DRAFT FOR OPEN COMMENT

GHG Protocol Agricultural Guidance

A sector-specific supplement to the Corporate Standard for agriculture, horticulture and fisheries

GREENHOUSE GAS PROTOCOL

WORLD RESOURCES INSTITUTE

World Resources Institute

Contents

Part 1: GENERAL INFORMATION

Chapter 1 : Introduction

Greenhouse gas (GHG) emissions inventories are fundamental to the design of credible emissions reduction strategies – they help companies identify emissions reduction opportunities, track progress towards reduction targets and communicate this progress to key audiences, including internal management and external stakeholders. Realizing these benefits requires that inventories are prepared according to industry-accepted best practices.

This chapter:

- Introduces the family of GHG Protocol publications that define best practices for developing GHG emissions inventories
- Describes why the Brazilian Agricultural Guidance was developed and for whom
- Describes what guidelines are (and are not) provided in the Brazilian Agricultural Guidance

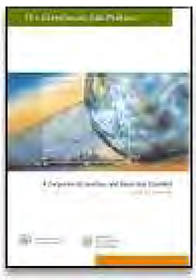
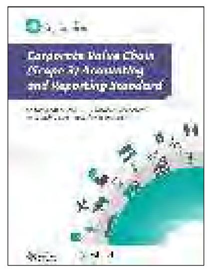
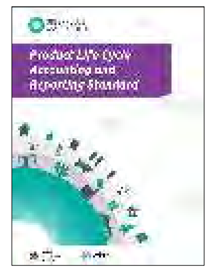
1.1 What is the Greenhouse Gas Protocol?

The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments and others convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Launched in 1998, the mission of the GHG Protocol is to develop internationally accepted GHG accounting and reporting standards and tools for business, and to promote their adoption worldwide. To date, GHG Protocol has released four framework publications that address how GHG emissions inventories should be prepared at the corporate, project, and product levels.

- Corporate-level: The *GHG Protocol Corporate Accounting and Reporting Standard* (‘Corporate Standard’) outlines a standard set of accounting and reporting rules for developing *corporate inventories*, which itemize the emissions from all of the operations that together comprise a company. Building from the Corporate Standard, the *GHG Protocol Scope 3 Accounting and Reporting Standard* (‘Scope 3 Standard’) provides additional guidance and requirements on developing comprehensive inventories of indirect (scope 3) emissions (see below and Box 1-1 for definitions).
- Project-level: The *GHG Protocol Project Protocol* (‘Project Protocol’) describes how companies can quantify the GHG impacts of projects undertaken to reduce emissions, avoid emissions occurring in the future or sequester carbon.
- Product-level: The *GHG Protocol Product Life Cycle Accounting and Reporting Standard* (‘Product Standard’) describes how companies can develop GHG emissions inventories of the entire life cycle of individual products or services, from raw material extraction to product disposal.

These publications, together with supplementary guidance for specific sectors or types of sources (Table 1-1), are available from the GHG Protocol website (www.ghgprotocol.org).

Table 1-1. The GHG Protocol family of publications

	Level of GHG analysis			
	Corporate		Project	Product
Framework GHG Protocol publication	*Corporate Accounting and Reporting Standard*, revised edition (2004) 	*Scope 3 Accounting and Reporting Standard* 	*Protocol for Project Accounting* 	*Product Life Cycle Accounting and Reporting Standard* 
Supplementary GHG Protocol guidance for specific sectors or types of sources	- *Power Accounting Guidelines* (cross-sector guidance on reporting investments in and purchases of various renewable energy products) - This *Agricultural Guidance*		*The Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting*	Forthcoming (e.g., ICT guidance)

1.2 Why an Agricultural Guidance?

Agricultural activities have a massive impact on the climate. While the exact contributions of food production to global greenhouse gas (GHG) emissions are uncertain, it has been estimated that the food supply chain contributes approximately 19 to 29% of total global anthropogenic emissions (on a *CO_2-equivalent* basis)[1]. Agriculture and agriculture-driven land use change (*LUC*) are responsible for 80-86% of this amount, each having perhaps a roughly equal impact. On-farm sources alone emit roughly 60% of all nitrous oxide (N_2O) emissions and 50% of all methane (CH_4) emissions (Placeholder2). Agriculture is also the largest proximate cause of land use change globally, with most land use change emissions resulting from the expansion of agricultural lands into tropical forests. The remainder of the emissions from the food supply chain come from the production of farm inputs, such as fertilizers, pesticides and

[1] Italicized terms are defined in the Glossary.

farm machinery, and from various postproduction activities, such as food processing, storage, packing, transport and refrigeration.

While the future impacts of climate change on agricultural systems are not yet fully understood, they are widely expected to be profound. Specific effects might include increased irrigation water needs, spread of animal and crop diseases and pests, reduced forage quality, and reduced crop and pasture yields in low-latitude regions or more broadly as a result of extreme weather events (Placeholder4). Reductions in agricultural emissions are therefore important in lessening the effects of climate change on the sector. And, at the farm level, activities undertaken to reduce emissions often have direct co-benefits, such as increased productivity and reduced costs (see Chapter 2.1).

Key to realizing emissions reductions is the ability to measure and track emissions. Corporate GHG emissions inventories provide this ability - they can be used to identify and prioritize reduction strategies at the corporate level, track progress toward reduction goals, and communicate this progress to investors and civil society.

The overarching goal of the GHG Protocol Agricultural Guidance is to supplement the Corporate Standard and provide more customized guidance to primary producers (‘producers’) on how they should incorporate the GHG emissions from agricultural production into their inventories. The specific objectives of this publication are to:

- Increase consistency and transparency in GHG accounting and reporting within the primary production sector
- Help companies cost-effectively prepare GHG inventories that are true and fair accounts of their climate impact, through the use of standardized approaches and principles
- Enable GHG inventories to meet the decision-making needs of both internal management and external stakeholders (e.g., investors) and so provide for the more effective management of emissions along the agricultural supply chain

This Guidance aims to be policy neutral, while retaining sufficient flexibility to meet the needs of future policy, market and program frameworks and to meet the above objectives.

1.3 *Who should use this Protocol?*

This publication is relevant to a wide array of organizations (Figure 1-1)[2] including:

- Producers – agricultural, fishery and horticultural operations that raise animals or catch seafood, or grow grains, vegetables, fruits, and other crops[3]. This publication includes guidance on accounting for the CO_2 fluxes associated with the *carbon stocks*

[2] The term ‘entities’ is used throughout the text to refer to those organizations that might undertake GHG accounting of agricultural GHG emissions, including producers and downstream buyers. The term ‘farm’ is occasionally used as a shorthand for an agricultural or harvesting enterprise.

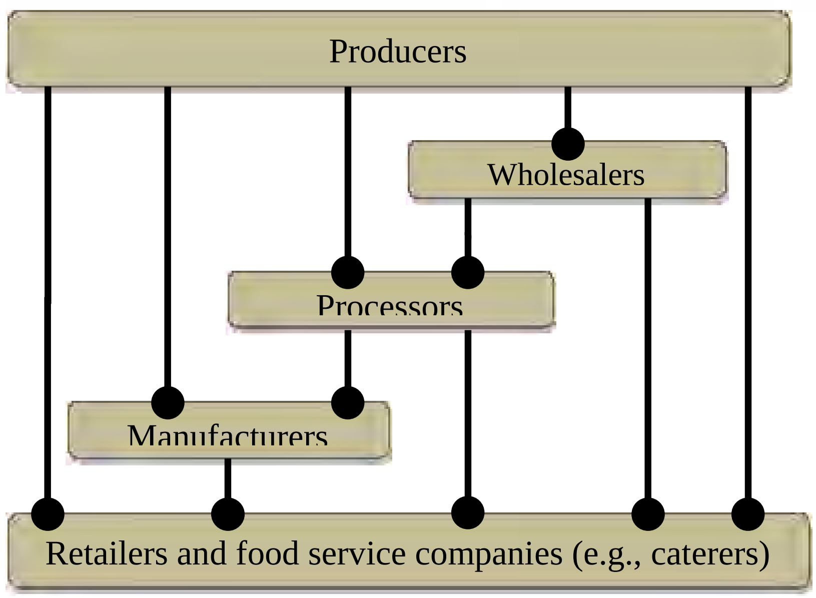
[3] The term ‘*agriculture’ or ‘agricultural products’* is used as a shorthand throughout the text to encompass these different sectors and outputs.

in *agroforestry systems*, short-rotation woody biomass plantations and forested conservation areas on farmland, including wood strips and riparian buffers. Consequently, while not specifically intended for use by forestry companies, this publication is expected to help inform inventory decisions in the forestry sector.

- Downstream companies that wish to understand how they can quantify and report the emissions resulting from their procurement of agricultural goods. These companies include processors (e.g., slaughterhouses), brand manufacturers that make packaged food products, retailers that sell their shelf space to brand manufacturers or make private label food products, food service companies such as restaurants and caterers, and wholesalers that obtain agricultural products from producers and sell them on to other components in the supply chain.
- GHG reporting programs and policy makers interested in developing accounting and reporting specifications for agricultural emissions sources. The Agricultural Guidance outlines globally applicable principles and methodologies that GHG programs may adopt directly or customize to meet their own reporting conventions.

Chapter 2 describes reasons why these different groups might wish to use this publication.

Figure 1-1. A simplified food production supply chain. Primary producers grow crops or raise livestock, which might then be packed and sold directly to retailers or wholesalers, or which may need processing and/or manufacture (e.g., into ready meals), before reaching the end retailers and the consumer's plate.



1.4 How does the Agricultural Guidance relate to other GHGP publications?

The Agricultural Guidance is not intended to be used as a stand-alone document, but rather to be used rather in conjunction with either the Corporate Standard, for producers that wish to develop inventories of their on-farm sources, and/or the Scope 3 standard, for downstream buyers that wish to include agricultural sources in their scope 3 inventories.

Relation to the Corporate Standard
The Corporate Standard is the leading international business tool for developing entity-level GHG inventories. It has been adopted by virtually all mandatory and voluntary GHG reporting programs around the world, such as the Carbon Disclosure Project and The Climate Registry; by multiple, industry-led sustainability initiatives, such as the Cement Sustainability Initiative; and by the International Standards Organization (ISO). Further examples of users of the Corporate Standard can be found at: http://www.ghgprotocol.org/standards/corporate-standard/users-of-the-corporate-standard.

Because the Corporate Standard provides a high-level, cross-sector accounting framework, it does not adequately address many of the accounting and reporting issues specific to agriculture. These include:

- The profound influence of environmental factors on agricultural GHG fluxes (emissions or removals), which complicate efforts to separate anthropogenic from non-anthropogenic effects and thus ensure that GHG inventories are actually useful as management tools.
- Setting and tracking progress toward emission reduction goals against a background of highly variable GHG fluxes.
- Carbon sequestration and accounting for changes in the management and ownership of different *carbon pools*.
- The types of organizational structures and operational practices specific to the sector.

The Agricultural Guidance addresses these and other sector-specific issues. It is intended to be used in conjunction with the Corporate Standard. Table 1-2 summarizes the main topics addressed in this Guidance and how they map onto the different chapters of the Corporate Standard.

The Corporate Standard has defined the scope framework for structuring GHG inventories (Box 1-1). The focus of this Guidance is on including scope 1 and scope 2 sources in inventories, although certain scope 3 sources are also discussed because of their importance in terms of GHG emissions.

Box 1. The Concept of Scopes

The emissions sources in an entity-level inventory are categorized as either *direct* or *indirect* and grouped into three scopes (Figure 1-4):

- Direct sources: These are owned or controlled by the reporting entity. All direct sources are classified as *scope 1*.
- Indirect sources are owned or controlled by a third party, but their emissions are nonetheless influenced by the reporting entity. Indirect sources are either *scope 2* or *scope 3*: scope 2 emissions stem from the generation of electricity that is purchased by the reporting entity, while scope 3 emissions are all other indirect emissions.

Figure 1-4. The classification of emissions sources into the three scopes in corporate inventories

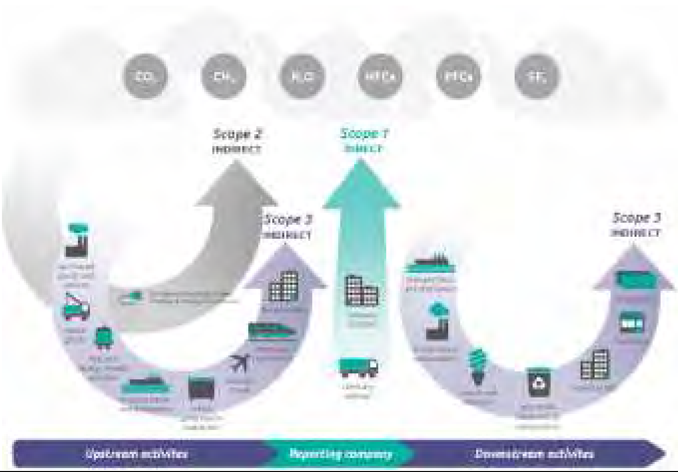


Table 1-2. Overview of how the content of this publication maps onto that of the Corporate Standard

Chapter in Corporate Standard	Corresponding guidelines in the Agricultural Guidance
Chapter 1: GHG Accounting and Reporting Principles	Chapter 3 reviews these principles and highlights tensions between principles that may be encountered in the sector
Chapter 2: Business Goals and Inventory Design	Chapter 2 highlights business goals specific to producers downstream buyers
Chapter 3: Setting Organizational Boundaries Chapter 4: Setting Operational Boundaries	Chapter 5 provides guidance on setting inventory boundaries in relation to common types of organizational structures and operational activities in the sector

Chapter 5: Tracking Emissions Over Time	Chapter 6 reviews how emissions performance can be tracked over time, including the selection and use of base periods and ratio indicators
Chapter 6: Identifying and Calculating GHG Emissions	• Chapter 4 reviews the emissions sources associated with agriculture • Chapter 7 reviews common approaches and data requirements for calculating emissions • Appendix 1 summarizes a range of GHG emissions calculation tools for agriculture
Chapter 7: Managing Inventory Quality	No supplementary guidance provided
Chapter 8: Accounting for GHG Reductions	Chapter 9 provides guidance on accounting for renewable energy projects on farms
Chapter 9: Reporting GHG Emissions	Chapter 9 describes the types of information that are either mandatory or optional in inventories
Chapter 10: Verification of GHG emissions	No supplementary guidance provided
Chapter 11: Setting GHG Targets	Chapter 6 describes new requirements for setting GHG targets and the utility of rolling base periods in the sector
Appendix A: Accounting for Indirect Emissions from Electricity	No supplementary guidance provided
Appendix B: Accounting for Sequestered Atmospheric Carbon	Chapter 8 introduces methodologies for accounting for changes in the management and ownership of carbon pools. This guidance supersedes that in the Corporate Standard
Appendix C: Overview of GHG Programs [a revised version of this Appendix will be released online shortly]	No supplementary guidance provided
Appendix D: Industry Sectors and Scopes	Not relevant to producers, but possibly relevant to downstream buyers with supply chains in other sectors. No supplementary guidance provided
Appendix E: Base Year Adjustments	No supplementary guidance provided
Appendix F: Categorizing GHG Emissions from Leased Assets[Note: This guidance may be revised in the near future, depending on what new financial accounting rules are released by the IASB for lease accounting]	Chapter 5 summarizes the requirements for lease accounting

Under the Corporate Standard, companies must report emissions of at least the seven *Kyoto GHGs*, which are: carbon dioxide (CO_2), CH_4, N_2O, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexaflouride (SF_6), and nitrogen triflouride (NF_3). This same principle applies to companies using the Agricultural Guidance. However, agricultural activities typically generate only a subset of these GHGs (see Chapter 4).

Finally, the Agricultural Guidance occasionally has recommendations that diverge from those in the Corporate Standard, primarily in relation to the reporting of biogenic CO_2 fluxes (Table 1-3). In such cases the Agricultural Guidance has primacy – in order for producers to be in conformance with GHG Protocol requirements, they should first defer to the Agricultural Guidance.

Table 1-3. Differences between the Agricultural Guidance and Corporate Standard

GHG accounting or reporting issue	Recommendation in the Agricultural Guidance	Requirement in the Corporate Standard
Biogenic CO_2 fluxes	• Generally, reported separately from the scopes and any other memo items, within a special category 'Biogenic carbon' • Biogenic CO_2 emissions from natural disturbances and unmanaged lands may be excluded from inventories • Biogenic CO2 fluxes from land use change and agricultural activities should be reported separately	Reported as a memo item, outside of the scopes
Reporting of *mechanical* versus *non-mechanical sources* in inventories (see Chapter 4.1 for explanations of these source categories)	Should be reported separately	None
GHG reduction targets	Disaggregated into two components: the emissions reported in the scopes and biogenic CO2 fluxes	No requirement to disaggregate targets
Others ?		

Throughout the text, this Guidance provides links to specific chapters of the Corporate Standard where additional guidance on the accounting topics at hand can be found.

Links to the Corporate Standard

Relation to the Scope 3 Standard

GHG emissions from agriculture are often the largest source of emissions for downstream buyers (see Chapter 2), and these buyers may also have significant opportunities to influence these emissions. Therefore, developing a full entity-level GHG emissions inventory– incorporating scope 1, scope 2, and scope 3 emissions – enables these buyers to focus on the greatest opportunities to reduce emissions across their value chains, leading to more sustainable decisions about their products, purchases, and business processes. The Scope 3 Standard is especially relevant for companies setting and tracking GHG targets in relation to corporate-wide goals.

While scope 3 emissions are reported optionally under the Corporate Standard, the Scope 3 Standard requires that all scope 3 emissions be reported to the extent relevant and practicable. The Scope 3 Standard identifies 15 different categories of scope 3 sources, ranging from upstream sources, such as the production of purchased goods and services, and business travel, through to downstream sources, such as the transportation, processing, use and disposal of sold products.

The Agricultural Guidance is relevant to one specific scope 3 category: Purchased Goods and Services (category # 1 in the Scope 3 Standard). The Agricultural Guidance does not introduce different requirements from those in the Scope 3 Standard.

Relation to the Product Standard

While product life cycle accounting (LCA) is commonly undertaken for food products, product LCA inventories and entity-level inventories can be developed independently. Nonetheless, product LCA inventories and entity-level inventories (when scope 3 emissions are included) are complementary and they together provide a comprehensive approach to value chain GHG emissions management. Instances where product LCA and entity-level inventories are mutually supportive include:

- The use of entity-level inventories as a screen to identify products that are likely to have the most significant footprints based on their use of highly emitting sources, such as specific raw materials (e.g., fertilizers), etc.
- The use of product LCA inventories to inform GHG reduction strategies that impact both product and entity-level inventories.
- The use of product LCA inventories to extrapolate to relevant upstream and downstream scope 3 emissions in an entity-level inventory.

Much of the same data used to complete a scope 3 inventory is also useful for product LCA inventories. Consequently, entities may find added business value and efficiencies in completing scope 3 and product inventories in parallel. However, entities should be mindful of differences in the reporting requirements of the Agricultural Guidance and Product Standard that can affect the extent to which both types of inventories are mutually supportive (Table 1-4).

Table 1-4. Differences in the reporting requirements of the Agricultural Guidance and Product Standard that affect how useful a corporate inventory is for product inventories (and vice-versa)

GHG reporting issue	Recommendation in the Agricultural Guidance	Requirement in the Product Standard
Emissions sources upstream or downstream of primary production	Need not be reported	Emissions from all relevant upstream and downstream sources should be reflected in the LCA inventory of a given product (though downstream emissions need not be considered

		in cradle-to-farm gate analyses)
CO_2 fluxes to/from carbon stocks in soils as a result of agriculture or LUC	Should be reported separately from the scopes and any other memo items, within a special category, 'Biogenic carbon'	• Need not be reported within a product inventory • If reported, shall be reported separately from non-biogenic fluxes
CO_2 fluxes to/from carbon stocks in biomass		• Shall be reported for all types of biomass stocks, including annual and herbaceous perennial crops, and pastures. • Shall be reported separately from non-biogenic fluxes
Timeline for reporting the GHG emissions from the biomass combustion associated with LUC	Should be reported in year concerned	All LUC emissions attributed to products produced from the land concerned shall be amortized over at least a 20-year period.
Others?		

Relation to the Project Protocol

The revenue from offset credits is often mentioned as a leading reason for why producers should become interested in managing their GHG emissions. Soil carbon sequestration, in particular, is considered an important potential source of offset credits because it offers most (~89%) of the global potential for reducing the emissions from agriculture (Placeholder8). The Corporate Standard, and therefore the Agricultural Guidance, does not address the accounting steps needed to create offset credits from soils, biomass or other sources located on farms (e.g., manure management). For example, the Agricultural Guidance is not concerned with the permanence of carbon sequestration. Instead, fluxes to/from carbon stocks are simply reported as they occur (or expected to occur) and there is no consideration of policy measures to ensure the permanence of sequestered carbon (e.g., insurance mechanisms, project buffers, etc.). For such guidance readers should instead refer to two companion GHG Protocol publications: *The GHG Protocol for Project Accounting* (*Project Protocol*) and *Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting*. See http://www.ghgprotocol.org/standards/project-protocol.

A note on terminology in GHG Protocol Standards

The GHG Protocol uses specific terms to connote reporting requirements and recommendations. The term "shall" is used to indicate what is required for a GHG inventory to conform to a given Standard. The term "should" is used to indicate a recommendation, but not a requirement. The term "may" is used to indicate an option that is permissible or allowable.

1.5 How was this Guidance developed?

[To be completed once the Protocol has been finalized]

1.6 What does this Guidance not do?

This Agricultural Guidance is squarely focused on entity-level accounting and reporting issues. As a result, it does not:

- Provide accounting methods for the CO_2 emissions from the production and combustion of commercial biofuels. While the CH_4 and N_2O emissions from biofuel combustion should be reported in inventories, consensus on the accounting methodologies for CO_2 emissions has not yet materialized and requires the analysis of complex life cycle and *indirect Land Use Change* (iLUC; see below) issues that are beyond the scope of the Corporate Standard and this publication. Note, however, that the Agricultural Guidance does provide guidance on accounting for the combustion of biomass that is not sent beyond the farm boundary as biofuel stock, but instead combusted on-site for energy production or other purposes (see Chapter 8).
- Provide accounting methods for iLUC. iLUC occurs when changes in the types of agricultural products farmed in one area lead to the expansion of agricultural land into native habitats in another. An example of iLUC is when a soybean field in one country is converted to corn, while the demand for soybean remains at a constant level, such that that demand is then met by converting a forest in another country to a soybean field. Accounting for such iLUC impacts requires a project-based approach to determine what the emissions would have been in the absence of any management changes on a farm (on the original soybean farm in the current example). The Project Protocol provides relevant guidance on accounting for iLUC.
- Provide guidance on the selection and deployment of GHG mitigation practices on farms. Individual mitigation measures will have a range of co-benefits and costs that would need to be evaluated at the field level in designing a corporate GHG reduction strategy (see Chapter 2.1 for examples of co-benefits), including trade-offs between the emissions of different GHGs. These trade-offs should be assessed using a whole-farm approach (see Chapter 7.1). Chapter 9.3 provides guidance on accounting for the development of on-farm renewable energy projects.
- Recommend sector-specific GHG performance metrics. To have most relevance, metrics that are used to assess performance against that of other businesses, as well as industry averages and best practices, should be developed through close sectoral cooperation. While the Agricultural Guidance does not recommend specific metrics, it does outline accounting procedures relevant to understanding what and how emissions sources should be included in metrics (e.g., through the use of boundary approaches; Chapter 5), as well as how emissions should be allocated to agricultural by-products (Chapter 2).
- State value positions on miscellaneous sustainability issues such as large versus small agriculture, GMOs, or food miles.

Chapter 2 : Business goals

The development of a GHG emissions inventory can be a significant undertaking. Entities should therefore have clearly defined goals for managing their GHG emissions and understand how inventories will allow them to meet those goals. Entities generally want their GHG inventories to be capable of serving multiple goals. It therefore makes sense to design the inventory process from the outset to provide information for a variety of different users and uses – both current and future. The Corporate Standard (and thus the Agricultural Guidance) has been designed as a comprehensive GHG accounting and reporting framework to provide the information building blocks capable of serving multiple business goals.

This chapter:

- Reviews the various goals that GHG emissions inventories can help producers, downstream buyers and policy makers meet
- Illustrates the value of developing inventories using real world examples

2.1 *Overview of business goals*

Entities along agricultural supply chains can have diverse reasons for developing inventories and managing the GHG emissions from agriculture. Many of these drivers are common to both producers and their downstream buyers, and these drivers generally involve (Table 2-1):

- Understanding the operational and reputational risks and opportunities associated with agricultural emissions
- Identifying GHG reduction opportunities, setting reduction targets, and tracking performance
- Reporting to stakeholders, including civil society and internal management
- Supply chain engagement and management

Entity-level inventories can also help policy makers plan and implement policies that aim to reduce emissions at the farm level.

Producers

Many of the GHG reduction measures that can be implemented on farms have other, positive impacts on the productivity and environmental status of farming systems. These co-benefits can include (Table 2-2):

- Increased productivity
- Reduced erosion and land degradation
- Reduced phosphorous (P) and nitrogen (N) runoff

- Improved water quality and retention
- Control of air pollutants (e.g, ammonia and hydrogen sulphide)
- Increased soil fertility
- Reduced energy costs

While a farm management practice is seldom adopted for its effect on GHG emissions alone, these co-benefits are often instrumental in driving the adoption of practices that do reduce emissions. The ability to maintain or increase productivity is often the overriding factor. Entity-level inventories are useful in identifying practices that both reduce emissions and increase productivity or yield other co-benefits (see Box 2-1 for examples).

Because agro-ecosystems are inherently complex, management practices that reduce emissions and yield other co-benefits should not be selected in isolation of each other, but rather selected using a whole-farm or systems approach. This ensures that interactions between the carbon (C) and N cycles on farms, as well as trade-offs between the emissions of different GHGs are taken into account, and that mitigation practices can be more effectively integrated into individual farming systems (see Chapter 7.1).

Box 2-1. Examples of how entity-level inventories can help identify opportunities to reduce emissions and realize other benefits.

Example A - A livestock enterprise in Victoria, Australia, holding over 2000 head of sheep and 77 cattle on 654 hectares. The owner conducted an inventory and determined that carbon sequestration in trees was at a minimum. He subsequently planted 10 hectares with mixed environmental plantings, helping to not only increase carbon sequestration but to also reduce land erosion. (source: here)

Example B - A mixed crop-livestock system in Scotland that consisted of permanent/rotational grassland, cropland (cereals), and grazed woodland on 457 ha, as well as 300 cattle and 355 over-wintering sheep. The inventory revealed that emissions were largely balanced by carbon sequestration, and that the major emissions sources were livestock and fertilizer and manure use. It was also determined that the following changes would reduce emissions and make the farm more efficient and perhaps more profitable.

- Altering animal diet/breeds
- Increased N uptake efficiency
- Improved manure management
- Improved cultivation practices (minimum tillage, one-pass)

(Source: www.sruc.ac.uk/downloads/file/81/carbon_footprint_reporting_for_a_scottish_livestock_farm)

Downstream buyers

Agricultural emissions dominate the emissions from the global food supply chain (Section 1.2). As such, many buyers find that their combined scope 1, 2 and 3 corporate inventories or the lifecycle inventories of the products they make are often dominated by the emissions from agriculture. For example:

- Kraft Foods reviewed their entire supply chain using secondary data and determined that emissions embedded in their purchased agricultural inputs were 17 times higher than their direct emissions from their own operations (Source: GHG Protocol Scope 3 Standard).
- 93% of emissions from milk production globally occur up to the farm gate (Placeholder9)
- Over 90% of the emissions from the production of retailed pork meat can occur on farms

In general, agricultural sources contribute less to the overall life-cycle inventories of crop-based products than they do to those of livestock-based products. However, the relative importance of on-farm and off-farm sources will vary considerably, depending on proximity to markets (i.e. transportation emissions), the amount of processing and packaging, the type and volume of farm inputs (especially fertilizer), and the agricultural practices used (e.g., the use of heated greenhouses, soil management practices, etc).

By engaging producers and including agricultural emissions in their inventories, supply chain partners can vastly increase their ability to understand and manage their value chain GHG impacts (see Box 2-2 for examples).

Box 2-2. Examples showing how supply chain partners can partner with producers to reduce emissions from agricultural production.

Example A - PepsiCo developed farm-level inventories for over 80 British potato farms supplying its Walkers crisps brand, allowing farm benchmarking and the development of carbon action plans, both for PepsiCo and its individual suppliers. Through this process, PepsiCo was able to identify a number of producers who were using as much as five times more fertilizer than required – these growers were subsequently able to reduce fertilizer applications while maintaining yields.

Example B - Sainsbury's determined the GHG inventories of 325 of its dairy suppliers, allowing these suppliers to implement measures that reduced emissions on a per liter milk basis. The mitigation measures included light control mechanisms, harvesting rainwater for re-use, and installing plate-coolers to cool milk. At the same time, the farmers were able to cut their unit cost of production by, for example, achieving higher yields per cow, by using their feed more efficiently, or managing their fertilizer and manure applications differently.

Example C - Costco assessed GHG emissions from organic egg production in the US, helping it understand how both geography and management practices affected emissions. This led to the identification of practical mitigation options, which their farmers are now in the process of evaluating. Costco also organized a live GHG assessment meeting with the farmers representing the country's entire supply of organic eggs to Costco stores. These growers were able to see how their practices measured up against other farmer's practices and to share tips and ideas for GHG emissions reductions.

(Source = SFL)

Policy makers

The spectrum of policy options to reduce agricultural GHG emissions is extremely broad and includes technical and business advice to build capacity in GHG management best practices; reporting programs to monitor patterns of emissions at the entity-level; regulatory controls, such as prohibitions on certain types of land use change or controls on the intensity and timing of field operations; and incentives, such as payments for emissions reductions or assistance with investments in less GHG-intensive technologies.

Accurate emissions data is crucial to ensuring that policy makers can properly plan, implement and track the impacts of such policies. Much of these data are required at the farm-level. For example, if farm-level emissions have been over-estimated, regulatory controls will force farmers to bear unnecessary adjustment costs and the GHG emissions reductions will be less than anticipated. Equally, if farm-level emissions have been under-estimated, farmers may receive insufficient credit for reducing emissions, leading to reduced rewards under any payment scheme.

Table 2-1. Business goals served by including agricultural emissions in entity-level inventories

Business Goal	Description
Understand operational and reputational risks and opportunities associated with agricultural emissions	Identify climate-related risks (e.g., determine whether agricultural or processing facility would be subject to government regulations, such as a cap and trade scheme or other reporting scheme)
	Understand economic and environmental co-benefits of managing emissions (see Table 2-2 for examples)
	Enhance market opportunities (e.g., access niche markets with potential price premiums)
	Guide investment and procurement decisions (e.g., supply chain partners can obtain assurance that the agricultural goods were produced under environmentally sustainable conditions)
Track and reduce emissions	Identify emissions hot spots and reduction opportunities, and prioritize GHG reduction efforts (see Box 2-1 and Box 2-2 for examples)
	Set GHG reduction targets
	Measure and report GHG performance over time
	Develop performance benchmarks and assess performance against industry averages and competitors
Report to stakeholders	Meet needs of stakeholders through public disclosure of GHG emissions and of progress towards GHG reduction targets
	Participate in voluntary reporting programs to disclose GHG related information to stakeholder groups
	Report to government reporting programs at the international, national, regional or local level
	Improve corporate reputation and accountability through public disclosure
Supply chain engagement and management	Partner with companies in the value chain to achieve GHG reductions (see Box 2-2 for examples)
	Expand GHG accountability, transparency, and management in the supply chain (e.g., through capacity building amongst suppliers)
	Enable greater transparency on companies' efforts to engage suppliers
	Reduce energy use, costs, and risks in the supply chain and avoid future costs related to energy and emissions

Table 2-2. Examples of agricultural practices that reduce GHG emissions, while improving other aspects of farm performance

GHG reduction measure	Description	Effect on GHGs	Environmental co-benefits	Agronomic / business benefits	Potential trade-offs or problems
Cover crops	Non-commodity crops planted in between rows of commodity crops or during fallow periods	Soil carbon sequestration through incorporation of crop residues into soil Reduced NO_3 leaching by intercepting N that would otherwise have been lost from the plant-soil system	• Add nutrients to soil • Reduce wind and water erosion	• Reduced fertilizer needs • Reduced weed growth • Reduced irrigation needs • Supplemental livestock feed (extends grazing season, cattle weight gain) • Increased profit	Requires extra time and knowledge to manage, and some new techniques for growing commodity crops
Conservation tillage	A range of cultivation techniques (including minimum till, strip till, no-till) designed to minimize soil disturbance for seed placement,	Soil carbon sequestration; Reducing N in overland flow (indirect emissions)	• Improved soil water retention and drainage • Reduced water and wind erosion	• Reduced fertilizer needs • Reduced fuel and labor costs • Improved yields	Potential increase in herbicide use, increased pest threats in repetitive single commodity production

GHG reduction measure	Description	Effect on GHGs	Environmental co-benefits	Agronomic / business benefits	Potential trade-offs or problems
	by allowing crop residue to remain on soil after planting				
Rotational or mob livestock grazing on pasture	Grazing practices that maximize plant health and diversity while increasing animal carrying capacity of the land	Soil carbon sequestration	• Increased plant cover and productivity • Improved soil water retention and drainage • Reduced water and wind erosion	• Increased herd size • Can increase length of grazing season • Reduced need for purchases of feed • Pastures more able to exclude weeds / exotic species • Potentially reduced herbicide costs	Requires careful management in some areas with sensitive species
Anaerobic digester	Enclosed system in which organic material such as manure is broken down by microorganisms under anaerobic conditions	Reduced N_2O and CH_4 emissions from manure management	• Reduced risk of accidental toxic leakages (pathogens killed) • Reduction in toxic odor and VOC emissions	• Processed solids can be used as bedding • Reduced costs • Reduced need for fertilizers (as nutrient availability in the digestate is increased) • Electricity / heat generation •	Digester technologies can be expensive
Windbreaks	Plantations usually made up of one or more rows of trees or shrubs planted in	Carbon sequestration in biomass and soils	• Reduced soil erosion	•	

GHG reduction measure	Description	Effect on GHGs	Environmental co-benefits	Agronomic / business benefits	Potential trade-offs or problems
	such a manner as to provide shelter from the wind and to protect soil from erosion				
Switch from constantly flooded to intermittently flooded rice fields		Reductions in methane emissions (oxygen is allowed to reach soil)	• Reduced water use and increased use of rainfall	• Less fuel used in irrigation	
Switch from 'active' fisheries techniques, such as dredging, bottom trawling and beam-trawling, **to 'passive' techniques**, such as creel or seine fishing		Reduced GHG emissions from fishing fleet fuel use	• Reduced by-catch of non-target species • Potentially, less squashing of catch in trawlers' nets. • Less destruction of benthic habitats		Switching may not be economically viable depending on the species concerned

Chapter 3 : Principles

As with financial accounting and reporting, generally accepted GHG accounting principles are intended to ensure an inventory represents a faithful, true, and fair account of a company's GHG emissions.

This chapter: ➢ Introduces generally accepted GHG accounting and reporting principles that should guide the use of the Agricultural Guidance

3.1 Overview of principles

The following principles are adapted from the Corporate Standard and are intended to guide the implementation of the Agricultural Guidance, particularly when its guidance in specific issues or situations is ambiguous.

Relevance: The GHG inventory should appropriately reflect the GHG emissions of the company and serve the decision-making needs of users – both internal and external to the company.

Completeness: Companies should account for and report on all GHG emission sources and activities within the inventory boundary, to the extent practicable and relevant to the purpose of the inventory

Consistency: Companies should use consistent methodologies to allow for meaningful performance tracking and comparison of GHG emissions data over time, business units, geographies or suppliers.

If there are changes to the inventory boundary that affect emission estimates (e.g., inclusion of previously excluded sources, methods, data or other factors), they should be transparently documented and justified, and may warrant recalculation of emissions data (see Chapter 6).

Transparency: Companies should address all relevant issues in a factual and coherent manner, based on a clear audit trail.

Transparency relates to the degree to which information on the processes and procedures of the GHG inventory are disclosed in a clear, factual, neutral, and understandable manner based on clear documentation and archives (i.e., an audit trail). A transparent report will allow internal reviewers and external assurance providers to attest to its credibility and allow a meaningful assessment of the emissions performance of the reporting company. In ensuring transparency, specific exclusions need to be clearly identified and justified, assumptions disclosed, and appropriate references provided for the methodologies applied and the data sources used.

Accuracy: Companies should ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. A level of accuracy is needed that will allow users to make decisions with reasonable confidence as to the integrity of the reported information.

The accuracy of emissions data is a particular concern for many agricultural sources (see Chapter 7). Reporting on measures taken to ensure accuracy and improve accuracy over time can help promote the credibility and enhance the transparency of inventories.

Trade-offs between principles

Companies may encounter trade-offs between principles when completing an inventory and should strike a balance between these principles, depending on their individual business goals.

Trade-offs will be particularly common in relation to accuracy. A company may find that achieving the most complete inventory requires the use of less accurate data, compromising overall accuracy. Conversely, achieving the most accurate inventory may require the exclusion of activities with low accuracy, compromising overall completeness. 0 provides guidance on developing inventories that balance competing principles, while remaining relevant to a company's business goals.

Chapter 4 : Overview of agricultural emission sources

Many different types of emissions sources are associated with agriculture. Understanding the qualitative differences amongst these is crucial to many steps in inventory development, including emissions calculation, emissions reporting and inventory quality control.

This chapter:

- Provides an overview of the main emissions sources directly associated with agriculture, both on farms and beyond the farm gate
- Distinguishes between two types of on-farm emissions sources – mechanical and non-mechanical sources – whose emissions differ in fundamental ways, with important implications for GHG inventory development
- Describes the relative importance of different on-farm sources, both at the farm- and the global-level

4.1 Overview of on-farm and supply chain emissions

GHG emissions vary markedly across the different phases of the global food chain. In general, the direct emissions from agricultural production and land use change dominate the emissions from the entire chain (Table 4-1), although the relative significance of pre- and post-production phases vary a lot, depending on the country and sector concerned. For instance, post-production stages will generally be more important in high-income countries. Regardless, a diverse range of emissions sources is connected with agriculture (Figure 4-1).

It is fundamentally important to distinguish between two categories of emission sources:

1. **Mechanical sources:** These consume fuels or electricity and largely emit GHGs through the physical process of combustion, either at the site of power generation or consumption. Their emissions generally depend on how much combustion has occurred. Examples of mechanical sources include harvesting or irrigation equipment, and fishing vessels. Mechanical sources are typically relatively small components of producer-level inventories (see Chapter 4.3), although they are relatively more important in certain sectors (e.g., fisheries).
2. **Non-mechanical sources:** These largely emit GHGs through bio-chemical processes and their emissions generally depend on a wide array of environmental conditions and are often connected by complex patterns of N and C flows through farms.

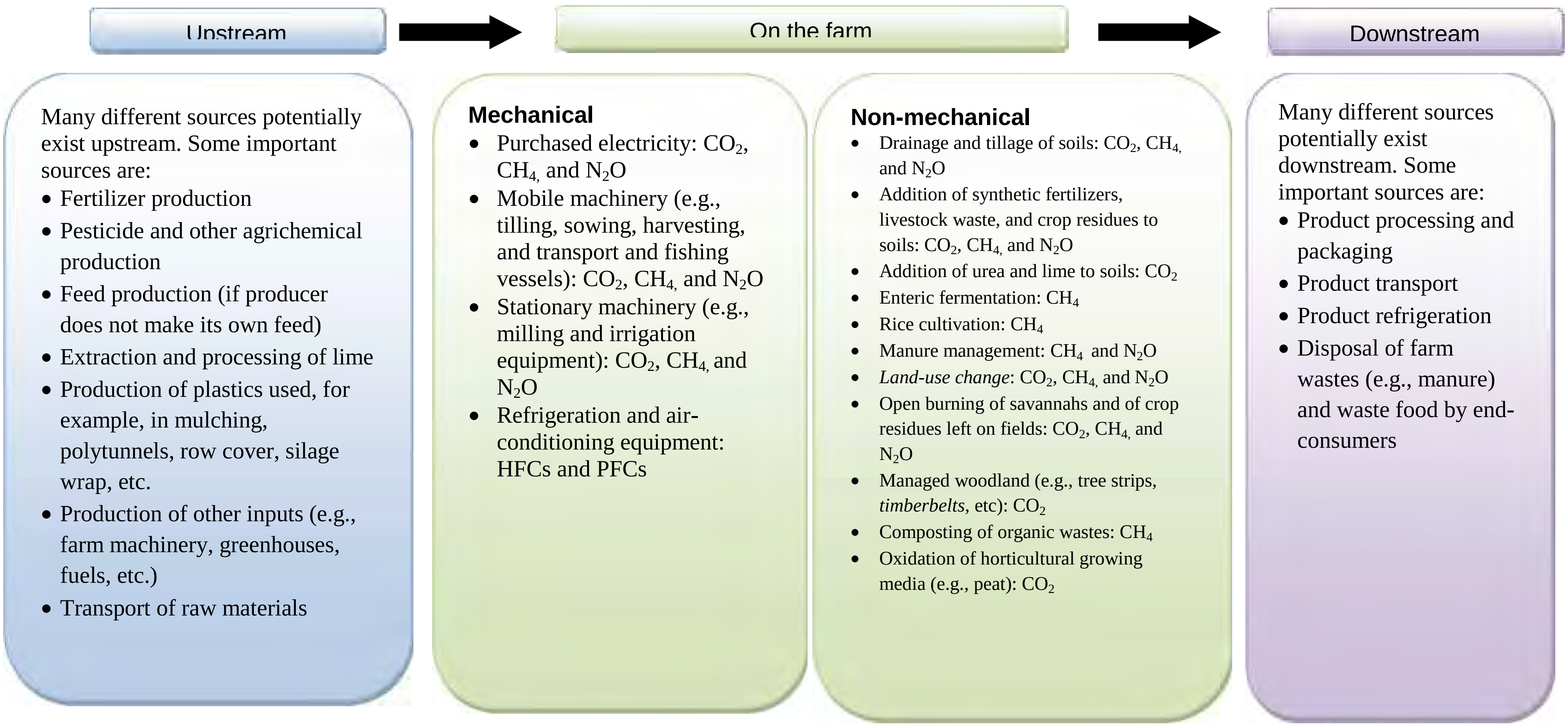
The remainder of this Chapter reviews two main categories of sources because of their importance in the sector: non-mechanical sources that are located on farms, as well as combustion/industrial sources that are located beyond the farm gate.

Table 4-1. GHG emissions from the global food supply chain

Stage of food chain		Emissions ($MtCO2_e$)
Preproduction	Fertilizer manufacture	282-575
	Animal feed production (energy use only)	60
	Pesticide production	3-140
Production	Direct emissions from agriculture	5,120 – 6,116
	Land use change	2,198 – 6,567
Postproduction	Primary and secondary processing	192
	Storage, packing and transport	396
	Refrigeration	490
	Retail activities	224
	Catering and domestic food management	160
	Waste disposal	72

Source: Vermuelen et al., 2012, Ann Rev Environ Resour. 37: 195 – 222.
Note: Data exclude emissions from fisheries and aquaculture.

Figure 4-1. Emission sources associated with agriculture



This figure does not provide an exhaustive list of emission sources, but rather highlights some of the most important emission sources associated with agriculture. This is a generalized depiction of the agricultural supply chain. Whether individual sources are located upstream, on the farm, or downstream will depend on the entity concerned. Also, this figure does not connote reporting requirements for emission sources, merely the types of sources commonly associated with farming. Subsequent sections of this Guidance outline whether individual sources should be reported in entity-level GHG inventories.

4.2 Non-mechanical sources on farms

The key GHGs from non-mechanical sources are CO_2, N_2O and CH_4. Biogenic CO_2 fluxes to or from soils or biomass are primarily controlled by uptake through plant photosynthesis and releases via respiration, decomposition and the combustion of organic matter. In turn, N_2O is primarily emitted as a by-product of *nitrification* and *denitrification* (see Box 4-1), while CH_4 is emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation, and during the incomplete combustion of organic matter. Non-mechanical sources also emits GHG precursors, such as NO_X, NH_3, NMVOC and CO, that then form GHGs.

The most important non-mechanical sources are:

Enteric fermentation (CH_4)
CH_4 is produced in herbivores as a by-product of enteric fermentation, whereby carbohydrates are broken down by bacteria in the digestive tract. The amount of methane that is produced depends on:

- The type of digestive tract. Ruminant livestock have an expansive chamber, the rumen, which fosters extensive enteric fermentation and high CH_4 emissions. The main ruminant livestock are cattle, buffalo, goats, sheep, deer and camelids. Non-ruminant livestock (horses, mules, asses) and monogastric livestock (swine) have relatively lower CH_4 emissions because much less CH_4-producing digestion takes place in their digestive systems.
- Quantity and quality of feed. Generally, the higher the feed intake, the higher the CH_4 emissions. The extent of CH_4 production is also affected by feed composition.
- Age and size of livestock. Feed intake is positively related to animal size, growth rate, and production (e.g., milk production, wool growth, or pregnancy).

Manure management (CH_4 and N_2O)
Manure (and urine) management releases both CH_4 and N_2O, although the emissions of these GHGs are influenced by different factors.

CH_4 is emitted during the storage and treatment of manure under anaerobic conditions. It is most readily emitted when:

- Large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms).
- When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits). When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited onto pastures and rangelands, it tends to decompose under more aerobic conditions, producing less CH_4.

N_2O is emitted either directly or indirectly from stored or treated manures (**Error! Reference source not found.**Box 4-1). N_2O emissions are influenced by:

- The N and C content of the manure, and on the duration of storage and type of treatment.
- Temperature and time - comparatively simple forms of organic N, such as urea (mammals) and uric acid (poultry) tend to lead to indirect N_2O emissions more quickly.
- The extent of leaching and run-off of N from treatment units.

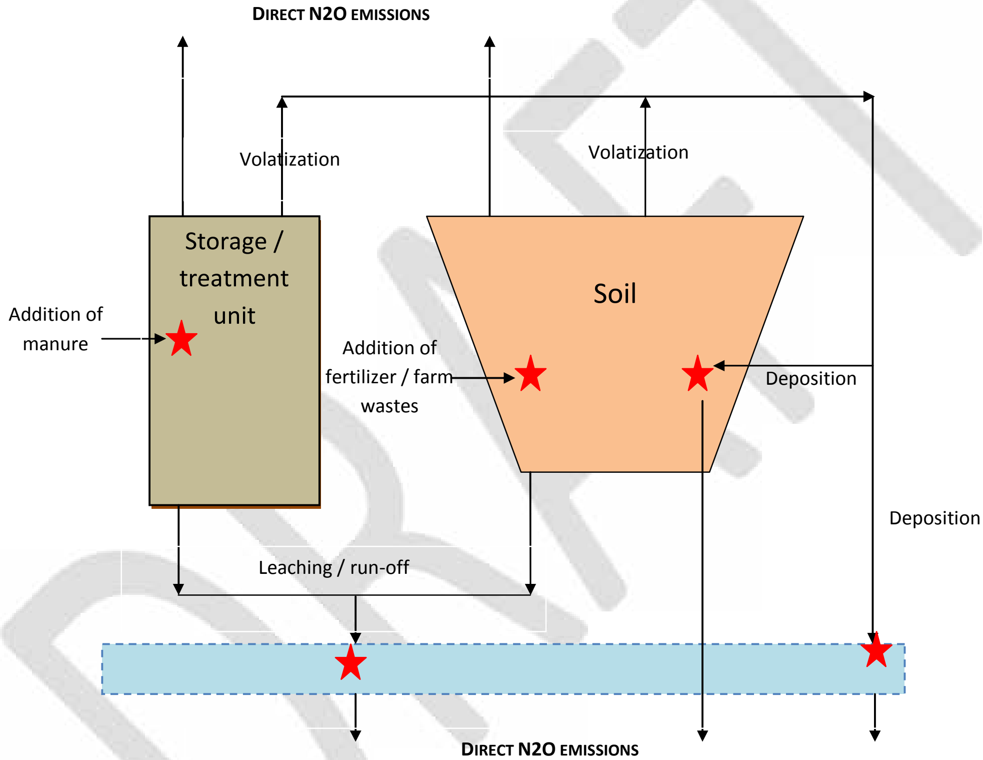
Soil amendments (N_2O)

Direct and indirect emissions of N_2O also occur from soils following the addition of N from:

- Synthetic N fertilizers and organic fertilizers (e.g., animal manure, compost, sewage sludge, rendering waste).
- Urine and dung N that is deposited onto pasture, ranges and paddocks by grazing animals.
- Incorporation of crop residues into soils and N-fixation by legumes.
- *N mineralisation* associated with the loss of soil organic matter and caused by changes in land use or soil management.
- Drainage or management of organic soils (i.e., histosols).

Box 4-1. Indirect and direct N_2O emissions from soils

N_2O emissions on farms are controlled by the supply of available N. Increases in available N, through the addition of fertilizers or animal wastes to soils, or from the storage and treatment of manure, stimulate denitrification and nitrification processes, which lead to N_2O emissions. The actual N_2O emissions may occur directly from the site of manure storage or fertilizer application, or they may occur indirectly, via leaching and *volatilization*. Volatilized N is ultimately deposited onto soils or onto the surface of lakes and other water bodies, where N_2O emissions then occur. Leached N leads to N_2O emissions in the groundwater below the farm or in ditches, rivers, estuaries, etc, that eventually receive the runoff. While indirect N_2O emissions may occur off the farm, they are accounted for no differently from direct N_2O emissions in corporate inventories.



 = Enhancement of denitrification and nitrification processes from increase in available N

Rice cultivation

The anaerobic decomposition of organic material in flooded rice fields produces CH_4, which escapes to the atmosphere, mostly by transport through the rice plants. The CH_4 emissions will depend on the number and duration of crops grown, water regimes before and during the cultivation period, and organic and inorganic soil amendments. Soil type, temperature, and rice cultivar are also important.

Soil liming

Liming is used to reduce soil acidity and improve plant growth. When added to soils, carbonate limes such as limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) dissolve and release bicarbonate ($2HCO_3^-$), which then evolves into CO_2. The amount of CO_2 emitted depends on soil factors, climate regime, and the type of lime applied (i.e., limestone or dolomite, fine or course textured). Non-carbonate limes, such as oxides (e.g., CaO) and hydroxides of lime, do not result in CO_2 emissions.

Carbon pools

The agricultural sector differs profoundly from industrial sectors in the importance of carbon pools, which may act either as sources or sinks of CO2 during agricultural land use or land use change. These pools are of four main types (Figure 4-2):

- Above-ground and below-ground biomass (e.g., trees, crops and roots).
- Dead organic matter (DOM) in or on soils (i.e., decaying wood and leaf litter).
- Soil organic matter. This category includes all non-living biomass that is too fine to be recognized as dead organic matter.
- Harvested products. Generally, this pool is short-lived in the agricultural sector as crop products are rapidly consumed following harvesting. Harvested woody products are a potential exception.

It is possible to disaggregate these pools further. For instance, the DOM and biomass pools can be subdivided into understory vegetation, standing dead tree, down dead tree, and litter pools, etc. This level of disaggregation may be useful depending on data availability and the intended accuracy of the inventory (see Chapter 8).

Carbon stocks represent the quantity of carbon stored in pools. It may take carbon stocks decades to reach equilibrium following a change in farm management. Ultimately, for agricultural land as a whole to sequester carbon, the sum of all stock increases must exceed the sum of all stock decreases (i.e., the sum of all carbon gains through CO_2 *fixation* must exceed the sum of all carbon losses through CO_2 and CH_4 emissions and harvested products).

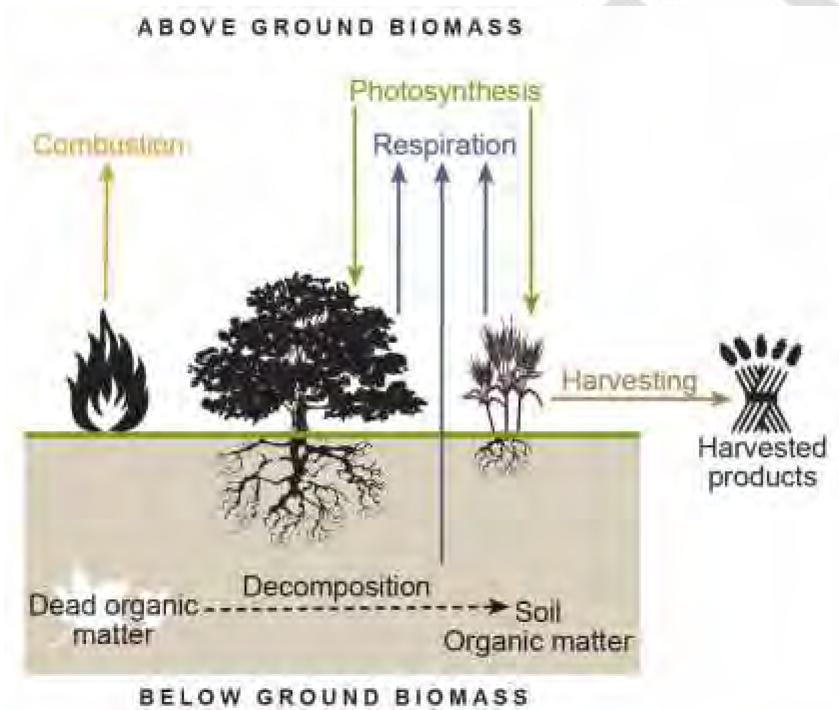
<u>Soil carbon pools</u>

Both organic and inorganic forms of C exist and are found in soils. However, agriculture typically has a larger impact on organic C pools, which are found in organic and mineral soils.

- Organic C pools in organic soils. Organic soils (e.g., those in peat and muck) have a high percentage of organic matter by mass and develop under the poorly drained conditions of wetlands when inputs of organic matter exceed losses of C from anaerobic decomposition. The drainage of organic soils to prepare land for agriculture leads to CO_2 emissions - emission rates vary by climate, with drainage under warmer conditions leading to faster decomposition rates. CO_2 emissions are also influenced by drainage depth, liming, and the fertility and consistency of the organic substrate.

- Organic C pools in mineral soils. All soils that are not organic soils are classified as mineral soils. They typically have relatively low amounts of organic matter, occur under moderate to well drained conditions, and predominate in most ecosystems, except wetlands. The organic C stocks of mineral soils can change if the net balance between C inputs and C losses from the soil is altered. C inputs can occur through the incorporation of biomass residues into soils after harvesting and fires, or through the direct additions of C in organic amendments. C losses are largely controlled by decomposition and are influenced by changes in moisture and temperature, soil properties and soil disturbance.

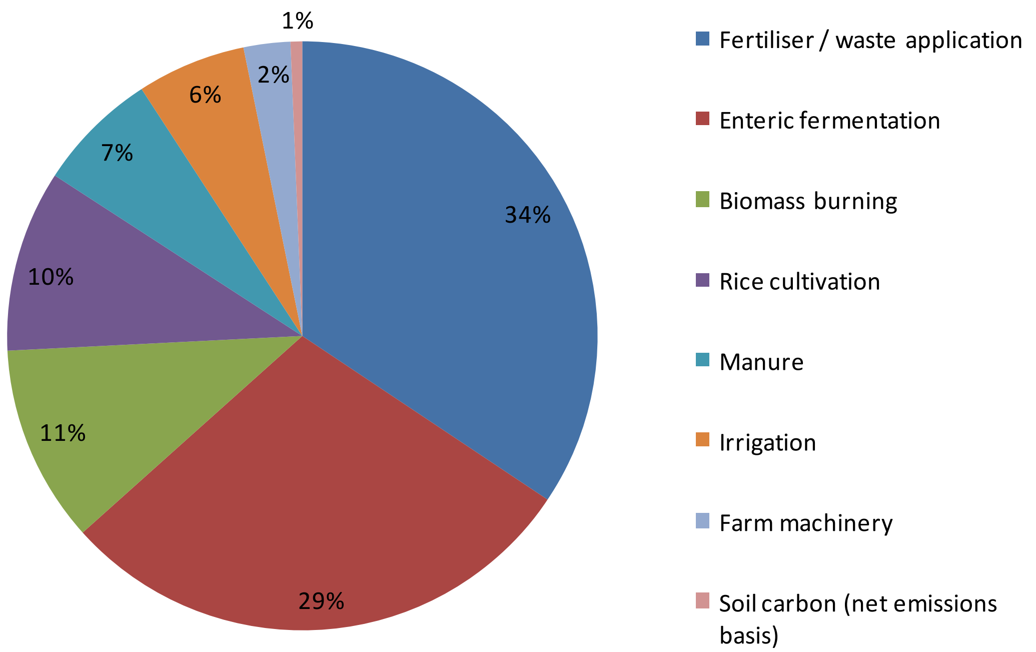
Figure 4-2. Carbon pools in agriculture



4.3 Relative importance of different on-farm sources

Which on-farm sources are likely to be the most important components of an inventory? At a global level, non-mechanical sources are more significant than mechanical sources (Figure 4-3), with enteric fermentation (CH_4) and soils (N_2O) being the most significant (Placeholder5). The exact contribution of agriculture to global CO_2 emissions is hard to quantify. This is because the biomass and soil carbon pools not only emit large amounts of CO_2, but also take up CO_2. However, it is likely that on a net basis managed agricultural soils contribute less than 1% to global anthropogenic CO_2 emissions and that, in most regions of the world, they emit or sequester only very small amounts of CO_2 ((Placeholder6); U.S. EPA, 2006b). Nevertheless, carbon sequestration offers most (~89%) of the global potential for reducing the emissions from agriculture (Placeholder7). In contrast to managed agricultural soils, land-use changes associated with agriculture are a globally important source of CO_2 emissions (Chapter 1.2).

Figure 4-3. Relative importance of different on-farm sources, globally (% of global anthropogenic emissions; data exclude land use change emissions) (Placeholder10)



At the farm scale, the relative importance of different emission sources and GHGs will vary widely depending on the type of farm, management practices and natural factors at play. These factors include farm topography; soil microbial density and ecology; soil temperature, moisture, organic content and composition; crop or livestock type; and land and waste management practices. Few studies have looked at the relative contribution of different emission sources to the whole-farm inventories of different farming systems using a consistent set of methods. It is therefore difficult to accurately predict the relative significance of different sources for a given farm. Nonetheless, certain broad patterns can be expected (e.g.,

Figure 4-4). Figure 4-5 shows data from one comparative study of a range of farming systems within a single region.

Figure 4-4. Typical patterns of the importance of different sources to overall emissions from select farming systems.

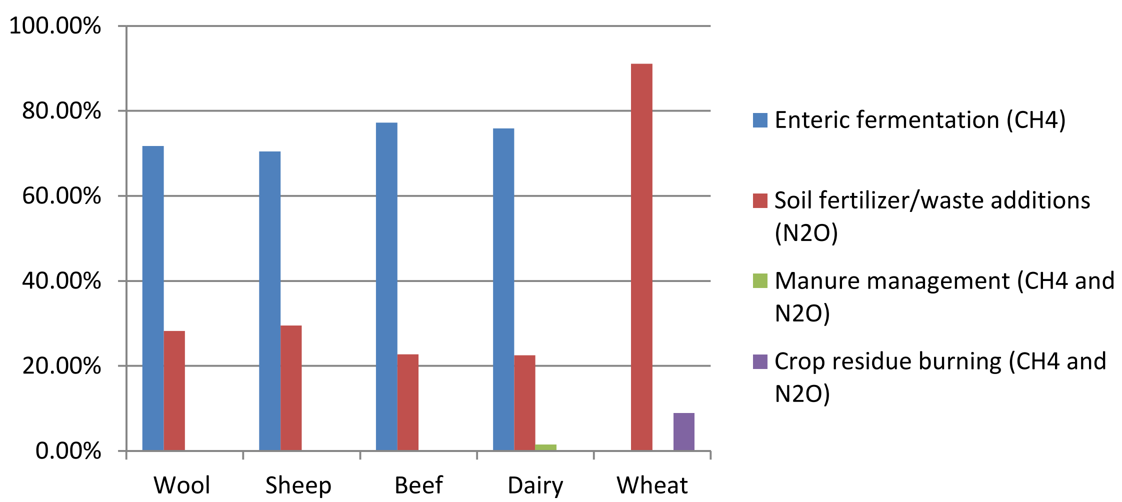
Emission sources	**Type of system**				
	Sheep	**Beef**	**Diary (pasture)**	**Arable crop**	**Horticulture**
Enteric fermentation	Highly significant	Highly significant	Highly significant	Not significant	Not significant
Deposition or application of fertilizer and/or wastes to soils	Highly significant	Highly significant	Highly significant	Highly significant	Highly significant
Crop residue burning	Not significant	Not significant	Not significant	Significant	Not significant
Manure management	Highly significant	Highly significant	Highly significant	Not significant	Not significant
Fuel use	Not significant	Not significant	Not significant	Significant	Significant
Soil CO_2	Not significant	Not significant	Significant	Significant	Significant

Key:

(green)	Not significant
(light orange)	Significant
(red)	Highly significant

Note: The actual emissions profile of a farm may (and in many cases will) deviate from the pattern in this figure, depending on the soil, climate and management conditions concerned.

Figure 4-5. Emissions profiles of different farming systems in south-eastern Australia



Notes:

1. All of the systems considered here are pasture-based. It is likely that non-pasture-based systems would show different emissions profiles, including lower enteric CH_4 (due to higher feed quality) and higher emissions from dairy effluent ponds (lagoons).
2. Data provided by N. Browne, University of Melbourne (private communication, July 10, 2011).

3. CO_2 emissions from soils or fuel use were not considered in the original study (Browne et al., 2011. Animal Feed Sci & Tech. 166 – 167: 641 -652).

4.4 Emission sources located beyond the farm gate

At the farm-level, the relative importance of different pre- and post-production sources will vary a lot with the type of farm. Still, three sources will be important for many types of farms: fertilizer and feed production, and the refrigeration of farm goods.

Fertilizer production:
The GHG emissions from fertilizer production are closely linked to energy consumption and vary with aspects of plant design and efficiency, emissions control mechanisms and raw material inputs. Three raw materials are particularly important:

- Ammonia. CO2 is emitted from the consumption of hydrocarbons (primarily natural gas) as a hydrocarbon feedstock (to supply H) and as an energy source.
- Nitric acid (HNO3). Nitric acid is the largest industrial source of N2O (IPCC 2000) and is emitted as a byproduct of the catalytic oxidation of ammonia to nitric acid.
- Phosphoric acid. Produced from reacting phosphate rock with sulphuric acid. The emissions from phosphoric acid production are mainly of CO2, emitted during the consumption of fossil fuels as an energy source for the various production processes.

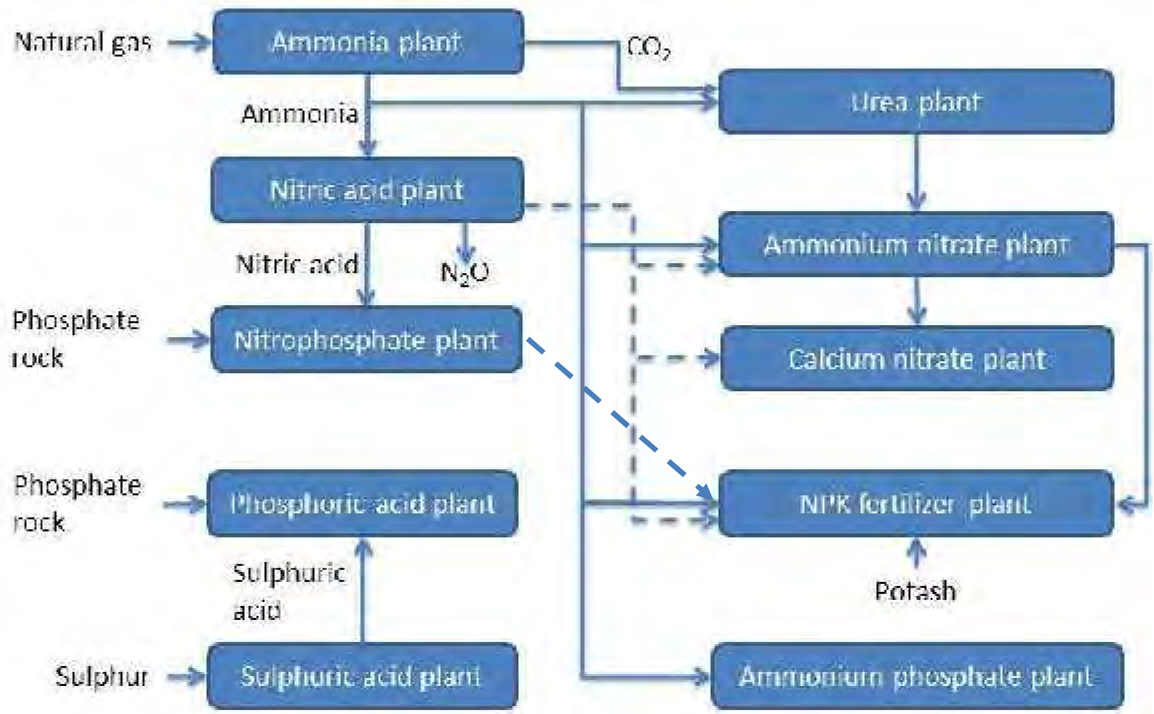
The GHG-intensity of the production of different fertilizers depends on the relative amounts of these chemicals in the final product. Figure 4-6 shows the production pathways for the main classes of P and N synthetic fertilizers.

Feed production:
Feed production is very important in the GHG emissions life cycle of livestock and aquaculture production. It may account for 60-80% of emissions up to the farm gate for eggs, chicken and pork, and for 35-45% for milk and beef. It makes up a relatively smaller proportion for ruminants because methane from feed digestion comprises the dominant fraction of total emissions for milk and beef. Feed production emissions come from many of the emissions sources described above, particularly, soil N2O emissions, land use change, and fertilizer production, as well as electricity use during drying and processing, etc.

Refrigeration
Refrigeration is the major GHG-intensive component of the postproduction supply chain. Limited data are available but the “cold chain” (refrigeration of food products from the farm to consumer’s plate) could account for ~1% of global emissions. Refrigeration causes emissions from energy use and from the operation of refrigeration equipment, which leak refrigerants during installation, maintenance, operation and disposal. While the mass of refrigerants released by the food supply chain may be small relative to the

mass of other GHGs, refrigerant gases (HFCs and PFCs) have high GWP values, and so may be much more important on a CO2e basis.

Figure 4-6. Production pathways for the main classes of P and N synthetic fertilizers.



Part 2: DEVELOPING FARM-LEVEL INVENTORIES

Chapter 5 : Setting Inventory Boundaries

Entities vary tremendously in terms of their organizational structures and business operations. Common examples include the degree of vertical integration, the types of leases entered into, and the manner in which agricultural products are sold off the farm. This variation poses a challenge to ensuring that emissions sources are included in inventories in a consistent way over time, both within and across entities. Fortunately, specific approaches are available to help entities determine which sources should be included – these approaches relate to setting *inventory boundaries*.

This chapter:

- Describes approaches for setting organizational boundaries to determine which business operations should be included in an inventory
- Describes approaches for setting operational boundaries that define whether and how emissions sources associated with specific operations should be reported in inventories.

5.1 *Setting organizational boundaries*

Organizational boundaries determine which business operations should be included in an inventory. Three 'consolidation' approaches can be used to set organizational boundaries:

1. *Operational control*. An entity accounts for 100% of the GHG fluxes to/from an operation over which it has the authority to introduce and implement its own operating policies.
2. *Financial control*. An entity accounts for 100% of the fluxes to/from an operation over which it has the ability to direct financial and operating policies with a view to gaining economic benefits.
3. *Equity-share approach*. An entity accounts for the emissions from an operation according to its share of equity (or percentage of economic interest) in that operation.

Various criteria can be used by entities to determine if they exert operational control of an operation. For instance, operational control would be held if:

- The operation is operated by the reporting entity, whether for itself or under a contractual obligation to other owners or participants in the operation
- The operation is operated by a joint venture (or equivalent), in respect of which the reporting entity has the ability to determine management and board-level decisions of the joint venture
- The reporting entity holds an operating license
- The reporting entity sets environmental, health and safety policies

Chapter
Standard provid
on setting organ
including:
- When operat
control is exe
scenarios
- Selecting cor
approaches b
business acti
accounting a
requirements

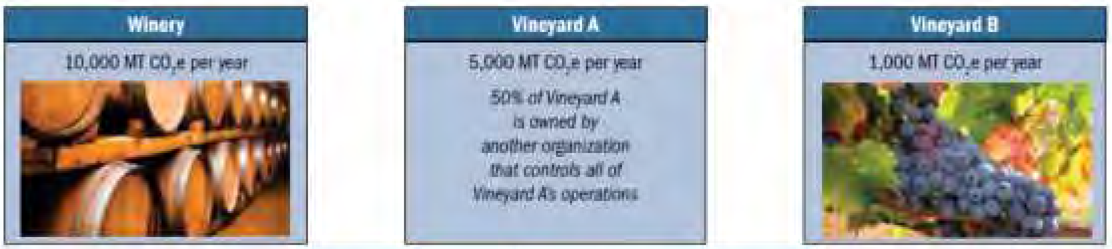
An entity must use only one consolidation approach (and related criterion) in creating an inventory, although it may choose to create multiple inventories using different approaches. Many entities are organized as sole proprietorships or family businesses and their organizational boundaries will be correspondingly simple. As business structures become more complex, organizational boundaries will become more valuable in ensuring consistent accounting practices. Exactly which agricultural operations are included in an inventory will depend on the business structures involved and the chosen consolidation approach (Table 5-1). For example, the member-patrons of a co-operative would not account for any of that co-operative's emissions under the financial control approach, but they would account for those emissions under the equity share approach (Table 5-1). Figure 5-1 illustrates the application of organizational boundaries for different accounting categories. *Co-operatives* are considered further in Chapter 5.2.

Importantly, an entity's business goals will inform which boundary approach is chosen. For instance, an entity may fall under the jurisdiction of a cap-and-trade program and choose operational control, since compliance with the program would typically rest with the operators of emission sources.

Table 5-1. Common types of business structures and outcomes of setting organizational boundaries

		Type of agricultural business			
Feature compared		**Individual (sole proprietorship)**	**Partnership**	**Corporation**	
				Investor-oriented	Co-operative
Who uses the services?		Non-owner customers	Generally, non-owner customers	Generally, non-owner customers	Chiefly, the co-operative's members
Who owns the business?		The individual	The partners	The stockholders	The member-patrons
Who votes?		None necessary	The partners	Common stockholders	The member-patrons
How is voting done?		None necessary	Usually by partners' share in capital	By shares of common stock	Usually, one member-one vote
Who determines policies		The individual	The partners	Common stockholders and directors	The member-patrons and directors
Who gets the operating proceeds?		The individual	The partners in proportion to interest in business	The stockholders in proportion to stock held	The member-patrons on a patronage basis
Who accounts for the emissions from the business? And what % of emissions?	Based on equity share	Owner accounts for 100% of emissions	Each partner accounts for a % of the emissions in proportion to interest in business	The company accounts for a % of emissions based on its share of equity in the business	The member-patrons on a patronage basis
	Based on financial control			The company accounts for 100% of the emissions	The co-operative accounts for 100% of the emissions

Figure 5-1. Applying organizational boundaries. A wine company owns and operates a winery and a vineyard (Vineyard B). It also owns 50% of a second vineyard (Vineyard A) that is operated by another company. The size of the wine company's inventory depends on the consolidation approach used.



Approach	Emissions (metric tons CO_2e / yr)
Equity share	13,500
Operational control	11,000
Financial control	11,000

5.2 Setting operational boundaries

Overview

Having set organizational boundaries using any one of the consolidation approaches, entities should then set operational boundaries for each of their sources. These boundaries define whether an emission source is direct (i.e., is controlled or owned by the reporting entity) or indirect (i.e., the emissions are influenced by the reporting entity, but the source itself is owned or controlled by a third party). Emission sources are further classified by scope (Box 1-1):

- Scope 1: All direct sources
- Scope 2: Consumption of purchased electricity (an indirect source)
- Scope 3: All other indirect sources

All scope 1 and 2 emissions should be reported in an inventory. Scope 3 emissions are reported optionally under the Corporate Standard, although it will be necessary to include many scope 3 sources in comprehensive analyses of supply chain emissions (see Chapter 9.2).

All CO_2 fluxes to/from biogenic sources (e.g., carbon pools in soils and biomass) that are owned or controlled by the reporting entity should be reported separately from the scopes. That is, if the biogenic CO2 source were otherwise to be considered scope 1, its fluxes should be reported outside of the scopes in a special ‘Biogenic Carbon’ category (see Chapter 9.1 for more information).

While an entity has control over its direct emissions, it has a degree of influence over its indirect emissions. Setting operational boundaries therefore provides for the more effective management of GHG risks and opportunities along the supply chain and also minimizes the problem of double counting emissions. Scope 1, scope 2 and scope 3 are mutually exclusive, such that there is no double counting of emissions between the scopes within an entity-level inventory. However, double counting will occur between different entities – an entity’s scope 3 emissions may also be the scope 3 emissions of a different entity, although GHG emissions should never be included under scope 1 (or scope 2) by more than one entity. For example, a producer’s scope 1 emissions from livestock production will be scope 3 for both the processing company and the retailer that source their meat from this producer. Each of these different entities has different and typically mutually exclusive opportunities to reduce these emissions. For example, the producer can increase the feed conversion efficiency of its livestock, the processor can contract less GHG-intensive production, and the retailer can offer less GHG-intensive food product choices. By allowing for the reporting of the same emissions by multiple users, each of these varied approaches to emissions reductions can be revealed and encouraged.

Specific issues in setting operational boundaries

Which scopes do different agricultural sources belong to? Under the most straightforward of circumstances, an entity would account for the sources occurring from operations falling within its organizational boundaries as shown in Table 5-2. However, a range of issues may complicate the setting of operational boundaries, including:

1. Production contracts
2. Other forms of agricultural contracting
3. Leases for land and equipment
4. Membership of co-operatives
5. Miscellaneous: manure transfers and share farming

Table 5-2. Simplest case scenario for setting operational boundaries. A producer owns or controls all of the sources occurring on its farm and sells its produce to a food processing company.

	As accounted by the:	
Emission source (example)	**Producer**	**Food processor**
Non-mechanical sources (e.g., enteric fermentation, manure management, and land-use change)	Scope 1	Scope 3
Mechanical sources (excluding purchased electricity)	Scope 1	Scope 3
Electricity purchased by the producer for use in agricultural operations	Scope 2	Scope 3[a]
Agrichemical production	Scope 3	Scope 3

Product processing	Scope 3	Scope 1 or 2

[a] The food processor would also have separate scope 2 emissions from the electricity it purchased itself.

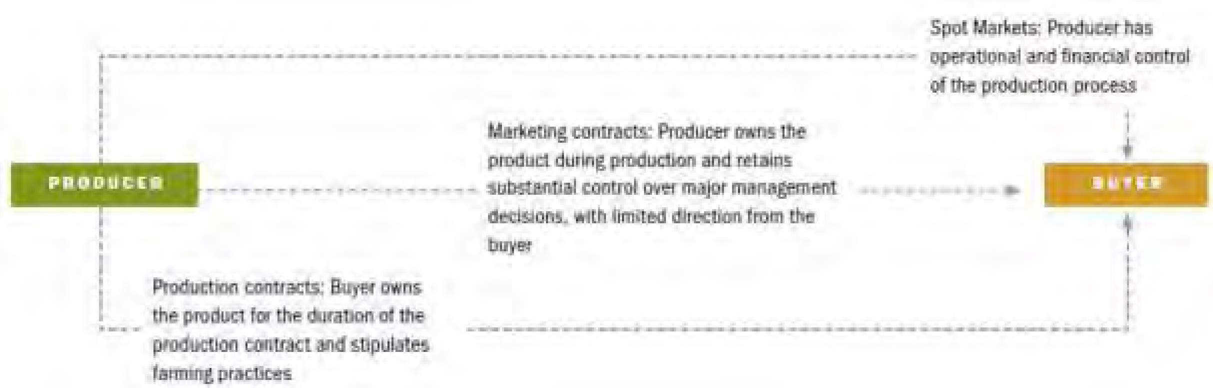
1. Production contracts

Agricultural products can be sold in various ways, including production contracts, marketing contracts and production contracts (Figure 5-2). Production contracts are distinct in that they are agreements between producers (often called growers) and other entities that cede some measure of control over the production process to the contractor (often called a processor). The contract specifies: (1) the services to be provided by the producer (e.g., fertilizer application schedules, husbandry conditions, etc.); (2) the manner in which the producer is to be compensated for the services; and (3) specific contractor responsibilities for the provision of any inputs. There are many different types of production contracts, which vary according to amongst the following features:

- Ownership of the product during production. Under production contracts, producers may either own the contracted agricultural products (identified prior to production) or agree to care for and raise agricultural products owned by the contractor.
- Nature of the contracting entity. Production contracts may be made between neighboring producers of roughly equally bargaining power (e.g., an alfalfa grower may contract production to a nearby dairy operation, or a livestock producer may contract another farmer to finish livestock production). Alternatively, producers may contract with relatively large agribusinesses such as food companies or processors - ‘industrial contract production’. The detailed terms of industrial production contracts are typically non-negotiable.
- Provision of inputs. Many agribusinesses provide extensive inputs to producers, including seedlings, seeds, fertilizer or vaccines. For instance, in the broiler industry integrators usually provide chicks, feed, veterinary services and other inputs to the producer, who, in turn, provides labor, covers utility expenses and invests in specialized poultry housing.

In all cases, producers are assumed to retain operational control over the contracted production and should therefore account for 100% of the associated emissions under scope 1 or 2 using the operational control approach. The accounting under financial or equity share approaches may differ. For instance, if the contractor has established multi-year contracts with individual growers and provides extensive inputs, it should then account for a portion of the emissions under the equity share approach.

Figure 5-2. Primary sales routes for agricultural products



2. Other forms of agricultural contracting

While entities can enter into production contracts that require them to raise livestock or grow crops for third parties, they may enter into other types of contracts that require third parties to perform agricultural activities on their own behalf. These activities may take place either on-farms or off-farms.

<u>On-farm activities:</u> Producers may contract firms to perform a subset of farming activities, such as harvesting or fertilizer application (see the example of service co-operatives below). At the other end of the spectrum, landowners may enter into *custom farming contracts* under which contract operators supply all the labor and equipment needed to perform tillage, planting, pest control, harvesting, crop storage, and other farm functions. With one exception, the emissions from agricultural production are scope 3 for the contract operator and scope 1 for the producer/landowner, under both the operational and financial control approaches. The exception relates to the emissions from equipment owned by the contractor, which would be scope 1 for the contractor.

<u>Off-farm activities:</u> Many different arrangements exist for the grazing or feeding of a producer's livestock on another organization's land. Examples include feedlots and *ajistments*[4]. While the livestock are on the service-provider's land, the production emissions (e.g., enteric fermentation, and soil N_2O and CH_4 from manure management) are also scope 1 for the service-provider and scope 3 for the producer, under both the operational and financial control approaches.

3. Leases for land and equipment

The Corporate Standard (Appendix F) distinguishes between two general types of leases:

- Capital (or financial) leases: This type of lease enables the lessee to operate an asset and also gives the lessee all the risks and rewards of owning the asset. In a capital lease the lessee has use of the asset over most of its useful life. Assets leased under a capital or financial lease are considered wholly-owned assets in financial accounting and are recorded as such on the balance sheet.

[4] Ajistments are typically defined for a shorter period of time than pasture or grazing leases, which are considered separately in "Leases for land and equipment"

- Operational leases: This type of lease enables the lessee to operate an asset, such as a building or a vehicle, but does not give the lessee any of the risks or rewards of owning that asset. In an operating lease the lessee only has use of the asset for some of its useful life. Any lease that is not a capital or financial lease is an operating lease.

Whether leased assets are scope 1 or 3 for a producer depends on the approach chosen to set organizational boundaries and on the type of leasing arrangement (see Table 5-3 and Table 5-4).

Land leases and operational control

In all cases, producers are considered to exert operational control of any land they lease (Table 5-3). This is true, regardless of the form of rent payment (cash, crops, or both), the amount of resources contributed by the landlord, or the extent to which the landlord is involved in management decisions.

Table 5-3. Emissions from leased assets: Lessee's perspective

	Type of leasing arrangement	
Approach used for organizational boundaries	**Financial/capital lease**	**Operating lease**
Equity share or financial control	Lessee does have ownership and financial control; therefore, the emissions from the leased asset (land or machinery) are scope 1 and those from purchased electricity are scope 2	Lessee does not have ownership or financial control; therefore, the emissions from the leased asset (land or machinery) are scope 3 and those from purchased electricity are scope 3
Operational control	Lessee does have operational control; therefore, the emissions from the leased asset (land or machinery) are scope 1 and those from purchased electricity are scope 2	

Table 5-4. Emissions from leased assets: Lessor's perspective

	Type of leasing arrangement	
Approach used for organizational boundaries	**Financial/capital lease**	**Operating lease**
Equity share or financial control	Lessor does not have ownership or financial control; therefore, the emissions from the leased asset (land or machinery) are scope 3 and those from purchased electricity are scope 3	Lessor does have ownership and financial control; therefore, the emissions from the leased asset (land or machinery) are scope 1 and those from purchased electricity are scope 2
Operational control	Lessor does not have operational control; therefore, the emissions from the leased asset (land or machinery) are scope 3 and those from purchased electricity are scope 3	

4. Membership of co-operatives

A co-operative is a business that is owned and controlled by the member organizations that use its services and whose benefits are shared by the members on the basis of use (Table 5-1). Agricultural co-operatives take many forms, but can broadly be grouped into three categories: marketing, purchasing, and service co-operatives (Table 5-5).

How should members account for the emissions from their co-operative? Many entities will have a relatively small percentage patronage of their co-operative and need not account for its emissions under the equity share approach. However, some entities may have a significant percentage patronage - these should account for the co-operative's scope 1, scope 2, and (optionally) scope 3 emissions under the equity share approach. Note that the nature of the emission source will vary widely depending on the type of co-operative (see Table 5-5). For instance, the members of a purchasing co-operative would have scope 1 emissions relating to the manufacture of feed and fertilizer.

Under either control approach, the co-operative would not fall within the organizational boundaries of its members, so its emissions would not be scope 1 or scope 2 for its members (only the co-operative itself would account for its emissions as scope 1 and 2 under a control approach). Instead, individual members may account for the scope 3 emissions arising from the activities conducted by the co-operative specifically on their own behalf (and not on that of other members). For instance, the member of a service co-operative might account for the mobile machinery operated by the co-operative to harvest that member's crops.

Table 5-5. Co-operatives and operational boundaries

Type of co-operative	Co-operative activity
Marketing	Negotiate prices and terms of sale of their members' products with buyers
	Process members' products into other products
	Distribute members' products to retailers under own brand name
Purchasing	Provide access to production supplies such as feed, fuel, fertilizer, and seed
	Produce fertilizers and feed
Service	Provide farm-specific services, such as applying fertilizer, lime, or pesticides; processing animal feed; and harvesting crops

5. Miscellaneous issues

Manure transfers: Manure may be exported to third-parties for re-use or disposal. In such cases, the emissions from re-use or disposal are scope 1 for the third-party and scope 3 for the producer.

Chapter 6: Tracking Performance over Time

Companies often undergo significant structural changes such as acquisitions, divestments, and mergers. Also, agricultural activities and natural factors that influence GHG fluxes frequently change. Together, these factors will make meaningful comparisons of 'like with like', and therefore tracking performance over time, more difficult.

This chapter:

- Describes the concept of base reporting periods, which help ensure inventories can be compared to a representative point in the past, allowing meaningful and consistent comparisons of performance over time.
- Details considerations in setting base periods and recalculating base period data to ensure historical comparisons are meaningful.
- Describes various types of ratio indicators that can assist entities in tracking the GHG performance of specific aspects of their agricultural operations.
- Describes methods for allocating GHG fluxes amongst various co-products or by-products when computing ratio indicators.

6.1 Setting and recalculating base periods

The base period is the period in history against which an organization's climate impact is tracked over time[5]. Base periods are particularly useful for setting and tracking progress towards emissions reduction targets, and putting the effects of inventory changes into context. The Corporate Standard requires entities to establish a base period.

What time period should the base period represent?

Entities should use as a base period the earliest relevant point in time for which they have verifiable data. Critically, the base period should be representative of an entity's climate impact.

The base period should not be an individual *crop year* or production season (for livestock) because, otherwise, the effects of seasonal management activities may not be reflected in the base period. For instance, tillage practices, winter cover crops and double cropping systems can cause emissions outside of the growing season. Also, the length of crop years and production seasons will vary between regions, potentially compromising the comparability of data from different facilities owned by the reporting entity.

[5] The Corporate Standard uses the term 'base year' instead of 'base period.' The latter is used here to avoid confusion because base periods may comprise more than one.

Oftentimes, individual years will not also serve as representative base periods (see Table 6.1 for examples). In such cases, companies should average GHG flux data from multiple, consecutive years to form a more representative base period. In general, this Guidance recommends a three-year base period, which is often sufficient to smooth over inter-annual variability. If a base year has already been set for non-agricultural emissions, then a multi-year base period can be centered on that year (i.e. one year on either side of base year).

Many calculation methodologies (e.g., Tier 1 IPCC methodologies; see Chapter 7.1) do not capture the effects of climate or environmental change on GHG emissions. Instead, they only pick up changes in activity data (e.g., number of hectares farmed, number of cattle raised, amount of fertilizer used, etc.). In such cases, the calculated GHG data only reflect management regimes. So, assuming that the management practices in an individual year are representative, it may be appropriate to select that year as the base period. (Caveat: Many calculation methodologies may not even be sensitive to changes in management practices and so may not allow changes in performance to be comprehensively tracked over time).

Table 6-1. Examples of when an individual year may not serve as a representative base period

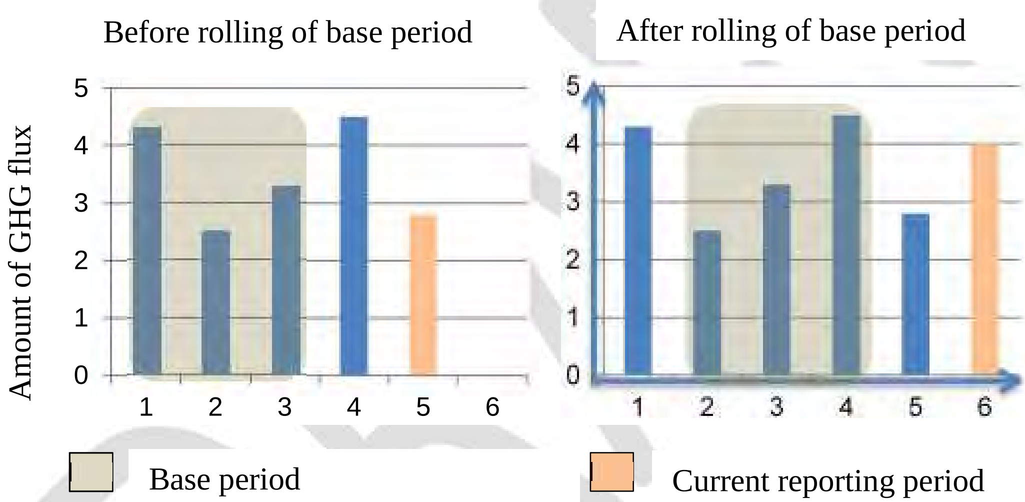
Why is the selected base period atypical?	Examples
Changes in environmental conditions occur that are beyond the control of the producer and that cause the base period inventory to depart significantly from typical emissions profiles	During a single growing season, a heat wave increases soil CO_2 emissions, as well as emissions from fuel use, owing to the greater use of irrigation equipment
Atypical or episodic changes in farming practices	Coppiced woodland is returned to crop production
	Forest is cleared for agricultural production
Farming activities vary cyclically over a set period of years, such that agricultural activities (and corresponding GHG fluxes) in one year differ from those in other years within the same cycle	A multi-year multiple crop rotation
	Coppicing of short-rotation woody crops (e.g., a row of willows that is harvested every three years)
	Rotational applications of lime

Rolling base periods

Long-term environmental trends, such as changes in precipitation and temperature that accompany climate change, can affect agricultural GHG fluxes. The more widely separated the base period is from the current reporting period, the more likely it is that at least some of the difference in GHG fluxes between the two periods is due to these trends. Consequently, entities may choose to use a *rolling base period* to help minimize the influence of these long-term trends and ensure that inventories are more useful as a basis for tracking the impacts of management practices. Using a rolling base period involves moving the base period forward with each reporting period (Fig 6-1). Chapter 8.2 discusses other ways entities can remove non-anthropogenic effects from their inventories.

Entities should be mindful of several disadvantages to using rolling base periods. One is that rolling base periods do not allow reduction targets to be expressed as a percentage reduction relative to a fixed point in the past, which is the most common form of expressing reduction targets. Also, under a rolling base period, the time series of absolute emissions reported by an entity may not be fully comparable. This is because base period recalculations only need to be performed for the current base period and not those of prior base periods.

Fig. 6-1. The concept of rolling base periods



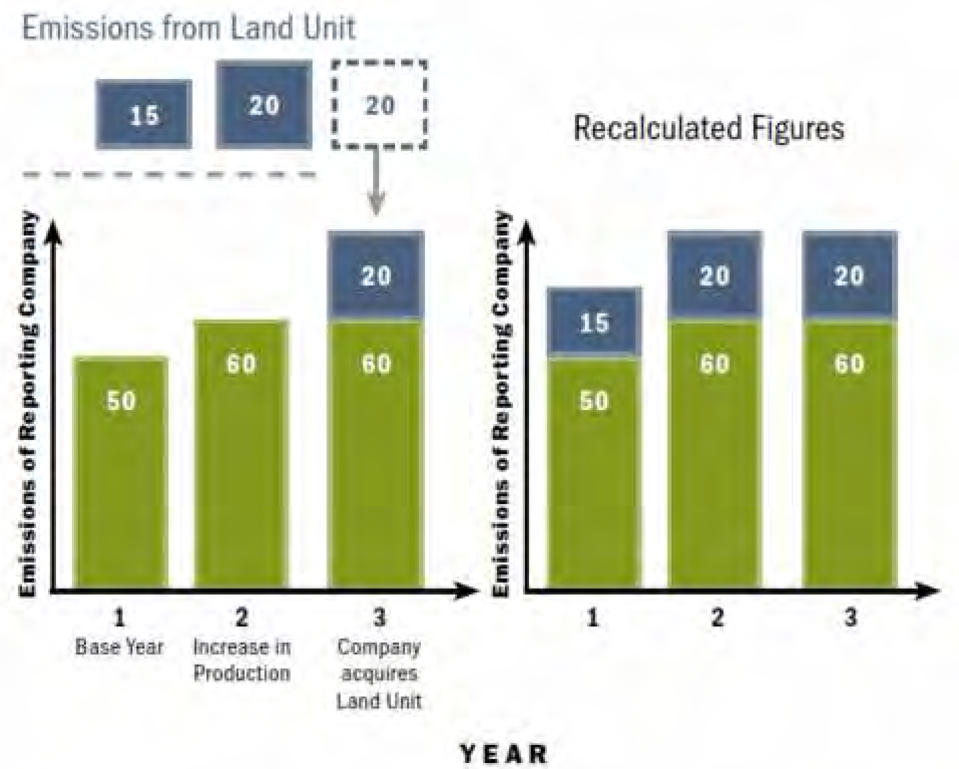
When should the base period inventory be recalculated?

To ensure consistent tracking of GHG fluxes over time, the base period inventory shall be recalculated when changes occur to the inventory boundary or inventory development process that would significantly impact the base year inventory. These changes include:

- Structural changes that transfer the ownership or control of operations from one company to another (e.g., mergers, acquisitions, and divestments), as long as those operations existed in the base period of the reporting entity (see Fig. 6-2 for an example).
- Changes in calculation methodologies (e.g., the use of improved emission factors)
- The discovery of errors that are significant on their own or collectively (e.g., the discovery of errors in activity data).

In determining whether changes are significant and thus merit base period recalculation, entities should set significance thresholds (i.e., changes are cumulatively significant if they cause a change that exceeds x% of the base period inventory). The GHG Protocol does not define significance thresholds, although many GHG reporting programs do. However, once defined, a significance threshold should be applied consistently over time.

Figure 6-2. Recalculating base period inventories upon the acquisition of a business unit. In this example, an entity acquires a business unit that owned a 'land unit' at the beginning of year 3. The emissions from the land unit during year 3 are therefore reflected in the entity's inventory for that year, but the inventories for the base period and year 2 have to be recalculated to include the land unit's emissions during those two years.



When recalculations are not necessary

Recalculations are not necessary in the following situations:

- When an entity experiences organic growth or decline. Organic growth and decline includes increases or decreases in production output, changes in product mix, and closures and openings of operating units that are owned or controlled by the reporting company. For instance, an egg producer would experience organic growth if it increased production, perhaps by building a new facility, but it would not experience organic growth if it bought out a pre-existing facility. Changes in the amount of land leased by an entity are also considered organic change and do not trigger recalculations.
- An entity acquires (or insources) an operation that did not exist in its base period.

- The outsourcing or insourcing of operations if the entity is reporting its indirect emissions from those operations. For example, outsourcing the production of electricity does not trigger base year emissions recalculation, since the Corporate Standard requires scope 2 reporting. However, outsourcing/insourcing that shifts significant emissions between scope 1 and scope 3, when scope 3 is not reported, does trigger the recalculation of base periods (e.g., when an entity outsources the production of animal feed or manure).

6.2 Using ratio indicators

Ratio indicators (or performance metrics) provide information on GHG emissions performance for a specific business operation and they can facilitate comparisons between similar operations over time.

Entities may choose to use GHG ratio indicators in order to:

- Evaluate performance over time (e.g., compare figures from different years, identify trends in data, and show performance in relation to targets and base periods).
- Improve comparability between different sizes of operations by normalizing figures (e.g., by assessing the impact of differently sized operations on the same scale).

Note that this Guidance does not require the reporting of ratio indicators.

Types of indicators

Some examples of ratio indicators are:

Productivity and efficiency ratios: These express the value or achievement of a business divided by its GHG impact. Increasing efficiency ratios therefore reflect a positive performance improvement. Examples of productivity/efficiency ratios include resource productivity ratios (e.g., sales per GHG) and process eco-efficiency ratios (e.g., production volume per amount of GHG).

Intensity ratios: Intensity (or ‘normalized’) ratios express GHG impact per unit of physical activity or unit of economic output. A physical intensity ratio is suitable when aggregating or comparing across businesses that have similar products. In turn, an economic intensity ratio is suitable when aggregating or comparing across businesses that produce different products. A declining intensity ratio reflects a positive performance improvement. Examples of intensity ratios include product emission intensity (e.g., tonnes of emissions per unit of sold livestock or crops generated) and sales intensity (e.g., emissions per sales). When calculating intensity ratios entities may have to allocate GHG fluxes amongst different product streams (see below).

Percentages: A percentage indicator is a ratio between two similar issues (with the same physical unit in the numerator and the denominator). Examples of percentages that can be meaningful in performance reports include current GHG emissions expressed as a percentage of base year GHG emissions.

Guidance on the selection and use of ratio indicators:
In selecting a ratio indicator, entities should consider which ratio indicators best capture the benefits and impacts of their business (e.g., its operations, its products, and its effects on the marketplace), as well as its intended application.

It is important to recognize that the inherent diversity of agricultural practices, as well as the influence of environmental factors on GHG fluxes, will affect the comparability of ratio indicators, both within and across businesses. For example:

- Intensity ratios will often be higher for self-replacing livestock herds than non-replacement herds. This is because self-replacing herds contain younger stock that emit enteric CH_4 and produce N_2O from urine depositions for a longer period of time before contributing to farm products.
- Adverse weather conditions can lower realized crop yields, causing inter-annual variation in intensity ratios, independent of any changes in farming practices. (In such cases, entities may find it useful to normalize and report emissions by expected yield, in addition to actual yield).

Without adequate context on the farming system, environmental effects, and the emissions sources that have been studied, ratio indicators are not useful for assessing performance. Therefore, to aid the reliable interpretation of ratio indicators, entities should provide perspective on such issues in their reports. Table describes various trade-offs associated with different types of indicators commonly used in the agricultural sector.

Ratio indicators should always be reported with data on the absolute GHG fluxes to/from a farm. This is because ratio indicators may exclude certain emissions, such as those associated with *by-products* or *co-products* (see below) or those not directly connected to the production system. For the same reason, entities may find it useful to track performance using different types of ratio indicators. The following scenarios show the importance of using additional ratio indicators (or absolute emissions data) to track performance at the whole farm level:

- Production intensification (e.g., an increased use of fertilizers and/or feed) might boost yields and result in a net reduction in GHG intensity per unit of agricultural output (provided the inputs are not excessive), but could also increase emissions on a per ha basis.
- Increasing the feed conversion efficiency of cattle can reduce emissions per product, but can lead to greater overall emissions (and emissions per ha) if any spare feed is diverted to new livestock.

.

Table 6-2. Advantages and disadvantages of common ratio indicators

Metric	Advantages	Disadvantages
GHG flux per unit land area (e.g., flux / ha)	• Useful to entities that define policies or that manage large amounts of land (e.g., government agencies) • Reflective of the overall level of GHG fluxes on farms	• Fails to consider efficiency of farm production • Does not directly allow for comparisons across farms within the same industry (i.e. is not industry specific)
GHG flux per unit product (e.g., flux / tonne beef)	• Better allows for comparisons within the same industry • Better able to represent the effects of mitigation measures that have a relatively small GHG impact, but that nonetheless improve productivity • Performance data are frequently sought by buyers on a per-product basis	• Calculation may be complicated by the variety of products that come from farms and the different allocation methods used to assign GHG fluxes (see below) • Does not consider product value (e.g., finer Merino wool versus coarser crossbred wool) • Does not reflect the overall climate impact of farms (which would vary depending on the volume of products produced)
GHG flux per unit of farm input (e.g., flux / MJ metabolisable energy intake)	• Provides an understanding of the effects of feed nutritional quality and feed levels on animal systems, or of the efficiency of nutrient use in cropping systems	• Calculation may be complicated by the need to allocate GHG fluxes
GHG flux per unit of quality content in final product (e.g., per unit of fat, protein or metabolisable energy content)	• Considers a fundamental objective of most agricultural production – to provide food energy	• Calculation may be complicated by the need to allocate GHG fluxes

Allocating emissions for intensity ratios

Agricultural production frequently results in the generation of by-products or co-products, especially if farms have on-site product processing facilities (Fig. 6-3). Common examples of by-products and co-products are shown in Table 6-3. In addition, certain agricultural activities will contribute to multiple streams of products (and their co/by-products), especially on mixed farms. For instance, fertilizer application will support not only crop growth, but also livestock production, if some of the primary output (the crop) is used as livestock feed. In such cases, it may be necessary to allocate emissions amongst the various products, before computing any intensity ratios (e.g., those that express emissions on a per product basis). *Allocation* is the process of partitioning GHG emissions data from a farming system to the different product streams from that system. Allocation will not be necessary where a farm produces only one output

Fig. 6-3. Illustrative common process requiring allocation

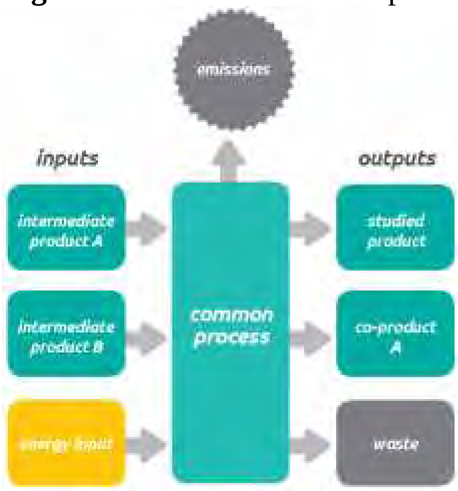


Table 6-3. Common examples of co-products and by-products from agricultural production

Co-product or by-product	Application
Beet pulp from sugar beet processing	Animal feed
Wheat middlings from milling of flour or semolina from wheat / duram	
Potato waste	
Residue from crushing of sugarcane stalks during juice extraction (bagasse)	Energy production
Corn stover (stalks and leaves)	
Dry stalks of cereal plants (straw)	Livestock bedding and fodder
Molasses from processing of sugar cane, grapes or sugar beets into sugar	Human food additive, brewing additive, livestock feed supplement
Poultry litter	Biofuel and fertilizer
Fish meal from unwanted whole fish and processed fish parts	Animal feed, fertilizer
Manure	Fertilizer
Cream from milk processing	Butter

It at all possible, entities should avoid allocation because allocation adds uncertainty to the intensity metrics. Entities may be able to avoid allocation in a number of ways:

1. Process subdivision. Here, the common GHG emitting process is disaggregated into sub-processes that separately produce the main product and the co-products. Process

subdivision is the favored approach and it may be accomplished by subdividing the farm and providing data on the quantities of inputs going to each farm enterprise. Mechanical sources will often be the most difficult to allocate because farm records are often on a whole-farm basis. One possible solution may be to set up energy use accounting on a per product basis by, for example, sub-metering individual facilities and tracking the amount of fuel used or the number of field passes made by field and date.

2. Redefining the unit of analysis so that the fluxes attributable to the main product and its co-products no longer have to be separated. For instance, by expressing GHG emissions on kg cattle raised basis as opposed to a kg beef basis, it is no longer necessary to separate out the emissions attributable to leather production.
3. System expansion. This method involves, first, estimating the GHG fluxes attributable to the co-products using information on a similar product or the same product produced elsewhere, and, second, deducting these fluxes from the overall entity-level inventory. The result is the flux attributable to the main product. For example, a dairy enterprise could use a life cycle emission factor to estimate the flux associated with butter production, before then subtracting this flux from the overall flux of the enterprise, to calculate emissions for milk production. Importantly, the data used to estimate the co-product's fluxes should come from farming systems that are comparable in terms of their climate and soil conditions (i.e., that come from the same region) and in terms of the products produced. Otherwise, system expansion will give misleading results. Also, the boundaries of the study identifying the co-product's fluxes should be comparable to those of reporting entity. For instance, if one excludes sources beyond the farm gate, the other should too.

Types of allocation approaches

In cases where allocation is unavoidable, producers may use amongst the following allocation approaches:

Physical allocation: Allocations are based on an underlying physical relationship between the multiple inputs/outputs and the quantity of emissions generated. For example, allocations can be based on the mass or volume of farm outputs:

$$\text{Allocated Emissions} = \left(\frac{\text{Mass (or volume) of specific product produced}}{\text{Total Mass (or volume) of all products produced}}\right) \text{ x Total Emissions}$$

Alternatively, physical allocations could be made based on the number or dietary quality of the products. The factor chosen should most accurately reflect the underlying physical relationship between the main product, co-product, and process GHG fluxes. For example, if the mass of the outputs determines the amount of flux, choosing an energy content factor would not provide the most accurate allocation.

Economic allocation: Allocations are based on the market value of each output/product leaving the multi-product process, as follows:

$$\text{Allocated Emissions} = \left(\frac{\text{Market Value of specific product produced}}{\text{Total market value of all products produced}}\right) \text{x Total Emissions}$$

The market value of co-product(s) should be the value of the co-products as they leave the common process (i.e. prior to any further processing). Also, entities should first establish a consistent policy for determining whether an output is a byproduct or a co-product based on financial criteria (e.g., based on relative market value). Finally, if prices for the outputs vary over the reporting period, it may be necessary to develop weighted average market values.

Under either physical or economic allocation, co-products without economic value are considered wastes and should have no GHG fluxes allocated to them.

Guidance on selecting an allocation approach

A single, consistent allocation approach should be used to allocate the emissions throughout the entire farming system. The sum of the allocated emissions for each output of a system should equal 100% of the emissions from that system. The use of multiple allocation methods for a single system can result in over-counting or under-counting of total emissions from that system.

Different allocation methods may yield significantly different results. For example, in cheese manufacture cheese is considered the main product, while whey powder, whey butter and grated cheese are considered co-products. Under an economic allocation approach, the higher value of cheese compared with the co-products results in most of the GHG fluxes being attributed to the cheese. In contrast, under a physical allocation approach, the greater mass of the co-products would result in most of the GHG fluxes being attributed to the co-products.

In general, entities should evaluate the possible results of different allocation methods before deciding which approach to use. Entities should select the allocation approach that:

- Best reflects the causal relationship between the production of the outputs and the resulting GHG fluxes;
- Results in the most accurate and credible flux estimates;
- Best supports effective decision-making and GHG reduction activities; and
- Otherwise adheres to the principles of relevance, accuracy, completeness, consistency and transparency.

Broadly, physical allocation is preferred when:

- A physical relationship amongst the products can be established and this relationship reflects their relative flux contributions.

- A change in the physical output of co-products is correlated to a change in the common process's fluxes (e.g., the more co-product produced, the greater the fluxes).
- Prices change significantly or frequently over time (e.g., fluctuation in commodity crop prices);
- Prices are not well-correlated with underlying physical properties and GHG fluxes (e.g., for agricultural products with a high value, such as certain niche crops)
- Companies pay different prices for the same product (due to different negotiated prices); or

Economic allocation is preferred when:

- A physical relationship amongst the products cannot be established or does not adequately reflect the relative flux contributions.
- The co-products would not be produced using the common process without the market demand for the main product and/or other valuable co-products
- The co-products were a waste output that acquires value in the market place as a replacement for another material input (e.g., manure as a replacement for fertilizer).

Box 6-1 describes specific cases where one allocation method is to be preferred over others. If one allocation method is not clearly more suitable than another based on these criteria, entities should perform multiple allocations with different methods and compare the results. If similar results are then obtained, the choice between the methods should not impact the inventory results and the entity should note this in the inventory report. But, if different results are obtained, entities should select the allocation method that provides the more conservative result (i.e. the method that allocates more emissions to the studied product as opposed to the co-products).

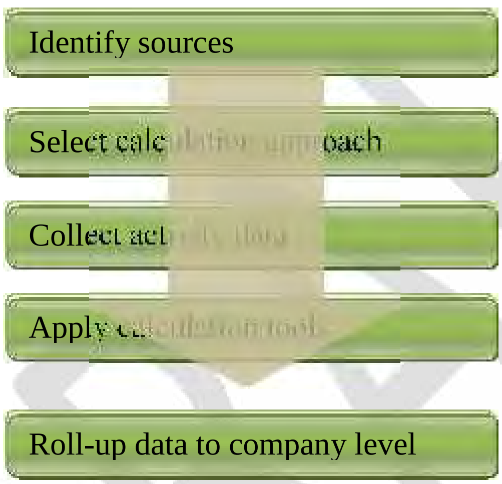
Box 6-1. Examples of when one allocation method is to be preferred over another

1. Fishery b-catch. In the process of catching lobster, additional fish are often caught by default and sold as by-catch. By-catch is much less valuable than lobster, but in some cases can account for a substantial portion of the mass output of the catching process. Economic allocation is preferred in this case because the co-product (by-catch) would most likely not be caught in the same manner if the fisherman were not also catching lobster, and because a change in the physical output of products is not strongly correlated to a change in process emissions (i.e., depending on the day more or less by-catch and lobster are possible using the same amount of fuel).
2. Other examples TBD

Chapter 7. Calculating GHG Fluxes

Calculating GHG fluxes can be the most challenging part of developing GHG inventories of agricultural sources. Entities should first identify the management practices and emissions sources that would need to be reflected in their inventories (see Chapter 4 and Chapter 5), before selecting a calculation approach and collecting input data. The selection of a calculation approach is a key step, because the likely accuracy of GHG flux data and the types of input data needed vary widely amongst approaches, affecting the ability of a company to realize its business goals for GHG reporting. The general approach for calculating emissions is depicted in Figure 7-1

Figure 7.1. Process for calculating GHG emissions



This chapter:

- Describes the general types of approaches that can be used to calculate the GHG fluxes to/from agricultural sources, particularly non-mechanical sources.
- Describes criteria that are useful in selecting specific tools or methodologies for calculating emissions.
- Describes the types of (primary) input data typically needed at the farm-level to calculate emissions.
- Provides guidance on prioritizing emissions sources for data collection.
- Describes common sources of uncertainty in calculating emissions that offer opportunities for improving inventory quality.

Please note that the Agricultural Guidance does not advance specific emission factors or formulae to calculate emissions. Instead, Appendix I: provides an overview of publicly available calculation tools.

7.1 Selecting a calculation approach

In general, the emissions from mechanical sources can be calculated with relatively high accuracy, compared to those from non-mechanical sources. This is especially true of mobile and stationary sources, whose emissions are primarily of CO_2 and can be calculated based on only a few items of information – mostly the type and amount of fuel used. Relevant quantification tools and protocols are available from a range of sources, including GHG reporting programs and the www.ghgprotocol.org

In contrast, the GHG fluxes to/from non-mechanical sources depend on complex interactions between management practices and variable environmental conditions. This means that the calculated GHG flux data for non-mechanical sources are likely to have much higher uncertainty, regardless of the calculation approach chosen. This difference has important implications for these data should be reported in inventories (see Chapter 9).

Chapt
Standard des
developed by
a range of cr
as transport v
machinery, s
and refrigera
conditioning

Calculation approaches for non-mechanical sources

Broadly, four different types of calculation approaches can be used for non-mechanical sources (Table 7-1):

- Field measurements
- *Emission factors*
- Empirical models
- Process-based models

Field measurements

The direct measurement of GHG fluxes on farms involves the use of specialized instruments that monitor the flow of GHGs from the source into the atmosphere. Many, but not all, GHG emissions sources in agriculture can be measured with such instrumentation. For example, techniques exist to measure the CH_4 emissions from enteric fermentation in livestock, such as controlled livestock chambers and pastures fitted with gas flux towers. Flux chambers can also be used to monitor the amount of N_2O and/or CO_2 emitted from plots of land, metering the products of nitrogen and carbon cycles. Emissions from livestock waste can be readily monitored in certain circumstances (e.g., covered anaerobic lagoons fitted with gas flux meters), although where waste is not managed in a confined system (e.g., manure deposited directly in pasture, range, or paddock), it is difficult, if not impossible, to directly measure the ensuing emissions. While useful for research, field measurement techniques are often too costly for developing farm-level inventories. They can, however, be used to sample emission sources and derive data to improve more approximate estimation techniques, such as emissions factors.

Emission factors

The simplest approach involves the multiplication of management activity data by a relevant emission factor, which is a coefficient describing the amount of GHG flux per unit of activity. For instance, to calculate the CH_4 emissions from enteric fermentation, emissions may be estimated by multiplying the number of dairy cattle owned by the entity by an emission factor that reflects how much CH_4 is emitted per head of dairy cattle. The accuracy of this approach varies depending on the specificity of the emission factor used and the accuracy of the input data. Emission factors for agricultural sources rarely capture the full complexity of underlying biological processes, which are driven by a number of external variables such as climate, soil conditions, livestock diet, and livestock/crop genetics.

Empirical and process-based models

Empirical models use field measurements to develop statistical relationships between GHG fluxes and agricultural management factors. On the other hand, process-based (or mechanistic) models mathematically link important biogeochemical processes that control the production, consumption, and emission of GHGs. Some models may only require one or several inputs to estimate GHG fluxes; others might require multiple inputs over different spatial and temporal scales. Input data can be physical variables such as temperature, precipitation, elevation, and soil nutrient levels, or biological variables such as soil microbial activity and plant diversity. The accuracy of models is variable and depends on the robustness of the model and the accuracy of the inputs. For instance, if a model is used in a new agro-climate regime for which it was not previously calibrated, the model will likely not be reliable.

GHG fluxes can also be calculated using any combination of the above approaches. For instance, a process-based model might employ emission factors for certain sources when experimental data are insufficient to model the emissions from those sources. And process models and direct measurements may also be used to derive more specific emission factors. The resulting hybrid designs may increase the accuracy and feasibility of the estimation approach for entity-level accounting.

These approaches differ in how they map onto the various tiers defined by the Intergovernmental Panel on Climate Change (IPCC) for the purposes of national reporting (see Box 7-1). In general, emission factors and empirical models (IPCC Tiers 1 and 2) are the easiest and least resource-intensive approaches to use. But they tend to become less accurate as the spatial scale decreases from a regional or national level to a local or farm-level. This is because they are not very effective in capturing the geographical variation in the biophysical processes that underpin GHG fluxes. As a result, their use may mask much of the variation in emissions rates that exists amongst farms and they may not be sensitive to many changes in farm management practices. Furthermore, emission factors and empirical models tend to be highly compartmentalized – they tend to focus on individual emissions sources one at a time. However, non-mechanical sources are often connected by complex flows of N and C through farms, such that the climate impact of agricultural practices is best evaluated simultaneously and at the farm-level. In contrast to emission factors and empirical models, field measurements (Tier 3) and process models (IPCC Tiers 2 and 3) integrate and link multiple sources, allowing a whole-farm analysis of emissions. They are particularly suited to understanding trade-offs in the emissions of different GHGs (see Box 7-2).

However, the use of field measurements and process models can require expertise, data and time that will often not be available to companies.

A note on quantifying changes in carbon stocks

Because of the reversibility of carbon stocks, changes to these stocks can be quantified using data on:

- Stock size, when measured in units of metric tonnes carbon (e.g., metric tonnes carbon/ha) at two points in time; or
- The net balance of CO_2 emissions and CO_2 removals ('net fluxes') to or from a stock, measured in units of metric tonnes CO_2.

Either approach is equally valid. Under either, entities should take care to use methods that treat soil depth consistently, particularly in the context of land use change. For instance, reference stock values might be available for biomass carbon stocks in forest and cropland; if these are not defined to a consistent depth, some of the estimated stock difference will be a methodological artifact.

This Guidance requires net CO_2fluxes to be reported and only for the stocks listed in Chapter 8.1. Data on stock size can be reported optionally – such data are more difficult to obtain but can provide useful context for interpreting inventory results. Stock size data can be converted to net flux data by multiplying the amount of stock change by $\frac{44}{12}$, which is the ratio of the molecular weight of $CO_2$to that of carbon.

Box 7-1. IPCC Methodologies for National GHG Emissions Inventories

The Intergovernmental Panel on Climate Change (IPCC) has developed a comprehensive set of methodologies -the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* - to guide the preparation of national GHG emissions inventories. Many of the tools listed in Appendix I: will rely on some portion of these Guidelines, especially the default emission factors and calculation formulae.

The Guidelines define three general tiers of methodologies based on their complexity and data requirements. Different tiers are used by different countries depending, in part, on the significance of the emissions sources under consideration.

- Tier 1: Simple, emission factor-based approach. Tier 1 emission factors are international defaults, although they will often have been based on studies conducted in a select few countries.
- Tier 2: More region-specific emission factors or more refined empirical estimation methodologies.
- Tier 3: Dynamic bio-geophysical simulation models using multi-year time series and context-specific parameterization.

These tiers provide a useful means for categorizing and understanding the likely accuracy of the different calculation methods that are available to companies. In general, Tier 3 methods are considered most accurate and Tier 1 methods least accurate.

Table 7-1. Summary of approaches for calculating the GHG to and from non-mechanical sources

Approach	Advantages	Disadvantages
Field measurements. This category includes lab measurements of soil carbon density	• Potentially highly accurate, but depends on sampling intensity • Implicitly capture the impacts of multiple, simultaneous farming practices (assuming multiple sources are measured)	• High capacity requirements for technical know-how and equipment • Limited to measurable variables • Time-consuming • Expensive, even if the measurement technologies are relatively low cost, because of need for many samples • Do not by themselves distinguish between the effects of anthropogenic factors from those of other factors, such as climate
Emission factors. Quantify the GHG flux as a function of farming activity (e.g., tonnes CO_2 emitted per ha of farmland)	• Inexpensive • Easy to use	• Low accuracy, but depends on specificity of the emission factor to field conditions • May not be sensitive to many changes in environment or management regime (e.g., new animal genotype, different method for applying fertilizer, different animal feed composition, etc.) • Do not capture the GHG impacts of multiple, simultaneous farming practices
Empirical models. Constructed from statistical relationships between empirical GHG data (e.g., existing inventory data or yield curves) and management factors	• Inexpensive • Low to medium accuracy • Easy to use	• May not be sensitive to changes in environment or management regime, especially at finer spatial scales • Do not capture the GHG impacts of multiple, simultaneous farming practices
Process-oriented models. Mathematical representations of the biogeochemical processes that drive GHG fluxes	• Medium to high accuracy, depending on the realism of the model and the availability of calibrating data • Can represent many different combinations of management practices and soil and climate conditions, and so may allow the GHG effects of relatively subtle changes in management practices to be quantified • Designed for use at fine spatial scales • Can be run at coarser spatial scales to help average out uncertainty, if calibrating	• Require vast background datasets (e.g., on multi-decade weather data series, biomass partitioning parameters, etc.) that may not be available for specific regions. Also require extensive farm-level data (e.g., on seeding and harvesting dates). • High capacity requirements for technical know-how • Time-consuming and so expensive to run

Approach	Advantages	Disadvantages
	background data are not available at the farm level (as is the case in many developing countries)	

Box 7-2. The value of a whole-farm or systems approach to calculating agricultural GHG fluxes

There is no single mitigation option that will reduce all agricultural pollutants, such as GHGs, NH_3 and NO_X. Pollution swapping is thus inevitable and occurs when a mitigation option or best management practice (BMP) is introduced to reduce emissions of one pollutant, only to increase that of another. Some examples of the pollution swapping of GHGs are:

- Measures taken to enhance soil carbon sequestration (e.g., no till-practices or increased irrigation) can lead to increased soil N_2O emissions because of increased soil moisture content, a supply of easily mineralizable N, and/or reduced soil aeration.
- Wooded riparian buffer zones can increase carbon sequestration but lead to increased soil N_2O emissions, compared to field margins.
- Constructed wetlands can sequester carbon over long time periods, but can also emit CH_4.
- Aerating a manure lagoon to reduce CH_4 emissions will increase N_2O emissions.
- Removal of straw from flooded rice paddies to reduce CH_4 emissions can lead to the requirement for more fertilizer and increased N_2O emissions.
- Leaving sugarcane residue on fields can increase soil carbon sequestration but also increase CH_4 emissions.
- The winter use of restricted grazing systems and stand-off pads – purpose built, drained resting surfaces to hold livestock over wet periods – to reduce soil N_2O emissions and N leaching can increase CH_4 emissions.
- The application of N-transformation inhibitors to soils to reduce the leaching of some N_2O precursors may increase that of others.

These trade-offs demonstrate the need to identify trade-offs and consider multiple sources and GHGs in tandem when evaluating possible mitigation measures. A whole-systems approach avoids potentially ill-advised practices based on preoccupation with one individual GHG or practice.

Available tools for calculating emissions

There is an increasing array of publicly available tools (spreadsheets, software and protocols) for calculating emissions based on emission factors, models or a combination of these approaches. Appendix I provides a non-exhaustive list of such tools. Most of the more accessible and user-friendly tools that would be most amenable to use by farm managers tend to implement Tier 1 or Tier 2 approaches. Unfortunately, process-oriented models are often unwieldy to use, although more user-friendly interfaces are available or under construction for some process models and specifically intended for use by farm managers, extension agents and consultants. These offer the most potential for accurately calculating farm-level emissions, at least in regions for which background, calibrating datasets are available.

Criteria for selecting a specific tool

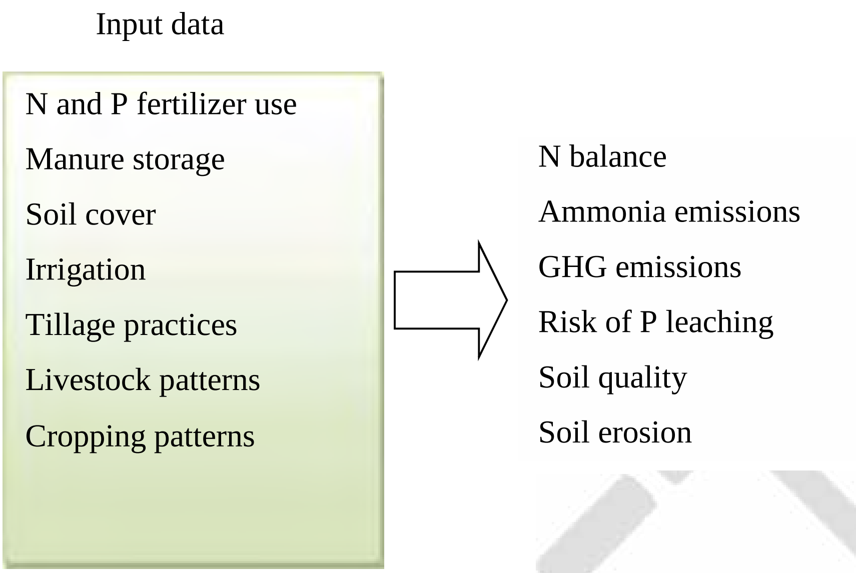
This Guidance does not recommend specific tools for calculating emissions – entities should instead select tools based on their business goals and agricultural operations. In evaluating individual tools, entities should consider a range of questions, including:

- Is the tool geographically representative? Is it tailored to the region/area of interest?
- Is the tool comprehensive in terms of its coverage of different emission sources, GHGs and management activities, particularly those that are practiced or planned on the farm? And does it integrate the effects of multiple management activities across the farm?
- Is the tool up-to-date?
- Can the tool quantify the co-benefits of GHG emissions reductions (e.g., nitrate or phosphorus pollution abatement; Figure).
- What input data are required and will farm managers be able to provide these data?
- How much labor and technical expertise is required to use the tool?
- Is the tool transparent about its limitations and assumptions?
- Is it otherwise consistent with the GHG accounting principles (see Chapter 3)?

Many of these questions impinge on the potential accuracy of the emissions data. In general, companies should not exclude required emissions sources from their inventories as a result of uncertainty in the results. Instead, to ensure the relevance and completeness of the inventory, companies may decide to use a less accurate approach for emissions sources that are expected to be relatively less significant, as long as the inventory is transparent about the limitations of the calculation approaches used (see Chapter 9).

Sometimes it is tempting to define a minimum emissions accounting threshold (often referred to as a *materiality threshold*) stating that a source not exceeding a certain size can be omitted from the inventory. Technically, such a threshold is simply a predefined and accepted negative bias in estimates (i.e., an underestimate). Although it appears useful in theory, the practical implementation of such a threshold is not compatible with the completeness principle of the Agricultural Guidance. In order to use a materiality threshold, the emissions from a particular source or activity would have to be quantified to ensure they were under the threshold. However, once emissions are quantified, most of the benefit of having a threshold is lost.

Figure 7-2. Much of the data used to calculate GHG emissions can also be used to quantify or identify co-benefits



7.2 Collecting activity data

Activity data can often be collected from existing data records held by producers, such as: invoices, electricity meters, crop insurance records, field records of tractor passes and crop operations, production records, land registry records, nutrient management plans, and livestock movement records. To the extent possible, these records should be used to reduce the GHG reporting burden and improve the audit trail. In general, data on energy consumption, procurement and production levels can often be obtained from high quality sources. In contrast, reliable data on land management practices and land use change can be more difficult to obtain. Table7-2 summarizes common types of required activity data and indicates the types of records that may help provide these data. The type of activity data required for any one source will vary widely, depending on the type of calculation approach - entities should consult individual calculation tools to determine their exact data requirements. It is recommended that large operations with geographically separated facilities should standardize inventory procedures and keep central records.

Common challenges

Certain challenges are commonly encountered when collecting activity data (Table 7-3), especially when attempting to separate data for different farming enterprises and then calculate product-specific metrics (see Chapter 6.3). Entities should be mindful of these challenges when designing inventories and inventory quality management plans.

Chapter
Standard descr
data from mult
and farms can
entity-level inv

Table 7-2. Types of input data that may be needed to calculate GHG fluxes to/from on-farm sources. Note that some calculation tools may have data requirements that are not reflected here and that not all types of input data may be required for a given source.

Source	Common of types of input data needed	Description of data record
General	- Soil texture, moisture, drainage and pH - Temperature - Area of different types of crops harvested and crop yield by crop	
Enteric fermentation	- Livestock numbers by age and type (e.g., calves, bulls, heifers, cows), disaggregated by season or month - Length of juvenile, adult production and adult non-production phases - Number of livestock managed off-site (e.g., off-site wintering, feedlots, ajistments) - Sales and purchases of animals - Amount and quality of feed (e.g., protein content) - Quality of forage in pastures or open grazing systems - Amount of time livestock were grazed - Dry matter intake per head - Type and amount of feed additives	
Manure management	- Type of management system - % of manure managed in this system - Number of days system used	
Application of synthetic fertilizers, livestock waste and crop residues to soils	- Type of fertilizer/farm waste and N content (e.g., %N/kg or liter) - Application rate (e.g., kg/ha) - Application method (e.g., broadcast, incorporated, etc.) - Dates of applications - Amount of crop residue returned to soil - Amounts of exported/imported manure	
Drainage and tillage of managed soils	- Types of tilling practices - Years tilling practices were changed - Area of cropland for which tilling practices were changed - Area of organic soil (e.g., peat, fen) drained to different depths - Soil organic matter (SOM) content	
Rice cultivation	- Crop acreage	

Source	Common of types of input data needed	Description of data record
Open burning of crop residues	- Acres burnt - Amount of crop residue left on field per acre	
Land use change – conversion of forests, grasslands and wetlands into farmland, and vice versa	- Land types and species concerned (e.g., type of woodland) - Area of land concerned - Year land use change occurred	
Woodland management (e.g., short-rotation woody crop plantations)	- Volume of harvested wood - Volume of woody detritus left on-site	
Fuel use in mobile and stationary equipment	- Amounts of different types of fuels used - Starting and ending volumes of different fuel stocks - Amounts of different types of fuels purchased For contractor operations: - Hours of different types of machinery operated by contractors (e.g., <150 hp, 150-200 hp, etc.). - Acres of cropland contracted	
Electricity use	- Amount of purchased electricity - Amount of electricity from on-farm renewable energy sources, used on-farm or sold to the grid	
Refrigeration or air-conditioning	- Amount of products refrigerated - Types and amounts of refrigerants used - Starting and ending volumes of different refrigerant stocks - Amounts of different types of refrigerants purchased	

Table 7.3. Common challenges in collecting activity data for on-farm emissions sources

Challenge	Solution
Calculating livestock emissions based on the number of head on the farm per year, when livestock numbers and categories vary a lot over the year (e.g., with spring and autumn calving there is a wide spectrum of ages of livestock on the farm)	Calculate emissions on a monthly basis
Calculating emissions from contractor fuel use on farms, when producers record only the contracted area rather than contracted time or fuel use	Back calculate the emissions using assumptions about the amount of fuel needed per area serviced, as well as the machinery employed (the CH_4 and N_2O emissions depend on the type of machinery, while the CO_2 emissions depend on the volume of fuel used)
Understanding the energy consumption of individual facilities or sources (e.g., pump)	Install meters or provide a use log that tabulates the number of hours per day of operation
Calculating soil N_2O emissions when slurry handling dates and application rates are not recorded	?
Determining the amount of crop residues burnt on fields	Determine the total amount of above-ground biomass grown over the reporting period, then subtract the fractions removed before burning due to animal consumption, decay in the field, and harvesting (for biofuels, domestic livestock feed or other use).

7.3 Uncertainty in emissions calculations

Understanding the uncertainty in agricultural GHG flux data is crucial for properly interpreting inventory results. Identifying sources of uncertainty can help companies understand the steps required to improve the inventory quality and the level of confidence users should have in the inventory results.

The accuracy of flux data is determined by a number of factors, including:

1. Model uncertainty, which refers to intrinsic limitations in the ability of the calculation approach to reflect real world conditions. Such uncertainty is particularly important for many agricultural sources whose emissions are often determined by complex interactions between biological processes (e.g, nitrification and decomposition), environmental factors (e.g., temperature, rainfall, soil pH) and management practices. Failure to reflect these interactions accurately in the calculation approach can lead to significant divergence between the actual and calculated values of fluxes. For some sources it may not be possible to improve accuracy until science has refined the calculation approach (i.e. until the model uncertainty has been reduced to an acceptable level).
2. Parameter uncertainty, which refers to the uncertainties associated with quantifying the parameters used as inputs into the calculation approach (e.g., activity data and emission factors). Parameter uncertainties can be evaluated through statistical analysis, measurement equipment, precision determinations, and expert judgment.
3. Scenario uncertainty. While parameter uncertainty is a measure of how close the data are to the true (though unknown) data, scenario uncertainty refers to variation in calculated fluxes due to methodological choices. Methodological choices may include modeling approaches, allocation procedures and inventory boundary approaches. The use of the Agricultural Guidance should help reduce methodological uncertainty by constraining the choices companies may make in their methodologies.

Chap
Standard pro
managing in

Cumulatively, these sources of uncertainty affect whether flux data are accurate enough to serve a useful purpose (i.e. to meet the business goals that are driving the development of inventories).

In general, understanding parameter uncertainty will be the primary focus of entities in managing inventory quality – most entities will lack the technical expertise to estimate model uncertainty or evaluate scenario uncertainty. As far as is possible, entities should identify and track key uncertainty sources throughout the inventory process and iteratively check whether the uncertainty of the results is adequate for the entity's business goals.

7.4 Guidance for prioritizing data collection efforts

Entities should prioritize data collection efforts on the sources and sinks that are expected to have the most GHG emissions, offer the most emissions reduction potential, and are most relevant to the company's business goals. This analysis should consider the range of different GHGs emitted from individual sources, because of the potential for pollutant swapping (see Box 7.2) and also because entities might have different amounts of control over the different GHGs. As far as possible, the prioritized sources should also be subject to the most accurate quantification methods and the focus of quality analysis/quality control procedures. Collecting higher quality data for priority sources will allow entities to more effectively set reduction targets and track and demonstrate progress over time, while making the most efficient use of available resources.

Table 7-4. Criteria for prioritizing data collection efforts

Criterion	Application to source (or sink)
Magnitude of GHG flux	The source (or sink) is large (or believed to be large) relative to most other sources
Trends in magnitude	There is a documented increase or decrease in the size of the source over time or a projected trend based on projected changes in agricultural practices
Uncertainty of GHG flux estimates	The GHG fluxes associated with the source are (or are believed to be) large
Degree of control	There are potential emissions reductions that could be undertaken or influenced by the company
Risk	The source contributes to the company's risk exposure (e.g., climate change related risks such as financial, regulatory, supply chain, product and customer, litigation, and reputational risks)
Stakeholders	The source is deemed critical by key stakeholders (e.g., customers, suppliers, investors or civil society)
Sector Guidance	The source has been identified as significant by sector-specific guidance
Other	The source meets any additional criteria developed by the company or industry sector

Prioritizing sources based on the magnitude of GHG fluxes

The most rigorous approach to identifying priority sources is to use quantitative data to rank the size of different sources (and sinks). This approach has three steps:

1. Obtaining GHG flux data. Preferentially, companies would use data from the latest available inventory, although certain sources will fluctuate in magnitude from one inventory period to another. Alternatively, entities may use initial GHG estimation (or screening) methods to estimate the fluxes for each source (e.g., by using industry-average data or rough estimates).
2. Ranking all sources from largest to smallest according to their estimated GHG fluxes. Removals should be listed as absolute values (i.e. no negative sign) to allow the proper identification of significant sinks.
3. Applying a pre-determined cumulative threshold to the identify priority sources, which would be those that together add up to a certain % of the overall emissions.

If quantitative data are not available, published studies may be used to obtain a qualitative understanding of the relative importance of different sources. For instance, product LCA studies of different food products could indicate the largest on-farm emissions sources associated with the production of those products. Also, whole-farm assessments of the climate impact of individual farms are comparatively uncommon, but may still provide a useful guide (e.g., see Figure 4-5 for an example). However, both LCA and whole-farm studies may not reflect the management activities and environmental conditions that are specific to the reporting company. Therefore, they may not, by themselves, provide a reliable guide to the relative magnitude of different sources.

<u>Trend assessments</u>

In addition to ranking sources for a given inventory period, it may also be useful to rank sources based on the percentage change in fluxes over time (e.g., between the base period and the latest inventory period), if data are available.

$$\text{Difference in GHG flux} = \frac{\text{latest inventory estimate} - \text{base period estimate}}{\text{absolute value of pase period estimate}}$$

This analysis is beneficial because it can identify sources whose trend is different from that of the overall inventory. Entities may choose not to invest additional resources in estimating emissions that show a declining trend (or sequestration that shows an increasing trend), especially if these trends result from the introduction of mitigation measures. However, prioritizing these sources is still recommended to help ensure inventories reflect mitigation efforts as much as possible. Entities may likewise chose to invest more in categories whose fluxes show large increases.

Factoring in data uncertainty into source prioritization

Because the GHG fluxes from agricultural sources are often calculated with substantial uncertainty it can be useful to incorporate measures of uncertainty when prioritizing sources. Measures of parameter uncertainty (Chapter 7.3) are particularly useful and will often be available (e.g., the IPCC often publishes uncertainty bounds for it default, Tier 1 emission factors). If the uncertainty bounds are asymmetrical, the larger uncertainty should be used to remain conservative.

Chapter 8: Accounting for Carbon Stocks

Carbon stocks are reversible - any carbon sequestered in carbon stocks will eventually be emitted to the atmosphere. Also, changes in carbon stocks can take decades to reach equilibrium following a change in farm management or land use. These special features of carbon stocks have important implications for whether and how changes to them should be accounted for and reported within an inventory.

This chapter:

- Describes the specific changes in carbon stocks that should be reported in inventories or that may be omitted from inventories because of their non-anthropogenic origin
- Describes how long-term changes in carbon stocks can be spread over multiple reporting periods

This chapter supersedes guidance (Appendix B) in the Corporate Standard for reporting carbon sequestration.

8.1 Which changes in carbon stocks should be accounted for?

Activities that impact C flows in agricultural systems will affect multiple carbon pools. The GHG accounting should thus be as comprehensive as possible, addressing the individual effects of the activities on the different pools.

As noted in Chapter 7.1, the Agricultural Guidance requires companies to only report net CO2 fluxes to/from carbon pools, and not actual stock data themselves. Changes in the following carbon stocks shall be accounted for:

(a) Organic carbon stocks in mineral and organic soils
(b) Below-ground and above-ground woody biomass stocks
(c) DOM stocks

The CO2 fluxes from these changes are reported in a special 'Biogenic C' category within inventories (see Chapter 9.1).

The following changes in carbon stocks do not need to be accounted for:

1. Net fluxes to/from inorganic carbon stocks in soils. In contrast to soil organic carbon stocks, inorganic carbon stocks are slow to respond to management changes and often will not exhibit significant changes. Moreover, quantifying such changes requires a detailed understanding of site hydrology and mineralogy. For instance, it may require following the fate of discharged dissolved inorganic C and base cations (e.g., Ca and Mg) from the managed land, at least until they are fully captured in the oceanic inorganic C cycle. Such analyses are highly complicated. For these reasons, entities do not generally need to report the net fluxes to/from inorganic soil carbon stocks.

   However, certain management practices can be expected to result in significant changes in soil chemistry or processes (e.g., increased soil acidity), which may be expected to lead to the breakdown of carbonates and the release of carbon compounds to the atmosphere. For instance, under some management regimes ammonium sulfate fertilizer may be added to high pH soils with the goal of reducing pH to a 6.5 to 7.5 range. This pH change will tend to result in the breakdown of inorganic soil carbon and the release of carbon compounds to the atmosphere. In these cases, entities should strongly consider quantifying these impacts.

2. Sequestration in organic soils. In general, the rates of C sequestration are relatively slow in wetland environments with organic soils and can be assumed to be negligible. In contrast, net fluxes from the organic carbon stocks in organic soils are often considerable and should be accounted for.

Additional exclusions relate to non-anthropogenic impacts and are discussed in Chapter 8.2. The carbon incorporated into animal tissues or lost through animal respiration shall not be reported in an inventory.

Guidance on accounting for biomass stocks

In general, entities shall report any fluxes from changes in standing biomass stocks, including the CO2 emissions from biomass combustion (e.g., from the open burning of crop residues on fields), but excluding the losses of carbon in harvested products and transfers of carbon to other carbon pools (e.g., the accumulation of slash and other plant detritus in the dead organic matter pool as a result of harvesting). These exclusions are needed to prevent double counting within an inventory or across inventories that have been compiled by different organizations.

Perennial woody vegetation in orchards, vineyards, and agroforestry systems can store significant carbon in long-lived biomass, the amount depending on species type and cultivar, density, growth rates, and harvesting and pruning practices. Consequently, entities should account for changes in these biomass stocks, in particular.

In contrast, the biomass associated with annual and perennial herbaceous plants and pastures is relatively ephemeral - reductions in these biomass stocks from harvesting, the burning of the crop residues, or the integration of crop residues into soils, are balanced by stock increases from plant re-growth over a period of only one to a few years. Consequently, entities should not report any sequestration in these biomass stocks (although any CO_2 emissions from the combustion of this biomass should be reported). However, if entities are contributing data to the life-cycle emission inventory of a product, they may still find value in reporting this sequestration. This is because the GHG Protocol Product Standard requires that all CO_2 emissions and sequestration be accounted for in the development of product-level GHG inventories. The sequestration of carbon in annual and perennial vegetation and crops can be reported as a memo item in a corporate inventory for this purpose.

8.2 Exclusion of non-anthropogenic impacts on carbon stocks

As discussed in Chapter 6.1, inventories are only useful for managing emissions as long as they allow companies to effectively track the effects of changes in management practices. Entities may therefore exclude the changes in carbon stocks that arise on unmanaged lands or as a result of natural disturbances that are beyond the control of the reporting entity. The ensuing CO_2 fluxes may instead be reported as a memo item. Similarly, CH_4 and N_2O emissions from unmanaged lands and natural disturbances may be excluded from the scopes and instead reported as a memo item.

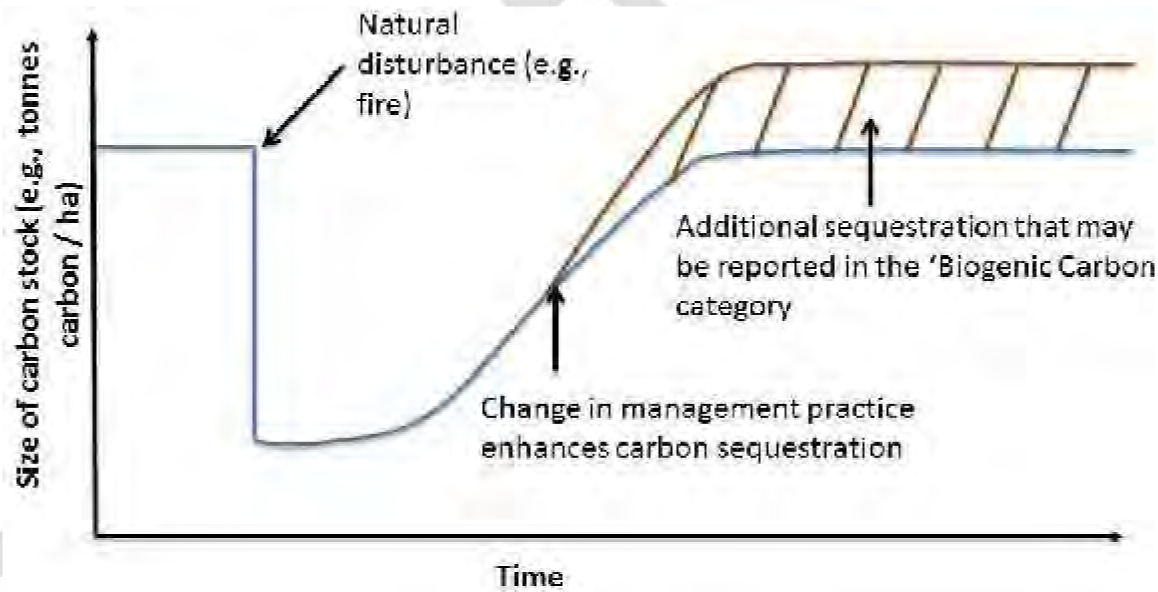
Natural disturbances on managed lands
Natural disturbances are varied and include fires, windstorms, landslides, droughts, and pest outbreaks. There are various considerations that entities should be mindful of to ensure the transparent and fair accounting of such events:

1. Accounting for post-disturbance carbon sequestration (e.g., sequestration in an orchard that is re-growing following a disturbance): entities should not account for any carbon sequestration until the amount of sequestered carbon has balanced the amount of carbon losses that were originally excluded from reporting (see Fig. 8.1).
2. Accounting for intentional land use change following a disturbance (e.g., conversion of disturbed forest to cropland): entities should not exclude any of the emissions associated with the disturbance form their inventories.
3. Understanding whether an event is anthropogenic or not: some events may have an anthropogenic basis (e.g., global warming might influence the severity of a disturbance), but if the event is not directly associated with a company's operations, it can be excluded. For the same reason, acts of arson may also be excluded from an inventory.
4. Understanding whether an event is a 'disturbance' or within the bounds of 'normal' variation: entities should develop a policy for defining disturbances that is applied consistently across inventories and that defines thresholds or criteria for recognizing when disturbances have occurred. It should be noted that landscape ecosystems are subject to long-term changes – entities may therefore have to adjust these criteria over time or simply accept that certain disturbances can no longer be excluded from inventories (e.g., as droughts become more commonplace as a result of global warming in certain regions, these droughts might constitute a new 'norm' that should be reflected in inventories as a cost of doing business in those regions).

Because of the challenges and uncertainty in recognizing and excluding the effects of disturbances, companies should evaluate the likely size of a disturbance before committing the resources to quantifying and removing it.

Some disturbances might have relatively short-lived impacts on carbon stocks, whilst others, such as windstorms, might also have long-lived effects through the decay of windblown trees. For the sake of practicality, if companies do choose to report disturbance emissions, they may assume that all post-disturbance emissions are emitted in the year of the disturbance event. Alternatively, they may amortize the post-disturbance CO2 emissions (see Chapter 8.3).

Figure 8.1. Accounting for natural disturbances. In this example, a natural disturbance (fire) immediately results in a reduction in the size of a forest's biomass carbon stock. At some point during the recovery of the affected forest, the forest owner implements a change in management practice that increases the size of the carbon stock over its original value. The forest owner may only account for this additional sequestration in its inventory.

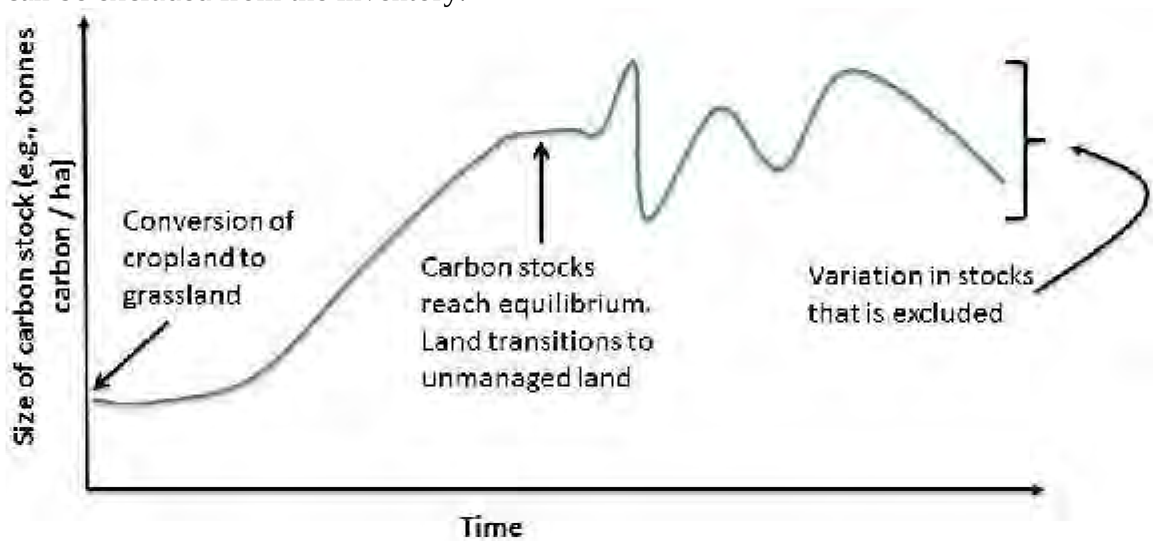


CO2 fluxes from unmanaged lands

Agricultural lands may contain conservation areas that are not managed for economic exploitation (i.e., areas that are not used for agricultural production). Examples include permanent preserves or legal reserves established in forests, riparian habitats, wetlands, etc. These lands are considered 'unmanaged' in this Guidance. Lands that are managed only to preserve ecological functions (e.g., the use of pesticides in a conservation area) and not for economic gain are likewise considered unmanaged.

The CO2 fluxes to/from unmanaged lands may be excluded from an inventory. Sometimes, some economic exploitation may occur on otherwise unmanaged lands (e.g., fruit trees might be planted in a forest reserve). In such cases, entities should account for the CO2 fluxes specifically associated with the agricultural activity (e.g., the cultivation of the fruit trees), but may exclude the CO2 fluxes from the unmanaged land as a whole. Also, should a natural disturbance lead to the conversion of unmanaged land to managed land, the disturbance emissions should be reported within the inventory. Finally, if an entity has set aside formerly productive agricultural land as a reserve, then it may account for the ensuing carbon sequestration until the carbon stocks have reached equilibrium, whereupon the land is considered unmanaged (see Fig. 8.2 for an example).

Figure 8.2. A company sets aside cropland as a permanent reserve. It then reports the ensuing carbon sequestration until carbon stocks have reached equilibrium. Thereafter, land is treated as unmanaged and any further change in carbon stocks can be excluded from the inventory.

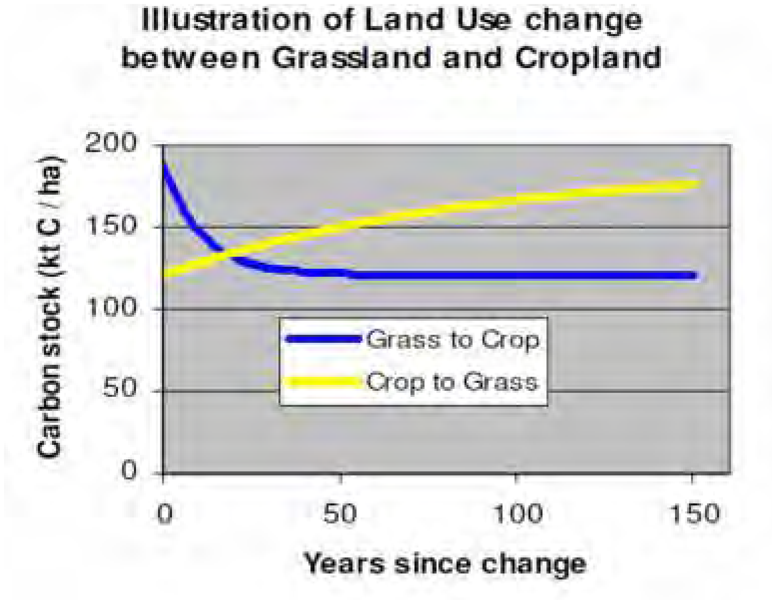


8.3 Amortizing changes in carbon stocks over time

What is 'amortizing' and why is it important?

Shifts in management practices during the reporting period will often have long-lasting effects on carbon pools that may persist for decades. For instance, following a change in management practices (e.g., adoption of no-till practices) soil carbon stocks may take 15 - 60 years to reach equilibrium, depending on the type of tillage and crop rotation regimes. Following a change in land use (e.g., conversion of cropland to grassland), the transition period will often exceed 100 years (e.g., Figure 3). As Figure 3 also demonstrates, the rate of change in carbon stocks will also vary over time. Amortizing changes in carbon stocks involves allocating these changes across time (and therefore multiple inventories) to ensure the more consistent accounting of carbon stock impacts.

Figure 8-3. Illustration of land use change between grassland and cropland (Placeholder11)



When is amortizing required?

Not all changes in carbon stocks will need to be amortized, depending on how stock impacts have been quantified and the management practice at hand.

As discussed in Chapter 7.1, a variety of methods can be used to quantify stock impacts. These methods generally either:

- Directly provide an estimate of the change that occurred in the reporting period, rather than in the transition period as a whole. For instance, a process model might estimate the cumulative net CO_2 flux over the reporting period, or an emission factor might have a time dependence of only one year. Amortizing will not be necessary in these cases.
- Estimate the total amount of change over the entire transition period, under permanent adoption of the practice at hand. For instance, reference stock sizes might be available for the amount of carbon typically stored in the biomass of grassland and woodland - the difference between these factors would thus represent the total change in stock from the conversion of grassland to woodland. Amortizing will be necessary in these cases.

Irrespective of the quantification approach, some changes in c stocks should never be amortized and the entirety of these changes should be reported in the year of the management practice. In particular:

- The emissions from biomass combustion should always be reported when they occur (e.g., the emissions from the open burning of crop residues or fires used to convert one land use category to another)

- Emissions from the organic carbon stocks of organic soils should be reported as they occur on an annual basis. This is because, once organic soils are put into cultivation, carbon losses typically continue until the organic soil layer has been completely depleted.

Finally, some management practices may shunt carbon to DOM stocks that is not then emitted in the year of the intervention. For instance, much of the C in biomass killed in a fire is added to dead wood, litter and soil pools from where the C will be emitted over years to decades, as the DOM decomposes. Quantifying the emissions from these DOM stock changes can be very challenging; for instance, DOM decay rates differ greatly between regions, depending on temperature and moisture regimes. Consequently, entities may either assume that the total C losses from DOM stocks occur in the year of the intervention, or, should capacity and data exist, they may amortize these losses over time.

Table 8.1 summarizes when it is and is not appropriate to amortize changes in carbon stocks.

Table 8.1: When changes in carbon stocks can be amortized

Biogenic carbon flux	**Time reporting requirement**
• Sequestration in woody biomass stocks • Sequestration in organic carbon stocks of mineral soils	• Amortize if the time interval of the quantification approach exceeds one year • Otherwise, report all sequestration in year of intervention (sequestration in annual and herbaceous perennial crops should not be reported)
Emissions from woody biomass stocks	• Biomass combustion emissions should be reported in the year of the intervention • The carbon embodied in (and subsequently lost from) harvested woody products (HWPs) should not be amortized but accounted for with scope 3 using guidance in the Scope 3 Standard.
Emissions from the decomposition of dead organic matter (DOM)	• Amortize, should capacity and data exist; or • Report in the year of intervention
Emissions from mineral soils	• Amortize if the time interval of the quantification approach exceeds one year • Otherwise, report all sequestration in year of intervention
Emissions from organic soils	Do not amortize – report in the year of the intervention
Sequestration in organic soils	Optional

How should changes be amortized?

When amortization is necessary, this Agricultural Guidance requires companies to use a linear-rate approach, wherein the total amount of change in a carbon stock is amortized evenly over multiple inventories. The amount of change to be amortized in each inventory is calculated by dividing the total amount of change by the number of years in the amortization period. The fixed-rate approach is recommended because it provides the most consistent way to distribute impacts for use in a GHG inventory.

The length of the amortization period may vary depending on the stock concerned and the quantification approach. In general, the amortization period for any one stock should be:

- The length of the time dependence of the stock change factor; or
- The length of the nominal harvest/maturity cycle, for woody biomass stocks (this assumes that woody crops accumulate biomass for a finite period until they are removed through harvest or reach a steady state where there is no net accumulation of carbon in biomass because growth rates have slowed and incremental gains from growth are offset by losses from natural mortality, pruning or other losses).

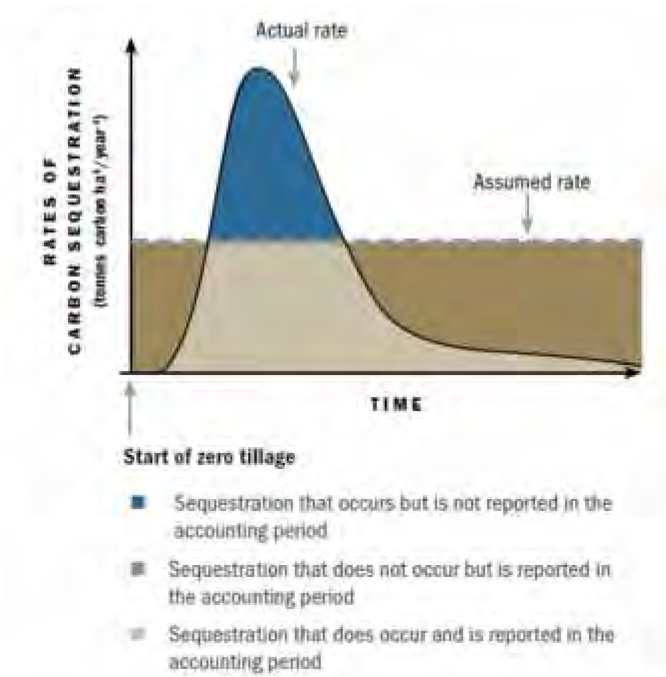
In the absence of other information, entities may assume an amortization period of 20 years for DOM stocks and the organic carbon stocks in mineral soils. This 20-year value is the default time horizon in national GHG inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC) [6]. Entities may alternatively assume more specific values used by individual countries in their national inventories[7].

Entities should note that the rate of amortization chosen by a company will likely not match actual patterns of change, and a given period's inventory may under- or over-estimate the actual amount of change (for instance, see Figure 8-4). As a result, entities should carefully document the assumptions they have made in amortizing changes (see Chapter 9.1).

If management shifts occur that would reverse any soil carbon sequestration that has previously been amortized, entities must ensure to account for the losses in their inventories. For instance, if no till practices were to cease at any point and be replaced by conventional till, carbon sequestration will be rapidly lost, and entities should record the cumulative gains up to that point as CO_2 emissions.

[6] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4.
[7] See http://unfccc.int/national_reports/annex_i_ghg_inventories/items/2715.php.

Figure 8-4. Rates of amortization assumed by companies may not match actual patterns of change. In this example carbon sequesters in a field at a non-linear rate following the adoption of reduced-tillage. The change in soil carbon is amortized at a fixed rate, causing actual amounts of change to be either under- or over-estimated in any one reporting period.



Accounting for historical changes in land use or management

Because stocks can take years to reach equilibrium, companies may have to account not only for management shifts that occur in the present, but also for those that occurred in the past. This Guidance requires that, at the very least, entities account for shifts in management practices that occurred during or after the base period. It is optional, but considered best practice, to also account for shifts in management practices that took place prior to the base period.

The older the shift in land management, the less likely it is to influence carbon stocks today. So, how far back in time should entities look? Entities should adopt an age threshold (*x* years) that is the same as the amortization period for the stock concerned (e.g., *x* is 20 years if the default IPCC amortization period for mineral soil organic stocks is used). Thus, if a shift in management practice happened within the *x* years preceding the base period, it is considered best practice to reflect it in the inventories for the base period and later reporting periods, as needed.

As discussed in Chapter 6.1, the acquisition (or divestment) of business units that own land can trigger base period recalculations (see Chapter 6.1). Carbon stocks may be changing on newly-transferred land as a result of activities of the prior land-owner.

Therefore, in conducting any recalculations, new landowners should assess the need to include these effects. Figure 8-5 provides an example.

Using proxy data on historical effects

Entities, and especially new landowners, may find it difficult to obtain information on historical land-use practices. What should they do in such cases? This Guidance recommends that entities identify and estimate historical effects using regional or local trends in, for example, the adoption of new agricultural technologies or land clearance. Alternatively, remote sensing data may be available from commercial or public databases, although the collection of such data can be time consuming and complicated.

To maintain the transparency of reported data, entities shall report when they have not been able to collect historical data and estimate historical effects.

Figure 8-5. Amortizing carbon stock changes caused by shifts in management practices. A subsidiary changes land management practices, causing a change in stock size, as represented by the slope. The parent company then divests the subsidiary and so the land concerned. The specific timing of both the divestment and the management shift differs between two scenarios (cases), which are depicted at the bottom of the graph. The new land owner applies an age threshold of 20 years to determine whether it needs to account for the management shift. In Case A, the new land owner does not need to recalculate its base period inventory because the management shift preceded the base period by more than 20 years. In Case B, the management shift occurs within 20 years of the present, so the new land owner must recalculate its inventories for the base period and each subsequent reporting period.

Chapter 9: Reporting GHG Data

Fundamentally, a credible inventory provides information that is complete, accurate, consistent and transparent, while meeting the decision-making needs of both internal management and external stakeholders.

This chapter:

- Describes information that must be reported in an inventory, including information on inventory boundaries and GHG fluxes
- Outlines specific requirements for reporting GHG flux data for carbon stocks
- Describes information that may be reported on an optional basis, including scope 3 emissions
- Provides guidance on reporting the offset and renewable energy projects undertaken on farms

9.1 Required information

General information on corporate and inventory boundaries

- The approach used to set the organizational boundaries (Chapter 5.1)
- An outline of the operational boundaries chosen and, if scope 3 is included, a list specifying which types of scope 3 activities are covered
- The reporting period covered
- The period chosen as the base period; the rationale for choosing the base period; the base period recalculation policy; base period inventory totals by category (see below and Fig 9-1), consistent with the base period recalculation policy; and appropriate context for any changes that trigger recalculation of the base period inventory (Chapter 6.1 and Chapter 8.3)
- Any specific exclusion of sources and/or operations from the inventory, including the exclusions of unmanaged lands, fluxes from natural disturbances and the impacts of historical management practices on carbon stocks.

Information on GHG flux data

- Emissions data for all seven GHGs (CO_2, CH_4, N_2O, SF_6, PFCs, HFCs and NF_3), disaggregated by GHG and reported in units of both metric tonnes and tonnes CO_2-equivalent (CO_2e)
- All scope 1 and 2 emissions
- Emissions data disaggregated by scope
- Emissions data disaggregated by mechanical versus non-mechanical sources (see Fig 9-1)
- All emissions reported in the scopes reported as gross figures, without subtractions for trades in offsets or other reductions
- A reference or link to the calculation methodologies used
- For non-mechanical sources: A description of whether the calculation methodologies are IPCC Tier 1, 2, or 3 (see Box).

<u>Biogenic CO_2 flux data:</u>

- Net CO_2 flux data for the carbon stocks in above-ground and below-ground biomass, dead organic matter (DOM) and soils (in tonnes CO_2), to the extent relevant and required, as defined in Chapter 8.1
- Reported outside of the scopes in a separate category ('Biogenic Carbon') that is distinct from any memo items (see Fig. 9-1)
- Disaggregated by whether the fluxes originate from land use management or land use change (Box 9-1)
- A description of the methodology used (where relevant) to amortize changes in carbon stocks, including the amortization period, the reporting period when changes were first amortized, and the total and residual biogenic CO_2 fluxes to be amortized (Chapter 8.3)
- Assumptions regarding the use of proxy data in calculating the impacts of historical changes in management on carbon stock (Chapter 8.3).
- If entities have set and are reporting against a GHG reduction target: the target should be disaggregated into two components – GHG emissions that fall under the scopes and GHG fluxes reported under the Biogenic Carbon category.

Fig. 9-1. Schematic illustrating the minimum requirements for disaggregating GHG flux data in inventories

Category of source or sink	**Subcategory**	**Example**
Scopes		
Scope 1	Mechanical sources	Mobile equipment, stationary combustion, and refrigeration and air-conditioning systems
	Non-mechanical sources	Enteric fermentation, soil management, and manure management
Scope 2	Purchased energy	Purchased electricity
Scope 3	All other indirect sources	Production of agrichemicals and purchased feed
Biogenic Carbon	Land use management	Net CO_2 fluxes from soils, decomposition of DOM and open burning of crop residues
	Land use change	Net CO_2 fluxes from soils, decomposition of DOM and biomass combustion
Memo items (optional)		Unmanaged lands and natural disturbances

Box 9-1. Defining land-use change

To determine when LUC has occurred and to ensure LUC impacts are accounted for consistently across inventories, companies should use a consistent set of definitions for land use categories over time. Currently, there is no single internationally accepted standard for land use classification – different countries and international organizations have developed their own sets of definitions. Companies may find it simpler to use a country-specific classification system should their operations occur within a single country. Companies with agricultural operations in multiple countries may instead find it easier to use internationally recognized classification systems (e.g., the EU's CORINE system). A simplified set of land use categories is shown below.

Land use change occurs when land is converted from one land use category to another; for instance, when cropland is converted to grassland or when mangroves are converted to aquacultural ponds. On occasion, the same area of land might be used to support multiple agricultural activities and so meet the definitions for different land-use categories. For instance, savannah woodland might be used both to graze livestock and as a source of wood fuel. In such cases, companies should categorize the land based on the agricultural activity that is economically most important.

Land use category	Definition
Forest land	
Cropland	Includes rice fields and agro-forestry systems.
Grassland	Managed grasslands, rangelands, pasture land.
Wetland	Areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into other categories.
Settlements	All developed land (e.g., roads, buildings, etc).
Unmanaged forest, grassland or wetlands	Land where human interventions and practices have not been applied to perform production, ecological or social functions

9.2 Optional Information

Besides the required reporting elements, entities may wish to report other information to enhance the transparency and relevance of their inventories, including:

- Data on the size of carbon stocks (in metric tonnes carbon per unit land area)
- GHG flux data further subdivided by the type of non-mechanical source (e.g., enteric fermentation versus manure management)
- Emissions of other GHGs or *GHG-precursors* such as SO_2, NO_x, NMVOC, and CO, including the N_2O precursors that are emitted through soil leaching and volatization.
- A description of performance measured against internal or external benchmarks
- Ratio indicators and a description of any allocation approach used in deriving these (see Chapter 6.2)
- A description of current management practices and, where obtainable, information on historical patterns of land use and land use change that are determined to significantly affect carbon stocks in the current reporting period (Chapter 8.3)
- An outline of any GHG management/reduction programs or strategies
- GHG fluxes from unmanaged lands and natural disturbances
- GHG flux data for relevant scope 3 sources for which reliable data can be obtained

Scope 3 sources

Scope 3 sources are many and diverse. The Scope 3 Standard identifies 15 distinct categories. These include the activities of a company's direct suppliers, cradle-to-gate impacts further upstream, as well as downstream activities such as customer use and disposal of products the company has manufactured and sold. Which scope 3 sources should an entity include in its inventory? Entities may either:

1. Report scope 3 emissions in accordance with the Corporate Standard (i.e. scope 3 sources are optional)
2. Report scope 3 emissions in accordance with the Scope 3 Standard.

For many entities, scope 3 emissions will represent a significant component of their overall GHG impacts. For instance, the manufacture of fertilizer and livestock feed will be an important scope 3 source for crop and livestock operations, respectively. Moreover, entities may undertake some actions that reduce their scope 1 and 2 emissions, but that then increase their scope 3 emissions (e.g., the outsourcing of feed production). For these reasons companies are encouraged to report specific scope 3 sources where those sources are likely considered to be significant. Criteria for assessing significance can include amounts of emissions, emissions reduction potential, contribution to risk exposure (e.g., regulatory or reputational risks), and importance to stakeholders. Entities are encouraged to include the scope 3 emissions from fertilizer and feed production, where possible.

9.3 On-farm offset and renewable energy projects

Entities can generate renewable energy in many ways, including:

- Developing their own wind turbines or leasing land to wind power development firms
- Growing trees, short rotation woodland and short rotation coppice as a source of biomass fuel stock
- Installing anaerobic digesters to produce methane as fuel for electricity or heat
- Developing farm-scale micro hydroelectricity schemes (typically less than ~ 100kW)
- Using solar panels

Also, these and other projects are a potential source of offset credits. Other offset projects could be based on the reforestation or restoration of degraded lands and changes in fertilizer management.

Accounting for renewable energy projects

The GHG impact of many these projects on an entity's inventory will depend on whether any of the energy that is generated is consumed on-site by the entity or sent to the grid. If the energy is consumed on-site, the project may reduce the amount of electricity or fuel consumed, resulting in a reduction in scope 1 or scope 2 emissions that will be evident when comparing inventories over time. On the other hand, if the energy is sent off-site, the associated 'zero' energy profile should not be used to lower scope 2 emissions; otherwise, double counting of the GHG benefit will occur.

Many of these projects may also have GHG impacts that extend beyond the farm gate – they may help to displace (or 'avoid') the emissions from fossil fuel-based electricity generation elsewhere on the grid that would have occurred in the absence of the project. Importantly, renewable energy generation projects do not always result in a physical reduction in emissions from fossil fuel consumption. For example:

- On-site renewable energy that is sold to the grid: the total emissions of a fossil-fuel plant are affected by the aggregate demand of all consumers connected to the grid, such that the sale of renewable energy may be balanced by an increased demand for electricity amongst other grid consumers, with no net change in absolute emissions from the fossil-fuel plant.
- Switching from residual fuel to wood waste produced on a farm: such switching may lead to emissions reductions from crude oil refining and waste fuel disposal, but whether these reductions are actually realized depends on the demand for fuel oil by other organizations.

In these cases, the behavior of other consumers – which is outside of the control of the reporting entity – means avoided emissions do not necessarily occur. As a result, avoided emissions should not be claimed as an emission reduction within the inventory and used to 'net' emissions.

Accounting for transactions in offset credits

Should an entity sell an offset that has been generated within its organizational boundaries, it should remove the associated emissions reductions from its entity-level inventory to prevent double counting. It should also disclose the protocol used to verify the emissions reductions.

Appendices

Appendix I: Tools for calculating emissions from agricultural sources

Overview

This Appendix lists some of the most widely used tools (spreadsheets, software and protocols) for calculating the emissions from agricultural sources. Three broad classes of tools are covered:

- Tools suitable for farm managers. These are generally web- or Excel-based calculators that can be used with commonly available types of activity data. They tend to implement a variety of the calculation approaches described in Table; namely, emission factors, empirical or process models, or some combination of these approaches.
- General catalogues of calculation methodologies. These describe formulae and default emission factors that can be used to calculate emissions for an extensive range of emissions sources. They do not provide an interface for calculating emissions.
- Tools suitable for academic use. These are primarily process-based models intended for academic research. They have extensive requirements in terms of data inputs, labor and expertise, and would not be recommended for use by farm managers. They are described here because they underpin many of the more accessible resources.

Table I-1 lists the GHGs and sources covered by each tool, while Table I-2 provides further information on each tool, such as its geographic focus, methodological approach and type of interface. This Appendix focuses on tools for non-mechanical sources, although many of these tools will also cover mechanical sources; mostly, fuel use and fertilizer production.

Notes and Caveats

- This Appendix does not attempt to provide an exhaustive list of tools, but is merely intended as an illustrative guide. The resources listed here may change over time and companies are encouraged to check the corresponding websites for updated information.
- Many different combinations of environmental and management factors will affect the GHG fluxes from many sources. So, even if a tool is relevant to, say, ‘cropland’ or ‘livestock’ operations, as indicated in Table I-1, it may not cover the specific combinations of interest.
- The tools’ coverage of specialty crops and more complex livestock systems is less comprehensive than that for commodity crops and relatively simple livestock systems.
- This Appendix excludes offset protocol methodologies, which, in many cases, will reference the process models listed.
- The tools may employ different definitions for the same management practices and land use categories. Users should ensure that consistent definitions are applied when using multiple tools for a single inventory.

Table I-1. A sample of publicly available tools for calculating the GHG emissions from on-farm sources

Tool	**GHGs covered**													
	CO_2	**N_2O**	**CH_4**	**Cropland**	**Horticulture**	**Grazing land**	**Grassland**	**Agroforestry**	**Vineyards / Orchards**	**Livestock**	**Forest**	**Land use change**	**Rice production**	**Wetlands**	**Energy use**
Calculators															
Carbon Accounting for Land Managers (CALM)	✓	✓	✓	✓	✓					✓	✓	✓			
Carbon calculator for New Zealand Agriculture and Horticulture	✓	✓	✓	✓	✓					✓					✓
Climate Friendly Food (CFF) Carbon Calculator	✓	✓	✓	✓	✓					✓					✓
COLE-EZ 1605b Forest Carbon Reporting Tool	✓										✓				
COLE-Lite	✓										✓				
COMET-Farm: CarbOn Management Evaluation Tool for whole FARM GHG accounting	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓		✓
COMET-VR: CarbOn Management Evaluation Tool for Voluntary Reporting of greenhouse gases V2.0	✓	✓		✓		✓	✓	✓	✓						✓

Cool Farm Tool	✓	✓	✓	✓			✓			✓	✓	✓	✓		✓
C-PLAN	✓	✓	✓	✓						✓	✓	✓			✓
CQuest Lite	✓			✓											
CStore															
Dairy Greenhouse Gas Model (DairyGHG)		✓	✓							✓					
DNDC NUGGET	✓	✓	✓	✓						✓		✓			
FarmGas	✓	✓	✓	✓	✓	✓				✓	✓				
Farming enterprise Greenhouse Gas Emissions Calculator	✓	✓	✓	✓		✓				✓					
Field to Market Fieldprint Calculator	✓	✓		✓											✓
Full Carbon Accounting Model (FullCAM)															
GES'TIM															
Greenhouse in Agriculture tools for Dairy, Sheep, Beef or Grain Farms	✓	✓	✓	✓						✓					✓
Holos	✓	✓	✓	✓			✓			✓	✓				✓
International Wine Carbon Calculator	✓	✓							✓						
Live Swine Carbon Footprint Calculator															
Livestock Analysis Model			✓							✓					

Manure and Nutrient Reduction Estimator (MANURE) TOOL		✓	✓							✓					
National Carbon Accounting Toolbox (NCAT)															
OVERSEER	✓	✓	✓	✓						✓					✓
US Cropland Greenhouse Gas Calculator For Farm Systems	✓	✓		✓											✓
USDA Nutrient Tracking Tool															
General catalogues of emissions calculation methodologies															
1605(b). Technical Guidelines for the Voluntary Reporting of Greenhouse Gases Program	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓		
IPCC. 2006 Intergovernmental Panel on Climate Change Guidelines on National Inventories	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Resources suitable for academic use															
Agricultural Policy/Environmental eXtender (APEX)	✓	✓		✓											

CENTURY	✓			✓		✓					✓				
CNCPS			✓							✓					
CQESTR	✓			✓											
DairyGEM	✓	✓	✓	✓		✓	✓			✓					
DairyGHG	✓	✓	✓	✓		✓	✓			✓					
DairyWise	✓	✓	✓				✓			✓					✓
DayCent	✓	✓	✓	✓			✓				✓				
DeNitrification-DeComposition (DNDC)	✓	✓	✓	✓		✓	✓				✓		✓	✓	
FarmGHG	✓	✓	✓							✓					✓
IFSM (Intrated Farm System Model)	✓	✓	✓	✓		✓	✓			✓					✓
NASA-CASA (Carnegie-Ames-Stanford Approach) model	✓	✓	✓	✓			✓				✓				
RothC	✓			✓			✓				✓				
SIMs Dairy		✓	✓							✓					
SOCRATES: Soil Organic Carbon Reserves And Transformations in Eco-systems	✓			✓			✓				✓				

Table I-2. Additional features of emissions calculators

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
		Calculators		
Carbon Accounting for Land Managers (CALM)	UK	Emission factors from UK national inventory	Web-based	
Carbon calculator for New Zealand Agriculture and Horticulture	New Zealand	Methodologies and emission factors from New Zealand's national inventory	Web-based	
Climate Friendly Food (CFF) Carbon Calculator	UK	Uses methodologies from UK national inventory (Tiers 1 and 2 methods), as well as methods and EFs from academic literature	Web-based	
COLE-EZ 1605b Forest Carbon Reporting Tool	US	Models and equations from academic literature	Web-based	✓
COLE-Lite	US	The results correspond to the entries needed to report under US 1605(b)	Web-based	✓
COMET-Farm: CarbOn Management Evaluation Tool for whole FARM GHG accounting	US	Combination of process models (CENTURY/DAYCENT), empirical models and IPCC Tier 1 emission factors	Web-based	✓
COMET-VR: CarbOn Management Evaluation Tool for Voluntary Reporting of greenhouse gases V2.0	Continental US	Combination of process models (CENTURY/DAYCENT), empirical models and IPCC Tier 1 emission factors	Web-based	✓
Cool Farm Tool	Global	*Combination of LCA emission factors, empirical models, Tier 1 and 2 methods and emission factors, and academic literature*	Excel-based	
C-PLAN	UK	Above ground biomass is for forests. IPCC Tier 1 EFs	Web-based	✓
CQuest Lite		Online interface to NASA-CASA model	Web-based	
CStore		Application of CENTURY model for farm managers. Under development		
Dairy Greenhouse Gas Model (DairyGHG)				

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
DNDC NUGGET	US	Online interface to DNDC model	Web-based	✓
FarmGas	Australia	Based on Australian national inventory - combination of country-specific and IPCC methodologies and emission factors.	Web-based	
Farming enterprise Greenhouse Gas Emissions Calculator	Australia	Combination of SOCRATES, IPCC and Australia national inventory emission factors	Web-based	
Field to Market Fieldprint Calculator	US	Based on methodologies in academic literature. Only outputs intensity metrics (per acre), so not useful for farm-level accounting	Web-based	
Full Carbon Accounting Model (FullCAM)	Australa			
GES'TIM				
Greenhouse in Agriculture tools for Dairy, Sheep, Beef or Grain Farms	Australia	Emission factors from Australia's national inventory practices	Excel-based	
Holos	Canada	Methodology is IPCC, but customized to Canada	Software application	✓ (expert opinion, not quantified)
International Wine Carbon Calculator	International	Tier 1 emission factors and academic literature	Excel-based	
Live Swine Carbon Footprint Calculator			Software application	
Livestock Analysis Model		Specific to cattle and buffalo		
Manure and Nutrient Reduction Estimator (MANURE) TOOL	US	IPCC methodology and emission factors from IPCC, EPA, and USDA	Web-based	
National Carbon Accounting Toolbox (NCAT)			Software application	
OVERSEER	New Zealand	Emission factors from New Zealand's national inventory practices	Software application	
US Cropland Greenhouse Gas Calculator For Farm Systems	US (but applicable to temperate region soils	Limited to corn, soybean, switchgrass, alfalfa and corn silage. Based on SOCRATES (for soil	Web-based	

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
	worldwide)	carbon) and IPCC emission factors (for other sources)		
USDA Nutrient Tracking Tool		Based on APEX		
General catalogues of emissions calculation methodologies				
1605(b). Technical Guidelines for the Voluntary Reporting of Greenhouse Gases Program	US	Combination of emission factors, process models, direct measurement and hybrid approaches	**N/A**	✓
IPCC. 2006 Intergovernmental Panel on Climate Change Guidelines on National Inventories	Global	Three tiers of methods outlined. Tier 1 emission factors provided for wide range of sources (see Box XX)	**N/A**	✓

Glossary

Accounting (GHG accounting)	Quantification and organization of information about GHG emissions (and carbon *sequestration*) based on common procedures, and correct attribution of the same to specific entities.
Agistment	An arrangement between a stock owner and the owner of a short-term supply of feed to use that feed.
Agricultural products	The outputs of agricultural and horticultural operations, including livestock, grains, vegetables, fruits and other crops.
Agroforestry	The cultivation of trees with crops or pasture
Allocation	The process of partitioning GHG emissions data from a farming system to the different product streams from that system
Amortization	The allocation of changes in *carbon stocks* (or emissions and *sequestration* data) over a period of time.
Base period	A historic period (a specific year, series of consecutive years, or production season) against which a company's emissions are tracked over time.
Biogenic CO_2 emissions	CO_2 emissions from biological sources or materials derived from biological matter.
By-product	A by-product is an incidental output from a process with a minor market value, rather than the primary product being produced or a *co-product*.
Carbon pools	Natural stores of carbon in either biomass, soil matter, or harvested products. Carbon pools both take-up and release CO_2.
Carbon stocks	The total amount of carbon stored on a plot of land at any given time in one or more *carbon pools*.
Carbon sequestration	The net carbon accumulation (i.e., *CO_2 fixation* minus CO_2 emissions) in *carbon pools*.
CO_2-equivalent (CO_2e)	The universal unit for comparing emissions of different greenhouse gases (GHGs), expressed in terms of the *global warming potential* (GWP) of one unit of CO_2.
CO_2 fixation	The addition of carbon to *carbon pools* through photosynthesis.
CO_2 flux	The exchange of CO_2 between *carbon stocks* and the atmosphere, either through CO_2 emissions or carbon *sequestration*.
Co-operative	A business that is owned and controlled by the people (members) who use its services and whose benefits are shared by the members on the basis of use.
Co-product	A co-product is an output of a system with a significant market value in another system.
Corporate GHG emissions inventory	A quantified list of the emissions from across the entire operations of a single company. Corporate inventories include the emissions of all six

	Kyoto GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).
Crop year	The period of time between two harvests. For many crops, this period approximates a calendar year, but for others several crop years may be possible each calendar year.
Custom farming contract	A contract between a landowner and an operator that requires the operator to supply all the labor and equipment needed to perform tillage, planting, pest control, harvesting, crop storage, and other farm functions. The custom operator receives a fixed payment per acre from the landowner, or a fixed payment for each operation performed. In turn, the landowner pays all other expenses and receives the entire crop.
Denitrification	The process whereby nitrates are reduced by bacteria and become N_2O, which is then released into the atmosphere.
Direct GHG emissions	Emissions from sources that are owned or controlled by the reporting company.
Emission factor	A factor allowing GHG emissions to be estimated from a unit of available activity data (e.g., tonnes of fuel consumed, tonnes of product produced).
Enteric fermentation	Fermentation that occurs in the digestive tracts of *ruminant* livestock species (e.g., cattle and sheep) and that releases CH_4.
Equity share approach	An approach used to *set organizational boundaries*, wherein an entity accounts for the emissions from an operation according to its share of equity (or percentage of economic interest) in that operation
Financial control	An approach used to set organizational boundaries, wherein an entity accounts for 100% of the emissions from an operation over which it has the ability to direct financial and operating policies with a view to gaining economic benefits.
GHG-precursors	Gases whose emissions lead to the formation of substances in the atmosphere with a climate change impact (e.g., NO_X, SO_2, NO_X, NMVOC, and CO).
Global warming potential (GWP)	The change in the climate system that would result from the emission of one unit of a given GHG compared to one unit of carbon dioxide (CO_2).
Harvested wood products (HWPs)	All wood material (including bark) that leaves the boundary of the reporting entity.
Indirect GHG emissions	Emissions that are a consequence of the operations of the reporting company, but that occur at sources owned or controlled by another company.
Indirect land use change (iLUC)	A pattern of land use wherein when changes in the types of agricultural products farmed in one area lead to the expansion of agricultural land into the native habitats of another area.
Kyoto greenhouse gases	The GHGs that are mandatorily reported in national GHG inventories to the United Nations Framework Convention on Climate Change (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).
Land-use change	The conversion of one category of land-use (e.g., forest) into another (e.g., cropland) through fire, draining, clear felling or soil preparation.

Non-mechanical sources (on farms)	Either bacterial processes shaped by climatic and soil conditions (e.g., decomposition) or the burning of crop residues. See also *Mechanical sources.*
Mechanical sources (on farms)	Equipment or machinery operated on farms, such as mobile machinery (e.g., harvesters), stationary equipment (e.g., boilers), and refrigeration and air-conditioning equipment. See also *Non-mechanical sources*.
Nitrification	During nitrification, bacteria and other microorganisms oxidize the nitrogen within ammonia (NH3) to create nitrites, which are further oxidized into nitrates.
Nitrogen mineralization	
Offset credits	Tradable commodities that typically represent one metric tonne of *CO_2-equivalent* emissions reductions or *sequestration*. In most cases, offset credits are generated at specific projects (offset projects).
Organizational boundaries	The boundaries that determine the operations owned or controlled by the reporting company, depending on the consolidation approach taken (equity or control approach).
Operational boundaries	The boundaries that determine the *direct* and *indirect* emissions associated with operations owned or controlled by the reporting company.
Operational control	An approach used to set organizational boundaries, wherein an entity accounts for 100% of the emissions from an operation over which it has the authority to introduce and implement its own operating policies.
Product life cycle GHG inventory	A compilation and evaluation of the inputs, outputs and the potential GHG impacts of a product – whether it be a good or a service – throughout its entire life cycle.
Product processing	The treatment of an agricultural product to change its properties with the intention of preserving it, improving its quality, or making it functionally more useful. On-farm product processing is product processing done on the farm with produce from the farm.
Ruminants	Mammals that digest plant-based food by softening it within a first stomach (the 'rumen'), then regurgitating the semi-digested mass (the 'cud') for further chewing. *Enteric fermentation* results from the microbial fermentation of food in the rumen. Examples of ruminants include cattle, goats, sheep, bison, yaks, water buffalo, and deer.
Scope	Defines the *operational boundaries* in relation to *direct* and *indirect* GHG emissions.
Scope 1	*Direct* GHG emissions from sources owned or controlled by the reporting company.
Scope 2	Emissions associated with the generation of electricity, heating/ cooling, or steam purchased for the reporting entity's own consumption.
Scope 3	*Indirect* emissions other than those covered in *scope 2*.
Share farming	An agreement between a landowner and a producer wherein the producer is granted rights to cultivate the landowner's property. The producer and the landowner share the profits and produce from the

	land. Share farming arrangements are not leases.
Supply chain partner	Any company downstream of producers along the agricultural supply chain (e.g., processors, brand manufacturers and retailers).
Timberbelt	Multiple row field windbreaks that are planted with commercially valuable, fast-growing trees (such as hybrid poplar or hybrid willow) to provide conservation benefits, improve adjacent crop yields, diversify on-farm income sources, and produce commercially valuable wood products.
Unmanaged lands	Land that is not managed for economic exploitation (i.e., not used for agricultural production).
Volatilization of soil nitrogen	The vaporization of soil NH_3 and NO_X and their subsequent release into the atmosphere.