosphere (Figure 2.1).

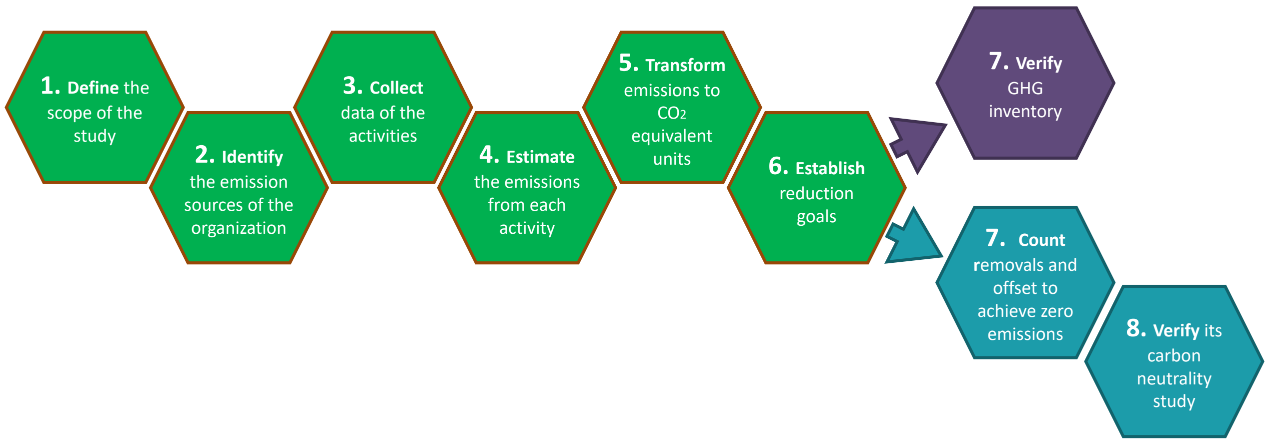


Figure 2.1. Emission inventory measurement process.

This guide focuses on the management of carbon emissions of an organization; its scope, indicated in the first step shown in Figure 2.1, covers emissions that can be generated from the plantation area (planting and harvesting) to the transport by road of the fruit to the ports for export (Figure 2.2).

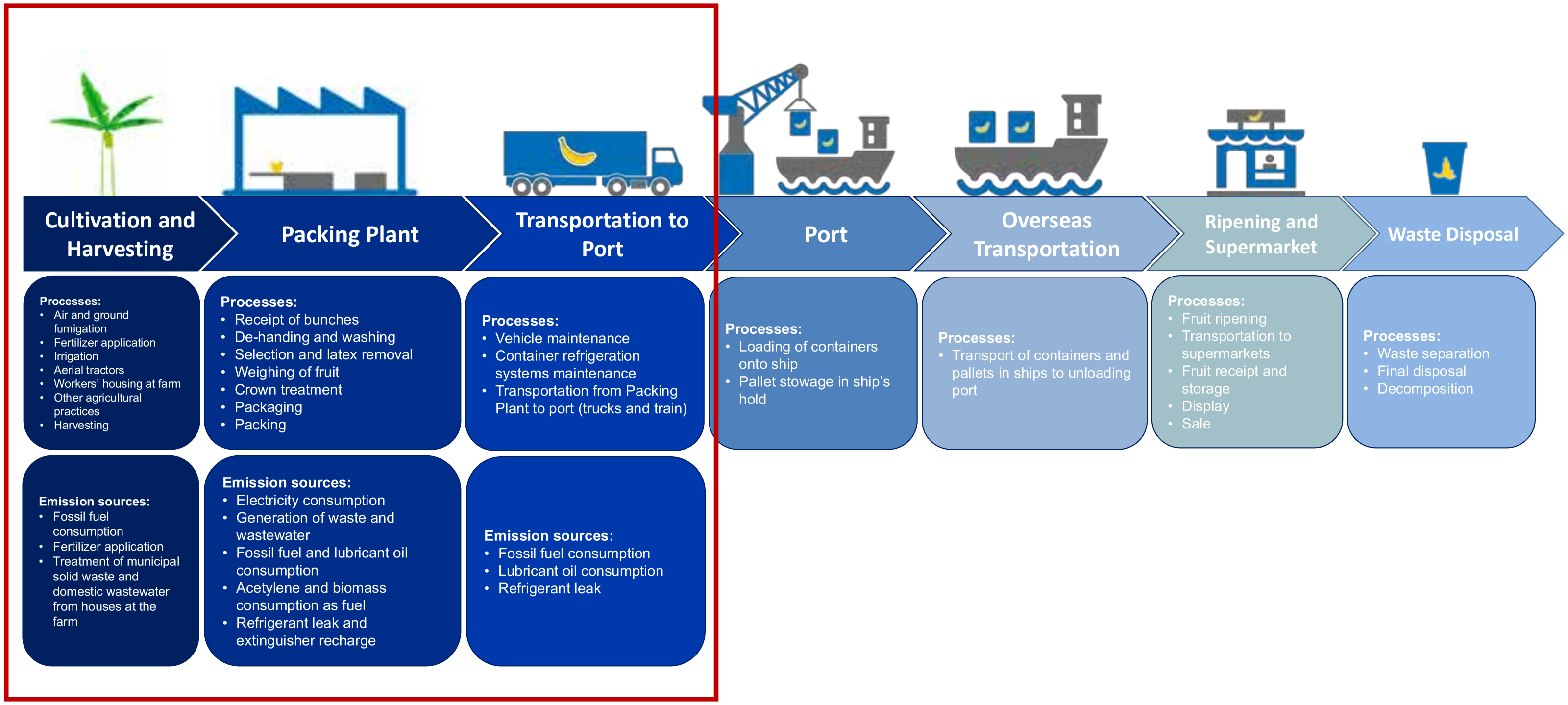


Figure 2.2. Stages in the banana value chain included in the guide.

2.1. Principles for accounting and reporting emissions

Five principles are recommended for the emission calculation process, in order to ensure that the reported results reflect the organization's reality as closely as possible. The principles are defined in Figure 2.3, as established in international standard ISO 14064.[10]

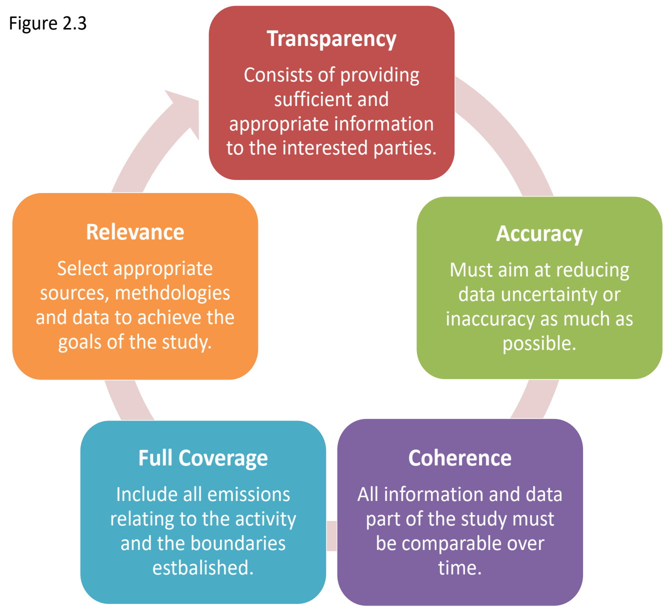


Figure 2.3. Accounting and reporting principles when managing GHG emissions.

2.2. Which concepts must I understand in order to properly manage my emissions?

- **Greenhouse gases (GHG):** Gases considered responsible for climate change according to the Kyoto Protocol. The GHG considered when carrying out an inventory include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) (Figure 2.4)[11]..

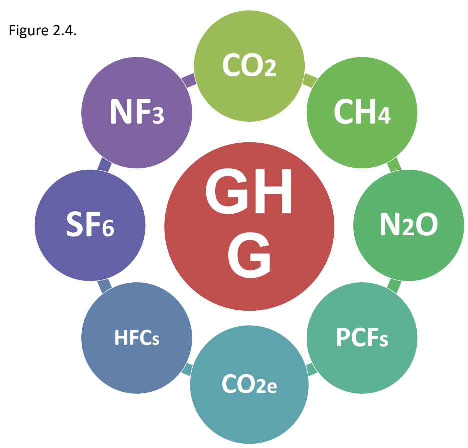


Figure 2.4. Greenhouse gases.

- **GHG emission:** Is the total mass of any GHG that has been released into the atmosphere at any given time.[10] The emissions from any activity will be estimated as shown in Figure 2.5.

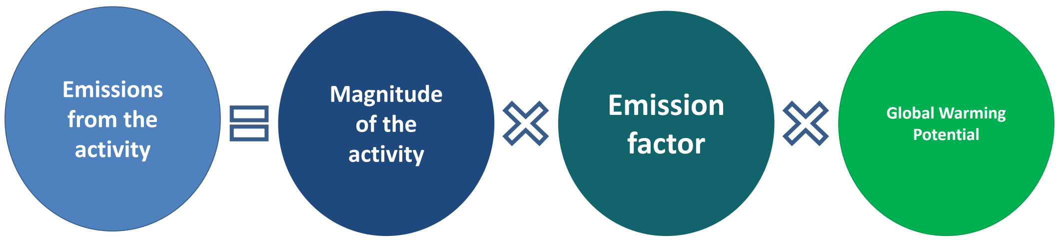


Figure 2.5. General equation for GHG emission calculation (IPCC, 2015)[12]

- **GHG removal:** The total mass of a GHG removed from the atmosphere at any given time.[10]
- **GHG emission source:** Any activity or process which, when conducted, causes GHG emissions into the atmosphere.[10]
- **GHG sink:** Any activity or physical and/or chemical process which, when conducted, causes a removal of GHG from the atmosphere.[10]
- **GHG emissions inventory:** Document that groups the GHG sources, sinks, emissions and removals of an organization.[13] This is a basic tool for the company to understand its emissions and the risks associated with these, identify emission reduction opportunities, establish reduction goals and targets, and report its performance to its stakeholders.[11]
- **Equivalent carbon dioxide (CO_2e):** Is the unit that enables comparing the radiation force of a given GHG with the carbon dioxide or CO_2.[10]
- **Magnitude of activity:** Specific quantitative measurement of the activity that generates the emissions, to enable quantification of their impact.[10,14]
- **Emission Factor (EF):** A factor that relates the magnitude of the activity with the emission of a given GHG.[10,14]
- **Global Warming Potential (GWP):** Is a value that describes the greenhouse effect impact of a given GHG, with respect to CO_2, enabling the final reporting of all emissions in terms of CO_2 equivalent (CO_2e).[10]
- **Mitigation measure:** Comprises an action that reduces the quantity of GHG emissions, or increases their removal or capture.[13]
- **Adaptation measure:** Comprises an action to tolerate or adapt to the expected consequences of climate change.[13]
- **Offset:** Is the voluntary purchase of offset mechanisms, in order to counteract emissions that have not been reduced.[13]

2.3. Defining the scope of the inventory

The organization must have a clear understanding of the purpose for which it will be quantifying its emissions. This purpose must be in line with the goals of the expected user, which may be the banana company, a country carbon neutrality program, or a verification agency. Once the purpose and reason for a study have been identified, its scope can be determined, including organizational and operational boundaries, emission sources, GHG types and period of time to be considered.[10] The scope will determine the extension of the inventory to be included.

2.3.1. Which must be the organizational and operational boundaries when managing my emissions?

The organization must define the organizational and operational boundaries foreseen in preparing the GHG inventory. The organizational boundaries refer to the areas of the company that will be considered: physical facilities, planting, processing, packaging and shipping areas.[15,16] The recommendation is to define them by selecting areas over which the company has control and decision-making authority in operational and financial aspects.

The operational boundaries refer to the types of emissions that will be considered in the study, and their classification. GHG emissions can be classified as direct or indirect, and categorized in scope 1, 2 or 3, as defined in Figure 2.6.

Figure 2.6.

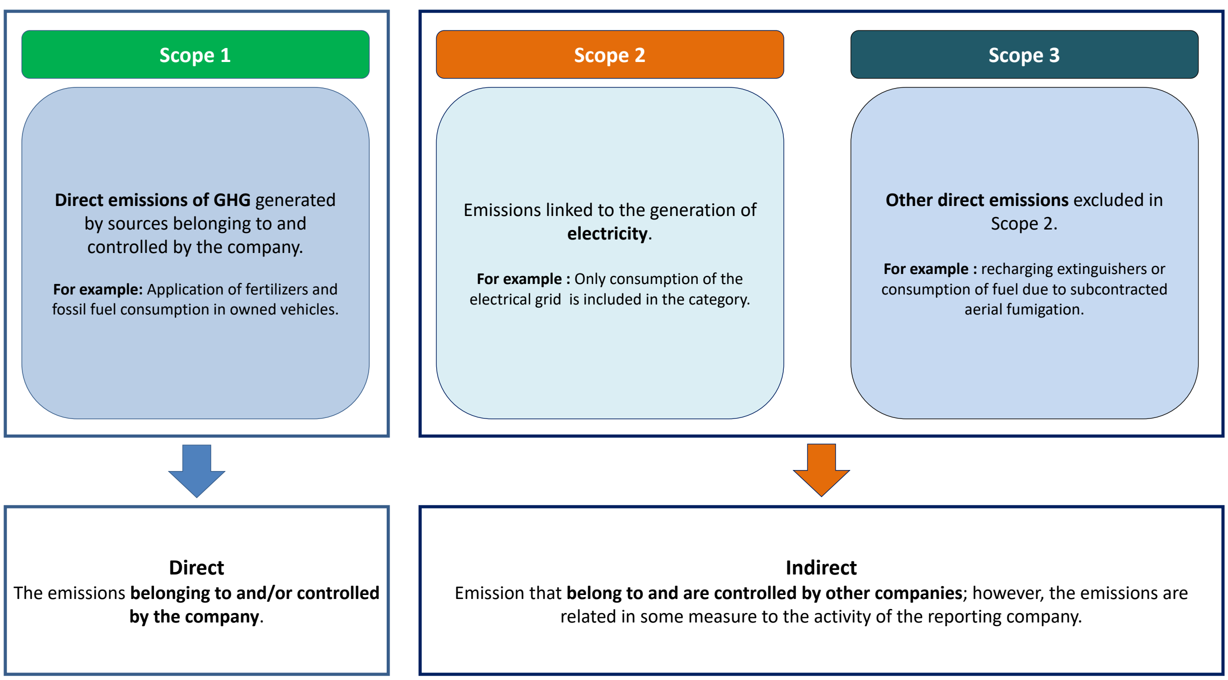


Figure 2.6. Categorization of emissions in an organization (Greenhouse Gas Protocol, 2014)[11]

2.3.2. Establishing a base year

The banana company must define a base year as the date from which it will begin to take control over its GHG performance. The base year represents a period of time to be selected by the company, to assess its emissions.[10] It is recommended to select the earliest possible year for which activity data are available, which can be verified and supported by invoices, reports, records or any other information to prove their accuracy.[11]

It is important to ensure that the base year reflects the reality of the company in the best possible manner, that is, a period where there is no significant change in the company, such as an inclusion or expansion which directly affects emissions, will be preferred. This period of time must include a total of twelve months, whether a calendar or a fiscal year. What is most important is for the organization to have complete and supported information for all GHG inventories.[17]

2.4. Which are the potential emission sources in a banana company?

Any activities that generate GHG emissions into the atmosphere, and which are within the proposed organizational and operational boundaries, must be identified and contemplated for the inventory. The following sections summarize the most important potential emission sources that may be found in the planting and harvesting, packaging and transport to port processes of bananas for export (Figure 2.2).

2.4.1. Most important emissions in the banana industry

The most important emission sources during banana production stages are detailed in Figure 2.7. Each source may have several emission origins (or subsources), which will be associated with different types of GHG. Only those sources that apply to the banana company conducting the study must be considered for the inventory.

Bear in mind:

The emissions that must necessarily be included in the inventory will be those corresponding to scopes 1 and 2. In addition, any emissions in scope 3 deemed to be of great impact and essential for the business must also be considered. This is the case of services that are subcontracted but of great significance for emissions and production, such as fuel consumption of the aircraft and trucks that transport the fruit.

Conversely, for the less relevant scope 3 emissions for which data is difficult to obtain (for example, municipal solid wastes), the company may determine whether or not to include them, according to its capacities.

Sources	Subsources	GHG
Fertilizer Application	Synthetic fertilizers Organic fertilizers (manure, compost, ash, sludge, etc.) Urea Lime (application of dolomite or limestone)	N_2O N_2O and CO_2 CO_2
Fossil Fuel Consumption (diesel, gasoline, LPG, Jet Fuel)	Vehicles for cargo, transportation and land fumigation Company-owned vehicles Machinery (pumps, generators, etc.) Aircraft	CO_2 N_2O and CH_4
Use of Lubricant Oils	Vehicles for cargo and transportation Company-owned vehicles Machinery (pumps, generators, gensets, furnaces, etc.) Aircraft	CO_2
Refrigerant Leaks	Air conditioners (offices) Cold storage rooms and cooling systems in transportation (containers)	HCF and PFC
Extinguisher Recharge	CO_2 extinguishers HCFC, HFC or PFC extinguishers	CO_2HCFC, HFC or PFC
Sold Waste Decomposition	Municipal solid waste (offices and cafeteria) Solid waste from process	CH_4
Wastewater Generation	Domestic wastewater (restrooms) Process wastewater (Packing Plant)	CH_4
Electricity Consumption	Consumption of electricity from power grid	CO_2
Acetylene Consumption	Welding processes (acetylene combustion)	CO_2
Consumption of Biomass as Fuel	Drying furnaces for pallet treatment (biomass combustion)	CO_2 N_2O and CH_4

Figure 2.7. Main emission sources in a banana company.

2.5. What data must be collected and how are emissions estimated?

The banana company must collect the data from each emission generating activity, based on reliable information. This enables identifying the origin of the information and ensures that it is clear and backed by documents.[17] Invoices for services or purchase of products, vouchers, safety data sheets, records, reports and maintenance data, are examples of reliable and direct references to obtain these data.

Bear in mind:

It is important to note that data cannot always be obtained from high-quality documents. In these cases, it will be necessary to perform additional calculations or use theoretical data. The company must focus its efforts on gathering data from the activities that are expected to have the highest impact on emission results.[11]

Table A1.1 of Schedule 1 contains a list of the information that must be gathered for emission calculations. In addition, the following sections describe the priority inventories and other additional inventories to be considered for a banana plantation. Schedule 2 includes calculation examples for each GHG emission source as reference for users of the Guide. These calculation examples are also supported by Schedule 3 of emission factors (EF), Schedule 4 of global warming potentials (GWP) and Schedules 5 and 6 which include the equations and their technical support.

! ***Important:*** All emissions of the various GHGs must be converted into carbon equivalent units (CO_2e), using the GWP. The inventory results must be reported in CO2e tons. For a better understanding of this step, we recommend reviewing the examples available in Schedule [2].

2.5.1. Priority GHG inventories in a banana plantation

2.5.1.1. Fertilizers for soil management

2.5.1.1.1. Synthetic and organic fertilizers

In any soil there is a natural process of nitrification-denitrification reactions, which depends on nitrogen availability and which releases a gas known as nitrous oxide (N_2O). Adding fertilizers to the soil with specified nitrogen percentages causes an alteration to this natural process, resulting in greater N_2O emissions.[12]

The application of fertilizers is a common practice in the banana sector, intended to increase harvest yields;[14] therefore, it must be an activity taken into account for the GHG inventory.

In order to estimate the direct N_2O emissions of this activity, synthetic fertilizers will need to be differentiated from organic fertilizers incorporated into the field. Synthetic fertilizers contain inorganic compounds from the oil industry (Table 2.1.). Conversely, organic fertilizers are obtained from animals, plants or compost (animal manure, compost, sludge, agricultural waste products).[14]

Table 2.1. Nitrogen content in various synthetic fertilizers based on studies of the International Fertilizer Association.

Fertilizer	% Nitrogen
Ammonium	82
Ammonium Sulfate	21
Ammonium Nitrate	33-34.5
Calcium and 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)[18]

Recommendation: When there are no fertilizer application records or soil fertilization programs available, these values must be quantified in order to carry out the carbon footprint study, since it constitutes one of the major emission sources in agriculture.

You may review the emission calculation examples for synthetic and organic fertilizers in Schedule 2; you can also use the Excel spreadsheet in this Guide to organize data and calculate the results of this inventory.

2.5.1.1.2. Fertilization with urea

Urea is classified among the synthetic fertilizers that are usually applied to the field to improve banana production yield. Being classified as such, it has associated N_2O emissions, which must be estimated following the same steps explained in the previous section.

In addition, in soils with a pH above 6.2, CO_2 emissions are attributed to urea when applied to the crop. These emissions correspond to the loss of this gas, which accumulates during the urea production process.[12]

To consider: Soil pH may vary according to geographical area; this value may be found in soil studies of the farm or in fertilization programs. If the farm does not have these sources of information, you may resort to the respective national agencies handling the topic of soils.

Examples of emission calculation from fertilization with urea may be reviewed in Schedule 2. This Guide also includes Excel spreadsheets to organize the data and obtain the results from this inventory.

2.5.1.1.3. Lime application to the soil

Soil acidity (low pH), caused by the type of soil or by the characteristics of fertilizer components (acid salts), must be controlled to promote productivity and fertility in banana growing farms,[12] a task that is generally carried out through lime application. The most commonly used products for this purpose are agricultural lime ($CaCO_3$) and dolomitic lime ($CaCO_3.MgCO_3$).[20] When these products are added to the soil, certain reactions occur which subsequently result in the release of CO_2.[11]

Lime compounds containing so-called oxides and hydroxides do not generate CO_2 emissions, due to the absence of inorganic carbon in their structure.[12] Although their use in the sector is limited, they must not be included in the inventory in case they are used by a company.

You may review the examples of emission calculation from lime application to the soil in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results from this inventory.

2.5.1.2. Fossil fuel consumption

The use of fossil fuels in energy production or to operate various types of vehicles and machinery is currently required in a large number of productive activities in banana growing farms. The burning of these in engine generates CO_2, CH_4 and N_2O emissions.[12] Both mobile sources (e.g. company vehicles, product cargo and transport vehicles and aircraft) and stationary or fixed sources (e.g. generator sets, pumps, etc.) used by the company in its activities must be included.

Recommendation:

When consumption levels and yields are expressed per hour for fixed sources (generators, gensets, etc.), these must be multiplied by total hours worked.

If there are no records of fuel volume consumed by mobile sources, there are two possible methods to estimate them:

Method 1. Use the kilometers travelled by each vehicle as reference. This parameter is divided by the average fuel consumption for each type of vehicle. In order to obtain the gas mileage of the vehicles used by staff or subcontractors (scope 3 estimate), it will be necessary to consult different information sources, such as the web pages of the vehicle suppliers or individual calculations made by the staff. The PAVE Vehicle Listing in Costa Rica or the ECO Vehicle Program in Mexico can also be used.

Method 2. Estimate the amount of fuel based on its cost to the company. The historical prices of the fuels, available from the corresponding agency in each country (RECOPE in Costa Rica), must be identified. The cost is then divided by the price per liter of fuel, on the date the vehicle is filled up.

Method 3. Estimate the volume of aircraft fuel. For each application made from aircraft, the starting and ending time must be recorded. The characteristics of each aircraft providing service to the company must be documented, particularly fuel consumption rating for a given period (liters/hour). The number of applications and times are calculated and total consumption is estimated for that period. GHG emissions are calculated for this total volume in liters.

If there are no records of the amounts of fuel used by fixed sources, working hours and yield can be correlated or a cost-volume ratio can be obtained.

You may review examples of fuel consumption emission calculation in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results of this inventory.

2.5.1.3. Electric power consumption

When a company purchases, acquires and consumes electric power from a grid, there are associated indirect GHG emissions that must be quantified. The emission source in question is considered only when the company consumes electricity obtained from a power grid, produced by a third party (e.g. in Costa Rica ICE, CNFL, COOPELESCA, others), and the emissions must be reported as scope 2.28 (See Figure 2.6).

Recommendation:

If the banana growing company generates its own electricity, this emission source must be reported as scope 1.28 If this energy is produced from fossil fuels, it must be included in the report for that source.

When the company consumes part of its electricity from the grid, but another part comes from its own generation (example: photovoltaic solar panels), the power consumption value to be considered in the calculations will be net consumption. This is obtained from the difference between the power that enters and the power that is returned to the grid.[28]

You may review examples of power consumption emission calculations in Schedule 2. This Guide also includes an Excel spreadsheet to organizae the data and obtain the results of this inventory.

2.5.1.4. Refrigerant leaks

The group of compounds known as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are widely used in cooling systems, such as banana transport containers and air conditioners in offices or vehicles. These gases are directly considered GHG, due to their properties for temperature regulation.[21]

Considering that some refrigerant escapes from any sealed system,[22] whether through pipe and valve joints, pipe cracks or flaws in the components,[12] there is an unplanned release of refrigerant gas in equipment and systems, known as a fugitive emission. When this happens, there may be a drop in the cooling capacity of the equipment and, on occasion, they require maintenance with a possible recharge of the refrigerant component which will constitute a GHG emission. Table 2.2. shows the commonly used refrigerants, with their respective global warming potentials (GWP).

Table 2.2. Commercial refrigerats and GWP.

Refrigerant	GWP
R-12	10.900
R-502	4.657
R-507a	3.990
R-404a	3.920
R-407a	2.110
R-22	1.810
R-407c	1.770
R-134a	1.430
R-32	675
R-290 (propane)	3,3
R-600a (isobutane)	3
R-1270 (propylene)	1,8
R-744 (CO_2)	1
R-717 (ammonia)	0

Source: (EPA, 2010)[23] and (Agarwal & Clark, 2016)[35]

To be considered:

If the equipment has not required recharging during the GHG estimation year, it is considered "leak-tight" equipment. In other words, this equipment has not leaked enough to affect its performance, and its leaks are considered non-measurable (less than 10% of the original charge).[22]

When there are no refrigerant recharge records, annual percentages of refrigerant losses per equipment or system may be used (Schedule 5). However, after the completion of the study, these recharges must begin to be quantified.

If the recharges are given in pounds, the conversion factor of 0.460 kg/pound is used to obtain the kilograms of the gas.[16]

You may review examples of refrigerant leak emission calculations in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results of this inventory.

2.5.2. Additional inventories to be considered for a banana farm

2.5.2.1. Use of lubricant oils

Lubricant oils are non-energy products derived from petroleum and used in lubricating the engines of various equipment used in the banana growing sector. These oils are associated with CO_2 emissions because a certain quantity is burned during their use. However, when the CO_2 emissions from the use of lubricants are quantified, it is assumed that they are burned in full.[12]

To estimate the emissions from this source, every cargo and transport vehicle associated with production activities, company vehicles, machinery (pumps, generator sets, etc.) and small planes using this non-energy product must be considered.

! ***Recommendation:*** If there is no information regarding the volume of lubricant oil used, it can be estimated from the oil storage capacity of the engines, and the frequency with which the oil is changed. As a last resource, theoretical data regarding oil use for each engine, obtained from the technical data sheets of the equipment or by reviewing the literature, can be used.

Examples of emission calculation from the use of lubricant oils can be found in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results of this inventory.

2.5.2.2. Recarga de extintores

Some fire extinguishers use CO_2, HFCs and, to a lesser extent, PFCs as extinguishing agents, all of which are gases considered GHG.[12,13,24] For an extinguisher to have the capacity to put out fires, the quality of its extinguishing agent must be assured. Therefore, this product must be periodically replaced. The most commonly used HFC extinguishing agents are shown in Table 2.3.

Table 2.3. Commonly used HFCs and some PFCs extinguishing agents..

Chemical	GWP
HFC-23	14.800
HFC-125	3.500
HFC-134a	1.430
HFC-227ea	3.220
HFC-236fa	9.810
PFC-143 (CF_4)	6.630
PFC-31-10 (C_4F_{10})	9.200

Source: Adapted from Table 7.1. in Chapter 7, Volume 3 of the IPCC (2015),[12] the Greenhouse Gas Protocol (2016)[25] and Ozone Secretariat (2016).[26]

Extinguisher emissions are calculated under an assumption that the entire agent is lost during its recharge.[13] Therefore, the total quantity of the agent recharged during the year of the study will represent the total emission of the respective GHG.

> **Recommendation:**
>
> To obtain the recharged quantity of the extinguishing agent, the recharged volume as such may be used, if the company providing the service reports this information to the banana company. Otherwise, the capacity of each extinguisher must be multiplied by the frequency of recharges during the year.
>
> If the recharges are given in pounds, a conversion factor of 0.460 kg/pound is used to obtain the kilograms of the gas.[16]

You may review examples of extinguisher recharge calculations in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results of this inventory.

2.5.2.3. Solid waste management

2.5.2.3.1. Organic waste from the process

Organic wastes (OW) generated as a result of the production process (rachis, reject banana discarded for other industrial use, peels, bunches, etc.) must be classified according to the treatment they are given or their manner of disposal: sent to the field, buried, sent to the landfill or sent for composting in the property of a third party, or composting by the organization itself.

> **Recommendation:**
>
> A good practice to avoid double accounting of emissions is to clearly separate the amount of organic waste from the process that is sent to the field, buried, sent to the landfill and sent for composting in the property of a third party or composting by the organization itself. Thus, emissions will be quantified separately as appropriate.
>
> If there is no measurement available for the weight of the organic waste distributed in each type of disposal, the yield from the crops can be used to estimate total mass. Theoretical volumes are then assigned to each form of disposal or appraisal, as appropriate.

You may review examples of emission calculations for organic wastes from the process in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results for this inventory.

2.5.2.3.2. Municipal solid wastes (packaging, offices and cafeteria)

Municipal solid wastes (MSW) include domestic wastes generated at offices and cafeterias, garden and park wastes, and other packaging wastes such as cardboard waste. The emissions generated from these occur in the decomposition stages in environments where there is no oxygen (anaerobic). To estimate emissions it is necessary to consider whether or not there is separation, quantity of waste generated (mainly biodegradable, such as food, garden, paper and cardboard wastes), and how they are treated.

You may review the emission calculations for municipal solid wastes in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results for this inventory.

2.5.2.4. Wastewater generation

2.5.2.4.1. Process wastewater (packing plant)

Solid waste trap at packing plant. Photo Miguel Vallejo

The industrial wastewaters (IWW) produced at banana packing plants, which contain significant organic material loads and which are treated under anaerobic conditions, produce high methane emissions.[12] Values for Biological Oxygen Demand (BOD) or Biochemical Oxygen Demand (COD) are generally used in IWW as the organic substance load in the water.[12,27] Therefore, one of these values can be used to estimate emissions from the packing process..

> **!** ***Recommendation:***
>
> The total volume of wastewater generated during the emission calculation period must include the total water used to wash the fruit. In case the tank water is recirculated, the daily volume and weekly volume of water used must be quantified..

You may review examples of emission calculations for processed wastewater in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results for this inventory.

2.5.2.4.2. Domestic wastewater (restrooms and taps)

Ordinary or domestic wastewaters (DWW) are those produced by restrooms, hand wash basins, boot wash basins and other taps located in offices and at the packing plant. When DWW are treated or disposed of under no oxygen (anaerobic) conditions, methane gas (CH_4) is released through the decomposition of the organic matter, recognized as a GHG.[13]

> **!** ***Recommendation:***
>
> When DWW are treated in an aerobic manner (in the presence of oxygen), no GHG emissions must be considered; therefore, they are not included in the inventory as an emission source.[13]

You may review examples of emission calculations for domestic wastewaters in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results for this inventory.

2.5.2.5. Acetylene consumption

Acetylene, whose chemical formula is C_2H_2, is a colorless flammable gas which requires minimum amounts of oxygen to reach full combustion. Due to its properties, acetylene is widely used for welding in maintenance and repair shops, and in wood pallet marking, among other uses,[12,29] common in the banana sector.

When acetylene is subjected to a combustion reaction, depending on its stoichiometry, CO_2 emissions are produced, which must be considered for the company's GHG inventory. It is assumed for calculation purposes that the entire gas content of the cylinder is acetylene, and that it reacts in a complete combustion forming CO_2 and water.

To be considered:

The emission factor is a constant value which derives from relations in the complete combustion reaction of acetylene (Schedule 2, section A2.11).

If the recharges are given in pounds, a conversion factor of 0.460 kg/pound is used to obtain the kilograms of the gas.[16]

You may review examples of emission calculations for acetylene consumption in Schedule 2. This Guide also includes an Excel spreadsheet to organize the data and obtain the results for this inventory.

2.5.2.6. Biomass consumption as fuel (drying ovens)

The ovens used to dry materials (e.g. pallets made by the banana companies themselves), are frequently heated with biomass.[30] Biomass is comprised of biodegradable organic material obtained from forest species, plants, animals and microorganisms (agricultural waste, municipal waste and wood).[31] The burning of these materials will result in CO_2, N_2O and CH_4 emissions, which must be considered in calculating the company's emissions.

You may review examples of emission calculation for biomass consumption as fuel in Schedule 2. This Guide also includes an Excel spreadsheet that can be used to organize the data and obtain the results for this inventory.

2.6. Correlating emissions and banana production

Emission results must be presented as the sum total of CO^2e tons; however, the company may establish a performance indicator to assess its progress over time at an internal level.

Taking into account the results for emissions and sales and production information of the banana company, a performance indicator can be established, enabling emission comparisons over several years. To this end, it is recommended to gather information regarding number of boxes sold, kilograms of banana sold and earnings for the period for which the inventory is being prepared, and then dividing the emission results with this information, as shown in example 2.1.

Example 2.1. Emission calculation per box of bananas, kg of bananas and sales

In a banana farm, total carbon emissions were 5 000 kg of CO2e during the study year. For this same year, 500 000 boxes of bananas were sold, equivalent to 9 070 000 kg of bananas and earnings of $10 000 000. To obtain the performance indicators, the data must be correlated as shown below:

Indicator per box=**5 000** kg CO_2e÷**500,000** boxes=**0.01 kg CO2e/box**
Indicator per kilogram=**5 000** kg CO_2e÷**9 070 000** kg=**0.00055 kg CO2e/k**g
Indicator per sales=**5 00**0 kg CO_2e÷$**10 000 000**=**0.0005 kg CO2e/$**

To be considered:

This guide presents the procedure to estimate the GHG emissions of an organization, that is, of a "banana company". The correlation with production data is recommended in order to evaluate the company's performance with these indicators (kg CO_2e/box, kg CO_2e/kg banana, kg CO_2e/$), but not to present the results in a statement, as these must be presented in CO_2 equivalent tons.

2.7. What comes after developing the inventory for my organization?

Once the company has completed its inventory, it can establish its mitigation measures.[13] These may consist of actions to reduce GHG emission sources, or actions to increase GHG absorption.[8]

To carry out actions of the first type, the organization must identify its main emission sources, and establish its reduction objectives in relation to these sources. Generally, these actions may involve adjustments to production processes, such as changes to more efficient technologies, use of renewable energies or input replacement. Sometimes, these actions will focus on correcting inefficiencies in certain processes.[8] This information is discussed in further detail in Chapter 4, in which reduction measures for the banana sector are proposed.

Actions to increase absorption (removal) are mainly aimed at promoting plant photosynthesis, in order to absorb or remove CO_2 from the atmosphere.

Removals also involve a principle of environmental responsibility on the part of the banana company. Forests and forest plantations belonging to the organization or leased from others, as well as the establishment of agroforestry systems combining timber, multiple use, leguminous and other trees in the farms, associated with both their productive and unproductive areas for banana growing, or in protection areas, may be used for these removal projects.

In addition, carbon removal capacity can be increased at the soil level through live covers and soil formation by incorporating organic material, which also improves water retention capacity as a strategy for adapting to climate change.

In order to implement areas and plots of land for measuring and monitoring tree growth and performance (in terms of carbon capture) in any of these options, the company requires the support of forestry professionals for the corresponding studies.

!

Recommendation:

It is also advisable to include carbon reserves or sinks, especially through forest resources (plantations and agroforestry systems), in the inventory. However, this aspect is beyond the scope of this guide. We recommend using ISO 14064-2:2006 Standard – Greenhouse gases – Part 2. Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements, and INTE/DN 03:2016 – Methodology for quantification and reporting of removals of greenhouse gases produced by forest activities, as well as consulting the IPCC Guidelines and the GHG Protocol Guidelines

2.8. Reporting the results for my organization

The banana company may decide whether or not it wishes to report the results of its study to user entities of this information (DCC, verifiers, clients, others). However, it must comply with accounting and reporting principles (section 2.1). In addition, it must be clear regarding the stakeholders interested in the information (clients, suppliers, community, etc.), decide on the means for publishing it (internal reports, website, etc.), and decide how to report its emissions[32].

The results of the study are generally presented in a report, which is a document designed for the stakeholders, including the scope, results and methodologies used, as well as any exclusions and assumptions made during the study.[11]

Figure 2.8 shows a list of the minimum information that must be contained in the report, according to GHG Protocol recommendations.

Mandatory Information for the GHG Report

- Description of the company
- Organizational boundaries
- Operational boundaries
- Information period covered
- Emission data
- Total emissions of Scope 1 and 2
- Emissions of Scope 1
- Emissions of Scope 2
- Emissions for each GHG
- Base year and emission profile over time
- Calculation methodologies used
- Report of any source or operation excluded

Optional Information for the GHG Report

- Emissions of Scope 3
- Emissions separated by source for each work center, country, operation, etc.
- GHG emissions not required to be reported
- Report on capture, fixation or purchase of carbon

Figura 2.8. Contenido del informe de resultados. Fuente: (Vallejo et al., 2013)[10]

Recommendation:

If the data for the calculations cannot be obtained from the relevant sources for the company (mainly scope 1 and 2 emissions), we recommend reassessing the base year, and conducting the study once there is a record of this information.

On the other hand, if the sources do not significantly impact the result, their exclusion can be justified.

It is extremely important to describe the emission sources from which emissions could not be clearly quantified due to the absence of data from the activity during the defined base year and the study year.[17]

Before excluding any emission source, its emissions must first be theoretically calculated, in order to justify the exclusion with criteria established in the respective regulations.[17,21]

The arguments for excluded inventories must be clearly indicated in the results report, and sources whose contribution is not significant, or whose quantification is neither technically feasible nor profitable, may be excluded.[10]

2.9. Verification of the emission inventory and declaration of Carbon Neutrality

When the company needs to make its results public, it is recommended to subject the study to a verification process. This process comprises a detailed review by an external third-party entity, independent from the company, of the information provided and calculations made in the GHG report. This process will demonstrate transparency and credibility to the stakeholders of the organization.[8]

There is a large number of entities globally, including standardization institutions, international consortiums, non-governmental organizations, environmental consultants, and universities, among others, which carry out verification processes.[8] Some of these entities will evaluate using their own methodologies, others through international or regional standards, and others through the use of already-available methodologies.

Selection of the entity will depend on the purpose for which the study was carried out. Some verification organizations are: INTECO (Technical Standards Institute of Costa Rica), which uses the standards of the International Organization for Standardization – ISO; the EARTH University; the CarbonTrust Program and CarboNZero.

The company may verify its own GHG inventory or it may request verification by any of the duly accredited organizations in order to declare itself Carbon Neutral.

To declare itself Carbon Neutral, the organization must offset the emissions that it was unable to reduce or remove in order to meet the equation shown in Figure 2.9.

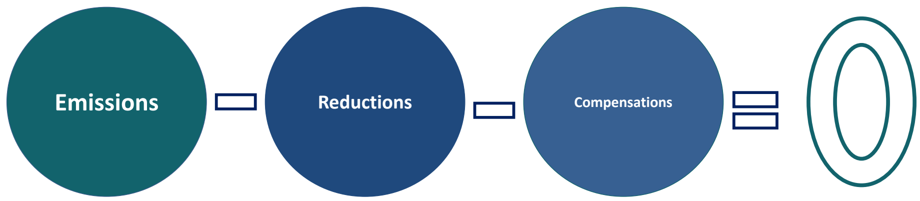


Figure 2.9. Content of results report.

The available offset mechanisms are:[13,33]

CER's: Certified Emission Reductions, such as the Clean Development Mechanisms at the international level.

VER's: Voluntary Emission Reductions, such as the Gold Standard at the international level.

DOU: Domestic Offset Units for each country. In the case of Costa Rica, these are managed through the National Forest Financing Fund (FONAFIFO), and are known as Costa Rican Offset Units or UCCs.

To be considered:

In Costa Rica, verifying agencies will assess compliance with the INTE/ISO 14064-1 voluntary standard in order to verify a GHG inventory, and the INTE 12-01-06 voluntary standard for carbon neutrality declarations. In addition, it is necessary to register and comply with the requirements of the DCC Country Program in order to use the national Carbon Neutrality stamp (Agreement-36-2012 – MINAET).

WATER FOOTPRINT

3.Calculating the water footprint from direct use by my organization

3.1.What factors can be included in applying this guide?

The proposed guide covers the banana cultivation and harvesting stages at the farms, the packing process at packing plants and the transport of the export product to the respective port, as shown in Figure 3.1.

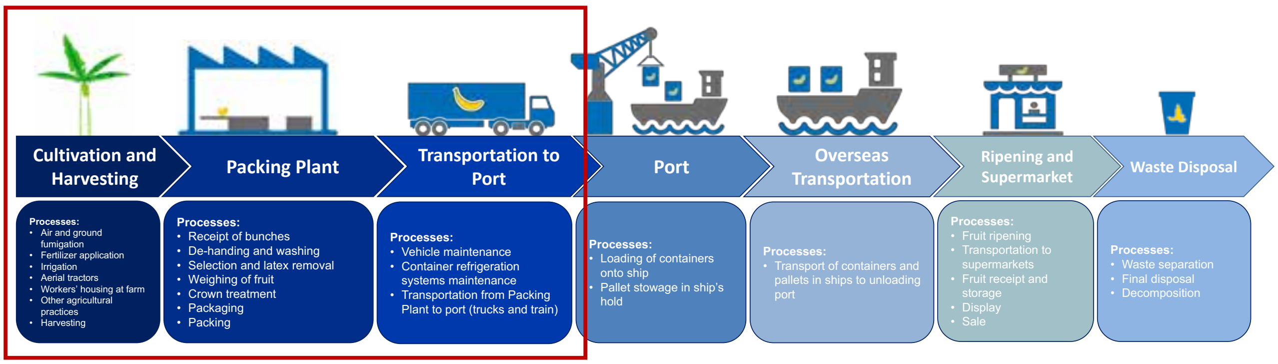


Figure 3.1. Stages of the export banana production process and scope of the guide.

This guide **includes only calculations to estimate the water footprint from direct use** (Figure 3.2), as it has only an organizational focus and does not contemplate a complete life cycle analysis.

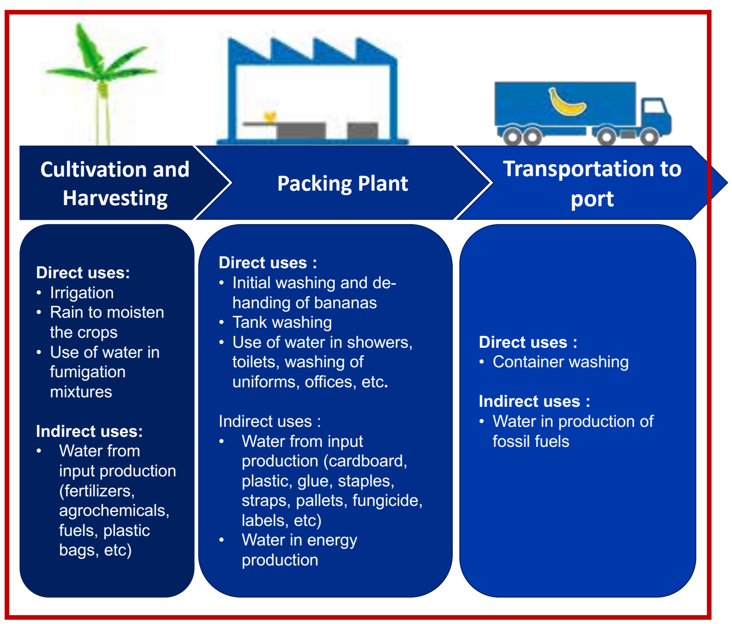


Figure 3.2. Direct and indirect uses of water in export banana production.

The purpose of calculating a water footprint (according to ISO 14046 standard) is to measure the potential impacts of using water resources in the activities of an organization.[39] The result obtained by applying the guide will be given in terms of "environmental impacts" from banana production at the farm.

With respect to the use of water, it will be necessary to consider the effects that banana production will have on the quantity (consumption or consumptive use) and quality of the resource (degradative use).[40,41]

Different methodologies may be applied in estimating environmental impact. The guide includes the methods that are most recommended and most widely used, to which banana companies have easy access. The methodologies used in the guide have a midpoint scope to measure impact, given that it has the greatest scientific backing and is most frequently used in these studies.[39] This scope evaluates the environmental impact that occurs from the release of the substance or consumption of the resource to its final effect.[41]

The guide follows the four stages proposed in the ISO 14046 standard, starting with the definition of a goal and scope, followed by the development and analysis of the water footprint inventory, assessment of the water footprint impacts and interpretation of results.[39,41,41] Figure 3.3 graphically shows the process, which must be subject to constant interpretation and review of results in order for the company to ensure that the objectives of the study are being met.[42]

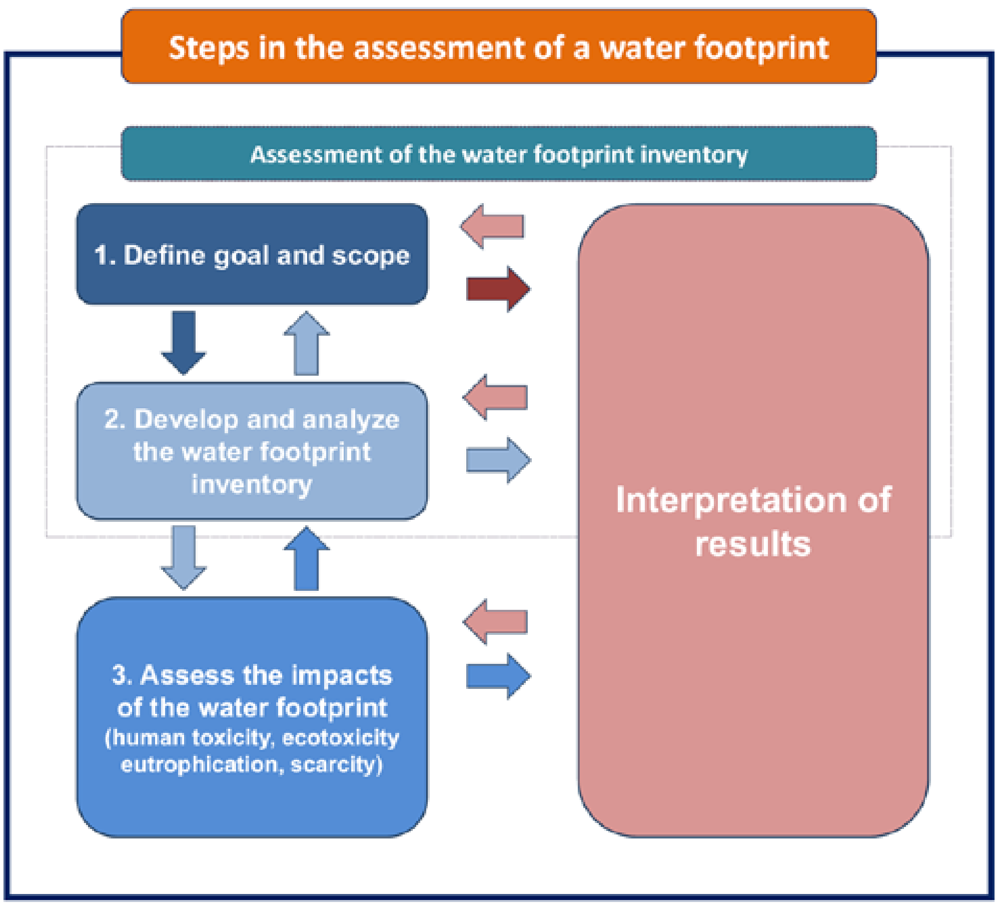


Figure 3.3. Steps in the study of a water footprint. Adapted from ISO 14046:2014 (ISO, 2014) standard.[40]

3.2. What concepts must I understand in order to calculate the water footprint?

Water footprint: Metric(s) used to quantify the potential environmental impacts related to water.[40]

Direct use of water: Uses taking place at the facilities of the organization for its operation.[41,42]

Indirect uses of water: Water consumptions during raw material production or power generation, related to the company's activities, but not carried out at its facilities.[41,42]

Watershed: Area where rainwater that runs off the surface drains through gravity into a river, lake, lagoon, etc.[40] Watersheds are generally defined by the main rivers in a given region and country.

Water use from human activity: Any extraction or release of water, or its use within the watershed itself, affecting the quantity and/or quality of the water.[40] It is important to differentiate between two types of water uses

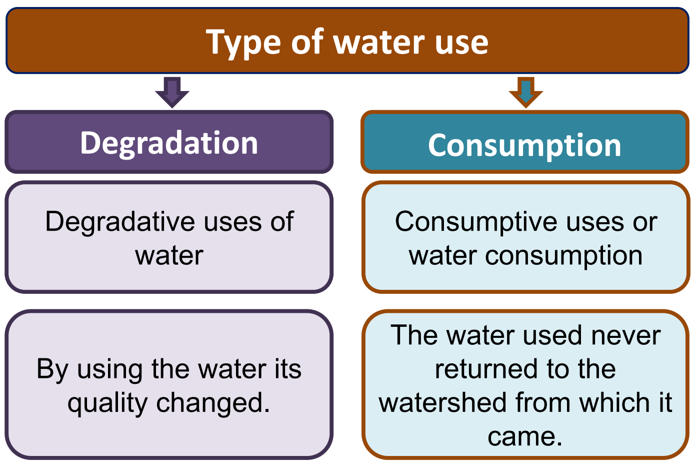


Figure 3.4. Types of water uses. Adapted from (Vallejo, 2016)[43]

(Figure 3.4): water consumption and degradative water use.

> **To be considered:** In the production of bananas for export, water consumption may occur when wastewater is discharged into other basins, different from that from which it was extracted, through water evaporated in tanks, or through water evapotranspired by plants.

Water quality: Characteristics (physical, chemical and biological) required for human beings or ecosystems to use water.[40]

> **To be considered:** In the production of bananas for export, the use of fertilizers and agrochemicals, as well as water enrichment with latex, are examples of sources contributing to water quality degradation.

Impact category: Classes representing important environmental aspects, related to water use in productive activities of the banana sector.[41] The most important impact categories for the banana sector are summarized in Figure 3.5 and will be detailed in subsequent sections of the guide.

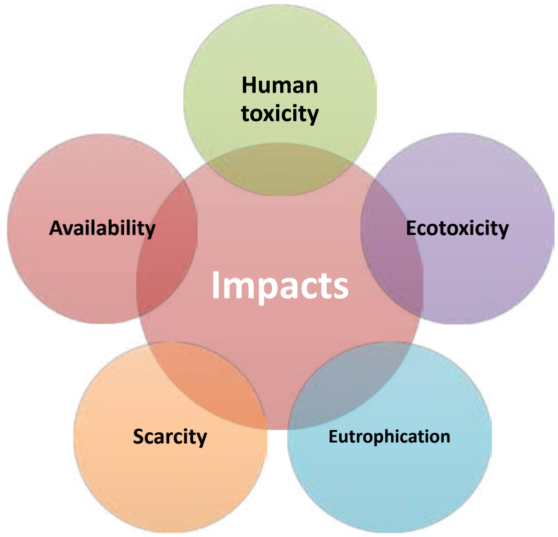


Figure 3.5. Impact categories recommended for the banana sector.

Impact category indicator: The value of each impact,[40] estimated by multiplying water consumption or amount of emission of a substance, as appropriate, by a value known as the characterization factor (CF),[41,44] as shown in Figure 3.6.

Figure 3.6. Quantification of an environmental impact.

3.3. Defining the objectives and scope of the study in my organization

To begin the study, the organization must ask itself why it should be carried out, what it expects to obtain from it, how it will use the results, and for whom it is conducted.[41,42] By answering these questions, it may proceed to define its objective and scope. It is important to stress that the objective and scope must be reassessed and adjusted at the end of each stage in the process (Figure 3.3).

3.3.1. Objectives

The objective must clearly state the intended application of the study, the reasons for conducting it, the anticipated audience, whether the study is a single assessment or is part of a life cycle analysis.[41] The organization must not lose sight of the fact that the procedure, data, calculations and assumptions made must be in line with the purpose defined for the study.[42]

Example 3.1. Statement of objective of the study

This organizational water footprint study was carried out in order to assess the environmental impact from direct use of the resource on the conduct of planting and harvesting activities, packing plant and transport to port of banana from farm "A" located at "B", in country "C", belonging to "Company X". The aim is to contribute to continuous improvement in water resource management by the organization and to propose options for reducing the environmental impacts caused by water consumption. The results report will be made available to all stakeholders in the company, from clients to its own employees.

3.3.2. Scope

The scope is a section focusing on a description of the study, which must specify the function of the organization, the facilities included, and the system contemplated in the study and its boundaries, which are the processes to be covered by it. The scope must also indicate the years selected for the study, the geographical location, the data and their quality, any assumptions and decisions made, impact assessment methodologies used, selected impact categories, how results will be expressed, potential environmental impacts considered and excluded, cutoff criteria for exclusions, limitations and uncertain details.[40,41]

To be considered: Table A7.1, available in Schedule 7, may be consulted to facilitate the preparation of a scope contemplating all mentioned aspects. A basic example of a scope defined by using this guide is also included in order to facilitate its preparation by the banana company.

Example 3.2. Describing the scope of the study

The expected scope for the water footprint study comprises only direct use of water in the activities carried out at banana farm "A" located at "B", in country "C", belonging to "Company X". The life cycle stages contemplated are: planting and harvesting, packing plant and banana transport to the port for export.

The phases comprising direct use of water are: irrigation, air spraying, plant evapotranspiration, agrochemical preparation, showers, restrooms, washing of uniforms and washing, cleansing, rinsing and latex removal from banana hands, washing of fruit tanks and general cleaning. The functional unit considered for the study is the organization, including the farm and the packing plant facilities. 2016 is the base year for recovery of information for the study. The data recovered regarding influent water are direct measurements, taken from the periodically calibrated "X" brand meter. The weekly discharged volume was estimated through the sum of the volumes in the fruit washing tanks and the daily discharged volumes. The emission data for agrochemicals and fertilizers were taken from the fertilization and spraying programs. The discharged water quality reports at the wastewater treatment plant, located at the packing plant, were used as reference for the quality of this water.

Potential environmental impacts considered include the categories of water scarcity, eutrophication, ecotoxicity and human toxicity. These were evaluated at their midpoint effect, through the AWARE, ReCiPe and USEtox methodologies, respectively. The results obtained were "X" m3 equivalents for scarcity, "Y" kg P equivalent for eutrophication, "Z" CTUe for ecotoxicity and "M" CTUh for human toxicity.

Data estimations, as well as the exclusion of impacts from direct uses of the resource, constitute important limitations to the study.

3.4. Developing the water footprint inventory

The second phase consists of gathering the information of each production stage contemplated (Figure 3.2). At the end of this phase, you will obtain the water footprint inventory, which is a document containing the information, data and calculations for the study in an organized manner.[40,41]

To be considered: This phase is the most critical in a water footprint study, as it is the longest phase and the data to be obtained must be of the highest possible quality so that the result is close to reality and of great quality.[39,42] All employees of the organization working at the farm and at the packing plant must be involved in order to make efficient use of time during this stage.

3.4.1. Data gathering

The data to be gathered must correspond to the years selected to conduct the study (base year and time coverage). These comprise input and output data for water (quantity and quality), chemical products, agrochemicals and fertilizers used, as well as production data and information for the geographical region of the study.[42].

To be considered: To facilitate the management and compilation of information, the recommendation is to include it in a template on a spreadsheet (for example, in Excel)..

It is preferable that the data come directly from measurements in each process (primary data). However, if there are no records of this information or if it is difficult to quantify, secondary sources of information may be used, provided they are properly supported and justified.

To be considered: Some useful sources of information may be the respective governmental institutions, statistics offices, business chamber, association or university reports, technical and scientific publications or freely accessible databases and programs such as FAOSTAT, developed by FAO.[39].

3.4.1.1. Banana planting and harvesting stage

Table 3.1 Summarizes the information that must be compiled for the planting and harvesting process at the banana farm.

Table 3.1. Information to be gathered in order to estimate the direct water footprint in the farm planting and harvesting process[1].

General information	Detailed information	Possible information sources
Water supply source for the plantation (wells, rivers, etc)	-Volume and frequency of irrigation -Volume of water incorporated into air spraying mixtures	-Records -Meters -Air spraying reports or tickets
Natural water supply for the plantation **(rainwater)**	-Climate conditions of the area: ▪ Monthly precipitation (mm/month) ▪ Monthly average minimum and maximum temperatures (°C) ▪ Monthly average humidity (%) ▪ Sunshine (hours) ▪ Monthly average wind speed (m/s)	-Nearby meteorological stations -National meteorological institute -Specialized programs for the sector (e.g. Banaclima in Costa Rica, FAO CLIMWAT) -Climate reports for the study years
Specific data for the plantation**	-Crop coefficient (Kc)* -Rooting depth (m)* -Critical depletion (fraction)* -Yield response (Ky)* -Crop height (m)*	-Records -Fertilization and/or spraying programs -References in literature (e.g. Allen G., Pereira, Raes & Smith, 2006) -Country soil maps -Reference of professionals in the subject matter
Soil data for the area	-Soil type -Available soil moisture (mm/m)* -Maximum precipitation infiltration rate (mm/day) -Maximum rooting depth (cm)* -Initial soil moisture depletion (as % of ADT)*	-Fertilization and/or spraying programs -References in literature (e.g. Allen G., Pereira, Raes & Smith, 2006) -Country soil maps -Reference of professionals in the subject matter
Farm data	-Total cultivated hectares (ha) -Watershed to which it belongs -Body of water from which the resource is taken -Body of water into which the farm water flows or is discharged	-Records -Watershed map of the country -Geographical maps

[1] The data shown in light blue will be used to estimate water consumptions or consumptive uses; conversely, the data shown in grey will be used to obtain the impacts from the degradative use of water.

Table 3.1. Information to be gathered in order to estimate the direct water footprint in the farm planting and harvesting process.

Crop evapotranspiration	-Total crop evapotranspiration (m_3/ year)[2]	-CROPWAT program developed by FAO (Schedule 9) -Banana sector publications in the respective country -References in literature (e.g. Allen G., Pereira, Raes & Smith, 2006)
Quantity of fertilizers added	-Phosphorus quantity in fertilizer application (kg P)	-Fertilization and/or spraying programs -Manual and aerial fertilizer application records -Chemical laboratory tests -Scientific research
Quantity of agrochemicals added	-Types of agrochemicals used (formulation, concentration, active ingredient) -Quantity of active ingredient applied with agrochemicals	-Spraying and/or agrochemical application programs -Agrochemical application records -Chemical product material safety data sheets (MSDS) -Chemical laboratory tests -Scientific research

*To facilitate the study, the indicated data may be obtained from FAO publication by authors Allen G., Pereira, Raes & Smith (2006)45, summarized in Schedule 11, Table A11.1.

[2] "Evapotranspiration (ET) is the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. (...) Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. (...) In the first stages of the crop, water is predominantly lost by direct evaporation from the soil, but once the cÍrop develops and finally when it completely covers the soil, transpiration becomes the main process. (...) Evapotranspiration is normally expressed in millimeters (mm) per unit time. This rate expresses the amount of water lost from a cropped surface in units of water depth." [45]

3.4.1.2. Packing plant stage of banana

Table 3.1. Details the information that must be gathered for the Packing Plant process.

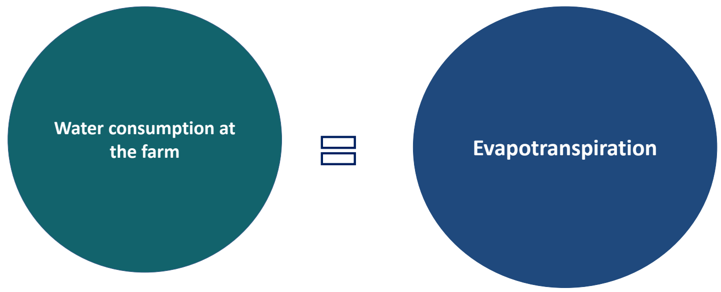
Table 3.2. Information to be gathered for estimating the direct water footprint in the Packing Plant process[3].

General information	Detailed information	Possible sources of information
Water supply	- Total volume of water inflow into the process and the facilities (banana hand washing, tank washing, tank filling, taps, etc.)	- Records - Meters
Water discharge	- Total volume of water outflow from Packing Plant (water discharged through channels, recirculation plants and/or water treatment plants, wastewater from taps and restrooms)	- Records - Meters - Discharge rate - Estimation from tank volume measurement and water change frequency
Quantity of organic material in discharge water	- BOD content in water outflow from Packing Plant (water discharged through channels, recirculation plants and/or water treatment plants)	- Chemical laboratory tests (preferable) - Estimations from latex content in water organic load
Quantity of agrochemicals in discharge water	- Quantity of active ingredient in crown fungicide - Quantity of agrochemicals in water (if detected)	- Chemical laboratory tests (preferable) - References in literature regarding other studies performed

[3] The data shown in light blue will be used to estimate water consumptions or consumptive uses; conversely, data shown in grey will be used to obtain the impacts from the degradative use of water. Water discharge will be used to determine the impact from both uses.

3.4.2. How much water was consumed and how much was degraded?

Water consumption (VC) will be obtained by subtracting water output from water input in a given process.[41,46] Water consumption at the farm will be given by the volume of evapotranspiration during the study year[47] (Figure 3.7), while water consumption at the Packing Plant will be the result of the water input during the study year, minus the volume of water discharged during the study year (Figure 3.8).



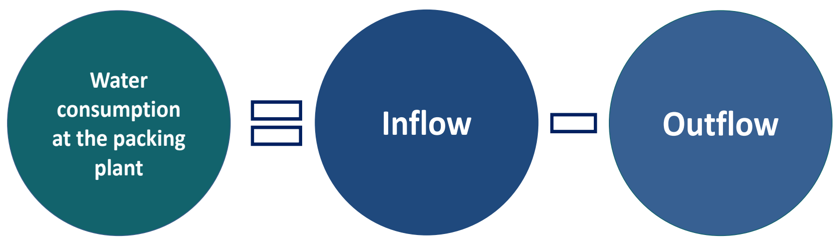


Figure 3.8. Water consumption at the packing plant.

Example 3.3. Calculation of water volume consumed (water consumption)

If the evapotranspiration from the banana plantation results in a total volume of **2 500 000 m³** for the study year, the water volume consumed in the planting and harvesting process ($VC_{P\&H}$) will be equal to this value.

$$VC_{P\&H} = 2\,500\,000\ m^3/year$$

If the water volume entry at the Packing Plant is **10 500 m³** for the study year, and the water volume discharge is **8 000 m³** during the same period, the water volume consumed in the Packing Plant process (VC_{PP}) will be given by:

$$VC_{PP} = 10\,500 - 8\,000 = 2500\ m^3/year$$

Water consumption for the system during the study year will be the sum of the consumptions of all processes (VC_T).

$$VC_{PP} = VC_{P\&H} + VC_{PP}$$

$$VC_T = 2\,500\,000\ m^3/year + 2\,500\ m^3/year = 2\,502\,500\ m^3/year$$

The degradative use of water (VD) will be estimated for the packing plant process. This volume will be equal to the total discharge (weekly and daily) (Figure 3.9).

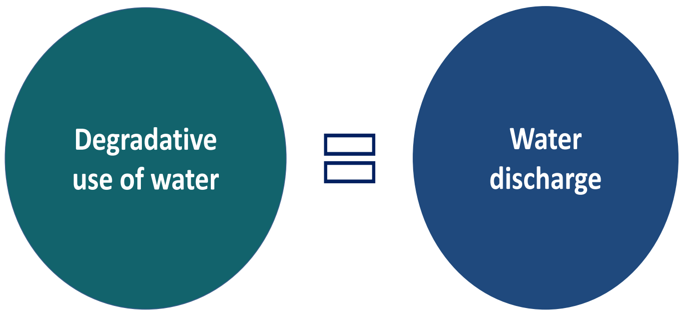


Figure 3.9. Degradative use of water.

Example 3.4. Calculation of degraded water volume (degradative use)

If we find that at the Packing Plant the discharged water volume was 8 000 m^3 during the study year, the degradative use of water in said process (VD_{PP}) will be equal to this value.

$$VD_{PP} = \mathbf{8\ 000 m^3/year}$$

The results of each water use must be given in terms of water consumption and the volume of degradative use for the entire organization (examples 3.3 and 3.4), which will be designated as the functional unit (FU). The FU is the reference unit in which the water footprint results will be expressed and will enable evaluating the performance of the organization.[40] .

Note: In the Water Footprint Network (WFN) methodology, the rainwater used will correspond to the green water footprint, and the water consumed from extractions carried out will correspond to the blue water footprint. However, these are different concepts that must not be confused in the water footprint inventory under ISO 14046.

3.4.3. Correlating water uses and banana production

The organization may establish an internal use indicator to correlate its results with banana production data. This will enable it to assess its performance and compare it with other banana companies that have conducted similar studies. We recommend using the number of 18.14 kg boxes of bananas for export[41] to calculate this comparative indicator (example 3.5).

Example 3.5. Correlating data with respect to the FU

Knowing that 290 000 18.14 kg boxes of bananas for export were produced during the study year, we can estimate the inventory results for this value as shown below:

For water consumption (VC):

$$VC_T/\text{production} = \frac{VC_T}{Production\ data} = \frac{2\ 502\ 500\ m^3/year}{290\,000\ 18.14\ kg\ boxes\ of\ bananas\ for\ export}$$

$$VC_T\ /\text{production} = 8.63\ m^3/year\ to\ produce\ one\ 18.14\ kg\ box\ of\ bananas\ for\ export$$

For degradative use of water (VD):

$$VD_{PP}/\text{production} = \frac{VD_{PP}}{Production\ data} = \frac{8\ 000\ m^3/year}{290\,000\ 18.14\ kg\ boxes\ of\ bananas\ for\ export}$$

$$VD_T\ /\text{production} = 0.028\ m^3/year\ to\ produce\ one\ 18.14\ kg\ box\ of\ bananas\ for\ export$$

3.5. Assessment of impacts from water use at the organization

The impact assessment phase will comprise the classification of potential environmental impacts related to water use in banana production processes, in their respective categories (Figure 3.5). In turn, this phase includes the calculation of indicators in each category in order to assess the magnitude and significance of the impacts.[41]

The result of this stage will be a set of values, which are the indicators of the various environmental impacts, constituting the water footprint profile from direct use of the resource.[40]

Para considerar: Las metodologías para cuantificar los impactos en la presente guía, se seleccionaron según las recomendaciones en la literatura[39,41,44], y la consulta a expertos en el tema. Cada una de estas se amplía en el Anexo 8.

3.5.1. What impacts relate to water quality degradation?

The release of chemical substances into the water as a result of the company’s activities (e.g. application of fertilizers, agrochemicals, latex exudation) may eventually affect the quality of freshwater sources.[41]

The emission of agrochemicals, fertilizers and latex into the water, as well as the degradation of the resource, will be taken into account in order to quantify the impacts on water quality. The assessed impacts must be human toxicity, ecotoxicity and eutrophication. Schedule 8, which includes the respective calculation equations, and Schedule 9, with calculation examples for each impact, may be consulted for further detail.

3.5.1.1. Human toxicity

Any substance released into freshwater sources as a consequence of the activities of the organization, which has the capacity to increase the risk of disease in human beings, must be considered in estimating this impact. In the case of the banana sector, the effects of agrochemicals, as well as of any chemical product used in the processes, must be taken into account. The USEtox methodology, recommended for this category, provides the characterization factors (CF) for substances emmited into the water.[48]

Impact will be estimated using the equation in Figure 3.6, and the results of this indicator will be given in Comparative Toxic Units on human health or CTUh.[48] The available CFs for products used in the banana sector are included in Schedule 10.

3.5.1.2. Ecotoxicity in freshwater

The release of chemical substances into freshwater due to activities of the banana sector can also have toxic effects on the ecosystems, known as ecotoxicity. It is recommended that banana companies assess the effect of all agrochemicals and chemical products used in production processes.

This impact category uses the USEtox methodology,[48] which estimates the decrease in water species, and its indicator is given in terms of Comparative Toxic Units in the ecosystem or CTUe. Schedule 10 provides the most relevant CFs.

3.5.1.3. Eutrophication in freshwater

Eutrophication is known as natural enrichment or that resulting from human activity, of nutrients in a body of water, resulting in an exponential growth of algae. This entails a decrease in water oxygen, deterioration in its quality and extinction of species.[41] This phenomenon may be caused by the enrichment of freshwater bodies, with fertilizers and latex emitted into the water as a result of banana sector activities.

Eutrophication impact is calculated by using the CFs proposed by the ReCiPe methodology. This methodology assumes that damage to aquatic species in freshwater is caused by the release of phosphorus, and therefore the indicator of this impact is given in equivalent phosphorus kilogram units (kg Pe).49 Schedule 10 provides the CFs for these calculations.

3.5.2. What impacts relate to water consumption?

3.5.2.1. Scarcity

Water scarcity occurs when this resource is not available in sufficient quantities for other users to satisfy their needs, which may originate in excessive use of bodies of water or due to specific characteristics of the regions.[50] The consequence of this for human beings may be diseases and malnutrition.[39]

In estimating the impacts of water scarcity, water consumption volume (waters that do not return to the same watershed) will be taken into account. This impact is caused by water extraction from the watershed where the Farm and Packing Plant are located. This loss of water from the water from the watershed may occur through water incorporated into the product, evaporated or discharged into bodies of water belonging to different watersheds.[41]

The AWARE ("Available Water Remaining") methodology is recommended for estimating scarcity, and its result will be given in terms of equivalent cubic meters (m^3e).51 The CFs are available in Schedule 8.

3.5.3. How can I understand the results?

In the results analysis stage, the most relevant findings obtained when interpreting the results must be identified and described. These must be studied considering specific characteristics of the region and of the study years, the limitations of the methods used, the uncertainty of the results and the specific limitations of each particular study.[40] Table 3.3 will help in the interpretation of results by users of the guide.

Table 3.3. Summary of impact indicators and their interpretation.

Impact Category	Impact Indicator	Interpretación
Human Toxicity (Degradation)	CTU_h	Results can be understood as the number of potential cases of associated diseases (carcinogenic and/or non-carcinogenic effects), due to emission into the water of chemical products from the banana production process[48].
Ecotoxicity (Degradation)	CTU_e	Results may be understood as the Potentially Affected Fraction (PAF) of species per cubic meter per day ($PAF.m^3.day$), due to the emission of chemical products from the banana production process.[48]
Eutrophication (Degradation)	kg Pe	This refers to the phosphorus portion of the total amount emitted into the water that may potentially cause the eutrophication of the body of water receiving the discharge.[49]
Scarcity (Consumption)	m^3e	The CF of the AWARE method may vary from 0.1 to 100, and refers to the number of times that water in the region is not available, with respect to the world average (e.g. a CF of 10 indicates that the remaining water available in the region will be 10 times less than the world average).[39]

The analysis of the results may lead to the identification of key points in the processes, on which the company can focus and prioritize its actions to reduce the environmental impacts of the banana sector through water consumption and degradation.[42]

3.6. Final water footprint report

It is advisable that in reporting results you follow the water footprint quantification stage structure, according to the ISO 14046 standard.[39,41] The following report structure is proposed in order to promote uniformity in the water footprint reports of the sector (Figure 3.10).

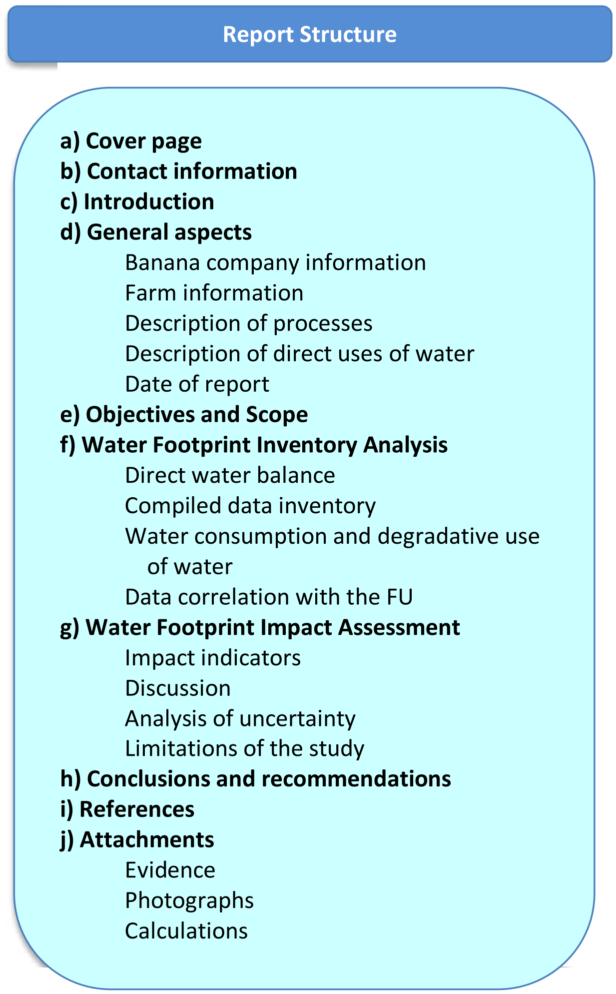


Figure 3.10. Proposed report structure. Adapted from the proposal by (COSUDE & CADIS, 2017; Vallejo, 2015)[39,41]

Information must be reported clearly and transparently. In addition, the report must include each data item, assumption, method, result, interpretation and limitation in detail so that the reader can fully understand the evaluation.[40,41].

3.7. Critical review of the water footprint

At present, water footprint studies may be subjected to a process known as a critical review, which is carried out by a verification and validation agency (VVA), in order to verify that the study meets the requirements of the ISO 14046 standard. This process is recommended when the company wishes to publish the results obtained.

In order to submit a water footprint study for critical review by INTECO, the detailed report in accordance with ISO 14046, as well as any other evidence backing the information contained in the report, must be made available.[39] In addition, during the review process, technical experts will need to visit the company's facilities and the study will be approved by a committee.[39]

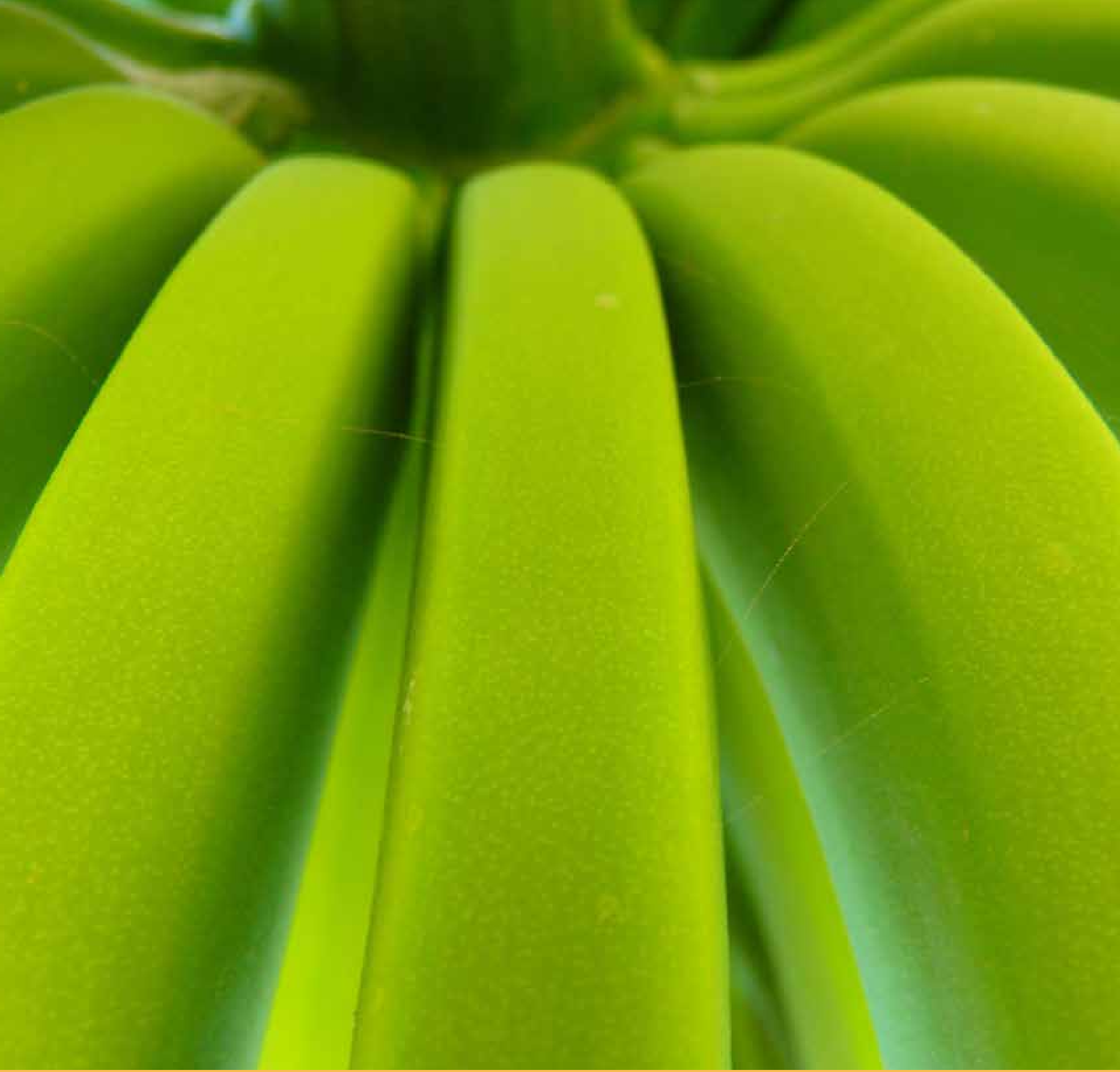
In case the company does not wish to subject the study to critical review, it may issue a declaration report. This is another form of communication of results, in which all data, methods, assumptions, limitations and results are published in detail so that whoever has access to these will understand the reported footprint.[39]

3.8. Recommendations

The water footprint concept is in constant evolution.[39,41] Therefore, it is important to include a review of the literature when preparing a study on the subject. This proposed guide is based on the most updated information as of its preparation date.

For a water footprint study to be considered comprehensive and thorough, it must contemplate all significant environmental impacts related to water.[40] It is advisable to include in a study of this topic, whenever possible for the company, the environmental impacts from indirect use of the resource. Otherwise, and in case it includes all impact categories proposed in the guide, the result of the study must be designated as "water footprint from direct use of the resource".

It is important to highlight that the final results obtained represent potential environmental impacts; therefore they are not necessarily occurring in those magnitudes. This is why the conclusions of a water footprint study focus mainly on the identification of key points for process improvement; in other words, those that generate the greatest environmental impacts from use of the resource.[41] Any water footprint reduction actions and programs will be developed using these critical points and findings (Chapter 4).



RECOMMENDATIONS

4. Technical recommendations for reducing carbon emissions and impacts on water in banana producing farms

4.1. Carbon emission reduction

The main reason for measuring GHG emissions is to **identify possible reduction opportunities, in order to contribute to lessen the effects of climate change**.[8] Reduction can be understood as the calculated decrease in emissions between estimates for the base year and the specific year where the reduction process is implemented.[56]

Therefore, once the GHG emissions from the specific sources in the banana company have been quantified, reduction strategies must be established. These strategies are include reduction goals and targets, as well as actions, measures and indicators to meet the respective goals and targets.13

Figure 4.1 describes the process to define a **Reduction Plan**, setting the emission reduction strategy or strategies of the banana company.

Establishing reduction strategies entails benefits for companies, including:

- Contributing to the sustainability of the business, an essential aspect in agriculture, given that lower GHG emissions will delay or reduce the effects of climate change. Therefore, adequate climate conditions for crops will be maintained for a longer period of time.[8]
- Allowing the identification of processes that must be adjusted to improve efficiency, establish recording and quantification systems and obtain a better knowledge of the business.[8]
- Reducing costs through process innovation and efficient use of resources, thereby increasing profitability of the banana business.[13]
- Promoting awareness among workers regarding risks and opportunities associated with climate change.[13]
- Becoming a differentiating factor in international markets, which contributes to product competitiveness.[8]

Establishing Reduction Goals.

Steps	Examples
Step 1. Select a reduction target that encompasses one or all emission sources included in the scope.	Reduce greenhouse gas emissions generated as a consequence of the electricity consumption of company A.
Step 2. Choose the limits of the target and set them in the goal. The limits will be: target base year, types of emissions and percentages or specific reduction amounts expected.	5% reduction compared to 2016 in CO_2 emissions of scope 2, generated by the electricity consumption of company A.
Step 3. Set a date for achieving the goal (short or long term).	The target will be reached by 2017.
Step 4. Define the indicators that will allow monitoring achievement of the target and the goal.	kg CO_{2e}/ kWh consumed kg CO_{2e}/ 18.14 kg packed box g CO_{2e}/ $ (sales)
Step 5. Define the measures and actions to be implemented in order to achieve the target and the goal, as well as the persons responsible and the resources needed for these activities.	Activity: Installation of solar panels. Responsible: Environmental Manager Resources: Financial, time

Figure 4.1. Steps to define emission reduction strategies.
Source: Adapted from DCC (2014)[13] and INTECO (2006)[56]

In any inventory development process and in setting reduction goals, it is essential to have the support of the senior management of the organization, as well as the support and understanding of its workers.[10] The following sections describe good practices, technologies and technical options that can be considered in the establishment of reduction strategies for the banana producing and exporting company.

4.1.1. Fertilizers

Fertilizer application generally constitutes the greatest emission source in the banana sector and, therefore, the critical point demanding greatest attention for reduction projects. Figure 4.2 shows different measures that can be implemented to reduce GHG emissions from this source in banana plantations. Schedule 12 describes the suggested reduction measures in detail.

The Dole company has attained a 50% reduction in the use of nitrogenous fertilizers over the past five years. This reduction was obtained through the implementation of slow-release fertilizers and certain precision agriculture techniques.[57]

Fertilizers	Benefit	Limitation
Application of Biochar to the soil	Enhances soil properties	Not all soils show the same improvements
Reduction of fertilizer application rates	Accepted by the markets	May potentially decrease productivity
Testing for nitrogen in the soil	Reduces over-fertilization	High cost
Optimizing of fertilization time	May represent monetary savings	Differentiated fertilization may be complicated
Placing fertilizer in the rhizosphere	May represent monetary savings	Fertilization processes may be complicated
Application of nitrification and urease inhibitors	Increases the plant's yield	High cost
Slow-release fertilizer application and manipulation technologies	Does not require major adjustments to current practices	High cost
Coordinate fertilizer application time with irrigation and rain periods	Increases the efficiency of nitrogen use	Application depends on the region
Use of fertilizers with lower N_2O emissions	Does not require major adjustments to current practices	Further investigation is required
Integrated management of soil fertility	Improves the soil's nutrient retention capacity	Requires more labor
Plant mycorrhiza	Fosters plant photosynthesis	Difficult to grow
Use of nitrogen-capturing plants	Reduction in the use of fertilizers	Use of arable land
Augment vegetation cover and prevent erosion	Improves soil productivity	Use of arable land
Introduction of new characteristics and varieties in the crops	Greater climate adaptation of the crops	Requires significant investment and research
Organic agriculture	Accepted by the markets	Entails significant changes in current practices

Figure 4.2. Emission reduction or absorption measures in fertilizer application.

Among the efforts implemented by CORBANA, its 40% reduction in nitrogenous fertilizers applied per hectare, with no significant effects on productivity, stand out. In addition, it implemented an agrometeorological information software known as BANACLIMA. This software enables a rational use of inputs, by monitoring pests and diseases.[57]

4.1.2. Fossil fuels and lubricating oils

The transportation sector is one of the most significant contributors of GHG emissions in the banana post-harvest stages. Therefore, transport efficiency improvements are important to reduce the impact of banana production for export.[58] In addition, the dependency of agriculture on fossil fuels constitutes a great threat to food security, due to the increase and volatility of prices. Therefore, reducing dependency on these products is a necessary challenge for the sector.3 Figure 4.3 shows various measurement option to contribute to emission reduction from this source. Schedule 12 describes the suggested reduction measures in detail.

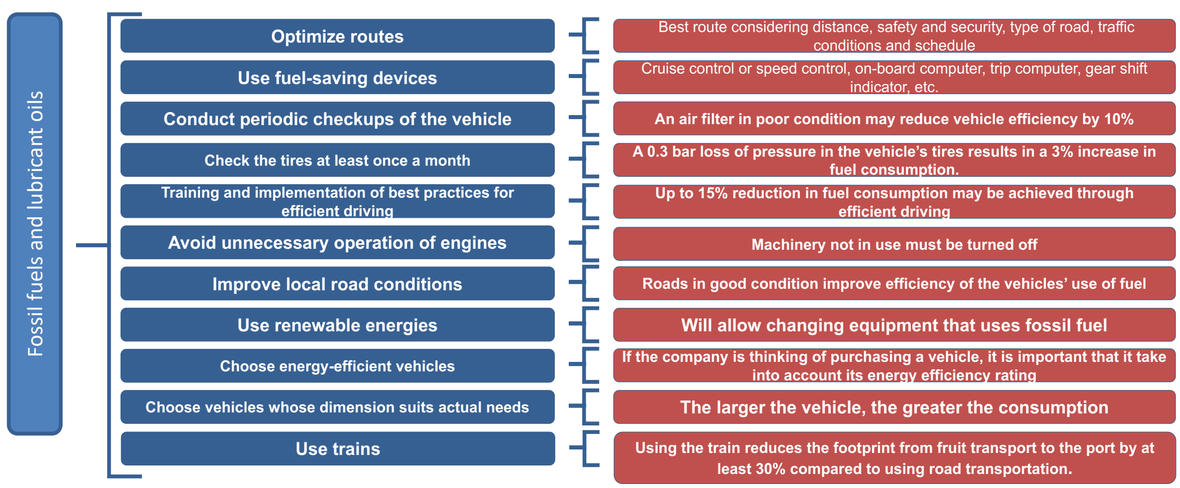


Figure 4.3. Emission reduction measures in fossil fuel consumption.

The Dole company implemented fossil fuel saving measures at the container terminal, achieving a reduction of 1 080 tons of CO_2e per year.[57]

4.1.3. Refrigerants and fire extinguishers

There is a global tendency towards elimination of refrigerants with GWP above 2 500. HFCs are very powerful GHG and their impacts can be significant, given that they contain global warming potentials of up to 140 to 11 700 times the potential of CO_2.[21] Some possible measures for reducing emissions from this source are shown in Figure 4.4.

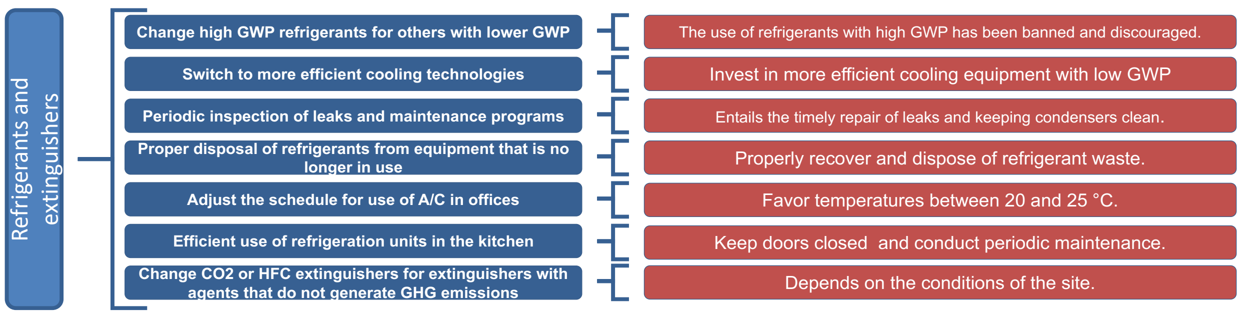


Figure 4.4. Emission reduction measures in refrigerant consumption.

Table 4.1 presents refrigerant gas alternatives with low global warming potential, which may be considered to substitute other coolants with higher GWP. However, it is important to remember that some of these are still under development, and therefore recommendations by technicians for the implementation of refrigerant mixtures can also be considered. Schedule 12 describes certain emission reduction measures in refrigerant consumption.

Table 4.1. Refrigerant alternatives with low GWP.

Refrigerante	PCG
R-449a	1.400
R-449b	1.412
R-448a	1.387
HFC-32	675
R-513a	630
R-450a	601
R-447a	583
R-446a	461
R-451b	164
R-451a	149
HFO-1234ze(E)	6
R-441a	<5
HFO-1234yf	4
R-600a (isobutane)	3
R-290 (propane)	3
R-744 (CO2)	1
R-717 (ammonium)	0

Source: Adapted from (Environmental Protection Agency [EPA], 2016)[59]

To be considered: The change to different refrigerants is normally determined by the refrigerating equipment; it is often necessary to invest in a retrofit or structural and technical change of the equipment. Therefore, the recommendation is to consider renewing the fleet with equipment designed for the new refrigerant, which will also be beneficial in the long run.

The Dole company achieved a 75% reduction in refrigerant related emissions through a change to more efficient systems.[57]

4.1.4. Liquid (wastewater) and solid waste management

Decomposition of liquid and solid wastes at banana industries contributes to methane emissions. Figure 4.5 shows certain options that might reduce GHG emissions from these sources in banana exporting companies. Schedule 12 describes the suggested reduction measures in detail.

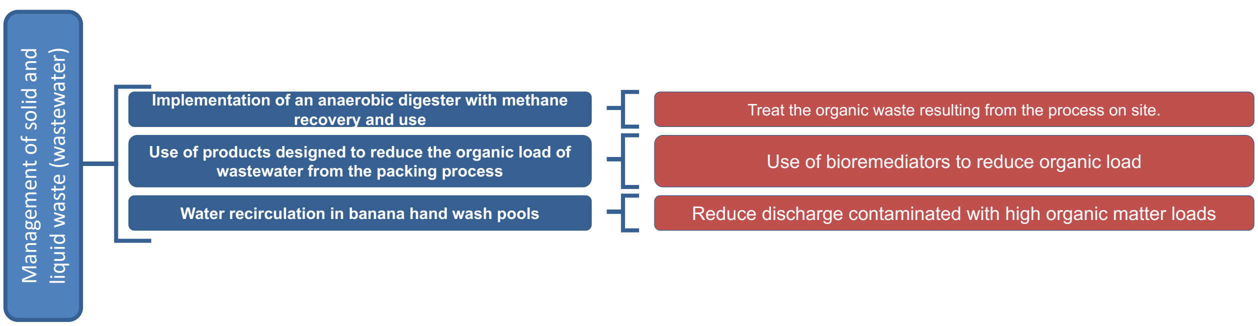
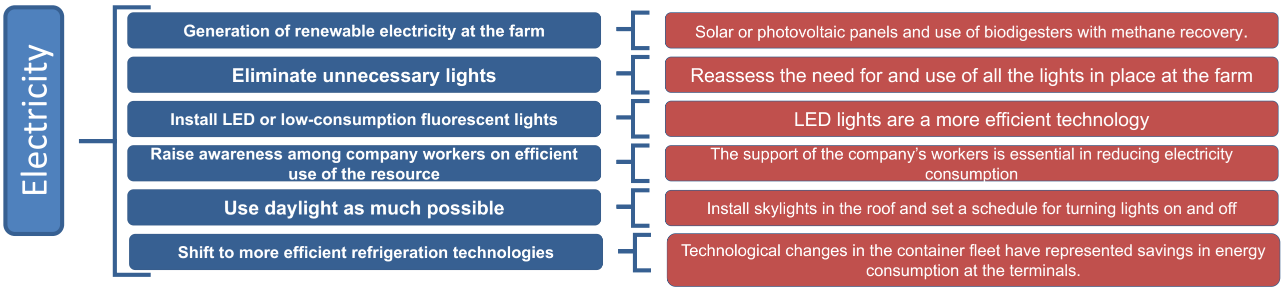


Figure 4.5.Emission reduction measures in solid and liquid waste management

4.1.5. Electricity

With respect to electric power consumption obtained from a grid (scope 2), there are several simple as well as complex alternatives for banana companies to reduce their consumption, cost and associated emissions. Figure 4.6. shows some of these as recommendations for the sector. Schedule 12 describes the suggested reduction measures in detail.



The Platanera Río Sixaola company covers 100% of its electric power needs through the use of solar panels.[60]

The Platanera Río Sixaola company covers 100% of its electric power needs through the use of solar panels.[60]

4.2. Carbon removals

Based on the description in section 2.7, banana companies may also want to consider the implementation of carbon removal strategies as part of their emission management plans. In this respect,

Vegetation cover in plantation drains. Photo Miguel Vallejo

- Reforestation of own or leased areas.
- Protection of own or leased forest (removal capacity is limited if the forest is already stabilized).
- Agroforestry systems in productive and unproductive farm areas, and in waterbody protection areas, housing area boundaries, packers or roads.
- Vegetation covers in plantations.

4.3 Water footprint reduction

In order to attain a reduction in the water footprint, efforts must focus on establishing measures that reduce water consumption or the emission of pollutants into it. In addition, offsetting actions may be carried out to protect water resources, such as planting trees in groundwater reserve recharge areas or in the surrounding areas of rivers and lakes, in addition to cleaning rivers and beaches.

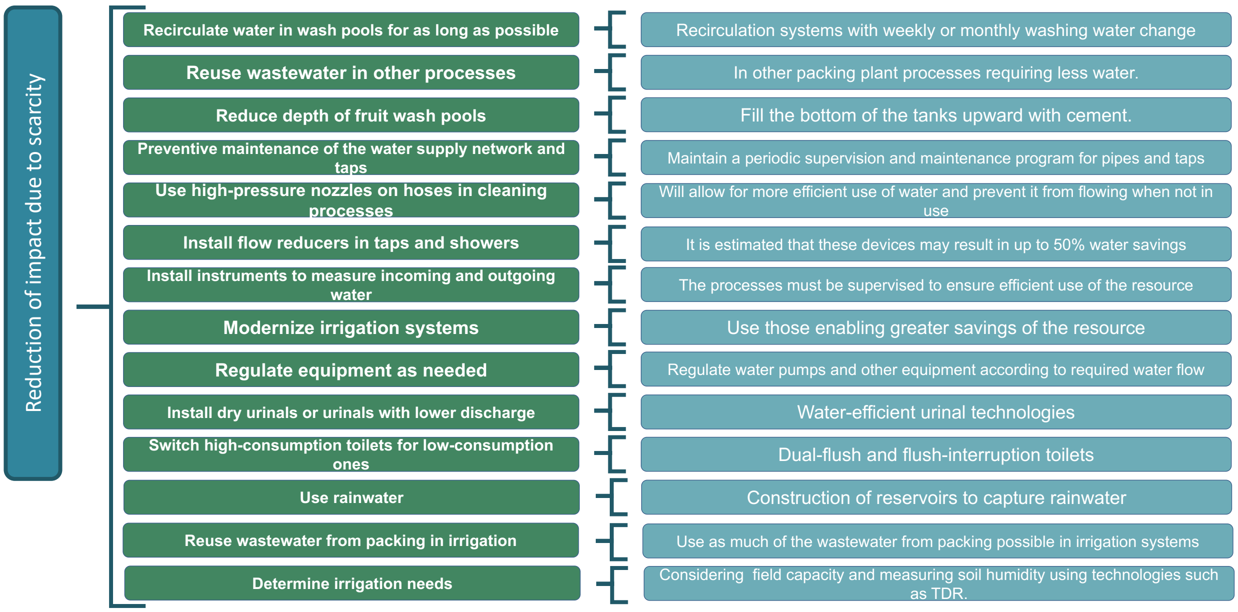


Figure 4.7. Water footprint reduction measures due to scarcity in the banana sector

CORBANA achieved a 50% reduction in its fruit-washing water consumption by reducing the depth of wash pools to 70 and 80 cm and reusing the water.[57]

Figure 4.7 includes some of the water footprint reduction measures due to scarcity, which can be implemented in banana farms. In addition, Figure 4.8 shows measures to be implemented for reducing the water footprint due to human toxicity, ecotoxicity and eutrophication.

Reductions in water use of up to 17% have been attained in certain packing plants of the Fyffes company by implementing the use of an enzyme-based product, which reduces the latex load in the water and allows using the same water for a longer period of time.

Adapted from personal communication with Hays, H., 2017.

Figure 4.8. Measures for reducing the water footprint from human toxicity, ecotoxicity and eutrophication in the banana sector.

To be considered:

The early alert model based on climate factors that favor the development of the Black Sigatoka (*Mycosphaerella fijensis*) disease, developed by the World Wildlife Fund (WWF) and the Belize Banana Growers Association (BGA) can be implemented to promote the rational use of agrochemicals.

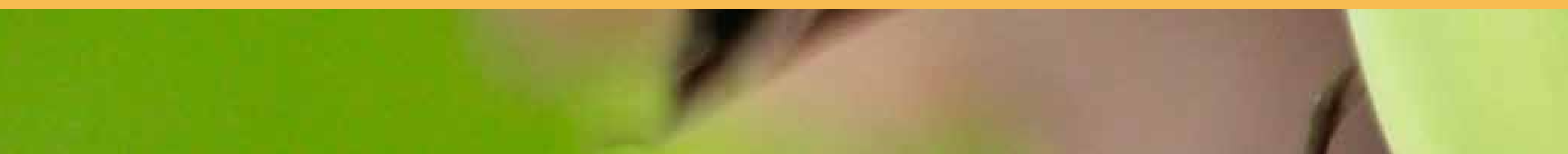
The model predicts disease evolution (DE) speed in advance and not when symptoms are detected. Given that it requires real-time information to determine daily risk, the model is used through the Agripanda online platform (agripanda.com). This platform is connected to a telemetric station network that is constantly sending the necessary climate information to model disease development which is then used to calculate the disease severity value (DSV). The DSV is used to determine whether the agrochemical must be applied or the company must wait until there are optimal conditions in the field, that is, whether there should be preventive or curative control.

This tool helps in making timely decisions regarding application and in selecting the fungicide to be applied. The implementation of the model can justify a reduction in the application of protective fungicides and, therefore, a reduction in environmental impact. In addition, it prevents outbreaks of the disease that cause severe losses of foliage and financial impacts.

Adapted from personal communication with Mejía, M. of the WWF, 2017.

The Platanera Río Sixaola company has 30 certified hectares of organic banana and promotes the implementation of products for integrated pest management and organic fertilization. It currently has a biofactory which produces 160 thousand liters per month of organic pest control products, and 220 square meters for producing organic fertilizer through earthworm farming. And, in addition, it has been able to make rational use of fungicides for controlling Black Sigatoka (25 to 30 aerial applications a year compared to the average of between 60 and 80).[60]

EXAMPLE CASE



5. Example case at Finca San Pablo

5.1. Example of carbon footprint measurement at Finca San Pablo, CORBANA, Costa Rica

Compañía Internacional de Banano S.A. (CIBSA) owns a farm located in the canton of Siquirres, in the province of Limón, Costa Rica. This farm is known as Finca San Pablo and it has a planted area of 284.07 hectares, which was verified for the year 2015 as Carbon Neutral, under the Country Program in Costa Rica and voluntary standard INTE 12-01-06:2016. Data from Finca San Pablo for the year 2016 will be used to exemplify the carbon footprint measurement.

For the organizational boundaries of the study, we will include as physical boundaries the entire area of the farm and the packing plant facilities located at Siquirres, Limón, Costa Rica. In addition, processes with operati control, which comprise banana cultivation, harvesting, packing and transport of the fruit to the port will also be included. The identified emission sources, together with the emission types that comprise the operational boundaries, are summarized in Table 5.1.

Table 5.1. Identified emission sources and their respective emission types and scope.

Emission source	Emission subsource	Emission type	Scope
Fertilizer application	Synthetic nitrogenous, organic and lime	Direct	1
Fossil fuel consumption	Farm electric power plant and brushcutter	Direct	1
	Farm owned vehicles (administrative and tractor)	Direct	1
	Contractor brushcutter	Other indirect	3
	Crop dusting planes	Other indirect	3
	Trucks for transporting the fruit to port	Other indirect	3
Use of lubricating oils	Farm electric power plant and brushcutter	Direct	1
	Farm owned vehicles (administrative and tractor)	Direct	1
	Contractor brushcutter	Other indirect	3
	Trucks for transporting the fruit to port	Other indirect	3
Refrigerant leak	Office air conditioning	Direct	1
	Refrigerants for containers used in transporting fruit to port	Other indirect	3
Extinguisher recharge	CO_2 extinguishers	Direct	1
Solid waste management	Solid waste sent to landfill	Other indirect	3
Wastewater generation	Domestic wastewater disposed of in septic tanks	Direct	1
	Wastewater from packing process, discharged into receiving body	Direct	1
Electricity consumption	Electricity consumption from power grid	Indirect	2
Acetylene consumption	Acetylene burned for workshop processes	Direct	1
LP gas consumption	LP gas consumption at cafeteria	Other indirect	3

Nitrogenous synthetic fertilizers are used at the farm; an estimated total of 105 100.92 kg N were applied during 2016. In addition, poultry manure and stalk wastes are applied in the field as organic fertilizers, a total of 1 156 160 kg and 2 227 119.3 kg, respectively, being applied during the same year. Limestone is used for soil amendment and a total of 178 900 kg were used during the year.

The farm has one tractor, four administrative vehicles, a brushcutter and an electric power plant to handle power cut emergencies. This machinery and equipment belong to the company, which therefore has direct control over their fuel and oil consumptions.

In addition, the contractor's brushcutter, the trucks that transport fruit to the port and the aircraft used in air spraying are fuel and oil consumption sources corresponding to subcontracted services. Nevertheless, as a good practice they are included in the inventory, given that operations of these sources are significant in fruit production.

Main sign of Finca San Pablo, CORBANA.
Photo Miguel Vallejo

The office area has eleven air conditioners that use R-22 refrigerant, and three that use R-410. In 2016, these were subject to a total recharge of 9.75 kg and 2.65 kg respectively. Fruit transport containers have a refrigeration system but, because this is a subcontracted service, it is not taken into account as an emission source of the organization.

The company has different fire extinguishers at its facilities. Among these, some use CO_2 as extinguishing agent, for which a total recharge of 11.30 kg was made during the study year. Ordinary wastes are sent to the sanitary landfill, and it is estimated that 133.5 kg of these were managed in 2016.

Domestic wastewaters from restrooms and taps are sent to a septic tank, for which it is important to point out that there were, on average, 267 workers during 2016. Wastewaters from the wash process at the packing plant are discharged weekly into a canal in the farm, after their recirculation and passage through a physical treatment plant. These waters were discharged at an average of 0.1315 kg BOD/m^3 during the year; weekly discharge is estimated at 268 m^3 according to the pool volume and daily refill requirement of the tanks.

Electricity consumption from the electric power grid during 2016 was 145 332 kWh. In addition, acetylene is used at the shop and liquefied petroleum gas is used in the kitchen (subcontracted service), for which the recharge was a total of 7 L and 2 100 lb respectively during this same period.

Once the data from each emission generating activity has been compiled, calculations will be made for each emission source, as shown below.

Calculations by emission source

Nitrogenous synthetic fertilizers:

The total quantity of nitrogen applied in the field was estimated for each type of synthetic fertilizer, by multiplying the total number of kilograms of each by its estimated nitrogen percentage. This corresponds to the (Fe X N) multiplication in equation A6.1 of Schedule 6. This yielded a result for total added hydrogen of 105 100.92 kg. Applying the rest of equation A6.1:

Synthetic Fertilizer Emissions: 105 100.92 kg N **x** 0.01 kg N_2O – N/kg N **x** 44/28 **x** 265 kg CO_2e/kg N_2O = 435 478.14 kg CO_2e

Organic fertilizers:

Banana stalks, one of the main organic wastes incorporated into banana cultivation, GHG emission source.
Photo Miguel Vallejo

- **Poultry manure** (20.95% moisture and nitrogen content of 1.14%, dry base):

Total nitrogen added with poultry manure: 1 156 160 kg poultry manure x ((100-20.95) /100) x 1.14/100 = 10 418.967 kg N

Poultry manure emissions: 10 418.967 kg N x 0.01 kg N2O-N/ kg N x 44/28 x 265 kg CO2e/kg N2O = 43 387.556 kg CO2eResiduos de pinzote (humedad del 94,6% y un contenido de nitrógeno de 1,34% en base seca):

- **Stalk waste (94.6% moisture and 1.34% nitrogen content, dry base):**

Total nitrogen added with waste: 2 227 119.3 kg stock **x ((**100-94.6**) /**100**) x** 1.34/100 = 1 611.543 kg N

Stalk Emissions: 1 611.543 kg N **x** 0.01 kg N_2O-N/kg N **x** 44/28 **x** 265 kg CO_2e/kg N_2O = 6 710.928 kg CO_2e

Lime application:

Emissions from Lime Application: 178 900 $kg_{total\ C}$ **x** 0.12 kg CO_2-C/$kg_{total\ C}$ **x** 44/12 **x** 1 CO_2e/kg CO_2 = 78 716 kg CO_2e

Fossil Fuel Consumption: **Diesel Power Plant (PP):**

PP CO_2 emissions: 1 051 L **x** 2.613 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 2 746.263 kg CO_2e

PP CH_4 emissions: 1 051 L **x** 0.122 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 3.590 kg CO_2e

PP N_2O emissions: 1 051 L **x** 0.02442 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 6.801 kg CO_2e

- **Own gasoline Brushcutter** (OB):

OB CO_2 emissions: 1 560.82 L **x** 2.231 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 3 482.189 kg CO_2e

OB CH_4 emissions: 1 560.82 L **x** 0.346 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 15.121 kg CO_2e

OB N_2O emissions: 1 560.82 L **x** 0.02211 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 9.145 kg CO_2e

- **Own diesel vehicles** (ODV):

ODV CO_2 emissions: 7 731.68 L **x** 2.613 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 20 202.880 kg CO_2e

ODV CH_4 emissions: 7 731.68 L **x** 0.149 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 32.257 kg CO_2e

ODV N_2O emissions: 7 731.68 L **x** 0.154 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 315.530 kg CO_2e

- **Own gasoline vehicles** (OGV):

Emisiones CO_2 VPG: 175,85 L **x** 2,231 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 392,321 kg CO_2e

Emisiones CH_4 VPG: 175,85 L **x** 0,907 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 4,466 kg CO_2e

Emisiones N_2O VPG: 175,85 L **x** 0,283 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 13,188 kg CO_2e

- **Diesel tractor** (DT):

DT CO_2 emissions: 1 102.78 L **x** 2.613 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 2 881.564 kg CO_2e

DT CH_4 emissions: 1 102.78 L **x** 0.382 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 11.795 kg CO_2e

DT N_2O emissions: 1 102.78 L **x** 0.02442 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 7.136 kg CO_2e

- **Contractor gasoline brushcutter** (CB):

Emisiones CO_2 MC: 5.619,42 L **x** 2,231 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 12.536,926 kg CO_2e

Emisiones CH_4 MC: 5.619,42 L **x** 0,346 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 54,441 kg CO_2e

Emisiones N_2O MC: 5.619,42 L **x** 0,02211 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 32,925 kg CO_2e

- **Jet fuel air spraying plane** (ASP):

Air spraying at banana plantation.
Photo Miguel Vallejo

ASP CO2 emissions: 22 689 L x 2.462 kg CO2/L x 1 CO2e/kg CO2 = 55 860.318 kg CO2e

ASP CH4 emissions: 22 689 L x 0.018 g CH4/L x (1/1000) x 28 CO2e/kg CH4 = 11 435 kg CO2e

ASP N2O emissions: 22 689 L x 0.071 g N2O/L x (1/1000) x 265 CO2e/kg N2O = 426.894 kg

- **Diesel fruit transport trucks (TT):**

TT CO_2 emissions: 30 708.03 L **x** 2.613 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 80.240 080 kg CO_2e

TT CH_4 emissions: 30 708.03 L **x** 0.149 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 128.114 kg CO_2e

TT N_2O emissions: 30 708.03 L **x** 0.154 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 1 253.195 kg CO_2e

Lubricating oil use:

- Diesel power plant (PP): No oil changes were made.
- Own gasoline brushcutter (OB):
- OB CO2 emissions: 54.87 L x 0.5101 kg CO2/L x 1 CO2e/kg CO2 = 27.989 kg CO2e
- Own diesel vehicles (ODV):
- ODV CO2 emissions: 109.50 L x 0.5101 kg CO2/L x 1 CO2e/kg CO2 = 55.856 kg CO2e
- Own gasoline vehicles (OGV):
- OGV CO2 emissions: 2 L x 0.5101 kg CO2/L x 1 CO2e/kg CO2 = 1.020 kg CO2e
- Diesel tractor (DT): No oil changes were made.
- Contractor gasoline brushcutter (CB):
- CB CO2 emissions: 13.66 L x 0.5101 kg CO2/L x 1 CO2e/kg CO2 = 6.968 kg CO2e
- Fruit transport trucks (TT): Not quantified because these are scope 3 emissions (other indirect).

Refrigerant leaks:

- Air conditioners (AC):

AC R-22 emissions: 9.75 kg R-22 x 1 810 kg CO2e/kg R-22 = 17 160 kg CO2e

AC R-410 emissions: 2.65 kg R-410 x 2 090 kg CO2e/kg R-410 = 5 538.5 kg CO2e

- Refrigerated Containers (RC): Not quantified because transport is a subcontracted service and therefore these emissions are not considered the company's responsibility.

Fire extinguisher recharge:

CO_2 Extinguisher emissions: 11.30 kg CO_2 **x** 1 CO_2e/kg CO_2 = 11.30 kg CO_2e

Municipal solid waste management:

MSW emissions: 133.5 kg MSW **x** 0.0581 kg CH_4/kg MSW **x** 28 CO_2e/kg CH_4 = 217.18 kg CO_2e

Domestic wastewater generation:

DWW emissions: 267 persons x 4.38 kg[4] CH4/person x 8/24 x 309/365[5] x 28 CO2e/kg CH4 = 9 240.336 kg CO2e

Process wastewater generation:

Discharged process wastewater: 268 m^3/week **x** 52 working weeks/year= 13 936 m^3/year

Average BOD: **((**120 mg BOD/L + 143 mg BOD/L**) / 2) x** (1/1000) = 0.1315 kg BOD/m^3

PWW emission: 13 936 m^3 **x** 0.1315 kg BOD/m^3 **x** 0.0250 kg CH_4/kg BOD **x** 28 CO_2e/kg CH_4 = 1 282.809 kg CO_2e

Electricity consumption:

The emission factor used for this calculation is the last value reported by the IMN in Costa Rica, according to the 2015 power matrix.

Electricity Emission: 145 332 kWh **x** 0.0381 kg CO_2/kWh **x** 1 CO_2e/kg CO_2 = 5 537.149 kg CO_2e

Acetylene consumption:

Acetylene emissions: 7 L **x** 0.00117 kg/L **x** 0.00338 kg CO_2/kg C_2H_2 **x** 1 CO_2e/kg CO_2 = 0.0000277 kg CO_2e

LP gas consumption:

Assuming an LP gas density of 0.98201 kg/L, emissions can be estimated.

CO_2 emissions: 2 100 lb **x** 0.460 kg/lb **x** (1 L **/** 0.98201 kg) **x** 1.611 kg CO_2/L **x** 1 CO_2e/kg CO_2 = 1 584.735 kg CO_2e

CH_4 emissions: 2 100 lb **x** 0.460 kg/lb **x** (1 L **/** 0.98201 kg) **x** 0.139 g CH_4/L **x (**1/1000**) x** 28 CO_2e/kg CH_4 = 3.829 kg CO_2e

N_2O emissions: 2 100 lb **x** 0.460 kg/lb **x** (1 L **/** 0.98201 kg) **x** 0.002745 g N_2O/L **x (**1/1000**) x** 265 CO_2e/kg N_2O = 0.729 kg CO_2e

[4] Emission correction factor, reflecting the fact that people are at the facilities only 8 hours a day.

[5] Emission correction factor, reflecting the fact that people are at the facilities only 309 days a year.

Emission summary and performance indicators

Reviewing the results, we can see that the sources responsible for the largest amount of GHG emissions are fertilizers (Table 5.2).

Table 5.2. Sample case emission summary.

Emission source	Emission (t CO_2e)
Fertilizers	564.293
Fossil Fuels	181.644
Lubricating oil use	0.092
Refrigerant leak	23.186
Extinguisher recharge	0.011
Municipal solid waste management	0.217
Wastewater generation	10.523
Electricity consumption	5.537
Acetylene consumption	0.00000003
LP gas consumption	1.589
Total	786.605

Contribution of each emission source to total emissions at Finca San Pablo during 2016

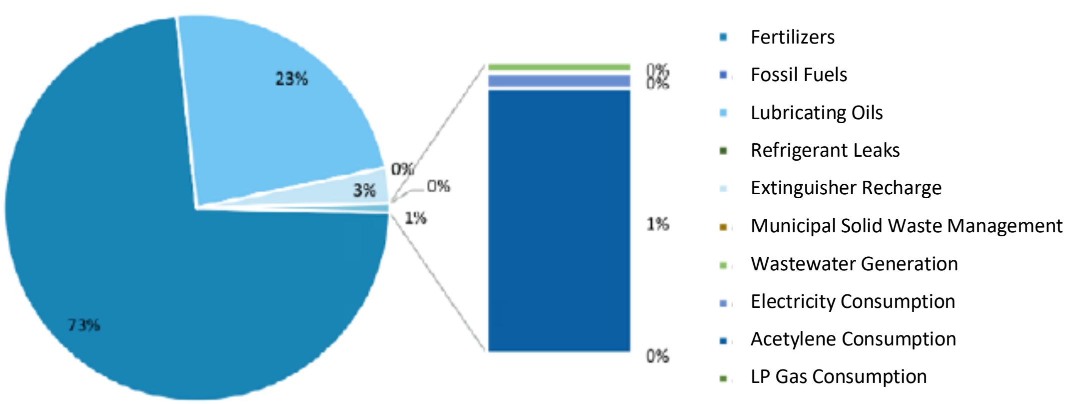


Figure 5.1 shows a graph of the reported results. The emission performance indicator result per box was 1.019 kg CO_2e/box.

5.2. Example of water footprint measurement at Finca San Pablo, CORBANA, Costa Rica

Finca San Pablo, which belongs to Compañía Internacional de Banano S.A. (CIBSA), has made efforts to quantify its direct water footprint due to scarcity and eutrophication during 2014. In addition, it achieved a reduction in water use of up to 41.7% from 2011 to 2014, through the implementation of good practices such as the use of a bioremediator, weekly water recirculation, and change in fruit washing tank depth. To illustrate the water footprint measurement using the guide, we will use data from Finca San Pablo for the year 2016.

It is important to highlight that only environmental impacts from direct use of water, that is, the footprint related to water uses at the farm site and the packing plant, will be assessed. The water footprint from indirect use of the resource (water consumption in fertilizer production, banana box production, plastic strap production for packaging, pallets, etc.) is excluded from the study. The estimated midpoint impacts include human toxicity, ecotoxicity, eutrophication and scarcity, assessed using the USEtox, ReCiPe and AWARE methodologies respectively.

The study to be carried out comprises the cradle-to-gate stages of the product, defined in functional units as “one 18.14 kg box of bananas for export”. To protect the confidentiality of the company’s information, the data used for evapotranspiration and agrochemicals were taken from the literature, and do not reflect the actual situation at this farm.

With respect to the data required for the farm, crop evapotranspiration was estimated by using the FAO program, CROPWAT, as shown in Schedule 11, obtaining the result of 2 554 974.28 m3 evapotranspired during the study year. The total phosphorus value applied with fertilizers was 6 468.39 kg P during 2016, obtained by correlating the quantity of each fertilizer with its phosphorus content. The values for agrochemicals used at the farm are taken from the literature for this sample case (they are not actual farm data), as summarized in Table 5.3.

Table 5.3. Assumed agrochemical application for 2016.

Agrochemical	Active Ingredient	Application (kg/ha/year)
Fungicide	Mancozeb	53.9
Nematicide	Oxamyl	8.8
Herbicide	Glyphosate	2.0
Insecticide	Bifenthrin	0.18

Adapted from (Corporación Bananera Nacional [CORBANA], 2011)[71]

The water inflow volumes indicated by the meter were taken monthly at the Packing Plant, and the daily water consumption by workers was subtracted from these (assuming a 200 liters per day consumption and 267 workers per month). A discharge of 268 m^3 per week is estimated, according to the tank volume and daily refill required by these. Water inflow and outflow data are shown in Table 5.4.

Table 5.4. Water inflow, outflow and consumption volumes at the Packing Plant.

Month	Inflow volume (m^3)	Outflow volume (m^3)	Water consumption (m^3)*
January	2 219.80	1 340.00	879.80
February	2 724.00	1 072.00	1 652.00
March	2 825.40	1 072.00	1 753.40
April	3 596.20	1 340.00	2 256.20
May	3 495.20	1 072.00	2 423.20
June	3 602.20	1 072.00	2 530.20
July	3 599.20	1 340.00	2 259.20
August	4 023.40	1 072.00	2 951.40
September	4 000.20	1 072.00	2 928.20
October	4 868.20	1 340.00	3 528.20
November	5 563.20	1 072.00	4 491.20
December	4 863.20	1 072.00	3 791.20
Total	**45 380.20**	**13 936.00**	**31 444.20**

*Inflow volume minus outflow volume.

Based on the operating reports submitted to the Ministry of Health, it was estimated that wastewater from the packing process is discharged with an average BOD of 0.03 kg BOD/m^3.

Water consumption calculations

Water consumption in the field is equal to the water volume evapotranspired by plants, 2 554 974.28 m^3/year.

Water consumption at the Packing Plant is the result of subtracting the outflow volume from the inflow volume, obtaining a difference of 31 444.20 m^3/year (Table 5.4).

Total water consumption: 2 554 974.28 m^3/year **+** 31 444.20 m^3/year= **2 586 418.48 m^3/year**

Degradative water use calculations

The degraded water volume at the Packing Plant is equal to the water outflow volume, which is 13 936.00 m^3/year (Table 5.4).

Total degradative water use: **13 936.00 m^3/year**

Calculations to determine internal performance indicators

Considering that total production in 2016 was 771 956 18.14 kg boxes of bananas for export:

Water consumption by FU: 2 586 418.48 m^3/year ÷ 771 956 boxes = 3.35 m^3/year/box

Degradative use of water per FU: 13 936.00 m^3/year ÷ 771 956 boxes = **0.02 m^3/year/box**

Impact calculations by category

Human toxicity (HT):

Mancozeb impact on HT: 53.9 kg/ha **x** 284.07 ha **x** 0.000002156 cases/kg= **0.0330113 cases**

Oxamyl impact on HT: 8.8 kg/ha **x** 284.07 ha **x** 0.000004146 cases/kg = **0.0103642 cases**

Glyphosate impact on HT: 2.0 kg/ha **x** 284.07 ha **x** 0.000000160 cases/kg = **0.0000909 cases**

Bifenthrin impact on HT: 0.18 kg/ha **x** 284.07 ha **x** 0.000124762 cases/kg = **0.0063794 cases**

Total impact on HT: 0.0330113 **+** 0.0103642 **+** 0.0000909 **+** 0.0063794 = **0.0498459 cases or CTU_h**

Freshwater ecotoxicity (ET):

Mancozeb impact on ET: 53.9 kg/ha **x** 284.07 ha **x** 52 559.66 PAF.m^3.day/kg = **804 760 559 PAF.m^3.day**

Oxamyl impact on ET: 8.8 kg/ha **x** 284.07 ha **x** 16 178.64 PAF.m^3.day/kg = **40 443 623 PAF.m^3.day**

Glyphosate impact on ET: 2.0 kg/ha **x** 284.07 ha **x** 320.79 PAF.m^3.day/kg = **182 254 PAF.m^3.day**

Bifenthrin impact on ET: 0.18 kg/ha **x** 284.07 ha **x** 6 578 866.63 PAF.m^3.day/kg = **336 394 556 PAF.m^3.day**

Total impact on ET: 804 760 559 **+** 40 443 623 **+** 182 254 **+** 336 394 556 = **1 181 780 992 PAF.m^3.day or CTU_e**

Freshwater eutrophication (Eu):

Field Impact on Eu: 6 468.39 kg P x 0.053 kg Pe/kg P = 342.82 kg Pe

Packing Plant impact on Eu:

Average BOD: ((21mg DBO/L +39 mg DBO/L) /2) x (1/1000) = 0.03 kg BOD/m3

Packing Plant impact on Eu: 0.03 kg BOD/m3 x 1/100 x 13.936 m3 x 1 kg Pe/kg P = 4.181 kg Pe

Total impact on Eu: 342.82 kg Pe + 4.181 kg Pe = 347.006 kg Pe

Scarcity (Sc):

Field impact on Sc: 2 554 974.28 m^3 **x** 0.4 m^3e/m^3 = **1 021 990 m^3e**

Packing Plant impact on Sc: 31 444.20 m^3 **x** 0.4 m^3e/m^3 = **12 578 m^3e**

Total impact on Sc: 1 021 990 **+** 12 578 = **1 034 567 m^3e**

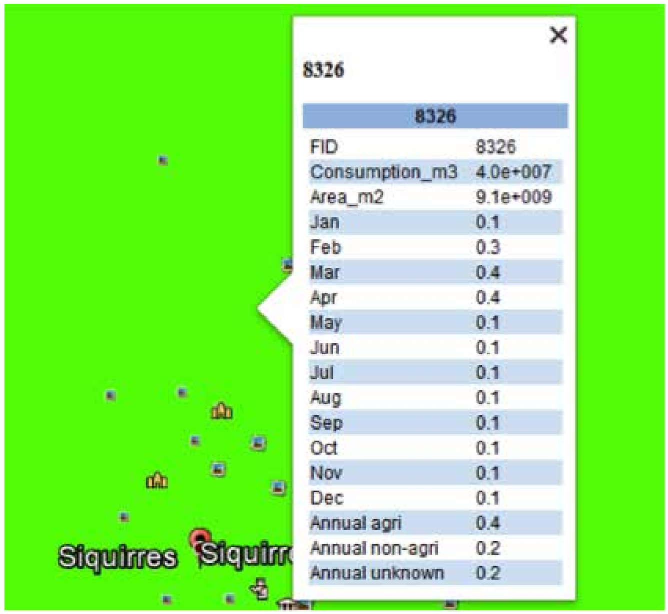


Figure 5.2. Characterization factor taken from Google Earth (Annual agri), specific to the drainage basin where the farm is located.

Impact summary

According to the results obtained, efforts at Finca San Pablo should be focused on reducing impacts from eutrophication and scarcity (Table 5.5).

Table 5.5. Water footprint profile, potential impacts obtained for 2016.

Impact category	Impact value	Indicator per box	Analysis
Human Toxicity	0.0498459 CTUh	0.000000065 CTUh/box	Corresponds to the potential number of disease cases that might appear in individuals due to contact with the agrochemical in water.
Ecotoxicity	1 181 780 992 CTUe	1 530.82 CTUe/box	This value refers to species potentially affected by contact with the agrochemical in water.
Eutrophication	347 006 kg Pe	0.00045 kg Pe/box	The impact result obtained corresponds to the phosphorus that might potentially cause the eutrophication of freshwater.
Scarcity	1 034 567 m^3e	1.34 m^3e/box	The characterization factor of the watershed is 0.4, which indicates that the water that remains available in the region is 0.4 times less than the world average. In other words, the area is rich in water resources.

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SCHEDULES

Schedules

Schedule 1. List of activity data to be collected

Table A1.1. Activity data to be collected for each emission source.

Emission Source	Data Required	Possible Information Sources
Synthetic fertilizers	-Type of synthetic fertilizers -Quantity of synthetic fertilizers applied by type -Nitrogen content in each type of fertilizer (consult the Safety Data Sheets for each product or Table 4.1) -Planted area (ha)	-Fertilization programs -Application records -Product safety data sheets (MSDS)
Organic fertilizers	-Type of organic fertilizers (animal manure, compost or sewage sludge) -Quantity of organic fertilizers applied by type -Nitrogen content in each type of organic fertilizer (Schedule X)	-Fertilization programs -Application records -Fertilizer supplier
Urea fertilization	-Total quantity of urea applied or application rate -Urea nitrogen content (consult the Safety Data Sheets for each product or Table 4.1) -Planted area (ha)	-Fertilization programs -Application records -Product safety data sheets (MSDS)
Lime application	-Type of lime applied associated with GHG emissions (limestone or dolomite) -Quantity of lime applied to soils during the study year	-Fertilization programs -Application records -Product safety data sheets (MSDS)
Fossil fuel consumption	-Types of fossil fuels used for company operations. Consider the following potential consumption sources: • Cargo and transport vehicles • Company-owned vehicles • Machinery (pumps, generator sets, brushcutters, etc.) • Light planes (only fuel used to spray company hectares) -Quantity of fossil fuel consumed by type (diesel, gasoline, LPG, Jet Fuel, etc.) -CO_2, CH_4 and N_2O emission factor specific for each type of fuel (preferably for the country in question, review Schedule 2)	-Fuel consumption records -Fuel invoicing -Air spraying tickets -Supplier

Emission Source	Data Required	Possible Information Sources
Use of lubricating oils	-Volume of oil changed at the following potential sources (review oil change invoices or available maintenance records): • Cargo and transport vehicles • Company-owned vehicles • Machinery (pumps, generator sets, brushcutters, etc.) • Light planes -CO_2 emission factor related to use of lubricating oils (preferably for the country in question, review Schedule 2)	-Oil change invoices -Company records
Refrigerant leaks	-Cooling systems used by the company, considering: • Fruit storage and transport containers • Air conditioning systems in offices • Other equipment using refrigerants, such as certain compressors -Type of refrigerant used in each system -Quantity of refrigerant recharged in the systems (according to maintenance records, invoices or estimates, review Schedule 5)	-Maintenance records -AC maintenance service invoices -AC maintenance service reports -Supplier
Extinguisher recharge with CO2, HFC or PFC	-Number of CO_2, HFC or PFC extinguishers available -Volumetric capacity of each extinguisher and recharge frequency during the year, or recharged quantity in each extinguisher	-Extinguisher ticket -Recharge records -Recharge invoices -Supplier
Process organic waste	-Quantity of organic waste generated during the study year subject to the same final disposal (e.g. how much is sent to the landfill, buried at the farm, sent for composting or sent to the drying oven)	-Generation records -Referenced estimations

Emission Source	Data Required	Possible Information Sources
Municipal solid wastes (MSW)	-If there is waste segregation (see Schedule 5): • Quantity of MSW generated during the study year by type • Type of treatment for each waste -If there is no waste segregation (see Schedule 5): • Quantity of MSW generated during the study year • Type of treatment -Emission factors related to waste treatment (preferably for the country in question, review Schedule 2)	-Generation records -Supplier -Referenced estimates
Process wastewater	-Biological Oxygen Demand (BOD) of the wastewater	-Operating reports -Laboratory tests -Referenced estimations
Ordinary wastewaters	-Average number of people working at the company during the study year, or Biological Oxygen Demand (BOD) of wastewater	-Payroll or records -Laboratory tests -Operating reports -Referenced estimations
Electricity consumption	-kWh consumed in all company operations -Emission factor from power consumption (preferably for the country in question, review Schedule 2)	-Electricity invoices
Acetylene consumption	-Number of acetylene cylinders in the company -Capacity of each acetylene cylinder and number of cylinder recharges during the study year, or recharged quantity of acetylene	-Recharge service invoices -Supplier -Maintenance records
Consumption of biomass as fuel (drying ovens)	-Quantity of Biomass used as fuel during the study year	-Records -Referenced and supported estimations

Schedule 2. Application examples by emission source

A2.1. Soil management fertilizers

A2.1.1. Synthetic and organic fertilizers

Example A2.1. Calculation of fertilization emissions

Part I. Calculation of synthetic fertilizer emissions

Step 1. Calculate the total quantity of each fertilizer applied in 10 ha of planting area, considering the following application:

Fertilizer	Application Rate	% N
Ammonium	150 kg/ha	82
Ammonium Nitrate	150 kg/ha	33-34.5

$$\text{Ammonium } (\text{Fe}_{\text{A}}) = 150 \text{ kg/ha } \times 10 \text{ ha} = 1\,500 \text{ kg}_{\text{total fert.}}$$

$$\text{Ammonium Nitrate } (\text{Fe}_{\text{AN}}) = 150 \text{ kg/ha} \times 10 \text{ ha} = 1\,500 \text{ kg}_{\text{total fert.}}$$

Step 2. Estimate the total amount of nitrogen applied, for which the nitrogen content in each fertilizer must be consulted in the product Safety Data Sheets. If this information is not available, use Table 2.1. The value of N for Ammonium will be 82% and for Ammonium Nitrate, the assigned value is 34.5%.

$$\text{Ammonium: } (\text{N}_{\text{A}}) = 1\,500 \text{ kg}_{\text{total fert.}} \times \frac{82}{100} = 1\,230 \text{ kg N}$$

$$\text{Ammonium Nitrate: } (\text{N}_{\text{AN}}) = 1\,500 \text{ kg}_{\text{total fert.}} \times \frac{34.5}{100} = 517.5 \text{ kg N}$$

The total nitrogen applied will be the sum of the content for both fertilizers:

$$\textbf{Total nitrogen in synthetic fertilizers } (\mathbf{N_t}) = 1\,230 \text{ kg N} + 517.5 \text{ kg N} = \mathbf{1\,747.5 \text{ kg N}}$$

Step 3. Identify the most appropriate Emission Factor for fertilizers (EF_{Fe}). It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC may be used (Schedule 3).

$\mathbf{EF_{Fe}}$	Reference
$0.01 \text{ kg N}_2\text{O} - \text{N/kg N}$	Global value recommended by the IPCC in Volume 4, Chapter 11, Table 11.1[12]

Step 4. To obtain CO_2 equivalent emissions (E_{Fe}), multiply the total nitrogen by the emission factor (EF_{Fe}), the global warming potential of nitrous oxide (Schedule 4) and a required factor for fertilizers of 44/28, in order to convert the nitrogen application into nitrous oxide emissions.

$$\text{Fertilizer emissions } (\text{E}_{\text{Fe}}) = \mathbf{1\,747.5} \text{ kg N} \times \mathbf{0.01} \text{ kg N}_2\text{O–N/kg N } \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{265} \text{ kg CO}_2\text{e/kg N}_2\text{O}$$

$$\text{E}_{\text{Fe}} = \mathbf{7\,277.09} \text{ kg CO}_2\text{e}$$

If the result is required in tons, multiply the above by 1/1000:

$$\text{E}_{\text{Fe}} = \mathbf{7\,277.09} \text{ kg CO}_2\text{e} \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{7.28} \text{ t CO}_2\text{e}$$

Part II. Example of emission calculation for organic fertilizers

Step 1. A total of 100 kg/ha of poultry manure was added during the year in a 10 ha planting area on a farm. First, the total quantity of fertilizer added must be calculated.

$$\text{Poultry manure } (\text{Fe}_{\text{M}}) = 100 \text{ kg/ha } \times 10 \text{ ha} = 1000 \text{ kg}_{\text{total fert.}}$$

Step 2. Estimate the total nitrogen applied with the poultry manure (Schedule 5). The use of laboratory tests to verify the nitrogen quantity in the specific organic fertilizer is recommended for this purpose. In case this information is not available, Table A5.1 of Annex 5 or literature data may be used. The value of N for poultry manure will be 6.11%.

$$\text{Total nitrogen in poultry manure } (N_t) = 1\,000\ \text{kg}_{\text{total fert.}} \times \frac{6.11}{100} = 61.1\ \text{kg N}$$

Step 3. Identify the most appropriate Emission Factor for fertilizers (EF_{Fe}). It is best to use the specific EF for each country, but in case these are not available, the EF recommended by the IPCC (Schedule 3) may be used.

$\mathbf{EF_{Fe}}$	**Reference**
$0.01\ \text{kg}\ N_2O - N/\text{kg N}$	Global value recommended by the IPCC in Volume 4, Chapter 11, Table 11.1[12]

Step 4. Multiply the total nitrogen by the emission factor (EF_{Fe}), the global warming potential of nitrous oxide (Schedule 4), and a required factor for fertilizers of 44/28, in order to obtain the CO_2 equivalent emissions (E_{Fe}).

$$\text{Fertilizer emissions } (E_{Fe}) = \mathbf{61.1}\ \text{kg N} \times \mathbf{0.01}\ N_2O\text{–}N/\text{kg N} \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{265}\ \text{kg}\ CO_2e/\text{kg}\ N_2O$$

$$E_{Fe} = \mathbf{254.44}\ \text{kg}\ CO_2e$$

If the result is required in tons, multiply the above by 1/1000:

$$E_{Fe} = \mathbf{254.44}\ \text{kg}\ CO_2e \times \frac{1\ \text{t}}{1000\ \text{kg}} = \mathbf{0.25\ t\ CO_2e}$$

A2.1.2. Fertilization with urea

Example A2.2. Calculation of emissions from fertilization with urea

Step 1. If 20 kg/ha of urea were applied in 10 ha planted with banana with a soil pH above 6.2, the total urea applied must be calculated (Fe_U):

$$\text{Urea: } (\text{Fe}_\text{U}) = 20 \text{ kg/ha } \times 10 \text{ ha} = 200 \text{ kg}_{\text{total urea}}$$

Step 2. Estimate the total nitrogen applied, consulting the urea Safety Data Sheets or Table 2.1. The value of N for urea is around 46%.

$$\textbf{Total nitrogen from urea } (\mathbf{N_t}) = 200 \text{ kg}_{\text{total urea}} \times \frac{46}{100} = 92 \text{ kg N}$$

Step 3. Identify the most appropriate Emission Factor. It is best to use the specific EF for each country, but if these are not available, the EF recommended by the IPCC may be used (Exhibit 3). Urea is related to nitrous oxide and carbon dioxide emissions, and therefore these two EFs (EF_{Fe} and EF_U respectively) will need to be calculated.

EF	Value	Reference
$\mathbf{EF_{Fe}}$	$0.01 \text{ kg } N_2O\text{–}N/\text{kg N}$	Global value recommended by the IPCC in Volume 4[12].
$\mathbf{EF_U}$	$0.20 \text{ kg } CO_2\text{–}C/\text{kg}_{\text{total urea}}$	

Step 4. Calculate the N_2O emissions by multiplying the total nitrogen by the fertilizer emission factor, the global warming potential of nitrous oxide (Exhibit 4) and a factor required for fertilizers of **44/28**, to obtain the emissions in equivalent CO_2 for the nitrous oxide (E_{Fe}).

$$\text{Urea fertilizer emissions } (\text{E}_{\text{Fe}}) = \mathbf{92} \text{ kg N} \times \mathbf{0.01} \text{ kg } N_2O\text{– N/kg N } \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{265} \text{ kg } CO_2e/\text{ kg } N_2O$$

$$\text{E}_{\text{Fe}} = \mathbf{383.11} \text{ kg } CO_2e$$

Step 5. Calculate the CO_2 emissions by multiplying the total quantity of applied urea by the urea emission factor, the global warming potential of carbon dioxide (Exhibit 4), and a factor required for urea of **44/12**, to obtain the emissions in equivalent CO_2 for emitting carbon dioxide (E_{Urea}).

$$\text{Urea emissions } (\text{E}_{\text{Urea}}) = \mathbf{200} \text{ kg}_{\text{total urea}} \times \mathbf{0.20} \text{ kg } CO_2\text{–}C/\text{kg}_{\text{total urea}} \times \frac{\mathbf{44}}{\mathbf{12}} \times \mathbf{1} \text{ kg } CO_2e \text{ / kg } CO_2$$

$$\text{E}_{\text{Urea}} = \mathbf{146.66} \text{ kg } CO_2e$$

Step 6. If the result is required in tons, multiply the above by 1/1000:

$$\text{E}_{\text{Fe}} = \mathbf{383.11} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{0.38 \text{ t } CO_2e}$$

$$\text{E}_{\text{Urea}} = \mathbf{146.66} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{0.15 \text{ t } CO_2e}$$

A2.1.3. Lime application to soils

Example A2.3. Calculation of emissions from lime application

Step 1. If 1 kg/ha of dolomitic lime (dolomite) and 3 kg/ha of calcic limestone were applied in the planted 10 ha, the total for each type of lime applied (C_D and C_C respectively) needs to be calculated.

$$\text{Total dolomite application } (C_D) = 1\ \text{kg/ha} \times 10\ \text{ha} = 10\ \text{kg}_{\text{total D}}$$
$$\text{Total calcic limestone application } (C_C) = 3\ \text{kg/ha} \times 10\ \text{ha} = 30\ \text{kg}_{\text{total C}}$$

Step 2. Identify the most appropriate Emission Factor for dolomite (EF_D) and calcic limestone (EF_C) application. It is preferable to use the specific EF for each country and type of lime, but if not available, the EF recommended by the IPCC (Exhibit 3), may be used.

EF	Value	Reference
$\mathbf{EF_D}$	$0.13\ \text{kg CO}_2\text{-C /kg}_{\text{total D}}$	Global value recommended by the IPCC in Volume 4[12].
$\mathbf{EF_C}$	$0.12\ \text{CO}_2\text{-C /kg}_{\text{total D}}$	

Step 3. Multiply the total quantity of each type of lime applied by the respective lime emission factor, the global warming potential of the CO_2 (Exhibit 4), and a factor required for lime of **44/12**, to obtain the emissions in equivalent CO_2 for carbon dioxide emission.

$$\text{Dolomite Emissions}(E_D) = \mathbf{10}\ \text{kg}_{\text{total D}} \times \mathbf{0.13}\ \text{kg CO}_2\text{-C/kg}_{\text{total D}} \times \frac{\mathbf{44}}{\mathbf{12}} \times \mathbf{1}\ \text{kg CO}_2\text{e/kg CO}_2$$
$$E_D = \mathbf{4.77}\ \text{kg CO}_2\text{e}$$
$$\text{Calcic Limestone Emissions}(E_C) = \mathbf{30}\ \text{kg}_{\text{total C}} \times \mathbf{0.12}\ \text{kg CO}_2\text{-C/kg}_{\text{total C}} \times \frac{\mathbf{44}}{\mathbf{12}} \times \mathbf{1}\ \text{kg CO}_2\text{e/kg CO}_2$$
$$E_C = \mathbf{13.20}\ \text{kg CO}_2\text{e}$$

Step 4. Add the quantity of emissions for calcic limestone and dolomite to obtain the total emissions from lime application (E_{Lime}).

$$\text{Emissions from lime application } (E_{\text{Lime}}) = \mathbf{4.77}\ \text{kg CO}_2\text{e} + \mathbf{13.20}\ \text{kg CO}_2\text{e}$$
$$E_{\text{Lime}} = \mathbf{17.97}\ \text{kg CO}_2\text{e}$$

Step 5. If the result is required in tons, multiply the above by 1/1000:

$$E_{\text{Lime}} = \mathbf{17.97}\ \text{kg CO}_2\text{e} \times \frac{1\ \text{t}}{1000\ \text{kg}} = \mathbf{0,02\ t\ CO_2e}$$

A2.2. Fossil fuel consumption

Example A2.4. Calculation of fossil fuel emissions

Step 1. If 3 000 liters of gasoline were consumed during the year in a banana farm located in Siquirres, the most appropriate emission factor (EF) for consumption of this fossil fuel will need to be identified. Fuels produce CO_2, N_2O and CH_4 emissions, and therefore an EF is needed for each of these ($EF_{gas,CO2}$, $EF_{gas,N2O}$ and $EF_{gas,CH4}$ respectively).

EF	Value	Reference
$\mathbf{EF_{gas,CO2}}$	2.231 $\mathrm{kg\ CO_2/L}$	Specific value for Costa Rica, given by the National Meteorological Institute.[19]
$\mathbf{EF_{gas,N2O}}$	0.02211 $\mathrm{g\ N_2O/L}$	
$\mathbf{EF_{gas,CH4}}$	0.346 $\mathrm{g\ CH_4/L}$	

It is preferable to use the specific EF for each country and type of fuel, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

Step 2. Multiply the total quantity of fuel by the respective emission factor and the respective global warming potential (Exhibit 4), to obtain the emissions in CO_2 equivalent.

$$\mathrm{CO_2\ Fuel\ Emissions\ (E_{CF,CO2})} = \mathbf{3\ 000}\ \mathrm{L} \times \mathbf{2.231}\ \mathrm{kg\ CO_2/L} \times \mathbf{1}\ \mathrm{kg\ CO_2e\ /\ kg\ CO_2}$$
$$\mathrm{E_{CF,CO2}} = \mathbf{6\ 693\ kg\ CO_2e}$$

$$\mathrm{N_2O\ Fuel\ Emissions\ (E_{CF,N2O})} = \mathbf{3\ 000}\ \mathrm{L} \times \frac{\mathbf{0.02211}}{1000}\ \mathrm{kg\ N_2O\ /L} \times \mathbf{265}\ \ \mathrm{CO_2e\ /\ kg\ N_2O}$$
$$\mathrm{E_{CF,N2O}} = \mathbf{17.58\ kg\ CO_2e}$$

$$\mathrm{CH_4\ Fuel\ Emissions\ (E_{CF,CH4})} = \mathbf{3\ 000}\ \mathrm{L} \times \frac{\mathbf{0.346}}{1000}\ \mathrm{kg\ CH_4/L} \times \mathbf{28}\ \mathrm{kg\ CO_2e\ /\ kg\ CH_4}$$
$$\mathrm{E_{CF,CH4}} = \mathbf{29.06\ kg\ CO_2e}$$

Step 3. Add the quantity of CO_2 equivalent emissions generated by the various gases to obtain the total (E_{CF}).

$$\mathrm{Total\ Fuel\ emissions\ (E_{CF})} = \mathbf{6\ 693}\ \mathrm{kg\ CO_2e} + \mathbf{17.58}\ \mathrm{kg\ CO_2e} + \mathbf{29.06}\ \mathrm{kg\ CO_2e}$$
$$\mathrm{E_{CF}} = \mathbf{6\ 739.64}\ \mathrm{kg\ CO_2e}$$

Step 4. If the result is required in tons, multiply the above by 1/1000:

$$\mathrm{E_{CF}} = \mathbf{6\ 739.64}\ \mathrm{kg\ CO_2e} \times \frac{1\ \mathrm{t}}{1000\ \mathrm{kg}} = \mathbf{6.74\ t\ CO_2e}$$

A2.3. Electricity consumption (scope 2)

Example A2.5. Calculation of electricity emissions

Step 1. At a farm located in Pococí, Costa Rica, 5 000 kWh of electricity, obtained from the grid, were consumed during 2015. The appropriate emission factor (EF_{CE}) must first be identified for this source, year and specific country. If an EF is not available at the country level, the EF recommended by the IPCC (Exhibit 3) may be used.

$\mathbf{EF_{CE}}$	**Reference**
0.0381 $\mathrm{kg\ CO_2/\ kWh}$	Specific value for Costa Rica[19]

Step 2. Multiply the total quantity of kWh consumed by the respective emission factor, and the respective global warming potential (Exhibit 4), to obtain the emissions in CO_2 equivalent (E_{CE}).

$$\text{Electricity emissions } (\mathrm{E_{CE}}) = \mathbf{5\ 000}\ \mathrm{kWh} \times \mathbf{0.0381}\ \mathrm{kg\ CO_2/kWh} \times 1\ \mathrm{kg\ CO_2e\ /kg\ CO_2}$$

$$\mathrm{E_{CE}} = \mathbf{190.5\ kg\ CO_2e}$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$\mathrm{E_{RSM}} = \mathbf{190.5}\ \mathrm{kg\ CO_2e} \times \frac{1\ \mathrm{t}}{1000\ \mathrm{kg}} = \mathbf{0.19\ t\ CO_2e}$$

A2.4. Refrigerant leaks

Example A2.6. Calculation of emissions from refrigerant leaks

Part I. Calculation of emissions from refrigerant leaks when there are records

Step 1. If 300 lb of R-134a refrigerant were recharged during the study year for maintenance of the company's air conditioners, the pounds must be converted to kilograms using a factor of 0.460 kg/lb.

$$\text{Refrigerant Recharge (RR)} = 300 \text{ lb} \times \frac{0.460 \text{ kg}}{1 \text{ lb}} = \mathbf{138} \text{ kg}$$

Step 2. Multiply the total quantity of recharged refrigerant by the global warming potential of R-134a (Table 2.2 or Exhibit 4) to obtain the emissions in CO_2 equivalent (E_R).

$$\text{Refrigerant emissions } (E_R) = \mathbf{138} \text{ kg} \times \mathbf{1\ 430} \text{ kg } CO_2e/\text{kg R134a} = \mathbf{197\ 340} \text{ kg } CO_2e$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_R = \mathbf{197\ 340} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{197.34} \text{ t } CO_2e$$

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

Step 1. A company decides to quantify the emissions from R-134a refrigerant leaks in the 576 containers where the fruit was transported during the study year. If there are no refrigerant recharge records, it will need to identify the type of equipment, its charge capacity and the emission factor or annual leak percentage. Using Table A6.1 of Exhibit 6 as reference, the following values are assumed:

Type of equipment	Load capacity (kg)	Emission Factor (% of capacity/year)
Transport refrigeration	8	50

Step 2. Multiply the total number of containers by the charge capacity, the annual leak percentage or emission factor, and the global warming potential of R-134a (Table 2.2 or Exhibit 4), to obtain the emissions in CO_2 equivalent (E_R).

$$E_R = \mathbf{576} \text{ containers} \times \mathbf{8} \text{ kg/container} \times \frac{\mathbf{50}}{100} \times \mathbf{1\ 430} \text{ kg } CO_2e \text{ / kg R134a} = \mathbf{3\ 294\ 720\ kg\ CO_2e}$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_R = \mathbf{3\ 294\ 720} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{3\ 294.72\ t\ CO_2e}$$

A2.5. Use of lubricating oils

Example A2.7. Calculation of lubricant emissions

Step 1. A total of 1 000 liters were quantified during the year from motor oil changes at a farm located in Costa Rica. The most appropriate emission factor for the use of lubricating oil (EF_{ULO}) was identified in order to make the estimates:

$\mathbf{EF_{ULO}}$	**Reference**
$0.5101 \text{ kg } CO_2/\text{ L}$	Specific value for Costa Rica[19].

It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

Step 2. Multiply the total quantity of oil used by the respective emission factor and the global warming potential of CO_2 (exhibit 4), to obtain the equivalent CO_2 emissions of lubricating oils (E_{LO}).

$$\text{Lub. oil emissions } (E_{LO}) = \mathbf{1\ 000} \text{ L} \times \mathbf{0.5101} \text{ kg } CO_2/\text{L} \times \mathbf{1} \text{kg } CO_2\text{e / kg } CO_2$$
$$E_{LO} = \mathbf{510.10 \text{ kg } CO_2e}$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_{LO} = \mathbf{510.10} \text{ kg } CO_2\text{e} \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{0.5102 \text{ t } CO_2e}$$

A2.6. Fire extinguisher recharge

Example A2.8. Calculation of emissions from extinguisher recharge

Step 1. If the company has 5 CO_2 extinguishers at its facilities, which were recharged once during the study year, and their capacity is 9 kg each, the total recharged quantity of CO_2 is estimated (ER_{CO2}).

$$\text{Extinguisher recharge } (ER_{CO2}) = 5 \text{ extinguishers} \times 1 \text{ recharge/extinguisher} \times 9 \text{ kg /recharge} = \mathbf{45} \text{ kg}$$

Step 2. Multiply the total quantity recharged by the global warming potential of CO_2 (Table 2.3 or Exhibit 4), to obtain the emissions in CO_2 equivalent (E_{Ex}).

$$\text{Extinguisher emissions}(E_{Ex}) = \mathbf{45} \text{ kg} \times \mathbf{1} \text{ kg } CO_2\text{e /kg } CO_2 = \mathbf{45 \text{ kg } CO_2e}$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_{Ex} = \mathbf{45} \text{ kg } CO_2\text{e} \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{0.045 \text{ t } CO_2e}$$

A2.7. Solid waste management

A2.7.1. Process organic waste management

Example A2.9. Calculation of emissions from process organic waste

Part I. Calculation of emissions from application of the rachis or stalk to the field

Step 1. At a banana farm, rachis or stalk wastes were incorporated into the field during the emission measurement year. Therefore, if the information is not available, the total quantity in kilograms of this waste added must be estimated (MRachis):

$$\text{Rachis mass (MRachis)} = \textbf{Average weight of rachis}\ (\text{kg}) \times \textbf{Total rachis during the year}$$

Rachis with an average weight of 3 kg are harvested at the farm, and during the study year a total of 100 000 of these were harvested.

$$\text{MRachis} = \mathbf{3}\ \text{kg} \times \mathbf{100\ 000} = \mathbf{300\ 000}\ \text{kg}$$

Step 2. The moisture percentage of the stalk waste, as well as its average nitrogen content, need to be identified (information from laboratory tests or from the literature). The company determines that the rachis has 90% moisture and 2% Nitrogen.

Step 3. Calculate the nitrogen quantity in the organic waste (NRachis), taking into account its total weight, moisture percentage and nitrogen percentage.

$$\text{Nitrogen in rachis (NRaquis)} = \mathbf{300\ 000}\ \text{kg} \times \frac{100 - \mathbf{90}}{100} \times \frac{\mathbf{2}}{100} = \mathbf{600}\ \text{kg N}$$

Step 4. Identify the most appropriate emission factor (EF) for fertilizer application (EF_{Fe}). It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

$\mathbf{EF_{Fe}}$	Reference
0.01 $\text{kg } N_2O\text{–N /kg N}$	Global value recommended by the IPCC in Volume 4, Chapter 11, Table 11.1.[12]

Step 5. Multiply the total quantity of nitrogen added with the stalk wastes (NRachis) by the respective emission factor, the respective global warming potential (Exhibit 4), and the **44/28** fertilizer factor, to obtain the emissions in CO_2 equivalent (E_{Fe}).

$$\text{Organic waste emissions } (E_{Fe}) = \mathbf{600}\ \text{kg N} \times \mathbf{0.01}\ \text{kg } N_2O\text{–N/kg N} \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{265}\ \text{kg } CO_2e/\text{kg } N_2O$$

$$E_{Fe} = \mathbf{2\ 498.57}\ \text{kg } CO_2e$$

Step 6. If the result is required in tons, multiply the above by 1/1000:

$$E_{Fe} = \mathbf{2\ 498.57}\ \text{kg } CO_2e \times \frac{1\ \text{t}}{1000\ \text{kg}} = \mathbf{2.50\ t\ CO_2e}$$

Part II. Calculation of emissions from banana waste composting

Step 1. At a banana farm located in Siquirres, Costa Rica, rejected banana wastes are sent for composting. During the study year, 30 000 kg of this waste were managed in this manner. To estimate the associated emissions, the most appropriate emission factor (EF) for this treatment must first be identified.

EF_{Comp}	Reference
$4\ \text{g } CH_4/\text{kg}$	Specific value for Costa Rica[19]

It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

It is important to note that if the EF is given in grams, it must be converted to kilograms by multiplying the figure by 1/1000 to obtain the emission data in this unit.

$$EF_{Comp} = 4 \text{ g } CH_4/kg \times \frac{1}{1000} = 0.004 \text{ kg } CH_4/kg$$

Step 2. Multiply the quantity of waste by the composting emission factor and the global warming potential of methane (Exhibit 4) to obtain the emissions in CO_2 equivalent (E_{Comp}).

$$\text{Enissions from organic waste composting } (E_{Comp}) = \mathbf{30\ 000} \text{ kg} \times \mathbf{0.004} \text{ kg } CH_4/kg \times \mathbf{28} \text{ kg } CO_2e/ \text{ kg } CH_4$$
$$E_{Comp} = \mathbf{3\ 360} \text{ kg } CO_2e$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_{Comp} = \mathbf{3\ 360} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{3.36\ t\ CO_2e}$$

A2.7.2. Municipal solid waste management (packaging, offices and cafeteria)

Example A2.10. Calculation of emissions from municipal solid wastes

Step 1. At a banana farm in Costa Rica, 20 400 kg of MSW were generated during the study year at the administrative offices, restrooms and cafeteria. These wastes are not segregated and are delivered to the municipality to be disposed of in a sanitary landfill. The appropriate Emission Factor ($EF_{Landfill,CH4}$) for this type of waste treatment must be identified.

$EF_{Landfill,CH4}$	Reference
$0.0581 \text{ kg } CH_4 \text{ / kg}$	Specific value for Costa Rica[19]

It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

Step 2. Multiply the total quantity of MSW generated by the emission factor and the respective global warming potential (Exhibit 4), to obtain the emissions in CO_2 equivalent.

$$\text{MSW emissions } (E_{MSW}) = \mathbf{20\ 400} \text{ kg} \times \mathbf{0.0581} \text{kg } CH_4/kg \times \mathbf{28} \text{ kg } CO_2e/kg\ CH_4$$
$$E_{MSW} = \mathbf{33\ 186.72\ kg\ CO_2e}$$

Step 3. If the result is required in tons, multiply the above by 1/1000:

$$E_{MSW} = \mathbf{197\ 340} \text{ kg } CO_2e \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{197.34\ t\ CO_2e}$$

A2.8. Wastewater generation

A2.8.1. Process wastewater (packing plant)

Example A2.11. Calculation of emissions from packing process wastewater

Step 1. At a farm located in Costa Rica, the packing plant produces wastewater which is reused during the week and then discharged into a river. It is first necessary to identify the appropriate emission factor (EF_t). It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

EF_t	Reference
$0.025 \text{ kg } CH_4/COD$	Specific value for Costa Rica[19]

Step 2. The identified EF_t is based on the COD (Chemical Oxygen Demand); therefore, the average quantity of COD in the waters discharged during the study year must be estimated. This farm submits semiannual reports to the Government regarding the condition of its discharged waters and the COD is measured as part of the laboratory tests.

Period	Semester I	Semester II
COD (kg / m^3)	100	110

The average COD (COD_A) will be estimated by adding all values and dividing by the number of values available.

$$\text{Average COD } (\text{COD}_A) = (100 + 110) \div 2 = \mathbf{105\ kg\ COD/m^3}$$

Step 3. The total volume discharged during the study year (V_{ARI}), including the daily discharged volumes and those discharged at the end of the week when emptying the banana washing tanks must be estimated, The company determines that its daily discharge is 2 m^3, which is the amount of water used to fill the tanks at the start of each day. At the end of each week, the total tank water is changed and therefore the equivalent of their complete volume, that is, a total of 232 m^3, is discharged. If the company worked 52 weeks and 315 days during the year, the volume discharged during the year (V_{ARI}) is calculated as follows:

$$\text{Discharged volume } (V_{ARI}) = (2\ m^3/\ \text{day} \times 315\ \text{days}) + (232\ m^3/\text{week} \times 52\ \text{weeks}) = \mathbf{12\ 694\ m^3}$$

Step 4. Multiply the average quantity of COD by the discharged volume of water, the emission factor, and the respective global warming potential (Exhibit 4), to obtain the emissions in equivalent CO_2 (E_{ARI}).

$$\text{ARI Emissions } (E_{ARI}) = \mathbf{105}\ kg/m^3 \times \mathbf{12\ 694}\ m^3 \times \mathbf{0.025}\ kg\ CH_4\ /COD\ \ \mathbf{28}\ kg\ CO_2e/kg\ CH_4$$
$$E_{ARI} = \mathbf{933\ 009\ kg\ CO_2e}$$

Step 5. If the result is required in tons, multiply the above by 1/1000:

$$E_{ARI} = \mathbf{933\ 009}\ kg\ CO_2e \times \frac{1\ t}{1000\ kg} = \mathbf{933\ t\ CO_2e}$$

A2.8.2. Domestic wastewater (restrooms and taps)

Example A2.12. Calculation of emissions from domestic wastewater

Step 1. At a farm located in Costa Rica, a septic tank is used to treat domestic wastewater (restrooms and taps). The appropriate emission factor (EF_t) must first be identified for this type of water treatment. It is preferable to use the specific EF for each country, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

EF_t	Reference
4.38 kg CH_4/person/year	Specific value for Costa Rica[19]

Step 2. The identified EF_t is given in emissions per person, and it is therefore necessary to determine the number of workers at the facilities during the study year. This farm provided the following monthly breakdown of workers during the study.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of workers	43	41	41	42	42	42	43	43	43	42	42	43

The average number of workers (P) will be estimated by adding all months and dividing by the twelve months of the year.

$$\text{Workers (P)} = (43 + 41 + 41 + 42 + 42 + 42 + 43 + 43 + 43 + 42 + 42 + 43) \div 12$$
$$P = \mathbf{42\ people}$$

Step 3. Since the EF is given per year, a correction must be made with the daily hours worked and days worked during the year. If 8 hours were worked per day, for 315 days during the year, the factor to be used is:

$$\text{Correction} = \frac{8}{24} \times \frac{315}{365}$$

Step 4. Multiply the average number of workers by the emission factor, the correction, and the respective global warming potential (Exhibit 4), to obtain the emissions in CO_2 equivalent (E_{ARO}).

$$\text{Emissions } (\text{E}_{\text{ARO}}) = \mathbf{42} \text{ persons} \times \mathbf{4.38} \text{ kg CH}_4\text{/person /year} \times \frac{\mathbf{8}}{\mathbf{24}} \times \frac{\mathbf{315}}{\mathbf{365}} \times \mathbf{28} \text{ kg CO}_2\text{e /kg CH}_4$$
$$\text{E}_{\text{ARO}} = \mathbf{1\,481.76} \text{ kg CO}_2\text{e}$$

Step 5. If the result is required in tons, multiply the above by 1/1000:

$$\text{E}_{\text{ARO}} = \mathbf{1\,481.76} \text{ kg CO}_2\text{e} \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{1.48 \text{ t CO}_2\text{e}}$$

A2.9. Acetylene consumption

Example A2.13. Calculation of emissions from acetylene

Step 1. 20 kg of acetylene was recharged in the cylinders at a farm. Knowing that the emission factor (EF) is always the same (Exhibit 3), emissions are estimated by multiplying the total quantity of recharged acetylene by the emission factor and the respective global warming potential (Exhibit 4).

$$\text{Acetylene emissions}(\text{E}_{\text{Ac}}) = \mathbf{20} \text{ kg C}_2\text{H}_2 \times \mathbf{0.0034} \text{ kg CO}_2\text{/kg C}_2\text{H}_2 \times \mathbf{1} \text{ kg CO}_2\text{e /kg CO}_2$$
$$\text{E}_{\text{Ac}} = \mathbf{0.068 \text{ kg CO}_2\text{e}}$$

Step 2. If the result is required in tons, multiply the above by 1/1000:

$$\text{E}_{\text{Ac}} = \mathbf{0.068} \text{ kg CO}_2\text{e} \times \frac{1 \text{ t}}{1000 \text{ kg}} = \mathbf{0.000068 \text{ t CO}_2\text{e}}$$

A2.10. Biomass consumption as fuel (drying ovens)

Example A2.14. Calculation of emissions from biomass consumption as fuel

Step 1. A farm uses wood waste as fuel for its drying oven, and during the study year it utilized 9 000 kg of this biomass. The appropriate emission factor (EF) for this source and specific country must first be identified. Fuels will have associated CO_2, N_2O and CH_4 emissions. Therefore, an EF will be needed for each of these ($EF_{CB,CO2}$, $EF_{CB,N2O}$ and $EF_{CB,CH4}$ respectively).

EF	Value	Reference
$\mathbf{EF_{CB,CO2}}$	112 000 kg CO_2/TJ	Values recommended by the IPCC[12]
$\mathbf{EF_{CB,N2O}}$	4 kg N_2O/TJ	
$\mathbf{EF_{CB,CH4}}$	30 kg CH_4/TJ	

It is preferable to use the specific EF for each country and type of fuel, but if not available, the EF recommended by the IPCC (Exhibit 3) may be used.

Step 2. Because the EFs are given in TJ (Terajoule) units, the calorific value of wood must be determined. These values may be obtained through laboratory tests, using literature references for the specific country or, ultimately, using the values recommended by the IPCC (Table A6.3 of Exhibit 6).

Biomass	Calorific value
Wood	15.6 TJ/Gg

Step 3. Multiply the total quantity of wood used by the calorific value (divided by 1 000 000), the emission factor, and the respective global warming potential (Exhibit 4), to obtain the emissions in CO_2 equivalent (E_{CB}).

$$\text{Biom. CO}_2\text{ emission } (E_{CB,CO2}) = \mathbf{9\,000}\text{ kg} \times \mathbf{112\,000}\,\frac{\text{kg CO}_2}{\text{TJ}} \times \mathbf{15.6}\,\frac{\text{TJ}}{\text{Gg}} \times \frac{1\text{ Gg}}{1\,000\,000\text{ kg}} \times 1\,\frac{\text{kg CO}_2\text{ e}}{\text{kg CO}_2}$$

$$E_{CB,CO2} = \mathbf{15\,724.8\ kg\ CO_2e}$$

$$\text{Biom. N}_2\text{O emission } (E_{CB,N2O}) = \mathbf{9\,000}\text{ kg} \times \mathbf{4}\,\frac{\text{kg N}_2\text{O}}{\text{TJ}} \times \mathbf{15.6}\,\frac{\text{TJ}}{\text{Gg}}\,\frac{1\text{ Gg}}{1\,000\,000\text{ kg}} \times \mathbf{265}\,\frac{\text{kg CO}_2\text{ e}}{\text{kg N}_2\text{O}}$$

$$E_{CB,N2O} = \mathbf{148.82\ kg\ CO_2e}$$

$$\text{Biom. CH}_4\text{emission } (E_{CB,CH4}) = \mathbf{9\,000}\text{ kg} \times \mathbf{30}\,\frac{\text{kg CH}_4}{\text{TJ}} \times \mathbf{15.6}\,\frac{\text{TJ}}{\text{Gg}} \times \frac{1\text{ Gg}}{1\,000\,000\text{ kg}} \times \mathbf{28}\,\frac{\text{kg CO}_2\text{ e}}{\text{kg CH}_4}$$

$$E_{CB,CH4} = \mathbf{117.94\ kg\ CO_2e}$$

Step 4. Add the amounts of CO_2 equivalent emissions generated by the various gases to obtain the total (E_{CB}).

$$\text{Total biom. emission } (E_{CB}) = \mathbf{15\,724.8}\text{ kg CO}_2\text{e} + \mathbf{148.82}\text{ kg CO}_2\text{e} + \mathbf{117.94}\text{ kg CO}_2\text{e}$$

$$E_{CB} = \mathbf{15\,991.56\ kg\ CO_2e}$$

Step 5. If the result is required in tons, multiply the above by 1/1000:

$$E_{CB} = \mathbf{15\,991.56}\text{ kg CO}_2\text{e} \times \frac{1\text{ t}}{1000\text{ kg}} = \mathbf{15.99\ t\ CO_2e}$$

Schedule 3. Emission factors (EF)

It is important to point out that emission factors are periodically updated, and therefore the the values to be used should be those corresponding to the year of the study. In the case of Costa Rica, EFs are updated annually by the National Meteorological Institute (IMN).

A3.1. Synthetic and organic fertilizers

Table A3.1. N_2O emission factors from use of synthetic and organic fertilizers.

Emission Factor	Region	Reference
4,85 kg N_2O/ha/year	Costa Rica	(IMN, 2017)[19]
0,01 kg N_2O-N/kg N	Global	(IPCC, 2015)[12]

A3.2. Fertilization with urea

Table A3.2. CO_2 emission factors from use of Urea as fertilizer.

Emission Factor	Region	Reference
0,20 kg CO_2-C/kg $_{urea}$	Global	(IPCC, 2015)[12]

A3.3. Lime application to the soil

Table A3.3. CO_2 emission factors from lime application to the soil.

Emission Factor	Region	Reference
0,785 kg CO_2/kg $_{lime}$	Costa Rica	(IMN, 2017)[19]
0,13 kg CO_2-C/kg $_{dolomita}$	Global	(IPCC, 2015)[12]
0,13 kg CO_2-C/kg $_{limestone}$	Global	(IPCC, 2015)[12]

3.4. Fossil fuel consumption

Table A3.4. CO_2 emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Gasoline	2,231 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Diesel	2,613 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Bunker	3,101 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Kerosene	2,541 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
LPG	1,611 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Aviation gasoline	2,227 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Jet fuel	2,505 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
Motor gasoline (mogas) (stationary)	2,289 kg CO_2/L	Global	Values calculated from EFs provided by the IPCC[12] and average fuel densities given by the Costa Rican Oil Refinery (RECOPE, 2015)[34].
Jet engine gasoline (stationary)	2,313 kg CO_2/L	Global	
Gas/Diesel oil (stationary))	2,698 kg CO_2/L	Global	
Liquefied petroleum gases (stationary)	1,588 kg CO_2/L	Global	
Gasoline for uncontrolled engines (mobile)	2,289 kg CO_2/L	Global	
Gasoline for engines with catalyst (mobile)	2,289 kg CO_2/L	Global	
Engine gasoline (low mileage light duty vehicle)	2,289 kg CO_2/L	Global	
Gas/Diesel oil (mobile)	2,679 kg CO_2/L	Global	
Liquefied petroleum gas	1,588 kg CO_2/L	Global	
Aviation gasoline	2,462 kg CO_2/L	Global	

Table A3.5. CH_4 emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Electric power generation/Diesel	0,122 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Electric power generation/Bunker	0,138 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/Gasoline	0,346 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/Diesel	0,382 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/Bunker	0,433 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/LPG	0,139 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Land transport/gasoline/ without catalyst	1,176 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Land transport/gasoline/with catalyst	0,907 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Land transport/diesel/ without catalyst	0,149 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Land transport/LPG	1,5835 g CH_4/L	Costa Rica	(IMN, 2017)[19]
Motor gasoline (stationary)	0,099 g CH_4/L	Global	Values calculated from EFs provided by the IPCC12 and average fuel densities given by the Costa Rican Oil Refinery (RECOPE, 2015)[34].
Jet engine gasoline (statonary)	0,099 g CH_4/L	Global	
Gas/Diesel oil (stationary)	0,364 g CH_4/L	Global	
Liquefied petroleum gases (stationary)	0,126 g CH_4/L	Global	
Gasoline for uncontrolled engines (mobile)	1,090 g CH_4/L	Global	
Gasoline for engines with catalyst (mobile)	0,826 g CH_4/L	Global	
Engine gasoline (low mileage light duty vehicle)	0,126 g CH_4/L	Global	
Gas/Diesel oil (mobile)	0,141 g CH_4/L	Global	
Liquefied petroleum gas	1,560 g CH_4/L	Global	
Aviation gasoline	0,018 g CH_4/L	Global	

Table A3.6. N_2O emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Electric power generation/ Diesel	0,02442 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Electric power generation/ Bunker	0,02769 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/ Gasoline	0,02211 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/ Diesel	0,02442 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/ Bunker	0,02769 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Residential and agricultural/ LPG	0,002745 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Land transport/gasoline/ without catalyst	0,116 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Land transport/gasoline/with catalyst	0,283 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Land transport/diesel/without catalyst	0,154 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Land transport/LPG	0,0051 g N_2O/L	Costa Rica	(IMN, 2017)[19]
Motor gasoline (stationary)	0,020 g N_2O/L	Global	Values calculated from EFs provided by the IPCC12 and average fuel densities given by the Costa Rican Oil Refinery (RECOPE, 2015)[34].
Jet engine gasoline (statonary)	0,020 g N_2O/L	Global	
Gas/Diesel oil (stationary)	0,022 g N_2O/L	Global	
Liquefied petroleum gases (stationary)	0,003 g N_2O/L	Global	
Gasoline for uncontrolled engines (mobile)	0,106 g N_2O/L	Global	
Gasoline for engines with catalyst (mobile)	0,264 g N_2O/L	Global	
Engine gasoline (low mileage light duty vehicle)	0,063 g N_2O/L	Global	
Gas/Diesel oil (mobile)	0,141 g N_2O/L	Global	
Liquefied petroleum gas	0,005 g N_2O/L	Global	
Aviation gasoline	0,071 g N_2O/L	Global	

A3.5. Electricity consumption (scope 2)

Table A3.7. CO_2 emission factors from electricity consumption in scope 2.

Region	Emission Factor	Period	Reference
Costa Rica	0,0557 kg CO_2/kWh	2016	(IMN, 2017)[19]

A3.6. se of lubricating oils

Table A3.8. CO_2 emission factors from use of lubricating oils.

Emission Factor	Region	Reference
0,5101 kg CO_2/L	Costa Rica	(IMN, 2017)[19]
0,53064 kg CO_2/L	Global	Value estimated from IPCC data (Chapter 1 of Volume 2 and Chapter 5 of Volume 3)12, and a density value of 0.9 kg/l for oil.

A3.7. Municipal solid waste management

Table A3.9. CH_4 emission factors by type of MSW treatment.

Type of Treatment	Emission Factor	Region	Reference
Sanitary Landfill	0,0581 kg CH_4/kg	Costa Rica	(IMN, 2017)[19]
Compost	4 g CH_4/kg	Costa Rica	(IMN, 2017)[19]
Biodigesters	2 g CH_4/kg	Costa Rica	(IMN, 2017)[19]

A3.8. Process wastewater generation

Table A3.10. CH_4 emission factors by type of PWW treatment.

Type of Treatment	Emission Factor	Region	Reference
Anaerobic reactor	0,2 kg CH_4/kg DQO	Costa Rica	(IMN, 2017)[19]
Deep anaerobic lagoon	0,2 kg CH_4/kg DQO	Costa Rica	(IMN, 2017)[19]
Shallow anaerobic lagoon	0,05 kg CH_4/kg DQO	Costa Rica	(IMN, 2017)[19]
Discharge into rivers	0,025 kg CH_4/kg DQO	Costa Rica	(IMN, 2017)[19]

A3.9. Domestic wastewater generation

Domestic wastewater generation.

Type of Treatment	Emission Factor	Region	Reference
Lagoons	2,63 kg CH_4/persona/year	Costa Rica	(IMN, 2017)[19]
Septic tank	4,38 kg CH_4/persona/year	Costa Rica	(IMN, 2017)[19]
Discharge into rivers	0,876 kg CH_4/persona/year	Costa Rica	(IMN, 2017)[19]
Disposal in river, lake and sea	0,06 kg CH_4/kg DBO	Global	Values estimated from data provided by the IPCC in Tables 6.2 and 6.3, Chapter 6, Volume 512.
Stagnant sewer (open and warm)	0,3 kg CH_4/kg DBO	Global	
Running sewer (open or closed)	0 kg CH_4/kg DBO	Global	
Aerobic centralized treatment plant (poorly operated and overloaded)	0,18 kg CH_4/kg DBO	Global	
Anaerobic sludge digester	0,48 kg CH_4/kg DBO	Global	
Anaerobic reactor	0,48 kg CH_4/kg DBO	Global	
Shallow anaerobic lagoon (less than 2 m)	0,12 kg CH_4/kg DBO	Global	
Deep anaerobic lagoon (more than 2 m)	0,48 kg CH_4/kg DBO	Global	
Septic system	0,3 kg CH_4/kg DBO	Global	
Latrine (dry climate and water table lower than latrine)	0,3 kg CH_4/kg DBO	Global	
Latrine (Humid climate/ discharge through water, water table higher than latrine)	0,42 kg CH_4/kg DBO	Global	
Latrine (Frequent sediment extraction for use as fertilizer)	0,06 kg CH_4/kg DBO	Global	

A3.10. Acetylene consumption

Acetylene reacts with oxygen producing carbon dioxide and water, a combustion reaction written as follows:

$$C_2H_2 + \frac{5}{2}O_2 \rightarrow 2CO_2 + H_2O$$

Por medio de las relaciones estequiométricas de la reacción química anterior, se obtiene la cantidad de CO_2 resultante de la reacción completa de 1 g de C_2H_2.

$$1\ g\ C_2H_2 \times \frac{1\ mol\ C_2H_2}{26.038\ g\ C_2H_2} \times \frac{2\ mol\ CO_2}{1\ mol\ C_2H_2} \times \frac{44.009\ g\ CO_2}{1\ mol\ CO_2} \times \frac{1\ kg}{1000\ g} = 0.0034\ \frac{kg\ CO_2}{kg\ C_2H_2}$$

The result of **0.0034 kg CO_2/kg C2H_2** represents the emission factor for the quantification of emissions from acetylene consumption..

A3.11. Biomass consumption

Table A3.12 CO_2 emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Wood/Wood waste	112.000 kg CO_2/TJ	Global	(IPCC, 2015)[12]
Otra biomasa sólida primaria	100.000 kg CO_2/TJ	Global	(IPCC, 2015)[12]

Table A3.13. CH_4 emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Wood/Wood waste	300 kg CH_4/TJ	Global	(IPCC, 2015)[12]
Otra biomasa sólida primaria	300 kg CH_4/TJ	Global	(IPCC, 2015)[12]

Table A3.14. N_2O emission factors by type of fuel.

Fuel	Emission Factor	Region	Reference
Wood/Wood waste	4 kg N_2O/TJ	Global	(IPCC, 2015)[12]
Otra biomasa sólida primaria	4 kg N_2O/TJ	Global	(IPCC, 2015)[12]

Schedule 4. Global Warming Potentials (GWP)

Table A4.1. Global Warming Potential (GWP)

Common Name	Chemical Formula	GWP
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
CFC-11*	CCl_3F	4.750
CFC-12*	CCl_2F_2	10.900
CFC-13*	$CClF_3$	13.900
CFC-113*	CCl_2FCClF_2	6.130
CFC-114*	$CClF_2CClF_2$	10.000
CFC-115*	$CBrF_3$	7.370
Halon-1301*	$CClF_2CF_3$	6.290
Halon-1211*	$CBrClF_2$	1.750
Halon-2402*	$CBrF_2CBrF_2$	1.470
HCFC-21*	$CHCl_2F$	151
HCFC-22*	$CHClF_2$	1.810
HCFC-123*	$CHCl_2CF_3$	77
HCFC-124*	$CHClFCF_3$	527
HCFC-141b*	CH_3CCl_2F	725
HCFC-142b*	CH_2CClF_2	2.310
HCFC-225ca*	$CHCl_2CF_2CF_2$	122
HCFC-225cb*	$CHClFCF_2CClF_2$	595
HFC-23	CHF_3	14.800
HFC-32	CH_2F_2	675
HFC-41	CH_3F_2	92
HFC-125	CHF_2CF_3	3.500
HFC-134	CHF_2CHF_2	1.100
HFC-134a	CH_2FCF_3	1.430
HFC-143	CH_2FCHF_2	353
HFC-143a	CH_3CF_3	4.470
HFC-152	CH_2FCH_2F	53
HFC-152a	CH_3CHF_2	124
HFC-161	CH_3CH_2F	4
HFC-227ea	CF_3CHFCF_3	3.220
HFC-236cb	$CH_2FCF_2CF_3$	1.340
HFC-236ea	CHF_2CHFCF_3	1.370
HFC-236fa	$CF_3CH_2CF_3$	9.810
HFC-245ca	$CH_2FCF_2CHF_2$	693
HFC-245fa	$CHF_2CH_2CF_3$	1.030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1.640
PFC-143	CF_4	6.630
PFC-116	C_2F_6	11.100
PFC-218	C_3F_8	8.900
PFC-318	C_4F_8	9.540
PFC-31-10	C_4F_{10}	9.200
PFC-41-12	C_5F_{12}	8.550
PFC-51-14	C_6F_{14}	7.910
PCF-91-18	$C_{10}F_{18}$	7.910

Source: Adapted from Greenhouse Gas Protocol (2016)[25] and Ozone Secretariat (2016)[26]

*Substances regulated by the Montreal Protocol.

Cuadro A4.2. Global Warming Potentials (GWP) of refrigerant mixtures.

Common Name	Chemical Formula	GWP
R-401a	HCFC-22/HFC-152a/HCFC-124	1.180
R-404a	HFC-125/HFC-143a/HFC-134a	3.920
R-407a	HFC-32/HFC-125/HFC-134a	2.110
R-407c	HFC-32/HFC-125/HFC-134a	1.770
R-407f	HFC-32/HFC-125/HFC-134a	1.820
R-410a	HFC-32/HFC-125	2.090
R-417a	HFC-125/HFC-134a/HC-600	2.350
R-444b	HFC-32/HFC-1234ze(E)/HFC-152a	290
R-446a	HFC-32/HFC-1234ze(E)/HC-600	460
R-449a	HFC-134a/HFC-125/HFC-1234yf/HFC-32	1.410
R-452a	HFC-1234yf/HFC-32/HFC-125	2.140
R-507a	HFC-125/HFC-143a	3.990
R-513a	HFC-1234yf/HFC-134a	630

Source: Adapted from (Agarwal & Clark, 2016)[35]

Schedule 5. Amount of nitrogen in organic fertilizers

A5.1. Amount of nitrogen in manure

The amount of nitrogen in manure distributed in a field as fertilizer can be estimated from equation A5.1.

$$\mathbf{N_t} = (\mathrm{Fe} \times \mathrm{N}) = \mathrm{Fe_{est}} \times \frac{\mathrm{N}}{100} \text{ (equation A5.1)}$$

$\mathbf{N_t}$ = Amount of nitrogen in manure (kg N)
$\mathbf{Fe_{est}}$ = Amount of manure added ($\mathrm{kg_{est}}$)
$\mathbf{N_{est}}$ = Fraction of N in manure by type of animal (%)

It is preferable to obtain the data for nitrogen content in manure (N) from laboratory tests or information provided by the supplier. However, when the information cannot be obtained from these sources, the theoretical values shown in Table A5.1 may be used.

Table A5.1. Nitrogen content in manure.

Animal of origin	Nitrogen content (%)
Cattle (f)	0,29
Cattle (d)	0,58
Sheep (f)	0,55
Sheep (d)	1,95
Horses (d)	1,55
Horses (f)	0,55
Swine (d)	0,60
Poultry (d)	6,11

f: indicates fresh; d: indicates dry. Source: (Tapia & Fries, 2007)[36]

A5.2. Amount of nitrogen in compost

The amount of nitrogen in applied compost varies widely, as it will depend on the materials making up the compost. We recommend consulting the compost supplier in order to obtain the specific figure for the compost that is applied. However, in case this value cannot be consulted, a nitrogen ratio between 0.3% and 1.5%[37] can be selected.

A5.3. Amount of nitrogen in agricultural waste disposed of in the field

In order to obtain the value of nitrogen disposed of in a field by using organic process waste (rachis, rejected banana, etc.), it will be necessary to determine the quantity distributed, moisture and nitrogen content of this waste. The required value can be obtained by applying equation A5.2.

$$\mathrm{N_t} = (\mathrm{Fe} \times \mathrm{N}) = \mathbf{M} \times \frac{100-\mathbf{H}}{100} \times \frac{\mathbf{N}}{100} \text{ (equation A5.2)}$$

$\mathbf{N_t}$ = Total nitrogen added with the organic waste (kg N)
$\mathbf{M}$ = Total mass of the added organic waste (kg waste)
$\mathbf{H}$ = Moisture percentage of the organic waste (%)
$\mathbf{N}$ = Nitrogen percentage in the organic waste (%)

Schedule 6. Equations for calculating GHG emissions

A6.1. Soil management fertilizers

A6.1.1. Synthetic and organic fertilizers

$$E_{Fe} = (Fe \times N) \times FE_{Fe} \times \frac{44}{28} \times GWP_{N2O}$$ (equation A6.1)[6]

$\mathbf{E_{Fe}}$ = CO_2 equivalent emissions from fertilizer application (kg CO_2e)

$\mathbf{Fe}$ = Total quantity of fertilizer applied during the study year ($kg_{total\ fert.}$)
$\mathbf{N}$ = Nitrogen ratio contained in total fertilizer (kg N/$kg_{total\ fert.}$)
$\mathbf{EF_{Fe}}$ = Emission factor in Nitrogen application (kg N_2O– N/kg N)
$\mathbf{\frac{44}{28}}$ = Conversion ratio of N_2O– N emissions into N_2O emissions
$\mathbf{GWP_{N2O}}$ = Global Warming Potential of N_2O (kg CO_2e/kg N)

Note: If the value of N is in %, it must be divided by 100.

A6.1.2. Fertilization with urea

Emissions associated with N_2O must be estimated using equation A6.1. Equation A6.2 must be used to estimate CO_2 emissions derived from fertilization with urea.

$$E_{Urea} = U \times EF_U \times \frac{44}{12} \times GWP_{CO2}$$ (equation A6.2)[7]

$\mathbf{E_{Urea}}$ = CO_2 equivalent emissions from Urea application (kg CO_2e)

$\mathbf{U}$ = Total quantity of Urea applied during the study year ($kg_{total\ Urea}$)
$\mathbf{EF_U}$ = Emission Factor from Urea application (0.20 kg CO_2– C/$kg_{total\ Urea}$)
$\mathbf{\frac{44}{12}}$ = Conversion ratio for CO_2– C emissions into CO_2 emissions
$\mathbf{GWP_{CO2}}$ = Global Warming Potential of CO_2(kg CO_2e/kg CO_2)

[6] Equation A6.1. is based on equation 11.1. of Chapter 11, Volume 4 of the IPCC Guidelines,[12] considering the annual quantity of N applied to the soils in the form of synthetic fertilizer and the annual quantity of animal manure, compost, sewage sludge, and other N contributions applied to the soils. The publications of Tubiello et al. (2015)[14] in section 5.1.4. Synthetic Fertilizers, and Vallejo et al. (2013)[16] in section 2.4.3. Pasture Fertilization, Table 2.4. were used as reference in adapting the equation.
[7] Equation A6.2. is based on equation 11.13. of Chapter 11, Volume 4 of the IPCC Guidelines (2015).[122].

A6.1.3. Lime Application to the Soil

$$E_{Lime} = (E_{Limestone} + E_{Dolomite}) \text{ (equation A6.3)}$$ [8]

$$E_{Limestone} = C_C \times EF_C \times \frac{44}{12} \times GWP_{CO2} \text{ (equation A5.4)}$$

$$E_{Dolomite} = C_D \times EF_D \times \frac{44}{12} \times GWP_{CO2} \text{ (equation A5.5)}$$

$\mathbf{E_{Lime}}$ = CO_2 equivalent emissions from lime application (kg CO_2e)
$\mathbf{E_{Limestone}}$ = CO_2 emissions from limestone application with lime (kg CO_2)
$\mathbf{E_{Dolomite}}$ = CO_2 emissions from lime application with dolomite (kg CO_2)
$\mathbf{C_C}$ = Total quantity of Limestone applied during the study year ($kg_{total\ C}$)
$\mathbf{C_D}$ = Total quantity of Dolomite applied during the study year ($kg_{total\ D}$)
$\mathbf{EF_C}$ = Emission Factor in Limestone application (0.12 kg CO_2– C/$kg_{total\ C}$)
$\mathbf{EF_D}$ = Emission Factor in Dolomitic Lime application (0.13 kg CO_2– C/$kg_{total\ D}$)
$\mathbf{\frac{44}{12}}$ = Conversion ratio of CO_2– C emissions into CO_2emissions
$\mathbf{GWP_{CO2}}$ = Global Warming Potential of CO_2(kg CO_2e/kg CO_2)

A6.2. Consumo de combustibles fósiles

$$E_{CF} = FFC \times FE_{CCF,X} \times GWP_X \text{ (equation A6.6)}$$ [9]

$\mathbf{E_{CF}}$ = CO_2 equivalent emissions from fuel consumption (kg CO_2e)
$\mathbf{FFC}$ = Total Fossil Fuel Consumption during the study year (L)
$\mathbf{EF_{FFC,X}}$ = GHG X emission factor from Fossil Fuel Consumption (kg_X/L)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2e/kg X)

[8] Equations A6.3., A6.4., and A6.5. were adapted from equation 11.12 of Chapter 11, Volume 4 of the IPCC Guidelines (2015).[12] .
[9] Equation A6.6. was adapted from Equation 2.1. of Chapter 2 and from Equations 3.2.1., 3.2.3. and 3.6.1. of Chapter 3, Volume 2, of the IPCC Guidelines (2015).[12]

A6.3. Electricity consumption

$$E_{El} = CE \times FE_{CE,X} \times GWP_X \quad \text{(equation A6.7)}^{10}$$

$\mathbf{E_{El}}$ = CO_2 equivalent emissions from electricity consumption (kg CO_2e)
$\mathbf{CE}$ = Total electricity consumption during the study year (kWh)
$\mathbf{EF_{CE,X}}$ = Emission Factor of GHG X from Electricity Consumption (kg$_X$/kWh)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2e/kg X)

Depending on the reference from which the emission factors are obtained, they may be given for CO_2 only, or for CO_2, CH_4 and N_2O.[28]

A6.4. Refrigerant Leaks

If the company keeps refrigerant recharge volume records, the emission will be equal to the quantity recharged in the equipment, and equation A6.8 is used.

$$E_R = RR_x \times GWP_X \quad \text{(equation A6.8)}$$

$\mathbf{E_R}$ = CO_2 equivalent emissions from Refrigerant x leaks (kg CO_2e)
$\mathbf{RR}$ = Total recharge of Refrigerant x during the study year (kg$_x$)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2e/kg X)

If the company does not keep recharge records for its refrigeration systems, these values may be estimated using annual leak percentages by piece of equipment during its useful life,[12] by applying equation A6.9.

$$E_R = CR_x \times \frac{Fu_i}{100} \times GWP_X \quad \text{(equation A6.9)}^{11}$$

$\mathbf{E_R}$ = CO_2 equivalent emissions from Refrigerant x leaks (kg CO_2e)
$\mathbf{CR_x}$ = Refrigerant x charge capacity of the system (kg$_x$)
$\mathbf{Fu}$ = Annual refrigerant leak percentage according to equipment i (%)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2e/kg X)

[11] Equation based on section 6.7 of the Guideline for Scope 2 published by the GHG Protocol (Greenhouse Gas Protocol, 2015; p.49).[28].
[12] Equation A6.9. is based on Equation 7.13 of Chapter 7, Volume 3 of the IPCC Guidelines (2015)[12]. Also recommended are the equations in the EPA publication (2008)[21] and the GHG Protocol Guidelines regarding refrigerants (Greenhouse Gas Protocol, 2005).[38]

The values recommended in Table A6.1 may be used for the annual refrigerant leak percentage according to equipment (Fu).

Table A6.1. Charge capacity and leak percentages for different types of air conditioning and refrigeration systems.

Type of Equipment	Capacidad de Carga (kg)	Factor de Emisión o Fu (% de la capacidad/ año)
Domestic refrigeration	0,05-0,5	0,5
Independent commercial applications	0,2-6	15
Medium and large commercial refrigeration	50-2.000	35
Transport refrigeration	3-8	50
Industrial refrigeration including food processing and cold storage	10-10.000	25
Mobile air conditioning	0,5-1,5	20

Source: Adapted from Bostock (2013)[22] and Table 7.9 of Chapter 7, Volume 3 of the IPCC (2015).[12]

A6.5. Use of lubricating oils

$$E_{LO} = ULO \times FE_{ULO} \times GWP_X \text{ (equation A6.10)}^{12}$$

$\mathbf{E_{LO}} = CO_2$ equivalent emissions from use of Lubricating Oils (kg CO_2e)
$\mathbf{ULO}$ = Total quantity of Lubricating Oil used during the study year (L)
$\mathbf{FE_{ULO}}$ = Emission Factor from use of Lubricating Oil (kg CO_2/L)
$\mathbf{GWP_{CO2}}$ = Global Warming Potential of CO_2 (kg CO_2e/kg CO_2)

A6.6. Extinguisher recharge

$$E_{Ex} = REx \times GWP_X \text{ (equation A6.11)}$$

$\mathbf{E_{Ex}} = CO_2$ equivalent emissions from extinguisher recharge (kg CO_2e)
$\mathbf{RE_X}$ = Total quantity of X extinguisher gas recharged during the study year (kg_X)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2e/kg X)

[12] Equation A6.10. was adapted from Equation 5.2. of Chapter 5, Section 5.2., Volume 3 of the IPCC Guidelines (2015,)[12].

A6.7. Solid waste management

A6.7.1. Process organic wastes

For the OW percentage disposed of in composting, emissions will be calculated by applying equation A6.12 from section A6.7.2 below. Methane and nitrous oxide emissions must be contemplated in the composting process. Emissions calculated for compost must not be accounted for in any other source, in order to avoid double counting.

In case wastes are disposed of in the cultivation area as a nitrogen source, emissions must be calculated with reference to equation A6.1 for organic fertilizers, supported by Schedule 5.

A6.7.2. Municipal solid wastes (offices, cafeteria and packing)

If there is waste segregation, and the quantity of each type of waste and its specific treatment are known, emissions will be calculated using equations A6.12 and A6.13 respectively.

$$E_{MSWi} = MSW_{i,t} \times FE_{i,t,X} \times GWP_X \quad \text{(equation A6.12)}$$

$$E_{MSW} = E_{MSWi1} + E_{MSWi2} + E_{MSWi3} + E_{MSWi4} + \cdots \quad \text{(equation A6.13)}$$

$\mathbf{E_{RSM_i}}$ = CO_2 equivalent emissions from MSW i disposal (kg CO_2e)
$\mathbf{MSW_{i,t}}$ = Quantity of type i wastes receiving the same treatment ($kg_{i,t}$)
$\mathbf{EF_{i,t,X}}$ = Emission Factor by type of waste, treatment and specific GHG ($kg_X/kg_{i,t}$)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X(kg CO_2 eq./kg X)
$\mathbf{E_{MSW}}$ = Total CO_2 equivalent emissions from MSW disposal (kg CO_2e)

The MSW and their possible treatments comprise the following categories shown in Table A6.2, for i and t values in the equation.

Table A6.2. MSW types and treatments.

MSW types (i)	• Plastic • Paper • Cardboard • Aluminum • Organic • Glass
Treatment Types (t)	• Sanitary Landfill • Composting • Biodigestion • Incineration or Coprocessing • Recycling

If there is no waste segregation, or if there is a single emission factor for the entire MSW stream, and knowing the treatment to be used, the appropriate equation would be A6.14

$$E_{MSW} = MSW_t \times EF_{t,X} \times GWP_X \quad \text{(equation A6.14)}$$

$\mathbf{E_{MSW}}$ = CO_2 equivalent emissions through MSW disposal (kg CO_2e)
$\mathbf{MSW_t}$ = Quantity of MSW receiving the same treatment t (kg_t)
$\mathbf{EF_{t,X}}$ = Emission Factor for wastes with treatment and specific GHG (kg_X/kg_t)
$\mathbf{GWP_X}$ = Global Warming Potential of GHG X (kg CO_2e/kg X)

A6.8. Wastewater generation

A6.8.1. Process wastewater (packing plant)

Emissions corresponding to wastewater generation in the banana hand washing process at packing plants, must be estimated using equation A6.15 from the following section (A6.8.2).

A6.8.2. Domestic wastewater (restrooms and taps)

When the volume of DWW and its average Biological Oxygen Demand (BOD) are known, equation A6.15 is used.

$$E_{DWW} = V_{DWW} \times OM_{DWW} \times EF_t \times GWP_{CH4} \quad \text{(equation A6.15)}$$

$\mathbf{E_{DWW}}$ = CO_2 equivalent emissions from DWW treatment (kg CO_2e)
$\mathbf{V_{DWW}}$ = Total volume of DWW generated in the study year (m^3)
$\mathbf{OM_{DWW}}$ = Organic Material concentration in DWW (kg BOD o COD/m^3)
$\mathbf{EF_t}$ = Emission Factor corresponding to type of treatment (kg CH_4/kg BOD)
$\mathbf{GWP_{CH4}}$ = Global Warming Potential of CH_4(kg CO_2e/kg CH_4)

In some cases, the emission factor is calculated on the basis of the number of people working at the company's facilities during the study year.[13] In these cases, emissions will be estimated using equation A6.16.

$$E_{OWW} = P \times EF_t \times GWP_{CH4} \quad \text{(equation A6.16)}$$

$\mathbf{E_{DWW}}$ = CO_2 equivalent emissions from DWW treatment (kg CO_2e)
$\mathbf{P}$ = Total number of personnel working during the study year (persons)
$\mathbf{EF_t}$ = Emission Factor corresponding to treatment type (kg CH_4/person/year)
$\mathbf{GWP_{CH4}}$ = Global Warming Potential of CH_4(kg CO_2e/kg CH_4)

The value of P must be taken from the average number of people who worked at the company during all months of the year, based on the payroll or personnel records available (this must be estimated in this way in order to make it traceable and acceptable to the verification entity when the company applies for a certification).

A6.9. Acetylene consumption

Assuming that the entire gas content of a cylinder is acetylene, and that it reacts in a complete combustion forming CO_2 and water, emissions can be estimated by applying equations A6.18 and A6.17 respectively.

$$E_{Ac} = CAc \times EF_{Ac} \quad \text{(equation A6.17)}$$

$$CAc = V \times R \quad \text{(equation A6.18)}$$

$\mathbf{E_{Ac}}$ = CO_2 equivalent emissions from acetylene combustion (kg CO_2e)

CAc = Total Acetylene consumption during the study year (kg C_2H_2)

$\mathbf{EF_{Ac}}$ = CO_2 Emission Factor from acetylene combustion (0.0034 kg CO_2 /kg C_2H_2)

V = Acetylene storage capacity of cylinder (kg C_2H_2)

R = Number of cylinder recharges during the study year

$\mathbf{GWP_{CO2}}$ = Global Warming Potential of CO_2 (kg CO_2e/kg CO_2)

Note: If a record of the quantity of acetylene recharged during the study year is available, only equation A6.17 will apply.

A6.10. Biomass consumption as fuel (drying ovens)

Considering that the biomass used for the drying oven may be wood or another primary solid biomass, equation A6.19 is used.

$$E_{CB} = CB \times CV \times \frac{1}{1\,000\,000} \times EF_{CB,X} \times GWP_X \quad \text{(equation A6.19)}^{13}$$

$\mathbf{E_{CB}}$ = Equivalent CO_2 emissions from biomass combustion (kg CO_2e)

CB = Total Biomass consumption during the study year (kg)

CV = Calorific value of the Biomass used in the study (TJ/Gg)

$\mathbf{EF_{CB,X}}$ = Emission Factor of GHG X from Biomass Combustion (kg X /TJ)

$\mathbf{GWP_X}$ = Global Warming Potential of GHG X (kg CO_2e/kg X)

For calorific values (CV) the data summarized in Table A6.3, taken from the IPCC,[12] may be used.

Table A6.3. Calorific values for biomass used as fuel.

Type of biomass used as fuel	Net calorific value (TJ/Gg)
Wood/Wood waste	15,6
Other primary solid biomass	11,6

Fuente: Adaptado del Cuadro 1.2 del Capítulo 1, Volumen 2 del IPCC (2015)[12].

[13] Equation A6.19 was adapted from Equation 2.1. of Chapter 2, Volume 2, of the IPCC Guidelines (2015).[12] .

Schedule 7. Aspects to be defined in the scope of the water footprint study

Table A7.1. Aspects to be included in the scope for a water footprint study.

Aspect	Description	Purpose
System and System Boundaries	A system is comprised of the different productive processes. The ***stages, processes and flows*** to be taken into account for the study must be clearly identified in the scope. In addition, it must contain the system boundaries, which comprise the **criteria** specifying the processes that will be included in evaluating the water footprint. Likewise, the ***focus*** of the water footprint (product, process or organization) must be clear. For purposes of this guide, studies will focus on the product (bananas for export).	Defines what is and what is not included in the study.
Functional Unit	The functional unit (FU) is the unit in which the water footprint results will be expressed. It is defined as the quantified performance of the product system, which will be used as ***reference unit***. The FU must reflect the reality of the assessed activity and must be in line with the study objectives. It is important to understand that, in producing a functional unit, certain process inputs and outputs, known as ***reference flows***, will be used.	Describes how and with respect to what the final results will be expressed. .
Time and Geographical Coverage	Water footprint assessments will always be carried out for a specified ***period of time***, comprising the year or years for which the data to be used in the calculations are obtained. Defining the time frame of the study will enable a comparison of the company's performance over time. In addition, the water footprint will be estimated for a specific ***physical location***, for which regional data should preferably be used. It is essential to bear in mind that one cubic meter of water does not have the same value in every region; this value will depend on factors such as water availability in the sector, climate and hydrological aspects, etc. In other words, the impact of consuming one cubic meter of water in Latin America will not be the same as consuming the same amount of water in Africa.	Indicates when and where the study was conducted.
Data and quality requirements, assumptions and decisions made	The ***information sources*** used for the study data must be defined in this section. These may be classified into ***primary data***, which will be that directly obtained from a process measurement, or through estimates obtained from direct measurements in the process; for example, data obtained from a water meter. On the other hand, in the absence of primary data, ***secondary data*** are used, obtained from information in the literature, databases or another secondary source. It is preferable to use primary data, whenever possible, to improve the accuracy of the results. In case secondary data must be used, the reasons and basis for the assumptions made in selecting this information must be justified in the scope.	Describes the quality of the information used.

Aspect	Description	Purpose
Potential environmental impacts considered and excluded, impact assessment methodologies, impact categories, impact indicators.	It will be necessary to specify what impacts are considered for the study and why. In case any relevant environmental impact for the organization's activity is excluded, the reason for the exclusion must be indicated. In addition, the impact categories contemplated (human toxicity, ecotoxicity, eutrophication, scarcity) must be identified, also indicating the methodology of the literature that was used to estimate impacts, and the units used to express the results (indicators). If this guide is used, the study must clearly indicate that the results are only for direct use of the resource ("water footprint from direct use of water resources"), and that the impact scope contemplated is the midpoint (as defined in section 5.1).	Recognizes the impact estimation process.
Limitations and uncertainties	The limitations of the study, associated with the functional unit, the methodologies used, assumptions, excluded information, quality of data used, data characteristics in relation to their period of time and geographical location, among others identified, must be defined.	Describes the details that may affect the certainty of the results.
Justification of excluded information and cutoff criteria	Any excluded information must be duly justified in the scope. "Cutoff criteria" may be used to exclude information that is not significant for the water footprint. For example, a cutoff criterion might be excluding from the study those fertilizers that do not represent more than 5% of the total applications made during the study year.	Explains the extent of the study and the reasons for the constraints
Base year	The base year of the study is the first year with the conditions enabling comparison of the organization's performance over time.	Defines the parameters for comparing results.

Schedule 8. Impact calculation equations for the water footprint

A8.1. Degradative water use

A8.1.1. Human toxicity

The USEtox[48] methodology is recommended for assessing this impact, as it enables a calculation of the characterization factors for substances emitted into the water, both carcinogenic and non-carcinogenic. This methodology uses equations A8.1, A8.2 and A8.3 represented below.

$$\mathrm{iF} = \mathrm{FF} \times \mathrm{XF} \text{ (equation A8.1)}$$

$$\mathrm{CF} = \mathrm{iF} \times \mathrm{EF} \text{ (equation A8.2)}$$

$$\mathrm{I}_{\mathrm{toxhum}} = \sum_i \sum_x \mathrm{M}_{\mathrm{x,i}} \times \mathrm{CF}_{\mathrm{x,i}} \text{(equation A8.3)}$$

$\mathbf{iF}$ = intake factor, fraction of the emitted mass that enters the human population

$\mathbf{FF}$ = fate factor, persistence of a chemical in the environment (days)

$\mathbf{XF}$ = human exposure factor, from water to individual (dimensionless)

$\mathbf{CF}$ = characterization factor of substance x released into water i (cases /$\mathrm{kg}_{\mathrm{emission}}$ x)

$\mathbf{EF}$ = effect factor, changes in probable life expectancy (cases /$\mathrm{kg}_{\mathrm{emission}}$ x)

$\mathbf{M}_{\mathbf{x,i}}$ = emission quantity of substance x into water i ($\mathrm{kg}_{\mathrm{emission}}$ x)

$\mathbf{I}_{\mathbf{toxhum}}$ = impact score(cases)

Note: Since the CFs are given, only equation A8.3 must be used.

A8.1.2. Ecotoxicity

The USEtox[48] methodology is recommended for assessing this impact. The characterization factor (FCx,i) for each substance is calculated using equation A8.4.

$$\mathrm{CF} = \mathrm{FF} \times \mathrm{XF} \times \mathrm{EF} \text{ (equation A8.4)}$$

$\mathbf{FC}$ = characterization factor of substance x released into water i (PAF. m^3. day /$\mathrm{kg}_{\mathrm{emission}}$ x)
$\mathbf{FF}$ = fate factor, persistence of a chemical in the environment (days)
$\mathbf{XF}$ = exposure factor, bioavailability of a chemical (dimensionless)
$\mathbf{EF}$ = effect factor, changes in the fraction of species (PAF. m^3. day/$\mathrm{kg}_{\mathrm{emission}}$ x)

To calculate the impact score for ecotoxicity (ISecotox), reported in PAF.m3.day, each characterization factor must be multiplied by the respective emission quantity for each substance, as shown in equation A8.5.

$$I_{ecotox} = \sum_i \sum_x M_{x,i} \times CF_{x,i} \text{ (equation A8.5)}$$

$\mathbf{I_{ecotox}}$ = impact score ($PAF.m^3.day$)

M FC

CF = characterization factor of substance x released into water i ($PAF.m^3.day/kg_{emission}$ x)

$\mathbf{M_{x,i}}$ = quantity of substance x emission into water i ($kg_{emission}$ x)

Note: Since the CFs are given, only equation A8.5 will be used to assess impact.

A8.1.3. Eutrophication

PThe ReCiPe[49] methodology is recommended for assessing this impact.

$$I_{eutroph.freshwater} = m_{Ptotal} \times CF_{eutroph,\ Ptotal} \text{ (equation A8.6)}$$

$\mathbf{I_{eutroph.freshwater}}$ = impact score (kg Pe)

$\mathbf{m_{P\ total}}$ = total quantity of phosphorus emitted by wastewater (kg P total)

$\mathbf{CF_{eutroph,Ptotal}}$ = characterization factor from freshwater eutrophication ($kg\ Pe/kg\ P_{total}$)

To obtain the total amount of phosphorus emitted by the wastewater from the banana packing process, a ratio must be established with the reported BOD results. Orozco (2005)[52] indicates that the BOD/P ratio is 100/1, and therefore the total emitted quantity of phosphorus must be calculated according to equation A8.7.

$$m_{Ptotal} = BOD \times \frac{1}{100} \times VD_T \text{ (equation A8.7)}$$

$\mathbf{m_{P\ total}}$ = total quantity of phosphorus emitted by wastewater (kg P total)

BOD = Biological Oxygen Demand (kg/m^3)

$\mathbf{VD_T}$ = total degradative water use (m^3)

A8.2. Resource consumption: Scarcity

Use of the AWARE[51] method is recommended for the characterization factors.

$$I_{scarcity} = VC_T \times CF_{region} \quad \text{(equation A8.8)}$$

$\mathbf{I_{scarcity}}$ = impact score (m^3e)

$\mathbf{VC_T}$ = total consumed volume (m^3)

$\mathbf{CF_{region}}$ = scarcity characterization factor by region, AWARE method ($m^3e/m^3{}_{region}$)

Note: The availability impact is not included in the guide because its contribution in midpoint scope does not provide relevant and significant additional information to that provided by the scarcity impact. Further information regarding this impact may be consulted in the publication of Boulay, Bulle, Bayart, Deschênes, & Margni, 2011.[53]

Schedule 9. Examples of application for each potential impact

A9.1.Human toxicity

Example A9.1. Impacts on human toxicity

Step 1. It was determined at a farm, through crop-spraying reports, that the following quantities of each product were applied during the study year:

Product	Active Ingredient	Product application (L/year)	Quantity of active ingredient in the product (%)
Diethane 60 SC	Mancozeb	7 000	46
Banazeb 60 SC	Mancozeb	1 500	43
Tilt 25 EC	Propiconazole	100	30

Step 2. The weight of each active ingredient applied with the product must be determined as follows (it is assumed that 1 liter is equal to 1 kg of product):

$$\textbf{Mass of active Ingredient } (\mathbf{M_X}) = \textbf{Application } (\mathbf{L}) \times \frac{\textbf{Active ingredient } (\%)}{\mathbf{100}} \times \frac{\mathbf{1\ kg}}{\mathbf{1\ L}}$$

$$\text{Mancozeb in Diethane: } M_{\text{Man}} = 7\,000\text{ L} \times \frac{46\%}{100} \times \frac{1\text{ kg}}{1\text{ L}} = 3\,220\text{ kg mancozeb}$$

$$\text{Mancozeb in Banazeb: } M_{\text{Man}} = 1\,500\text{ L} \times \frac{43\%}{100} \times \frac{1\text{ kg}}{1\text{ L}} = 645\text{ kg mancozeb}$$

$$\text{Propiconazole in Tilt: } M_{\text{Prop}} = 100\text{ L} \times \frac{30\%}{100} \times \frac{1\text{ kg}}{1\text{ L}} = 30\text{ kg propiconazole}$$

Step 3. Calculate the total quantity of each active ingredient added.

$$\textbf{Total Mancozeb}: M_{\text{Man}} = 3\,220\text{ kg} + 645\text{ kg} = \mathbf{3\,865\ kg\ mancozeb}$$

$$\textbf{Total Propiconazole}: M_{\text{Prop}} = \mathbf{30\ kg\ propiconazole}$$

Step 4. Identify the most appropriate characterization factors for the active ingredients applied (Schedule 10). In this case, the characterization factors (CF) for total effects (carcinogenic and non carcinogenic) will be selected.

Active Ingredient	CF (CTUh or cases/$kg_{emitted}$)
Mancozeb	0.000002156
Propiconazole	0.000015367

Step 5. Estimate the impact on human toxicity (I_{HT}) by multiplying the respective CF by the total quantity of active ingredient applied.

$$\textbf{Impact Hum. Tox. Mancozeb } (\mathbf{I_{HT,Man}}) = \mathbf{3\,865\ kg\ mancozeb} \times 0.000002156\text{ cases/kg}$$

$$\mathbf{I_{HT,Man}} = 0.00833294\text{ cases or CTUh}$$

$$\textbf{Impact Hum. Tox. Propiconazole } (\mathbf{I_{HT,Prop}}) = \mathbf{30\ kg\ propiconazole} \times 0.000015367\text{ cases/kg}$$

$$\mathbf{I_{HT,Prop}} = 0.00046101\text{ cases or CTUh}$$

A9.2. Ecotoxicity in freshwater

Example A9.2. Impacts on freshwater ecotoxicity

Step 1. Continuing with Example A9.1, a total application of 3 865 kg mancozeb and 30 kg propiconazole was determined. The respective characterization factor for impact on freshwater ecotoxicity must be identified for these active ingredients (Schedule 10).

Active ingredient	CF (CTUe or PAF.m^3.day/$kg_{emitted}$)
Mancozeb	52 559.66
Propiconazole	22 239.49

Step 2. Estimate the impact on aquatic ecotoxicity (I_{Ecotox}) by multiplying the respective CF by the total applied quantity of the active ingredient.

$$\textbf{Impact Ecotox. Mancozeb } (\mathbf{I}_{\mathbf{Ecotox,Man}}) = \textbf{3 865 kg mancozeb} \times 52\ 559.66\ \mathrm{PAF.m^3.day/kg}$$

$$\mathbf{I}_{\mathbf{Ecotox,Man}} = 203\ 143\ 085.9\ \mathrm{PAF.m^3.day\ or\ CTUe}$$

$$\textbf{Impact Ecotox. Propiconazole } (\mathbf{I}_{\mathbf{Ecotox,Prop}}) = \textbf{30 kg propiconazole} \times 22\ 239.49\ \mathrm{PAF.m^3.day/kg}$$

$$\mathbf{I}_{\mathbf{Ecotox,Prop}} = 667\ 184.7\ \mathrm{PAF.m^3.day\ or\ CTUh}$$

A9.3. Eutrophication in freshwater

Example A9.3. Impacts on freshwater eutrophication

Part I. Impact from fertilizer use

Step 1. In a 10 hectare farm it was determined, through the fertilization programs, that the following quantities of fertilizers were applied during the study year:

Origin of phosphorus	Fertilizer application (kg/ha/year)	Phosphorus quantity in fertilizer (%)
Synthetic fertilizers	300	20
Poultry manure	5	5

The quantity of phosphorus (PM) added by each fertilizer must be determined as follows:

$$\textbf{Phosphorus mass (PM)} = \textbf{Hectares(ha)} \times \textbf{Application (kg/ha)} \times \frac{\textbf{Phosphorus quantity (\%)}}{100}$$

$$\textbf{Phosphorus mass Synthetic Fert. }(\mathbf{PM_{SF}}) = 10\text{ ha} \times 300\text{ kg/ha} \times \frac{20}{100}$$

$$\mathbf{PM_{SF}} = 600\text{ kg P}$$

$$\textbf{Phosphorus mass Poultry Manure }(\mathbf{PM_{Man}}) = 10\text{ ha} \times 5\text{ kg/ha} \times \frac{5}{100}$$

$$\mathbf{PM_{Man}} = 2.5\text{ kg P}$$

Step 2. Identify the most appropriate characterization factors to estimate eutrophication impacts (Schedule 10). In this case, the fertilizers were released into the soil through application of synthetic fertilizers and poultry manure.

Nature compartment of release	Substance name	CF (kg Pe/ kg $_{\text{emitted}}$)
Soil	Fertilizer application (phosphorus component)	0.053
Soil	Manure application (phosphorus component)	0.05

Step 3. Estimate the eutrophication impacts from application of synthetic fertilizers and poultry manure ($I_{Eut,fert}$).

$$\textbf{Impact Eutroph. Synt. Fert. }(\mathbf{I_{Eut,syn.fert}}) = \mathbf{600\ kg\ P} \times 0.053\text{ kg Pe /kg P}$$

$$\mathbf{I_{Eut,syn.fert}} = 31.8\text{ kg Pe}$$

$$\textbf{Impact Eutroph. Manure }(\mathbf{I_{Eut,Man}}) = \mathbf{2.5\ kg\ P} \times 0.05\text{ kg Pe /kg P}$$

$$\mathbf{I_{Eut,Man}} = 0.125\text{ kg Pe}$$

Part II. Impact from discharge of wastewater from fruit washing process

Step 1. Three reports on discharged water quality were submitted by the farm to the respective government entity during the year. The reports showed the following BOD values for these waters:

Report	BOD (kg/m^3)
First Report	300
Second Report	350
Third Report	260

The average BOD in the wastewater (BOD_A) must be estimated by adding together all values and dividing by the number of reports.

$$\textbf{Average BOD } (\mathbf{BOD_A})(300 + 350 + 260) \div 3 = 303 \text{ kg/m}^3$$

Step 2. Calculate the quantity of phosphorus (M_{Ptotal}) discharged into the water in relation to this BOD_A measurement, considering that at the packing plant the degradative water use was 8 000 m^3.

$$\textbf{Phosphorus mass in water } (\mathbf{M_{Ptotal}}) = BOD_A \times \frac{1}{100} \times VD_{PE}$$

$$\mathbf{M_{Ptotal}} = 303 \times \frac{1}{100} \times 8\,000 = 24\,240 \text{ kg P}$$

Step 3. Identify the most appropriate characterization factors to estimate eutrophication impacts (Schedule 10). In this case, fertilizers were released into the water.

Nature compartment of release	Substance name	CF (kg Pe/ kg $_{issued}$)
Water	Total phosphorus	1

Step 4. Estimate the eutrophication impacts from enrichment of wastewaters with latex, that is, organic matter ($I_{Eut,WW}$).

$$\textbf{Impact Eutroph. Wastewater.} (\mathbf{I_{Eut,WW}}) = \mathbf{24\,240 \text{ kg P}} \times 1 \text{ kg Pe /kg P}$$
$$\mathbf{I_{Eut,WW}} = 24\,240 \text{ kg Pe}$$

A9.4. Scarcity

Example 9.4. Impact from scarcity

Step 1. At a farm located in Costa Rica, a total volume of 2 502 500 m^3 were consumed during the study year. The most appropriate characterization factor for the region must first be identified.

Region	CF (m^3e/m^3 $_{consumed}$)
Costa Rica	11.1

Step 2. Estimate the scarcity impact (I_{Sc}) by multiplying the characterization factor by the total volume consumed.

$$\textbf{Scarcity Impact } (\mathbf{I_{Sc}}) = 2\,502\,500 \text{ m}^3 \times 11.1 \text{ m}^3\text{e/m}^3$$
$$\mathbf{I_{Sc}} = 27\,777\,750 \text{ m}^3\text{e}$$

Schedule 10. Characterization Factors

A10.1. Degradative water use

A10.1.1. Human toxicity

Table A10.1. Characterization factors to estimate impacts on human toxicity.

CAS Number	Name of active Ingredient	Brand names	CF of midpoint (cases/kg$_{emitted}$)		
			Carcinogenic	Non- carcinogenic	Total
77-92-9	Citric acid	Citric Acid	0.000000000	n/a	0.000000000
77-06-5	Gibberellic acid	Ryzup	0.000000000	n/a	0.000000000
17804-35-2	Benomyl	Benomil, Benlate, Benex, Forlate, Polyben, Bankit	n/a	0.000000143	0.000000143
82657-04-3	Bifenthrin	-	0.000000000	0.000124762	0.000124762
55179-31-2	Bitertanol	Baycor	n/a	0.000034627	0.000034627
188425-85-6	Boscalid	Boscalid, Endura	n/a	n/a	n/a
1563-66-2	Carbofuran	Carbodán, Carbofurán, Curater, Furadán	0.000000000	0.000036923	0.000036923
5234-68-4	Carboxin	Vitavax 300	n/a	0.000001082	0.000001082
5598-13-0	Chlorpyrifos Methyl	Lorsban 4-E	n/a	0.000441223	0.000441223
1897-45-6	Chlorothalonil	Balear, Bravo, Daconil, Dacapo, Fungil	0.000000110	0.000003312	0.000003422
333-41-5	Diazinon	Basudin, Gusadrín, Gusafós, Hormiguín	0.000000000	0.000155119	0.000155119
119446-68-3	Difenoconazole	Difenoconazole, Score, Sico	n/a	n/a	n/a
115-29-7	Endosulfan	Thiodan, Endoside, Phaser	0.000000000	0.000030022	0.000030022
133855988	Epxiconazole	Corbel, Opal, Opus, Sopral	n/a	n/a	n/a
22224-92-6	Fenamiphos	Nemacur	n/a	0.000087708	0.000087708
114369-43-6	Fenbuconazole	Indar	n/a	0.000010560	0.000010560
67564-91-4	Fenpropimorph	Volley OI	n/a	n/a	n/a
77182-82-2	Glufosinate-Ammonium	Finale	n/a	0.000002469	0.000002469
1071-83-6	Glyphosate	Ranger, Arrasador, Basuka, Coloso, Glifoklin, Glitex, Ruster, Thorranto, Roundup	n/a	0.000000160	0.000000160
35554-44-0	Imazalil (Base)	Fungaflor, Imazalil	n/a	0.000009444	0.000009444
67-63-0	Isopropanol	Ryzup	0.000000000	n/a	0.000000000
121-75-5	Malathion	Malathion, Granathión	0.000000000	0.000000214	0.000000214

CAS Number	Name of active Ingredient	Brand names	CF of midpoint (cases/kg$_{emitted}$)		
8018017	Mancozeb	Agromanco, Agromart M-45, Amarillo, Argenol, Bioman,Bioman Aceite, Cadozeb, Cerko, Critox, Curtine, Dithane, Flonex, Fore, Fungal, Galben, M-80, Mancofungil, Mancol, Mancoop, Mancoxil, Mancozeb, Mancozin, Mancu, Mangazin, Manteno, Manzate, Manzicarb, Manzin, Novazeb, Penncozeb,Penncozeb Plus, Policar, Reycozeb, Rhodax, Ridodur, Ridomil Plus, Tenaz, Titan,Titano, Vivax	n/a	0.000002156	0.000002156
23135-22-0	Oxamyl	Vydate	0.000000000	0.000004146	0.000004146
4685-14-7	Paraquat	Gramoxone, Paraquat, Plus, Pillarzone	n/a	0.000005087	0.000005087
175013180	Pyraclostrobin	Regnum	n/a	n/a	n/a
60207-90-1	Propiconazole	Propicon, Propiconazol, Propilaq, Propizole, Tilt	n/a	0.000015367	0.000015367
53112-28-0	Pyrimethanil	Scala, Siganex	n/a	n/a	n/a
118134-30-8	Spiroxamine	Impulse	n/a	n/a	n/a
107534-96-3	Tebuconazole	Folicur, Orius, Silvacur, Tebuconazell, Tebucoz	n/a	0.000007528	0.000007528
13071-79-9	Terbufos	Avance, Counter, Forater	n/a	0.001518922	0.001518922
55219-65-3	Triadimenol	Bayfidan, Baytan, Bulldock, Caporal, Royzell, Shavit	n/a	0.000005426	0.000005426
24602-86-6	Tridemorph	Banaclean, Calixin, Ringer, Tridemorph	n/a	n/a	n/a
57-13-6	Urea	Urea	0.000000000	n/a	0.000000000

n/a: Characterization factors not yet available.

Adapted from spreadsheets with characterization factors available at the official USEtox methodology site.54.

A10.1.2. Ecotoxicity

Table A10.2. Characterization factors to estimate ecotoxicity impacts**.**

CAS Number	Name of active Ingredient	Trade names	CF of midpoint (PAF.m^3.day/$kg_{emitted}$)
77-92-9	Citric acid	Citric Acid	22.01
77-06-5	Gibberellic acid	Ryzup	n/a
17804-35-2	Benomyl	Benomil, Benlate, Benex, Forlate, Polyben, Bankit	24 019.89
82657-04-3	Bifenthrin	-	6 578 866.63
55179-31-2	Bitertanol	Baycor	16 215.84
188425-85-6	Boscalid	Boscalid, Endura	n/a
1563-66-2	Carbofuran	Carbodán, Carbofurán, Curater, Furadán	112 189.24
5234-68-4	Carboxin	Vitavax 300	24 613.86
5598-13-0	Chlorpyrifos Methyl	Lorsban 4-E	728 531.39
1897-45-6	Chlorothalonil	Balear, Bravo, Daconil, Dacapo, Fungil	1 143 877.78
333-41-5	Diazinon	Basudin, Gusadrín, Gusafós, Hormiguín	185 207.95
119446-68-3	Difenoconazole	Difenoconazole, Score, Sico	128 639.76
115-29-7	Endosulfan	Thiodan, Endoside, Phaser	594 227.73
133855988	Epxiconazole	Corbel, Opal, Opus, Sopral	n/a
22224-92-6	Fenamiphos	Nemacur	519 712.78
114369-43-6	Fenbuconazole	Indar	117 306.34
67564-91-4	Fenpropimorph	Volley Ol	11 775.29
77182-82-2	Glufosinate-Ammonium	Finale	577.86
1071-83-6	Glyphosate	Ranger, Arrasador, Basuka, Coloso, Glifoklin, Glitex, Ruster, Thorranto, Roundup	320.79
35554-44-0	Imazalil (Base)	Fungaflor, Imazalil	16 282.87
67-63-0	Isopropanol	Ryzup	2.47
121-75-5	Malathion	Malathion, Granathión	62 162.84
8018017	Mancozeb	Agromanco, Agromart M-45, Amarillo, Argenol, Bioman, Bioman Aceite, Cadozeb, Cerko, Critox, Curtine, Dithane, Flonex, Fore, Fungal, Galben, M80, Mancofungil, Mancol, Mancoop, Mancoxil, Mancozeb, Mancozin, Mancu, Mangazin, Manteno, Manzate, Manzicarb, Manzin, Novazeb, Penncozeb, Penncozeb Plus, Policar, Reycozeb, Rhodax, Ridodur, Ridomil Plus, Tenaz, Titan, Titano, Vivax	52 559.66
23135-22-0	Oxamyl	Vydate	16 178.64
4685-14-7	Paraquat	Gramoxone, Paraquat, Plus, Pillarzone	118 530.68
175013180	Pyraclostrobin	Regnum	n/a
60207-90-1	Propiconazole	Propicon, Propiconazol, Propilaq, Propizole, Tilt	22 239.49
53112-28-0	Pyrimethanil	Scala, Siganex	3 406.74

CAS Number	Name of active Ingredient	Trade names	CF of midpoint (PAF. m^3.day/$kg_{emitted}$)
118134-30-8	Spiroxamine	Impulse	n/a
107534-96-3	Tebuconazole	Folicur, Orius, Silvacur, Tebuconazell, Tebucoz	68 572.88
13071-79-9	Terbufos	Avance, Counter, Forater	2 227 105.84
55219-65-3	Triadimenol	Bayfidan, Baytan, Bulldock, Caporal, Royzell, Shavit	5 704.15
24602-86-6	Tridemorph	Banaclean, Calixin, Ringer, Tridemorph	53 119.04
57-13-6	Urea	Urea	10.23

n/a: Characterization factors not yet available.
Adapted from spreadsheets with characterization factors available at the official USEtox methodology site.[54]

A10.1.3. Eutrophication

Table A10.3. Characterization factors to estimate eutrophication impacts.

Nature compartment of release	Subcompartment	Substance name	Midpoint CF (kg Pe)
Soil	Agriculture	Phosphorus	1
Soil	Not specified	Fertilizer application (phosphorus component)	0.053
Soil	Not specified	Manure application (phosphorus component)	0.05
Water	Not specified	Total phosphorus	1

Adapted from spreadsheets with characterization factors available at the official website of the ReCiPe methodology.[55]

A10.2. Consumo de agua

A10.2.1. Scarcity

The characterization factors (CF) of the AWARE methodology are available by country or by specific geographical location. Table A10.4 shows the CFs by country, where in some countries the space CF must be used and in others it is better to use the time CF. It is important to underscore that the most advisable method for a water footprint study will be to use the specific CFs of the watershed where the study is carried out, rather than the CFs by country.

Table A10.4. Characterization factors by country to estimate impacts on scarcity.

Country	Midpoint CF ($m^3e/m^3_{consumed}$)		Priority CF to be used by country
	Time	Space	
Brazil	1.1	7.2	Space
Cameroon	2.7	5.8	Space
Colombia	0.2	26.7	Space
Costa Rica	0.6	11.1	Space
Cote d'Ivore	3.7	6.0	Space
Dominica	3.2	2.8	Time
Dominican Republic	5.2	21.5	Space
Ecuador	6.5	17.3	Space
Ghana	1.8	12.1	Time
Guadeloupe	5.8	4.7	Time
Guatemala	1.1	21.7	Space
Honduras	0.7	0.5	Time
Martinique	4.5	22.5	Space
Nicaragua	1.8	11.0	Space
Panama	1.5	6.8	Space
Peru	12.2	33.8	Space
St. Lucia	22.7	0.0	Time
St. Vincent	8.0	0.0	Time

Adapted from spreadsheets with characterization factors by country available at the official website of the Water Use In Life Cycle Assessment organization (WULCA, 2017).[51]

In order to obtain the specific characterization factors for the farm location, we recommend using the Google Earth program, which may be downloaded from: https://www.google.es/earth/download/ge/agree.html

Once the program has been downloaded and installed on the computer, it will be necessary to download the layer to be used in this program, which contains the characterization factors by latitude and longitude. These are available on the official web page of WULCA (under the icon "Google Layer Document"): http://www.wulca-waterlca.org/aware.html As shown in Figure A10.1, the layer will appear immediately in the Google Earth program (in order to be used it must be selected with a check).

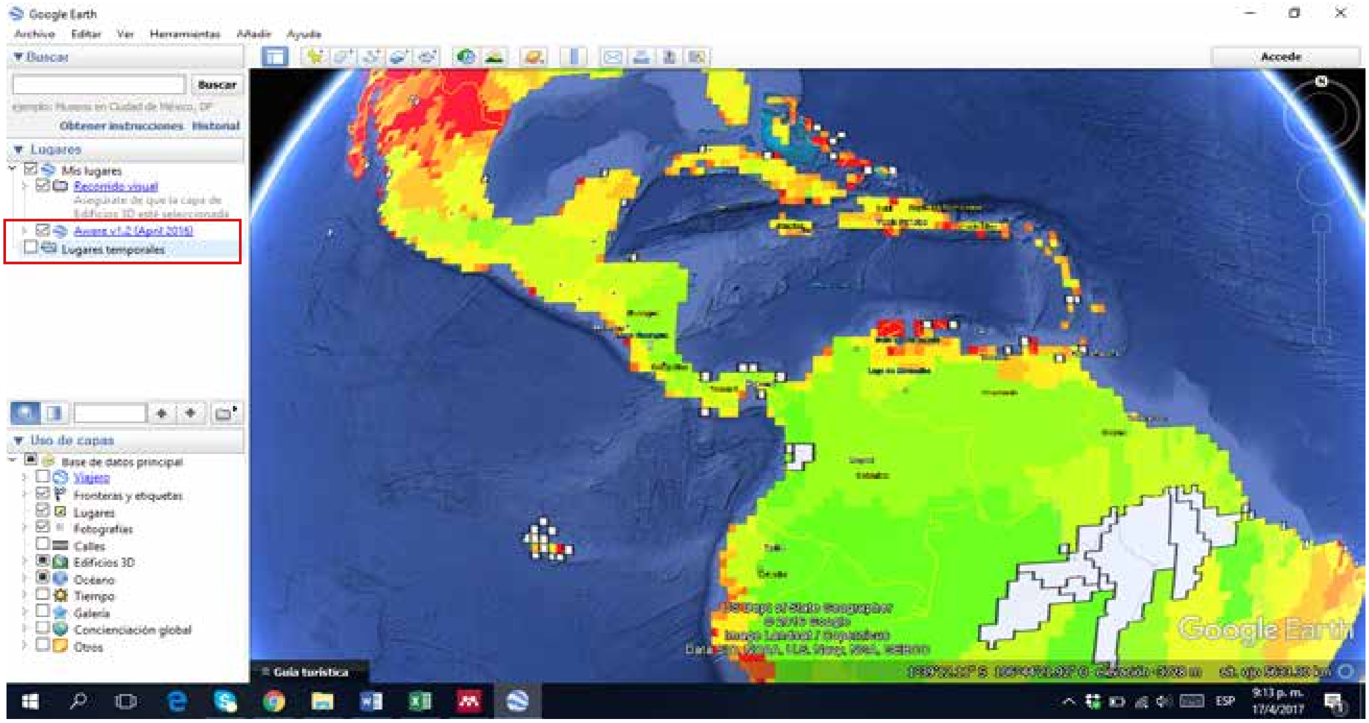


Figure A10.1. Google Earth program with AWARE characterization factors.

In order to obtain the specific characterization factors for the location of the farm, you must go to the location and click on it. A box will come up showing the CFs by month or by year for different applications, to be used in calculating the impact on scarcity (Figure A10.2).

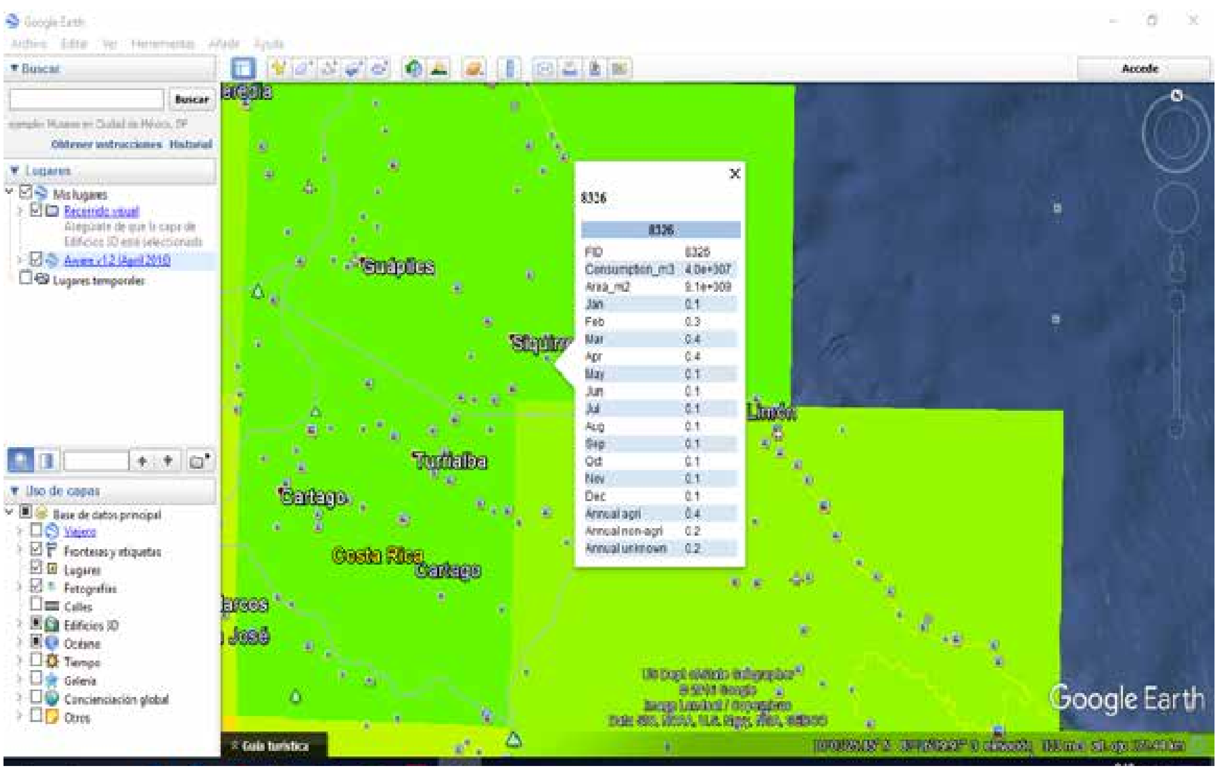


Figure A10.2. AWARE characterization factors for a specific region in the Google Earth program.

Schedule 11. Use of CROPWAT to estimate crop evapotranspiration

The software developed by FAO and known as CROPWAT is freely available for download and use on your computer. It may obtained from the following web page: http://www.fao.org/land-water/databases-and-software/cropwat/es/

The use of CROPWAT is recommended to estimate evapotranspiration and the steps for calculation are included below.

Step 1. Select the “Climate/ETo” button in the left column of the screen. Enter the climate data for minimum and maximum monthly average temperature (°C), monthly average humidity (%), wind (m/s) and sun (hours) in the table that pops up.

It is advisable to include the country, altitude (m a.s.l), latitude and longitude of the farm, as well as the name of the meteorological station. If the sun datum is not available, the program will estimate it from the location (latitude and longitude) that is introduced.

The yellow cells must not be filled in, as this value is calculated by the program

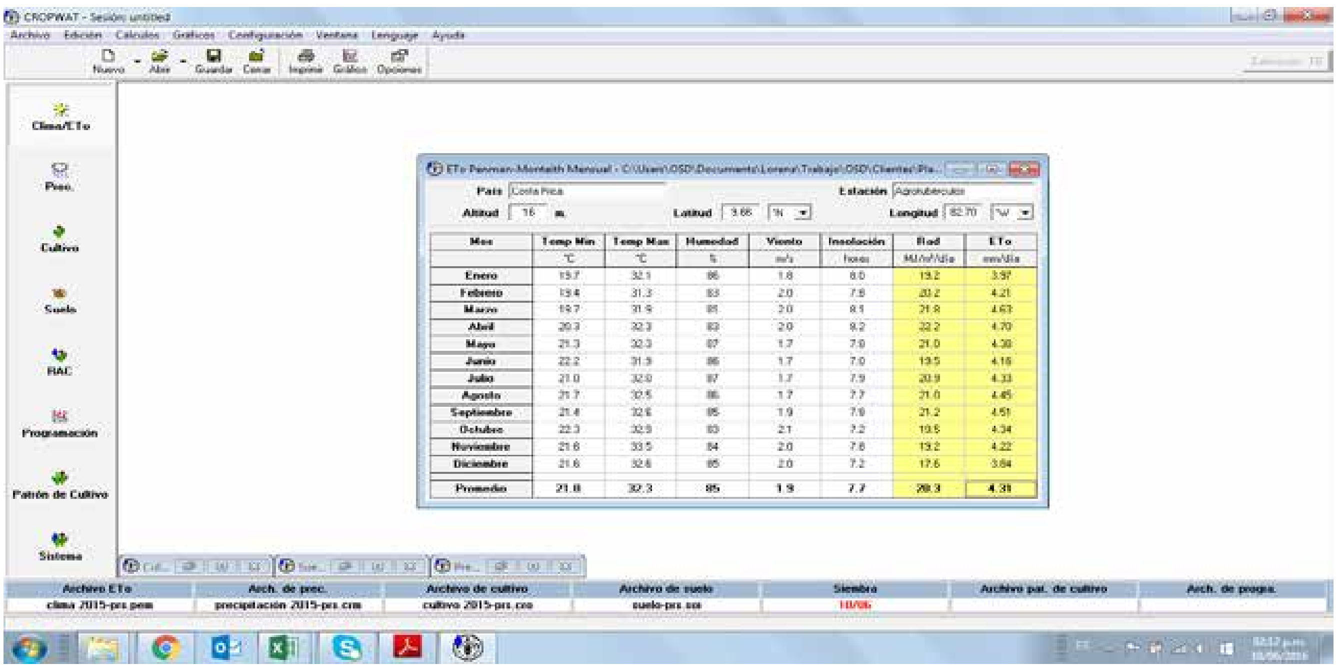


Figure A11.1. Step 1, climate data in CROPWAT.

Step 2. Select the “Rain” button in the left column of the screen. Enter the monthly precipitation data. The yellow column will show the data estimated by the program.

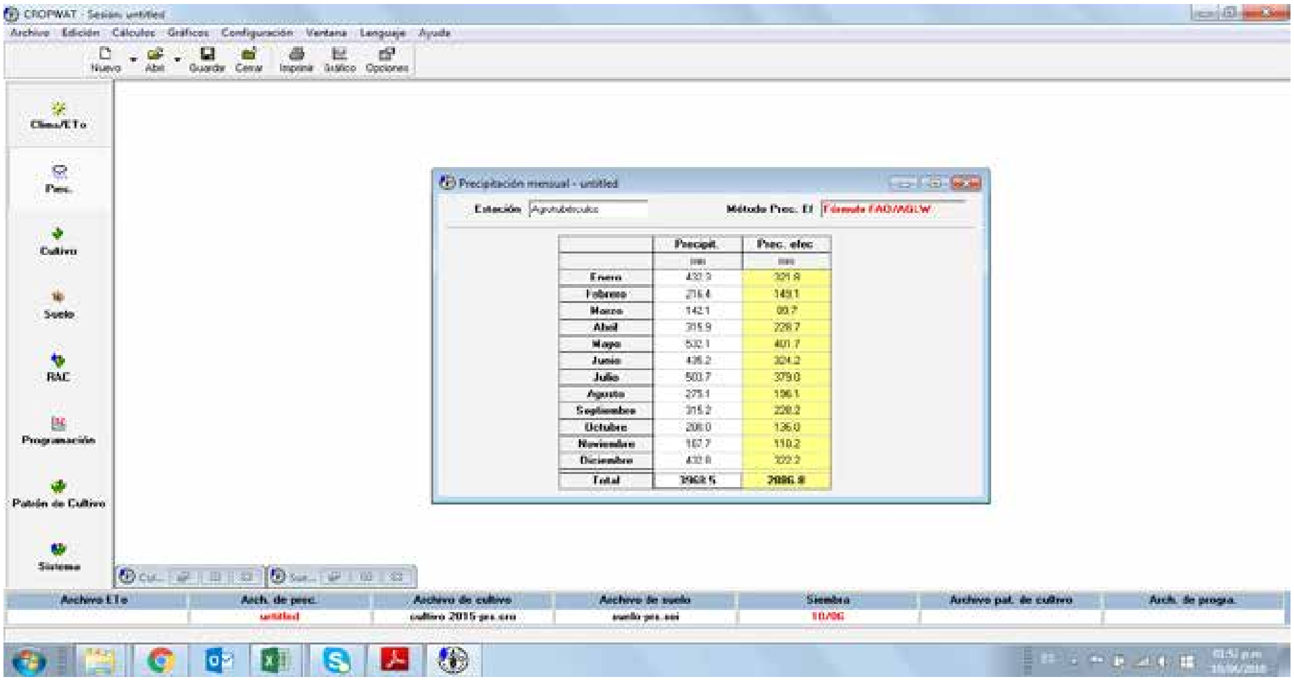


Figure A11.2. Step 2, precipitation data in CROPWAT.

Step 3. Select the "Crop" button in the left column of the screen. Enter the information provided by the FAO publication[45] and included in Table A11.1.

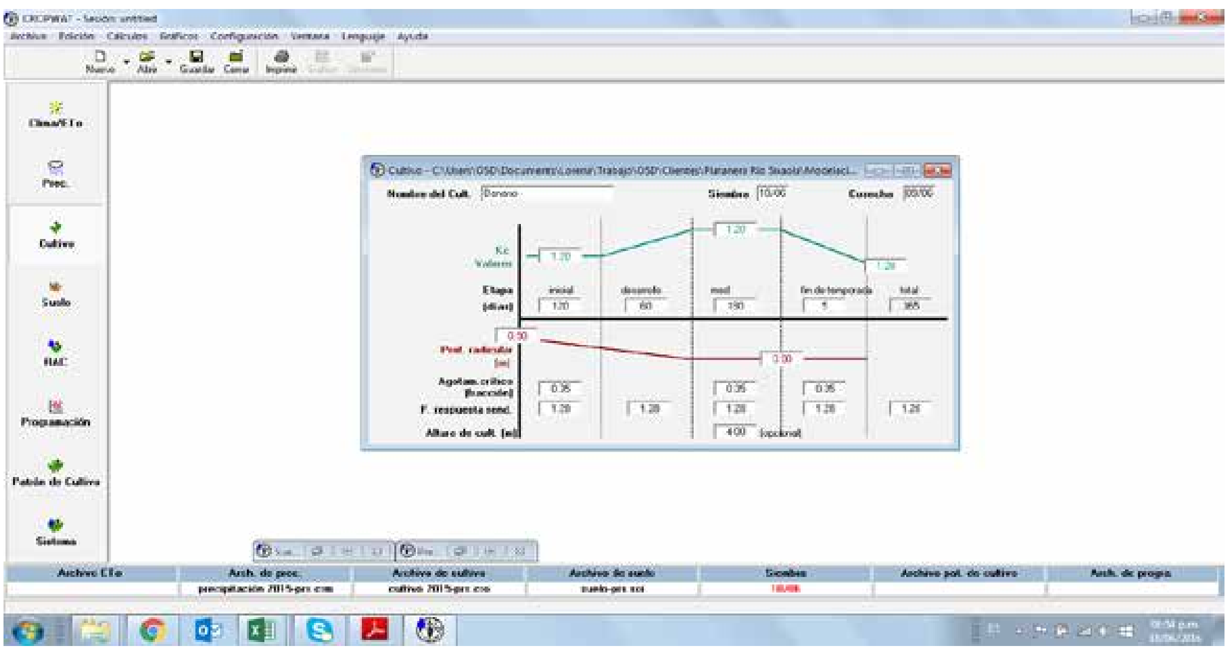
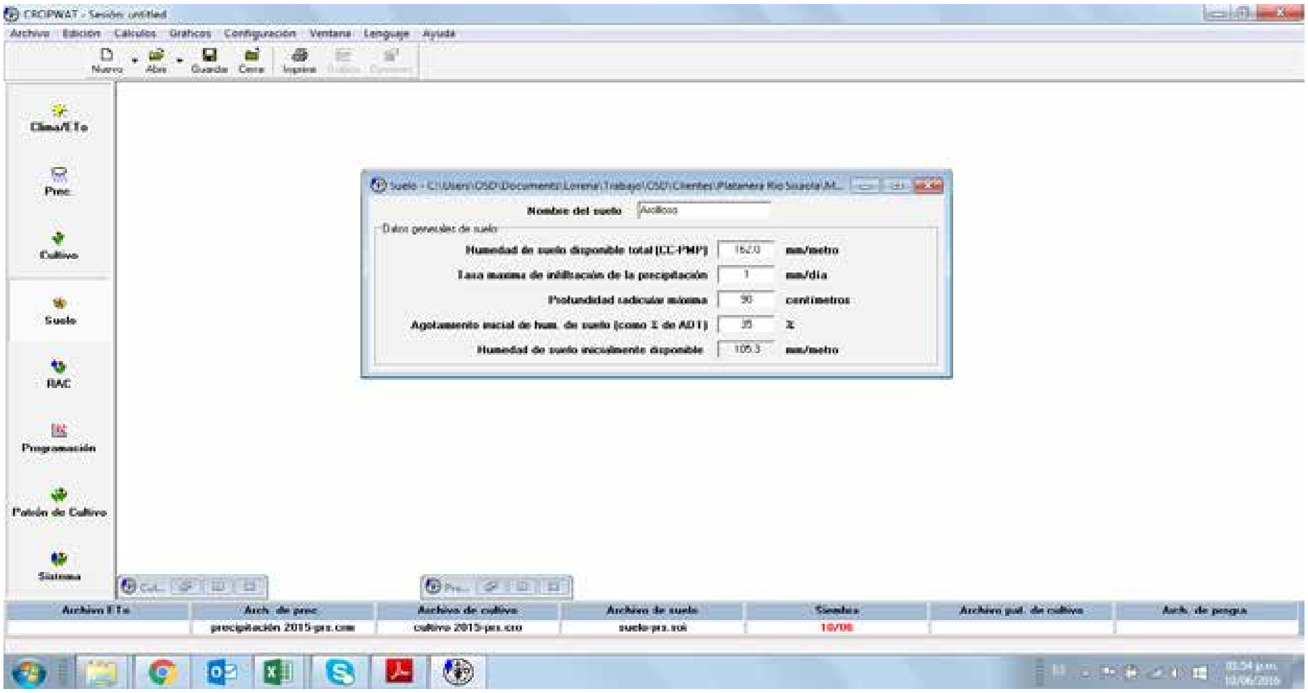


Figure A11.3. Step 3, crop data in CROPWAT.

Table A11.1. Theoretical crop data for use in CROPWAT.

Stage	Initial	Development	Mid-season	Late season	Source
Kc	1,2		1,2	1,2	Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 12, page 112.
Days	120	60	180	5	Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 11, page 107.
Rooting depth (m)	0,9		0,9		Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 22, page 165.
Critical depletion (fraction)	0,35		0,35	0,35	Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 22, page 165..
Yield response F. (Ky))	1,28	1,28	1,28	1,28	Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 24, page 181.
Crop height (m)			4		Food and Agriculture Organization of the United Nations [FAO]. (2006). Crop Evapotranspiration-Guidelines for computing crop water requirements. Rome, Italy. 298 p. ISSN 0254-5293. Taken from Table 12, page 112.

Step 4. Select the “Soil” button in the left column of the screen. Enter the soil characteristics for the region.



Step 5. Analysis of results and estimation of crop evapotranspiration.

The results obtained for evapotranspiration will be the column under ETc and will be given in mm/day/m². Therefore, the total crop evapotranspiration per month (ET_M) can be obtained by applying equation A4.1.

$$\text{Evapotranspiración Mensual } (ET_M) = ET_c \times D \times 10 \quad \text{(ecuación A11.1)}$$

ET_M = Evapotranspiración mensual (m^3/mes)

ET_C = Evapotranspiración diaria del cultivo en el mes (mm/día)

D = Días del mes (días)

10 = factor de conversión

A = Área sembrada en la finca (ha)

Note: 1 mm of evapotranspiration in 1 ha is equivalent to 0.001 X 10 000 = 10 m^3; the conversion factor is obtained from this operation.[47]

Schedule 12. Measures towards reducing GHG emissions

A12.1. Fertilizers

Table A12.1. Measures towards reducing or absorbing emissions in fertilizer application

Action	Description	Advantage	Disadvantage
Application of Biochar to the soil[3,58,61,62]	Biochar is a charcoal soil amendment made by exposing biomass to temperatures between 400 and 600 °C, with limited oxygen. When added to the soil, this product is capable of improving its fertility (increases biological activity and enables the efficient use of nutrients), while serving to remove carbon due to its porosity, thus reducing nitrous oxide emissions. The following are a few of the characteristics of biochar: -Wood and herbal material constitute the ideal biomass for obtaining biochar with enhanced nitrous oxide emission reduction capacity. -Biochar with carbon-nitrogen ratios above 30 has been found identified as ideal for favoring emission reduction (application rates over 1 and 2% on a dry base reduce N_2O emissions by up to 87%). -Biochar has greater potential to reduce emissions in moist, fine-grained soils, as well as in low-humidity, coarse soils. -Biochar is not recommended as a mitigation method in acid soils with a pH under 5. The best results are achieved in soils with a pH that is close to neutral (pH = 7). -Biochar achieves better results when applied with nitrate-based (NO_3-) fertilizers: it has been proven to reduce N_2O emissions by up to 80%.	The use of biochar has other benefits, such as its capacity to retain water in the soil, which fosters the growth of plants, retains nutrients and enhances the soil's properties. It also serves as habitat for microorganisms, thus improving the diversity of crop soils.	Further research is required concerning its mitigation effects, since not all soils show the same improvements upon its application. In addition, we must point out that it may sometimes foster the growth of weeds, increase the soil's alkalinity if left uncontrolled, and its cost is variable depending on the biomass and the producer.

Action	Description	Advantage	Disadvantage
Reduction of fertilizer application rates[3,61]	As a mitigation action, a few banana companies have chosen to reduce fertilizer application rates. This is an effective reduction measure, as it directly contributes to decreasing the emission of nitrous oxide. However, we recommend conducting tests on small crop plots prior to the new application rates. This will allow selecting the best application rate that will reduce emissions without significantly affecting productivity.	This reduction measure is widely accepted by both markets and consumers, which may entail economic and environmental advantages.	Reducing the fertilizer application rate may potentially decrease productivity
Soil nitrogen tests[3,61]	Scheduling and periodically conducting laboratory tests to determine the amount of nitrogen in the soil may help reduce the application of nitrogen fertilizers, therefore reducing N_2O emissions. Knowing the condition, status and properties of the soil is key to making decisions regarding sustainable management practices.	May reduce over-fertilization and lead to monetary savings.	High cost depending on the region.
Optimize fertilization time[3,61,63]	In order to optimize the use of nitrogen fertilizer, fertilization must be coordinated in the phases during which the crop truly requires nutrients. This is why we recommend fertilizing during the crop's active growth phase, which is when the plants will have a greater need for nitrogen. The early growth and maturity phases require less nitrogen.	Does not require investment and may represent monetary savings.	Differentiated fertilization by growth phase may become complicated, since shoots, seedlings that are starting to grow and plants undergoing active growth are side-side-side throughout the fields.
Placing fertilizer in the rhizosphere[3,61,63,64]	The rhizosphere is the area of the soil closest to the absorption zone of the plant's active roots. Placing the fertilizer in this area may increase the plant's efficiency in its use of nitrogen, therefore helping to decrease nitrous oxide emissions.	Allows saving significant amounts of nitrogen fertilizers.	May lead to complicated banana fertilization processes, due to the difficulty of fertilizing each plant in the active zone of its roots.
Application of urease and nitrification inhibitors[3,61,64]	Inhibitors are products aiming at delaying the reaction of soil microorganisms, which transform ammonium into nitrous oxide. By slowing down these transformation processes N_2O emissions are reduced. SBT butanoate, SBT furoate, DCD (dicyandiamide) and Nitrapyrin are a few of these inhibitors.	Inhibitors increase the plant's yield and it has been estimated that they reduce nitrous oxide emissions by 4 to 5%.	The main disadvantage is that they are not effective in all types of soils and may be linked to high costs.

Action	Description	Advantage	Disadvantage
Slow-release fertilizer application and manipulation technologies[3,61,65]	Slow-release fertilizers differ from conventional fertilizers in that, by using several coatings, chemical modifications and changes to the size of the fertilizer grains, it is released slowly, gradually and in a controlled manner. Their application may increase the effectiveness of added nutrients, as it extends the time for the plant, optimizes the use of the product by simplifying its dosage, avoiding losses due to degradation, saving product, reducing fertilizer contamination of others and reducing N_2O emissions. A study found that by applying slow-release fertilizer, nitrous oxide emissions were reduced up to 45% compared to traditional fertilization.	Does not require major adjustments to current practices in banana farms.	Cost may limit its use.
Coordinate fertilizer application time with irrigation and rain periods[3,61]	We recommend applying the fertilizer immediately after irrigation or rainfall in order to augment the efficiency of the plants' use of nitrogen. When plants are efficiently using the applied nitrogen, N_2O emissions decrease.	Increases the efficiency of nitrogen use and requires negligible adjustments to conventional practices.	Due to the climate of the different regions it is not always possible to implement this action.
Use of fertilizers with lower N_2O emissions[3,61,64]	Multiple studies have proven that nitrous oxide emissions are directly linked to the type of fertilizer used. The Food and Agriculture Organization of the United Nations (FAO) recommends changing ammonium-based fertilizers for urea fertilizers.	Does not require major adjustments to current practices in banana farms.	Further research is required to determine which type of fertilizer effectively generates lower N2O emissions.
Integrated management of soil fertility[3,63,64]	The integrated management of soil fertility encompasses a strategy that combines organic products such as compost, crop residues, manure, organic fertilizers, etc., with synthetic fertilizers in order to avoid the latter's nutrient deficiencies. Additional organic matter added to synthetic fertilizers will not only help provide nutrients to the soil, but will promote carbon sequestration and water retention as well. It is also pointed out that the use of organic fertilizers generates less N_2O emissions, which will ultimately help reduce the company's emissions.	Profitable and improves the soil's nutrient retention capacity.	Requires more labor for the application of organic fertilizers.
Plant Mycorrhiza[61]	The beneficial relation between certain fungi and plant roots is known as mycorrhiza. Fostering the growth of mycorrhiza facilitates the plants' nutrient absorption from the soil. They also enhance their physical properties and are a means for sequestering carbon in the soil. It is also pointed out that mycorrhiza are more active during photosynthesis, thus capturing larger quantities of atmospheric CO_2.	They are means to strengthen carbon removal for longer periods of time and foster plant photosynthesis.	Inhibitory effects may be observed by applying only synthetic fertilizers without combining them with organic fertilizers. Mycorrhiza are difficult to grow..

Action	Description	Advantage	Disadvantage
Use of nitrogen-capturing plants[3,633]	Growing nitrogen-capturing plants improves the quality of the soil and provides it with nutrients, as they convert nitrogen from the atmosphere into nitrogen available for plants and soil microorganisms. Leguminosae are the plants most used to carry out this function. A few examples include Gliricidia sepium and multiple Erithryna species.	Greater efficiency in capturing nitrogen from the soil and potential reduction in the use of fertilizers.	Nitrogen-capturing plants will take up space in the farm's plots.
Augment vegetation cover and prevent erosion[3]	Degraded soils are at greater risk of suffering the consequences of climate change, which is aggravated by the fact that they easily lose organic matter and biodiversity. A good practice to implement in farms entails increasing the vegetation cover by growing trees all around the crop areas or wherever there is free space in the farm. This will not only help prevent erosion, but also enable a greater atmospheric carbon capture.	Improves soil productivity, increases water retention capacity, creates habitats for the animals of the area and acts as protection barriers.	The main limitation is the use of the areas of the farm, which are potentially exploitable for production.
Introduction of new characteristics and varieties in the crops that are most resilient and better adapted to climate change[3,58,61,63]	Selection via research of banana plant varieties with certain favorable characteristics may constitute in the future a positive action toward reducing emissions and increasing productivity. By selecting the plants, it is possible to develop crops that are more resilient to climate change (resisting drier conditions) and to diseases, and crops with greater atmospheric carbon absorption. These new varieties are still under development, but FAO has stated that they are the cornerstone for sustainable agriculture and food security.	Greater productivity and climate adaptation.	Requires significant investment, many years of research and development of generations of these enhanced plants. Biotechnological interventions have faced opposition.
Agricultura orgánica[3,61,63]	The shift to organic agriculture fosters the reduction of GHG emissions through the use of more ecofriendly inputs in all areas, including the elimination of synthetic fertilizers.	Agricultural products are in greater demand and broadly accepted by markets and consumers, which may represent a competitive edge over other products.	Entails significant changes in the current practices of a conventional farm, Potential productivity decrease.

A12.2. Fossil fuels and lubricant oils

Table A12.2. Measures towards reducing emissions from fossil fuel consumption.

Action	Description
Optimize routes[66,67]	Planning the routes of the trucks that transport the fruit, as well as of company vehicles on required trips, entails studying the best route considering distance, safety and security, type of road, traffic conditions and schedule. This will allow selecting the optimum route that will foster the efficient use of fuels.
Use fuel-saving devices[66,67]	There are devices that may be easily acquired and installed in the vehicles, whose purpose is to reduce fuel consumption. These include tachometers, cruise control or speed control, on-board computer, trip computer, gear shift indicator and speed and overspeed bolt trip.
Conduct periodic checkups of the vehicle[66,67]	It is important to carry out preventive and periodic maintenance of the vehicle in line with the manufacturer's or responsible mechanic's recommendations. Changing oil and filters is important to maintain the vehicle's efficiency, therefore increasing fuel efficiency. We must point out that an air filter in poor condition may reduce the vehicle's efficiency by 10%.
Check the tires at least once a month[66]	The loss of pressure in and the differentiated wear of the tires lead to rolling resistance, which causes a greater need for fuel. It is estimated that a 0.3 bar loss of pressure in the vehicle's tires results in a 3% increase in fuel consumption.
Training in efficient driving and implementation of best practices for efficient driving[66]	In order to achieve significant reductions in this area, awareness must be raised among company workers who drive its vehicles. Up to 15% reduction in fuel consumption may be achieved by driving efficiently. The following are just a few recommended practices: -Efficient use of first gear (only to start the vehicle). -Change gears as soon as possible (for gasoline or LPG vehicles, gears must be changed before reaching 2 500 rpm, and in diesel vehicles before reaching 2 000 rpm). -Delay gear changes in ascents and anticipate the gear change in descents. -Maintain uniform speed (avoid repeated speeding and stopping). -Avoid carrying unnecessary loads.
Avoid unnecessary operation of motors[7]	Power generators, gasoline pumps and other company machinery that is not in use must be kept off. Likewise, use must only respond to their need at a certain time. Saving water and implementing efficiency measures in processes may lead to a reduction in the fuel consumption of equipment
Improve conditions of local roads[7]	Roads that are in good condition improve the efficiency of the vehicles' use of fuel. The company could choose to fix the roads surrounding the farm on which its vehicles and trucks must travel, whenever it can and is able to do so, as a reduction measure

Action	Description
Use renewable energies[3]	Promoting and implementing the use of renewable energies in the farm will allow changing the equipment that uses fossil fuel to electric equipment that is more efficient in terms of emissions generated. Photovoltaic or solar panels or biogas production units for generating electricity may allow replacing fuel pumps with electric pumps operated by renewable energy. Likewise, the need for fossil fuel-based power generators would be reduced. The use of hybrid, electric or LPG vehicles would also reduce emissions from this source.
Choose energy-efficient vehicles[66,67]	If the company is considering the purchase of a vehicle, it is important that it take into account its energy efficiency rating: the more efficient the vehicle, the sounder the purchase in terms of contributing to reducing emissions. It is estimated that by choosing a more efficient vehicle, up to 15% may be saved in fuel, which represents monetary savings to the company. We recommend considering the purchase of vehicles that use fuels other than gasoline or diesel, such as those that use LPG, natural gas, or hybrid or electric vehicles.
Choose vehicles whose dimension suits actual needs[66,67]	It is essential that the company purchase vehicles whose dimensions suit its needs. Banana companies usually require large vehicles to transport certain loads in crates. However, they must take into account that the larger the vehicle, the greater the consumption.

A12.3. Refrigerants and extinguishers

Table A12.3. Measures towards reducing emissions from refrigerant consumption.

Action	Description
Change high GWP refrigerants for others with lower GWP[59]	International agreements to which many countries have adhered have banned and disincentivized the use of refrigerants with high global warming potential (GWP), such as R-22 and R-502. Because of this, refrigerants with lower GWP have been developed and are an alternative to change the refrigerants used in banana company equipment (containers, office A/C, cooling equipment for cafeterias, etc). A few of these alternatives are shown in Table 4.1. In order to select any one of these, a specialized technician must be consulted to ensure the change is suitable for the equipment. For instance, equipment using R-404a may be changed to R-407a, R-407f, R-422a or R-S50, which would not require a change in technology. However, the use of alternatives R-410a, R-417a and R-407c would entail changing the equipment's technology.
Switch to more efficient cooling technologies	If the company has the capacity to do so, we recommend investing in more efficient cooling equipment containing the lowest amount of GWP.
Periodic inspection of leaks and maintenance programs[22,68]	Concerning preventive practices, we recommend conducting periodic inspections to the equipment (containers, office A/C, cooling equipment for cafeterias, etc.), in order to identify and rapidly take care of any leak. By keeping this preventive maintenance system, emissions will be reduced and savings will be made, by avoiding the loss of refrigerants in any potential leaks. We recommend, as stated by the UE, conducting leak tests once a year for systems with 3 to 30kg refrigerant use, and twice a year for systems using a larger amount. Likewise, we recommend as a good practice the engagement of certified companies to conduct these tests. We also recommend keeping water condensers clean in order to ensure the proper efficiency of refrigeration or cooling equipment.
Proper disposal of refrigerants from equipment that is no longer in use	The company must make sure that when it disposes of old equipment containing a refrigerant, the latter is properly recovered and treated in order to ensure it is not released into the atmosphere.
Adjust the schedule for the use of A/C in offices[68]	It is important to make sure that the company's office A/C, if any, be kept off when not in use, and is set at temperatures from 20 to 25 °C.
Efficient use of refrigeration units in kitchens[68]	If the facilities of the Packing Plant or the offices have cafeterias with cooling equipment, we recommend implementing the following measures: -Keep the doors closed for as long as possible and in good condition (air-tight closing). -Periodic maintenance of the installation.
Change CO_2 or HFC extinguishers for extinguishers with agents that do not represent GHG emissions	These may be replaced depending on the type of materials on site. Should it be necessary to fight fires caused by solid fuels (wood, carton, plastic), where there is no electricity or liquid fuel (gasoline, diesel, etc.), water extinguishers may be used.

A12.4. Management of solid and liquid waste (wastewater)

Table A12.4. Measures towards reducing emissions from solid and liquid waste management.

Action	Description
Implementing an anaerobic digester with methane recovery and use (CH_4)[61,69]	A good alternative to reduce the emissions caused by the decomposition of the organic waste resulting from the packing process and not sent to the field as fertilizer or utilized in any other way, is to treat it on site by way of an anaerobic digester. This includes a waste treatment system, in which the waste is placed in a sealed bag, providing an oxygen-free (anaerobic) environment, which will foster the decomposition of the waste and the generation of a gas called "biogas". This gas concentrates approximately 60% methane gas (CH_4), which may be recovered and used to generate electricity for certain farm processes, or to generate thermal energy for furnaces or kitchens. In both cases, the methane combusts producing carbon dioxide (CO_2), a gas with lower global warming potential.
Use of products designed to reduce the organic load of wastewater from the packing process	There are different synthetic and natural products (bioremediators) available in the market, which, when applied in certain doses to the wastewater resulting from washing the fruit, are able to accelerate the degradation of the organic matter found in this water. Degrading the organic matter reduces the chemical and biological oxygen demand of the discharged water (COD and BOD, respectively), thus reducing GHG emissions. We recommend consulting the manufacturer of these products and requesting the safety data sheet to guarantee that it will not jeopardize the quality of the fruit.
Water recirculation in banana washpools	Re-circulating the water in the banana washing process is a practice that has been successfully implemented in certain farms all over the world. This action would reduce emissions by reducing the discharge contaminated with degradable organic matter being dumped into water bodies.

A12.5. Electricity

Table A12.5. Measures towards reducing emissions in consumption from the electrical grid.

Action	Description
Generation of renewable electricity at the farm[11]	Companies may generate their own electricity by way of renewable sources, which would reduce and could even eliminate GHG emissions from this source. Some of the most feasible options for generating electricity using renewable sources are solar or photovoltaic panels and the use of biodigestors with methane recovery. Other options, such as using wind to produce energy or hydro-electricity micro-schemes are also available, but are somewhat more complex and depend on the area.
Eliminate unnecessary lights[68]	It is important to reassess the need for and use of all lights in place at the farm. This will allow identifying and eliminating those that are unnecessary and promoting a more efficient use of electricity.
Install LED or low-consumption fluorescent lights	LED lights are a more efficient technology in terms of electricity consumption, followed by long-lifespan fluorescent lights. We recommend changing the conventional light bulbs in use at the farm, packing plant and offices for any of these lighting systems for a more efficient energy use, therefore reducing emissions as well.
Raise awareness among company workers on the efficient use of the resource	The support of the company's workers is essential in order to reduce electricity consumption, which is why we recommend implementing awareness campaigns on the efficient use of the resource.
Use daylight as much possible	A good practice in the rational use of electricity in a banana company facility includes using daylight for as long as possible. This can be achieved by installing skylights in the roof and setting a schedule for turning lights on and off, considering the work schedule of the farm.

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