GREENHOUSE GAS PROTOCOL

GHG Protocol Agricultural Guidance

Interpreting the Corporate Accounting and Reporting Standard for the agricultural sector

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Contents

A note on terminology in GHG Protocol publications

The GHG Protocol uses specific terms to connote reporting requirements and recommendations. The term "shall" is used in this Guidance to indicate what is required for a GHG inventory to conform to the GHG Protocol Corporate Accounting and Reporting 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. This publication contains requirements and guidance from the Corporate Standard, and additional, sector-specific recommendations.

Part 1: GENERAL INFORMATION

Chapter 1: Introduction

Agriculture is a major contributor to global emissions of the *greenhouse gases* (GHGs) that drive climate change. Leadership and innovation from the sector is therefore vital in making progress in reducing these emissions and in abating the worst effects of climate change on agricultural production. Action in this arena also makes good business sense. By addressing GHG emissions, companies (and producers[1]) can identify opportunities to bolster their bottom line, reduce risk, and discover competitive advantages.

A GHG emissions inventory is the foundational tool that allows a company to understand its GHG emissions and build effective climate change strategies. GHG inventories help companies understand their exposure to GHG-related risks, identify emissions reduction opportunities, create baseline data and reduction targets for tracking performance, and communicate performance 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 how and why the Agricultural Guidance ('Guidance') was developed, and for whom.
- Describes what guidance is (and is not) provided in this publication.
- Summarizes how the Guidance differs from the GHG Protocol Corporate Accounting and Reporting Standard, and relates to other GHG Protocol publications.

1.1 Agriculture and climate change

The international community has adopted a goal to restrict global warming to 2°C above pre-industrial levels[2]. Temperature rise above 2°C will produce increasingly unpredictable and dangerous impacts for people and ecosystems, but particularly for agricultural systems. Impacts on the agricultural sector that are already occurring but expected to intensify include increased irrigation water needs, increased spread of animal and crop diseases and pests, reduced forage quality, and reduced crop and pasture yields (Easterling et al., 2007). These impacts stem from changes in surface temperatures, the timing of seasons, and in the frequency and severity of severe weather events, such as droughts, floods, and heatwaves.

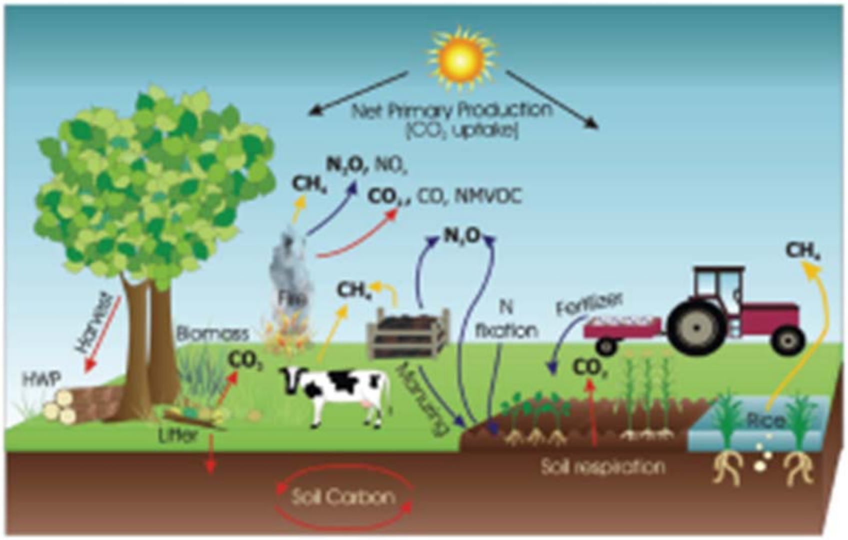
Achieving the 2°C goal will require drastic reductions in GHG emissions. Here, again, the agricultural sector is central. A wide range of agricultural activities emit GHGs

[1] In this Guidance, the terms 'producer' and 'company' are used synonymously to refer to any entity that develops an inventory of the agricultural GHG emissions. The terms 'farm', 'farmland' and 'agricultural land' are also used interchangeably to refer to the land on which agriculture is practiced.

[2] See paragraph 1 of 'Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009' (http://unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600005735)

(Figure 1-1), and together they directly contributed about 11%[3] of total global anthropogenic emissions in 2010, and roughly 60% of all nitrous oxide (N_2O) emissions and 50% of all methane (CH_4) emissions in 2007 (Smith et al., 2007a). *Land use change* (LUC), caused by the conversion of native habitats to farmland, contributes a comparable amount of emissions (Houghton, 2012). Finally, the production of agricultural inputs and various downstream activities, such as the processing and transport of agricultural products, contributes a further 3 - 6 % of global emissions (Vermuelen et al., 2012).

Figure 1-1. Agricultural practices that emit GHGs.



Source: IPPC (2006), with permission.

1.2 What is the Greenhouse Gas Protocol?

The GHG Protocol 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 and promote the use of industry-accepted best practices for GHG accounting. To date, the GHG Protocol has released four standards that define best practices for how GHG emissions inventories should be performed at the enterprise, project, and product levels (Table 1-1). All publications are available from the GHG Protocol website (www.ghgprotocol.org).

[3] Value calculated using data from Tubiello et al., (2014) and WRI (2014)

Table 1-1. The GHG Protocol family of publications

Type of GHG assessment		**GHG Protocol publication**
Enterprise-level	Development of GHG emissions inventories that itemize the emissions from all of the operations that together comprise the reporting company	*Corporate Accounting and Reporting Standard* ('Corporate Standard')
		The Corporate Value Chain (Scope 3) Accounting and Reporting Standard ('Scope 3 Standard') provides additional requirements and guidance on developing comprehensive inventories of *scope 3* emissions (see Box 1-1 for an introduction to the concept of 'scopes')
Project-level	The quantification of the GHG impacts of projects that have been undertaken to reduce emissions, avoid emissions occurring in the future, or sequester carbon	*Project Protocol*
Product-level	The development of GHG emissions inventories of the entire life cycle impacts of individual products or services, from raw material extraction to product disposal	*Product Life Cycle Accounting and Reporting Standard* ('Product Standard')

1.3 Why an Agricultural Guidance?

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

- The profound influence of environmental factors on agricultural *GHG fluxes* (emissions or removals)[4], which complicates efforts to separate anthropogenic from non-anthropogenic effects and thus ensure that GHG inventories are useful as management tools.
- Obtaining accurate, site-specific flux data when environmental conditions vary a lot across landscapes.
- Setting and tracking progress toward emission reduction goals against a background of highly variable GHG fluxes.

This Guidance defines agriculture as the cultivation of animals, plants, and fungi for food, fiber, biofuels, drugs or other purposes.*

Definition developed by the stakeholders involved in this Guidance's development process.

[4] GHG fluxes are the emissions to or removals from the atmosphere of GHGs.

- *Carbon (C) sequestration* and accounting for changes in the management and ownership of different *carbon pools*.
- The fact that agricultural activities do not immediately result in GHG fluxes (e.g., delayed emissions from decomposition of post-harvest detritus).
- The types of organizational structures and operational practices specific to agriculture.

This Guidance outlines recommended methodologies to address these and other issues important to the sector, while incorporating requirements in the Corporate Standard. Because the agricultural sector is highly diverse, this Guidance aims to establish a common framework that is applicable to the myriad subsectors within agriculture. This Guidance can largely be used on its own for developing GHG inventories. However, it does not address certain topics covered by the Corporate Standard, such as the verification of GHG inventories or setting of GHG reduction targets (see Chapter 1.5).

The specific objectives of this Guidance are to:

- Increase consistency and transparency in *GHG accounting* and reporting within the agricultural sector.
- Help companies cost-effectively prepare GHG inventories that are true and fair accounts of their climate impact.
- 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 agricultural GHG fluxes.

What does this Guidance not do?

This Guidance is squarely focused on corporate- or farm-level accounting and reporting issues and:

- Does not advance methods for project- or product-level GHG accounting (e.g., product category rules).
- Does not provide accounting methods for *indirect Land Use Change* (iLUC). iLUC occurs when an existing crop is diverted for another purpose, such as transportation fuel production, and replacement crops are then grown on formerly non-agricultural lands. An example of iLUC is when sugarcane is diverted from sugar to biofuel production, causing forests to be cleared for additional sugarcane production. Accounting for such iLUC impacts requires a project-based approach to determine what the GHG fluxes would have been in the absence of the market intervention. The Project Protocol provides general, high-level guidance that can help inform how to account for iLUC impacts.
- Does not require sector-specific GHG performance metrics. The choice of a metric has to be guided by a company's objectives in developing an inventory and by the specific operations and sources that characterize that company. (Appendix I provides an overview of the advantages and disadvantages of different types of metrics.)
- Does not require specific methods or tools for calculating agricultural GHG fluxes.
- Does not provide guidance on the selection and deployment of GHG mitigation practices on farms.

- Does not address environmental impacts other than GHG fluxes, such as water use, eutrophication, and emissions of air pollutants. Consequently, this Guidance cannot be used by itself to evaluate the possible trade-offs between GHG emissions reductions and other environmental impacts of a given farming practice.

1.4 Who should use this Guidance?

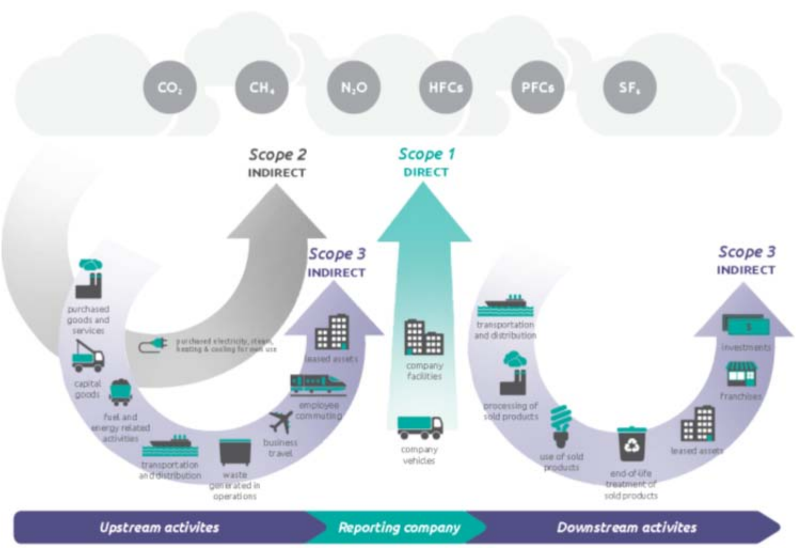
This Guidance is primarily intended for producers and companies that seek to develop scope 1 and 2 inventories of their agricultural operations (Box 1-1). Examples include fruit and crop growers, ranchers, and biofuel producers. While producers with small agricultural operations may find it difficult to devote the resources to use this Guidance, it is applicable to operations of all sizes.

Box 1-1. The concept of scopes

Under the Corporate Standard emissions sources are categorized as *direct* or *indirect* and then further divided into 'scopes':

- Direct sources: Owned or controlled by the reporting company. All direct sources are classified as *scope 1*.
- Indirect sources: Owned or controlled by another company, but a portion of whose emissions are a consequence of the activities of the reporting company. Indirect sources are either *scope 2* or *scope 3*: scope 2 emissions stem from the generation of electricity, heat, or steam that is purchased by the reporting company, while scope 3 emissions are all other indirect emissions.

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 they are highly emitting.



Other users
This Guidance will be helpful to downstream or upstream companies that seek to understand their value chain GHG impacts from agriculture. Downstream companies include processors (e.g., slaughterhouses and biofuel makers), brand manufacturers that make packaged food products, and retailers that make private label food products, while upstream companies include manufacturers of farm inputs, such as seeds, fertilizers, herbicides, and pesticides. Agricultural emissions will often form a substantial part of the scope 3 inventories of these companies and will fall into the Scope 3 Standard's Category 1 (Purchased Goods and Services) and Category 11 (Use of Sold Products) for downstream and upstream companies, respectively. Companies completing a value chain assessment should consult the Scope 3 Standard for additional requirements and guidance on including agriculture in their inventories.

GHG reporting programs and policy makers may also be interested in incorporating this Guidance into their policy or program design.

Many companies in other sectors also have land-based GHG fluxes. Examples include the construction, mining, and utility sectors. While this Guidance is likely broadly applicable to these sectors, it has not been evaluated for use outside of the agricultural sector.

1.5 Relationship between this Guidance and the Corporate Standard

The Corporate Standard outlines requirements and/or guidance on a range of topics, ranging from inventory design to tracking emissions over time. This Guidance summarizes and customizes most of this content to the agricultural sector, adding additional recommendations in many areas. However, this Guidance does not include guidance on inventory verification and target setting, and on other topics that are included in the Corporate Standard, but not relevant to the sector. For such guidance, users should consult the Corporate Standard. Table 1-2 maps the content of this Guidance onto that of the Corporate Standard, while Table 1-3 summarizes the main recommendations made in this Guidance.

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

Table 1-2. Summary of how this Guidance maps onto each Chapter in the Corporate Standard

Chapter in Corporate Standard	Corresponding content in the Agricultural Guidance
Chapter 1: GHG Accounting and Reporting Principles	Chapter 3 reviews these principles
Chapter 2: Business Goals and Inventory Design	Chapter 2 highlights business goals specific to the agricultural sector
Chapter 3: Setting Organizational Boundaries	Chapter 5 outlines recommendations on setting inventory boundaries in relation to common types of organizational structures and operational activities in the sector
Chapter 4: Setting Operational Boundaries	
Chapter 5: Tracking Emissions Over Time	Chapter 6 provides requirements and recommendations for selecting and using base periods. Appendix I provides general information on performance metrics
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 GHG fluxes • Appendix III summarizes a range of tools for calculating agricultural GHG fluxes
Chapter 7: Managing Inventory Quality	• Chapter 7 outlines recommendations for addressing uncertainty in GHG flux data and prioritizing data collection efforts
Chapter 8: Accounting for GHG Reductions	Chapter 9 provides requirements for 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 to publicly report
Chapter 10: Verification of GHG emissions	
Chapter 11: Setting GHG Targets	
Appendix A: Accounting for Indirect Emissions from Electricity	
Appendix B: Accounting for Sequestered Atmospheric Carbon	Chapter 8 outlines requirements and recommendations for accounting for the emissions and removals of biogenic CO_2. Appendix II provides examples to illustrate this accounting.
Appendix C: Overview of GHG Programs	
Appendix D: Industry Sectors	

and Scopes	
Appendix E: Base Year Adjustments	
Appendix F: Categorizing GHG Emissions from Leased Assets	Chapter 5 summarizes the requirements for lease accounting

Table 1-3. Summary of main recommendations in this Guidance for applying requirements in the Corporate Standard.

Chapter in the Corporate Standard	Requirements in the Corporate Standard	Additional, sector-specific recommendations in the Agricultural Guidance
Chapter 1. GHG Accounting and Reporting Principles	• Base GHG accounting and reporting on the following principles: relevance, completeness, consistency, transparency, and accuracy.	
Chapter 3. Setting Organizational Boundaries	• Select a single consolidation approach to establish the organizational boundaries.	
Chapter 4. Setting Operational Boundaries	• Separately account for and report on scope 1 and 2, at a minimum.	• Accounting should take appropriate note of production contracts and other forms of agricultural contracting, land and equipment leases, and membership of co-operatives.
Chapter 6. Tracking Emissions Over Time	• Choose and establish a base period, and specify the reasons for choosing that period. • The base period shall be the earliest point in time for which verifiable data are available on scope 1 and scope 2 emissions. • Develop a base period emissions recalculation policy, and clearly articulate the basis and context for any recalculations. If applicable, the policy shall state any "significant threshold". • Recalculate the base period	• Multi-year base periods are recommended for many companies.

	inventory to reflect changes in organizational structures or calculation methods, or the discovery of errors, that significantly impact the base period inventory.	
Chapter 9. Reporting GHG Emissions	Companies shall report: • An outline of the operational boundaries chosen and, if scope 3 is included, a list specifying which types of activities are covered. • An outline of the organizational boundaries chosen, including the chosen consolidation approach.	Companies should report:
	• The reporting period covered.	
	• 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).	
	• Total scope 1 and 2 emissions.	
	• Data disaggregated by scope.	• Scope 1 data disaggregated by mechanical versus non-mechanical sources.
	• Data reported in the scopes without subtractions for trades in offsets.	
	• Methodologies used to calculate or measure emissions, providing a reference or link to any calculation tools used.	• Whether the calculation methodologies used for 'non-mechanical' sources are IPCC Tier 1, 2, or 3. • Methodology used (where relevant) to amortize the CO_2 fluxes to/from C stocks. • Assumptions regarding any use of proxy data in calculating the impacts of historical changes in management on C stocks.

	• Year chosen as base year, and an emissions profile over time that is consistent with and clarifies the chosen policy for making base year emissions recalculations.	
	• Appropriate context for any significant emissions changes that trigger base year emissions recalculation.	
	• Any specific exclusions of sources, facilities, and / or operations.	• Any exclusions of the impacts of historical management practices on C stocks.
	• CO_2 emissions from biologically sequestered carbon, separately from the scopes. • Biologically sequestered carbon reported outside of the scopes (but is optional to report).	• Net CO_2 flux data for the C stocks in above-ground and below-ground biomass, DOM and soils (in tonnes CO_2). • Where LUC results in a reduction in the size of C stocks, report the CO_2 emissions in Scope 1. • Otherwise, report all CO_2 fluxes outside of the scopes in a separate category (‘Biogenic Carbon’) divided into three components: (1) CO_2 fluxes (emissions or removals) during land use management; (2) Sequestration during LUC; and (3) CO_2 emissions from biofuel combustion. • Account for historical changes in land use or management occurring on or after the base period. • Use a ‘fixed-rate’ approach to amortize change in C stocks over time.

1.6 How does this Guidance relate to the GHG Protocol Product Standard?

Product GHG inventories and corporate inventories (when scope 3 emissions are included) are complementary and they together provide a comprehensive approach to value chain GHG management. For example, product and corporate inventories are mutually supportive when:

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

Companies may wish to complete scope 3 and product GHG inventories in parallel. Alternatively, they may develop scope 1 and 2 inventories to supply information requested by a buyer for the purpose of its scope 3 and product inventories. In either case, companies should be mindful of certain differences between this Guidance and the Product Standard that can affect the extent to which both types of inventories are mutually supportive (Table 1-4).

Table 1-4. Differences in methodologies between this Guidance and the Product Standard that affect how useful a corporate inventory is for product GHG inventories (and vice-versa).

GHG reporting issue	Recommendation in the Agricultural Guidance	Requirement in the Product Standard
Scope 3 sources	Should be reported	Emissions from all relevant upstream and downstream sources shall be reflected in the 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	• Should be reported	The following fluxes shall be accounted for: • CO_2 emissions and removals due to C stock change occurring as a result of land conversion within or between land use categories (e.g., adoption of no-till practices or land use change) • Emissions from the preparation of converted land (e.g., biomass burning or liming) • The CO_2 fluxes to/from soils that occur as a result of subsequent land use (e.g., fertilizer application and harvesting) are optional and may be included, provided
CO_2 fluxes to/from C stocks in biomass and *dead organic matter (DOM)*	• CO_2 emissions should be reported • CO_2 removals by woody vegetation should be reported • CO_2 removals by herbaceous vegetation, should not be reported	

GHG reporting issue	Recommendation in the Agricultural Guidance	Requirement in the Product Standard
		the fluxes can be estimated reasonably • Biogenic CO2 fluxes shall be reported separately from non-biogenic fluxes
Timeline for amortizing the CO_2 fluxes from changes in carbon stocks	Varies depending on site-specific conditions	In the context of land use change: 20 years or the length of one harvest, whichever is longer

1.7 How does this guidance relate to the GHG Project Protocol?

The revenue from *offset credits* is often mentioned as a leading reason for why agricultural companies should become interested in managing their GHG fluxes. Soil C 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 (Smith et al., 2007b). The Corporate Standard, and therefore this Guidance, do not address the accounting steps needed to create offset credits from soils, biomass or other sources located on farms. For example, this Guidance does not consider the permanence of C sequestration. Instead, fluxes to/from C stocks are simply reported as they occur (or projected to occur[5]) and there is no consideration of policy measures to ensure the permanence of sequestered C (e.g., insurance mechanisms, project buffers, etc.). For such guidance readers should instead refer to the *Project Protocol* and its companion document, the *Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting*.

1.8 How was this Guidance developed?

This Guidance is the culmination of an international, three-year stakeholder consultation process that involved over 150 Technical Working Group (TWG) members from businesses, government agencies, NGOs, and academic institutions. Milestones include:

- January, 2011: Publication of WRI Working Paper
- March, 2011: Formation of TWG
- January, 2012: First draft of Guidance
- April, 2012: Stakeholder workshop in Washington, DC
- August, 2012: Second draft of Guidance
- September, 2012: TWG workshop in Sao Paulo
- January, 2013: TWG workshop in Sao Paulo
- March – August, 2013: Road testing and public open comment period
- October, 2013: Third draft of Guidance

[5] Chapter 8 describes how projected changes in C stocks can be calculated and reflected in inventories.

Chapter 2: Business goals

The development of a GHG inventory can be a significant undertaking. Companies should therefore have clearly defined goals for managing their GHG fluxes and understand how inventories will allow them to meet those goals. Companies 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.

This chapter:

- Reviews the various goals that GHG emissions inventories can help companies meet.
- Describes the potential economic and environmental benefits from a range of GHG reduction measures.

2.1 Overview of business goals

Agricultural companies can have diverse reasons for developing inventories. These reasons generally involve (Table 2-1):

- Identifying opportunities to reduce GHG emissions (or sequester C), setting baselines and reduction targets, and tracking performance.
- Identifying opportunities to reduce costs and increase productivity (e.g., conservation tillage and cover cropping can help to reduce fertilizer and fuel costs; Table 2-2).
- Managing reputational risks and opportunities associated with agricultural GHG fluxes (e.g., meeting the requirements of buyers such as processors and food and drink companies, and reporting to civil society).
- A desire to sustain farmlands for future generations.

GHG emissions reduction measures may also offer co-benefits such as:

- 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

Often, these co-benefits can help to reduce costs and increase productivity on farms. Table 2-2 summarizes common agricultural practices that provide GHG and other benefits. Stockwell & Bitan (2011) provide further information on these practices. Because agro-ecosystems are inherently complex, reduction measures 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 C and nitrogen (N) cycles on farms, as well as trade-offs between the emissions of different GHGs, are taken into account and that reduction measures can be more effectively integrated into individual farming systems (see Chapter 7.1). Because this Guidance only considers GHGs, it cannot be used by itself to assess trade-offs between GHGs and other environmental impacts.

Table 2-1. Business goals served by including agricultural GHG emissions in corporate inventories.

Business Goal	**Description**
Track and reduce GHG impacts	Identify emissions hot spots and reduction opportunities, and prioritize GHG reduction efforts
	Set GHG reduction targets
	Measure and report GHG performance over time
	Develop performance benchmarks and assess performance against sector averages and competitors
Understand operational and reputational risks and opportunities associated with agricultural GHG fluxes	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 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., to purchase relatively less GHG-intensive goods)
Report to stakeholders	Meet needs of stakeholders through public disclosure of GHG fluxes 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 levels
	Improve reputation and accountability through public disclosure

Table 2-2. Some agricultural practices that can reduce GHG emissions and improve farm performance*

Practice	Potential GHG benefits	Potential environmental co-benefits	Potential agronomic / business benefits	Potential trade-offs or problems
Cover crops Non-commodity crops planted in between rows of commodity crops or during fallow periods	• Increased soil C sequestration • Reduced *indirect N_2O emissions from soils* due to a reduction in N leaching • Reduced scope 3 emissions from fertilizer manufacture	• Improved soil nutrient content • Reduced wind and water erosion • Reduced nutrient and sediment run off and leaching	• 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 • Requires more fuel use for crop planting
Conservation tillage A range of cultivation techniques (including minimum till, strip till, no-till) designed to minimize soil disturbance for seed placement, by allowing crop residue to remain on soil after planting	• Increased soil C sequestration • Reduced indirect N_2O emissions from reduction in run-off • Reduced scope 3 emissions from fertilizer manufacture	• Improved soil water retention and drainage • Reduced water and wind erosion • Reduced nutrient and sediment runoff	• Reduced fertilizer needs • Reduced fuel and labor costs from fewer field passes • Improved yields • Retains top soil	• Potential increase in herbicide use • Increased pest threats in repetitive single commodity production
Rotational or mob livestock grazing on pasture Grazing practices that maximize plant health and diversity, while increasing the animal carrying capacity of the land	• Increased soil C sequestration • Reduced CH_4 emissions from enteric fermentation (due to improved feed)	• Increased plant cover and productivity • Improved soil water retention and drainage • Reduced water and wind erosion • Reduced nutrient and sediment runoff	• 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 • Helps avoid burning	• Requires careful management in some areas with sensitive species • Labor intensive

Practice	Potential GHG benefits	Potential environmental co-benefits	Potential agronomic / business benefits	Potential trade-offs or problems
			fields as a management practice	
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 scope 3 emissions from fertilizer manufacture	• Reduced risk of accidental toxic leakages (pathogens killed) • Reduced ammonia and VOC emissions	• Processed solids can be used as bedding • 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	• Increased C sequestration in biomass and soils	• Reduced soil erosion	• Greater animal survival and health in livestock systems	• May take some land out of production
Switch from constantly flooded to intermittently flooded rice fields	• Reductions in CH_4 emissions (as oxygen is allowed to reach soil)	• Reduced water use and increased use of rainfall	• Less fuel used in irrigation	

*, A more extensive discussion of the advantages and disadvantages of different management practices can be found in Stockwell & Bitan (2011)

Chapter 3: Principles

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

This chapter:

- Introduces GHG accounting and reporting principles as they apply to farms, businesses and others in the agriculture sector.

3.1 Overview of principles

GHG accounting and reporting shall be based on the following principles:

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

Completeness: Companies shall 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. Any specific exclusions shall be disclosed and justified.

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

Transparency: Companies shall address all relevant issues in a factual and coherent manner, based on a clear audit trail. Companies shall also disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.

Accuracy: Companies shall ensure that estimates of GHG fluxes are as accurate as possible and that they are not systematically over or under actual fluxes, as far as can be judged. 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 GHG flux data is a particular concern for many agricultural GHG sources, including C stocks, soils, and enteric fermentation (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.

In practice, companies may encounter trade-offs between principles when completing an inventory. In particular, 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.

Companies should balance tradeoffs between principles depending on their individual business goals. For instance, relatively less accurate data may be appropriate for the initial evaluation of GHG reduction opportunities, whereas more accurate data may be required to track progress toward a specific GHG reduction target.

Chapter 4: Overview of agricultural emission sources

Many different types of emission sources are associated with agriculture, such as fuel use, soils, and manure management. Understanding the qualitative differences amongst these is crucial to many steps in inventory development, including calculating, reporting, and undertaking the quality control of GHG flux data.

This chapter:

- Distinguishes between two types of emissions sources – *mechanical* and *non-mechanical sources* – whose fluxes differ in fundamental ways, with important implications for GHG inventory development.
- Describes the variety and relative importance of these sources along agricultural value chains.

4.1 Overview of agricultural sources

Figure 4-1 lists the principal emission sources found on farmland. An important distinction for the agricultural sector is between mechanical and non-mechanical sources. This is because agriculture relies on biological systems, whose emissions or removals of GHGs generally occur through much more complex mechanisms than the emissions from the mechanical equipment used on farmland.

Non-mechanical sources are either biological processes shaped by climatic and soil conditions (e.g., decomposition) or the burning of crop residues. They are often connected by complex patterns of N and C flows through farms. Non-mechanical sources emit CO_2, CH_4 and N_2O (or precursors of these GHGs) through different routes. CO_2 fluxes are mostly controlled by uptake through plant photosynthesis and releases via respiration, decomposition and the combustion of organic matter. In turn, N_2O emissions result from *nitrification* and *denitrification* (see Box 4-1), and CH_4 emissions result from methanogenesis under anaerobic conditions in soils and manure storage, enteric fermentation, and the incomplete combustion of organic matter.

Mechanical sources are equipment or machinery operated on farms, such as mobile machinery (e.g., harvesters), stationary equipment (e.g., boilers), and refrigeration and air-conditioning equipment. These sources emit CO_2, CH_4, and N_2O, or HFCs and PFCs, and their emissions are wholly determined by the properties of the source equipment and material inputs (e.g., fuel composition).

Figure 4-1. Agricultural emissions sources

Mechanical

- Purchased electricity: CO_2, CH_4, and N_2O
- Mobile machinery (e.g., tilling, sowing, harvesting, and transport and fishing vessels): CO_2, CH_4, and N_2O
- Stationary machinery (e.g., milling and irrigation equipment): CO_2, CH_4, and N_2O
- Refrigeration and air-conditioning equipment: HFCs and PFCs

Non-mechanical

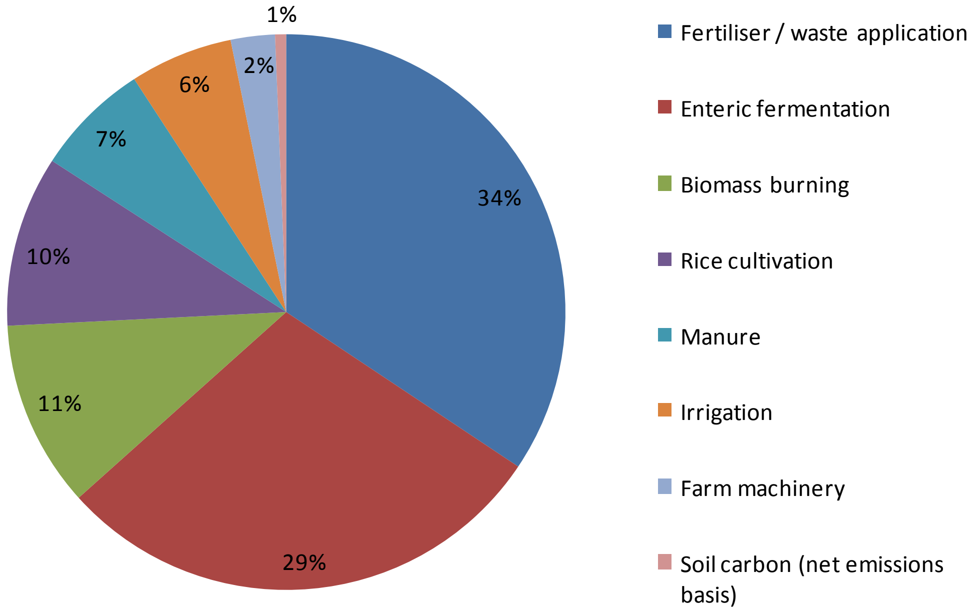
- Drainage and tillage of soils: CO_2, CH_4, and N_2O
- Addition of synthetic fertilizers, livestock waste, and crop residues to soils: CO_2, CH_4, and N_2O
- Addition of urea and lime to soils: CO_2
- Enteric fermentation: CH_4
- Rice cultivation: CH_4
- Manure management: CH_4 and N_2O
- *Land-use change*: CO_2, CH_4, and N_2O
- Open burning of savannahs and of crop residues left on fields: CO_2, CH_4, and N_2O
- Managed woodland (e.g., tree strips, *timberbelts*): CO_2
- Composting of organic wastes: CH_4
- Oxidation of horticultural growing media (e.g., peat): CO_2

Relative importance of different agricultural sources

Globally, non-mechanical sources are larger than mechanical sources (Figure 4-2; U.S. EPA, 2006a), with enteric fermentation (CH_4) and soils (N_2O) being the largest sources (U.S. EPA, 2006b). The exact contribution of agriculture to global CO_2 emissions is hard to quantify. This is because the biomass and soil C pools not only emit large amounts of CO_2, but also take up CO_2. Nevertheless, additional C sequestration offers most (~89%) of the global emissions mitigation potential in agriculture (Smith et al., 2007b). Agriculture-driven LUC is also a globally important source of CO_2 emissions.

At the farm scale, the relative magnitude of different emission sources and of different GHGs will vary widely depending on the type of farm, management practices, and natural factors at play. These factors include original land cover; farm topography and hydrology; 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 sources to the whole-farm inventories of different farming systems using a consistent set of methods. It is difficult to accurately predict the relative magnitude of different sources for a given farm. Nonetheless, certain broad patterns can be expected (e.g., Figure 4-3).

Figure 4-2. Relative contribution of different agricultural sources to global anthropogenic emissions (percent)



Notes:
1. Data are from U.S. EPA (2006a) and exclude emissions sources located upstream or downstream of farms.
2. Data exclude LUC emissions.
3. The 'soil carbon' value represents the net emissions from agricultural soils after subtracting C sequestration from gross soil C emissions. It represents the summed effect of different management practices on soil organic C.

Figure 4-3. Typical patterns of the contribution of different sources to overall GHG fluxes from select farming systems.

Emission source	**Type of system**				
	Sheep	**Beef**	**Dairy (pasture)**	**Arable crop**	**Horticulture**
Enteric fermentation	Large	Large	Large	Small	Small
Deposition or application of fertilizer and/or wastes to soils	Large	Large	Large	Large	Large
Crop residue burning	Small	Small	Small	Medium	Small
Manure management	Large	Large	Large	Small	Small
Fuel use	Small	Small	Small	Medium	Medium
Soil CO_2	Small	Small	Medium	Medium	Medium

Key:

(green)	Small contribution
(beige)	Medium contribution
(pink)	Large contribution

Notes:
1. 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.
2. Figure based on expert opinion of the Technical Working Group.

4.2 Individual agricultural sources

Non-mechanical sources

The non-mechanical sources that are globally largest in magnitude 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 CH_4 that is produced depends on:

- The type of animal. 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, and deer. Non-ruminant livestock (horses, mules, donkeys) and monogastric livestock (swine) have relatively lower CH_4 emissions.
- Quantity and composition of feed. Generally, the higher the feed intake, the higher the CH_4 emissions.
- Age and size of livestock. Feed intake increases with animal size, growth rate, and production (e.g., milk production, wool growth, or pregnancy).

Soil amendments and soil management (N_2O)
Direct and indirect emissions of N_2O also occur from soils following increases in available N (see Box 4-1) from:

- Synthetic N fertilizers and organic fertilizers (e.g., animal manure, compost, sewage sludge, and rendering waste).
- Urine and dung that is deposited onto pastures, ranges and paddocks by grazing animals.
- Incorporation of crop residues into soils and N-fixation by legumes. (Note: crop residue management and legume growing can reduce field fertilizer requirements and ultimately reduce overall soil N_2O emissions.)
- *N mineralisation* associated with the loss of soil organic matter and caused by changes in land use or soil management, such as the drainage or management of organic soils (i.e. histosols).

Manure management (CH_4 and N_2O)
Manure 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:

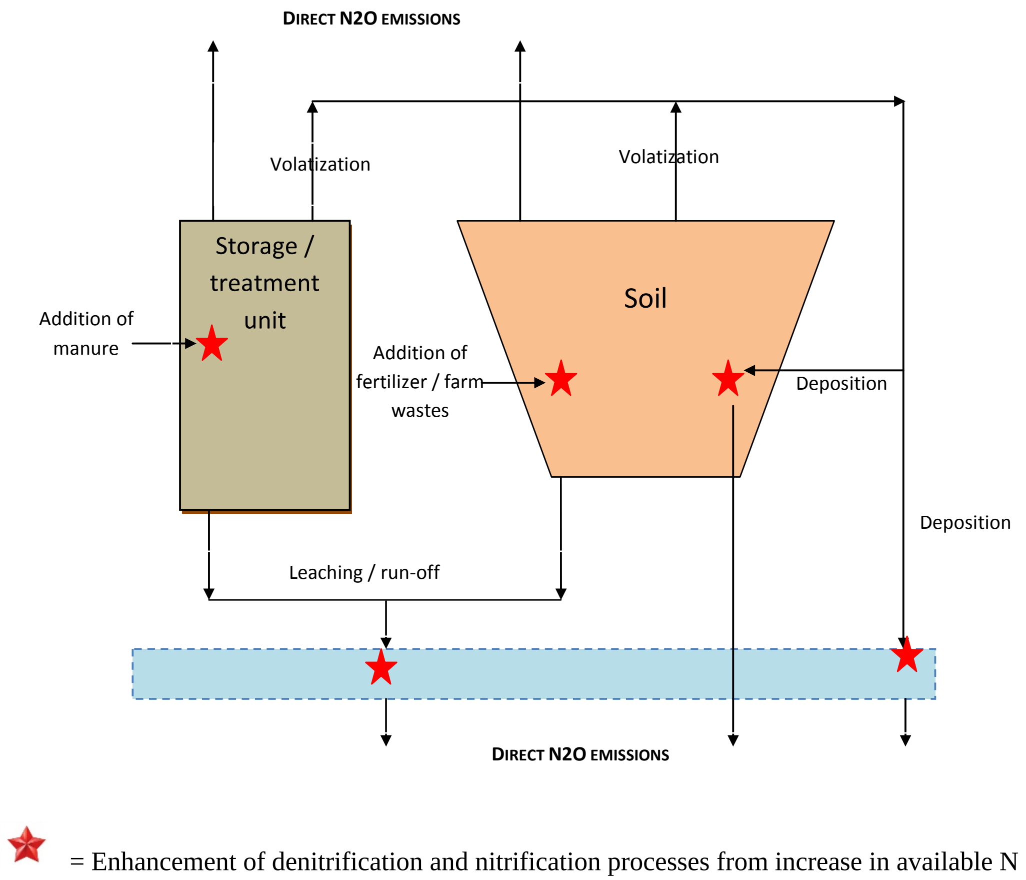
- Large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms).
- When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits). In contrast, when manure is handled as a solid (e.g., in stacks or piles) or when it is 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 (see Box 4-1). N_2O emissions are influenced by:

- The N and C content of the manure, and 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 leaching and run-off of N from treatment units.

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 and in ditches, rivers, estuaries, etc., that eventually receive the leachate. While indirect N_2O emissions may occur off the farm, they are accounted for in the same way as direct N_2O emissions in this Guidance.



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 may release bicarbonate (HCO_3^-), which then forms CO_2 through additional chemical reactions. Whether CO_2 is emitted and the amount of emissions 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 on farms, but their production causes CO_2 emissions from the breakdown of carbonate raw materials.

Management of carbon pools
The agricultural sector differs profoundly from industrial sectors in the importance of C pools, which may act either as sources or sinks of CO_2 during agricultural land use or LUC. These pools are of four main types (Figure 4-4):

- 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 wood products* (HWPs) 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).

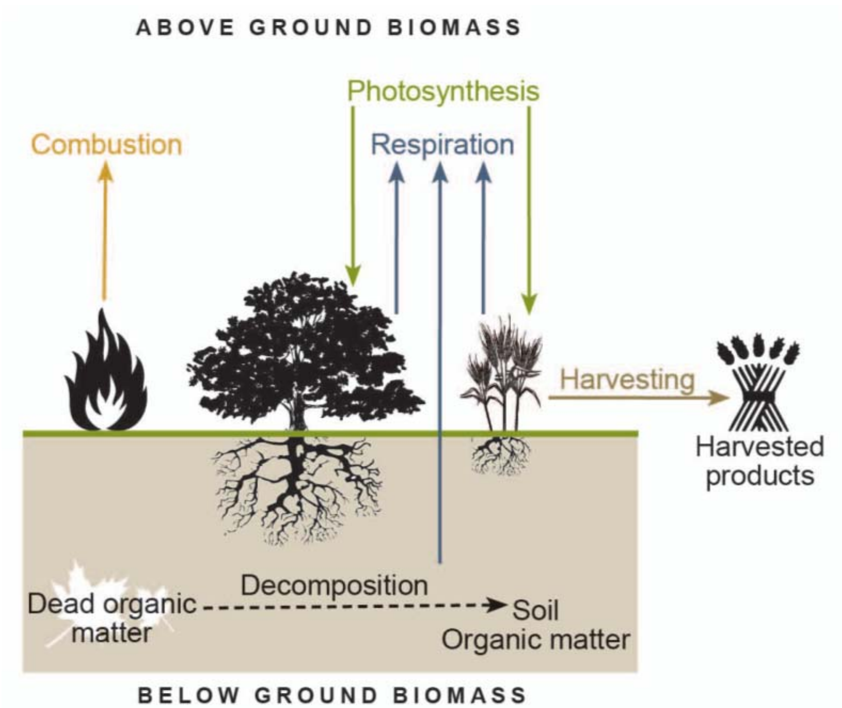
Carbon stocks represent the quantity of C stored in pools. It may take C stocks decades to reach equilibrium following a change in farm management. Ultimately, for agricultural land as a whole to sequester C, the sum of all stock increases must exceed the sum of all stock decreases (i.e., the sum of all C gains through CO_2 *fixation* must exceed the sum of all C 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 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 4-4. Carbon pools in agriculture



Mechanical sources

The following categories of mechanical sources exist on farms:

- Stationary and mobile combustion sources. Stationary combustion sources are devices such as boilers, furnaces, and electric generators and are used to power a wide range of equipment, such as milling and irrigation equipment. Mobile combustion sources are vehicles and mobile equipment, such as tractors, combine harvesters, and trucks. The CO_2 emissions from all combustion sources are primarily determined by the C content of the fuel used. In contrast, the CH_4 and

N_2O emissions are primarily determined by the combustion and emissions control technologies present.

- Purchased electricity. The associated emissions will depend on the mix of fuel types and technologies used on the grid concerned.
- Refrigerant and air-conditioning equipment. These equipment leak refrigerants – high Global Warming Potential (GWP) GHGs - during installation, maintenance, operation and disposal.

4.3 Off-site emission sources beyond the farm gate

The relative importance of different upstream and downstream processes will vary, depending on the proximity to markets (i.e. transportation distance), the amount of processing and packaging, and the type and volume of farm inputs (especially fertilizer). The following sources will be important for many types of farms:

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 technologies, and raw material inputs. Three raw materials are particularly important:

- Ammonia. CO_2 is emitted from the consumption of hydrocarbons (primarily natural gas) as a hydrocarbon feedstock (to supply H) and as an energy source.
- Nitric acid (HNO_3). Nitric acid production is the largest industrial source of N_2O (IPCC 2006) 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 resultant emissions are mainly of CO_2, from fuel use and from the C compounds contained in the rock.

To a large degree, the GHGs embedded in a fertilizer product will reflect the relative amounts of these ingredients.

Feed production
Globally, feed production accounts for 45% of the product-level GHG emissions across all types of livestock (Gerber et al., 2013). It is more important in the life cycle inventories of egg, chicken and pork, compared to those of milk and beef, where enteric fermentation dominates. Feed production emissions come from many of the sources described in Chapter 4.2; particularly, soil management, LUC, and fertilizer production, as well as electricity use during drying and processing.

Refrigeration
Refrigeration is the major GHG-intensive component of the downstream supply chain. Refrigeration emissions occur during initial chilling, transport, storage, catering and retail. Limited data are available, but this "cold chain" could account for about one percent of global GHG emissions (James and James, 2010).

Part 2: DEVELOPING CORPORATE INVENTORIES

Chapter 5: Setting Inventory Boundaries

Agricultural companies 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 for land and equipment, 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 companies. Fortunately, specific approaches are available to help companies 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 these operations should be reported in inventories.

Summary of requirements and main recommendations:

- Companies shall separately account for and report on scope 1 and 2 at a minimum.
- When setting operational boundaries, companies should take appropriate account of production contracts and other forms of agricultural contracting, land and equipment leases, and membership of co-operatives.

5.1 Setting organizational boundaries

Organizational boundaries determine which land and operating facilities, such as barns and processing plants (collectively termed 'operations' in this Guidance), shall be included in an inventory. Three 'consolidation' approaches can be used to set organizational boundaries:

1. *Operational control*. A company 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*. A company 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*. A company accounts for the fluxes to/from an operation according to its share of equity (or percentage of economic interest) in that operation.

Various criteria can be used by companies 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 company, 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 company has the ability to determine management and board-level decisions of the joint venture.
- The reporting company holds an operating license.
- The reporting company sets environmental, health and safety policies.

A company 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 agricultural businesses 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 fluxes under the financial control approach, but they would account for those fluxes 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.

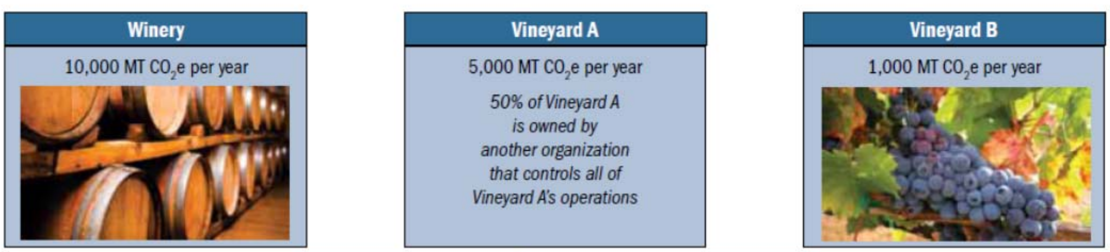
This Guidance makes no recommendations about which consolidation approach should be used in the sector. Rather, many companies will likely need to consider a range of factors when selecting an approach and that selection should be based on the reporting company's business goals for GHG reporting (Table 5-2). For instance, a company with a large cattle feedlot may fall under the jurisdiction of a mandatory GHG reporting program. Because compliance with such programs typically rests with the operators of emission sources, the company may choose the operational control approach to streamline its reporting processes. In general, sole proprietorships will typically find the operational control the most straightforward approach to apply, while companies with other business structures may prefer any of the three approaches based on their specific business goals.

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	By shares of	Usually, one

<table>
<tr><td colspan="2"></td><td></td><td>partners' share in capital</td><td>common stock</td><td>member-one vote</td></tr>
<tr><td colspan="2">Who determines policies</td><td>The individual</td><td>The partners</td><td>Common stockholders and directors</td><td>The member-patrons and directors</td></tr>
<tr><td colspan="2">Who gets the operating proceeds?</td><td>The individual</td><td>The partners in proportion to interest in business</td><td>The stockholders in proportion to stock held</td><td>The member-patrons on a patronage basis</td></tr>
<tr><td rowspan="3">Who accounts for the GHG fluxes from business's agricultural production? And at what percent?</td><td>Based on equity share</td><td rowspan="3">Owner accounts for 100% of fluxes</td><td rowspan="2">Each partner accounts for a % of the fluxes in proportion to interest in business</td><td>The company accounts for a % of fluxes based on its share of equity in the business</td><td>The member-patrons on a patronage basis</td></tr>
<tr><td>Based on financial control</td><td>The company accounts for 100% of fluxes</td><td>The co-operative accounts for 100% of the fluxes</td></tr>
<tr><td>Based on operational control</td><td colspan="2">Varies depending on contractual and other legal provisions</td><td>The co-operative accounts for 100% of the fluxes</td></tr>
</table>

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

Table 5-2. Considerations for choosing an organizational boundary approach.

Consideration	Preferred boundary approach	Explanation
Reflection of commercial reality	Equity share	Equity share is based on the share of economic interest in a business activity, which is a reflection of commercial reality
Government reporting and emissions trading programs	Operational control	Programs usually require reporting on the basis of operational control
Liability and risk management	Equity share or financial control	The ultimate financial liability for GHG emissions often rests with the group company that holds an equity share in the operation or has financial control over it
Alignment with financial accounting	Equity share or financial control	These approaches result in the closest alignment between GHG and financial accounting
Management information and performance tracking	Operational control or financial control	Managers can only be held accountable for activities under their control
Cost of administration and data access	Operational control or financial control	The equity share approach can result in higher costs because of resource requirements of collecting data from joint operations not under the control of the reporting company.

5.2 Setting operational boundaries

Having set organizational boundaries using any one of the consolidation approaches, companies 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 company) or indirect (i.e., owned or controlled by another company, but a portion of whose emissions are a consequence of the activities of the reporting company). Emission sources are further classified by scope (Box 1-1):

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

All scope 1 and 2 sources shall be reported in an inventory. Scope 3 sources are optional under the Corporate Standard, although it is recommended to measure and report significant scope 3 sources (see Chapter 9.3). Also, with the exception of LUC, all CO_2 fluxes to/from C pools that are owned or controlled by the reporting company should be reported separately from the scopes in a special 'Biogenic Carbon' category. Biogenic CO_2 fluxes are considered further in Chapters 8 and 9.

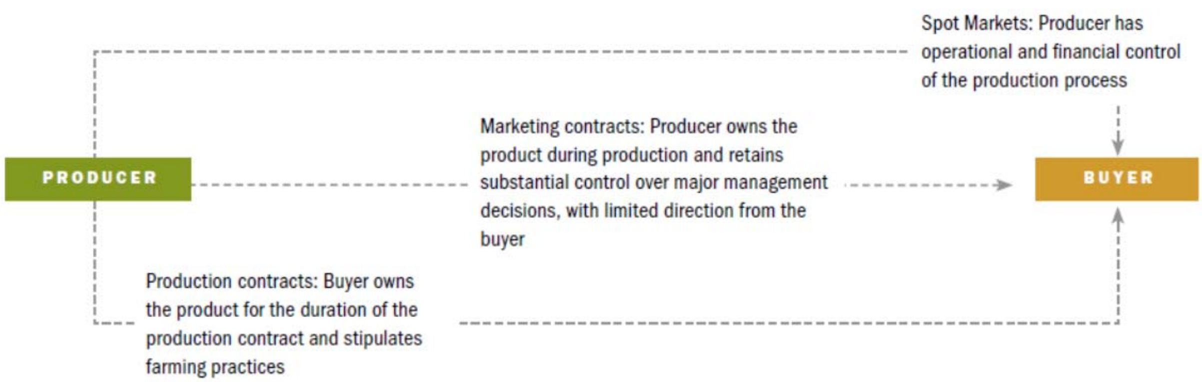
What factors affect how operational boundaries are set?

Companies may encounter the following factors for consideration when determining which scope a given source falls under:

1. Production contracts
Agricultural products can be sold in various ways, including production contracts, marketing contracts and spot markets (Figure 5-2). Production contracts are distinct in that they are agreements between contractors (often called growers) and contractees (often called integrators) that cede some measure of control over the production process to the integrator. The contract specifies: (1) the services to be provided by the grower (e.g., fertilizer application schedules, husbandry conditions); (2) the manner in which the grower is to be compensated for the services; and (3) specific integrator responsibilities for the provision of any inputs. There are many different types of production contracts, which vary according to whether the integrator or grower owns the product during production; whether the terms of the contract are non-negotiable; and the extent to which the integrator provides inputs.

For the purposes of reporting under this Guidance, growers 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. In particular, if the integrator has established multi-year contracts with individual growers and provides extensive inputs, the integrators and growers should each then account for a portion of the emissions according to their share of investments in the production process.

Figure 5-2. Primary sales routes for agricultural products



2. Other forms of agricultural contracting
While companies 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 or off the reporting companies' farmland.

On-farm activities: Companies may contract third parties 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 the exception of contractor-owned equipment, the on-farm sources are scope 3 for the contractor and scope 1 for the producer/landowner, under both the operational and financial control approaches.

Off-farm activities: Many different arrangements exist for the grazing or feeding of a company's livestock on a third party's land. Examples include feedlots and *ajistments*[6]. While the livestock are on the third party's land, the agricultural emissions (e.g., CH_4 emissions from enteric fermentation and manure management) are scope 1 for the third party 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 that 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.
- 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 the reporting company 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

For the purposes of reporting under this Guidance, the reporting company is considered to exert operational control of any land it leases (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. For instance, permits for the lease of national-owned grazing lands from governments might contain requirements related to resting periods and reseeding. The lessee retains operational control of the land in these cases.

[6] 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"

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, machinery, or purchased electricity) are scope 3 (Scope 3 Category 8: "Upstream leased assets")
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, machinery, or purchased electricity) are scope 3 (Scope 3 Category 8: "Upstream leased assets")	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, machinery, or purchased electricity) are scope 3 (Scope 3 Category 8: "Upstream leased assets")	

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 marketing, purchasing, and service co-operatives (Table 5-5).

<u>Accounting under the equity share approach.</u> Many producers 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 producers may have a significant percentage patronage and should account for a corresponding percentage of the co-operative's scope 1, scope 2, and (optionally) scope 3 emissions under the equity share approach. Note that the nature of the emissions 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.

Accounting under either control approach. A Co-operative does not fall within the organizational boundaries of its members and only the co-operative itself should account for its emissions under scope 1 and 2. Individual members may account for certain emissions under scope 3 should those arise from 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 emissions from the co-operative's processing of animal feed, should that feed be used by that member (the relevant scope 3 category is Category 1: "Purchased goods and services").

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

Chapter 6: Tracking GHG fluxes over Time

Setting and using base periods is a fundamental step in designing GHG inventories. They help companies compare performance against a point in the past and they put the effects of changes in inventory methodologies into context, allowing meaningful and consistent comparisons of performance over time. Agricultural activities and environmental conditions that affect GHG fluxes can change a lot over time. Also, structural changes such as acquisitions, divestments, and mergers, can affect the types of operations that need to be reported in inventories. Companies need to take these changes into account whilst setting and using base periods.

This chapter:

- Details requirements and recommendations for choosing a base period and for recalculating base period data to ensure historical comparisons are meaningful.

Summary of requirements and main recommendations:

- Companies shall choose and establish a base period, and specify the reasons for choosing that period.
- The base period shall be the earliest point in time for which verifiable data are available on scope 1 and scope 2 emissions.
- Multi-year base periods are recommended for many companies.
- Companies shall develop a base period emissions recalculation policy, and clearly articulate the basis and context for any recalculations. If applicable, the policy shall state any "significant threshold".
- Companies shall recalculate the base period inventory to reflect changes in organizational structures or calculation methods, or the discovery of errors, which significantly impact the base period inventory.

6.1 Setting base periods

The base period is the period in history against which an organization's GHG fluxes are tracked over time[7]. Both the Corporate Standard and this Guidance require companies to establish a base period. Companies shall use as a base period the earliest relevant point in time for which they have verifiable data on scope 1 and scope 2 emissions. Critically, the base period should be representative of a company's GHG profile. This has several implications:

Base periods shall not be less than one year

The base period should not be an individual *crop year* or production season (for livestock) that is less than one year. 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

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

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 company.

Multi-year base periods are recommended

Oftentimes, individual years will not 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 at least 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.

Many calculation methodologies (e.g., Tier 1 IPCC methodologies; see Chapter 7.3) do not capture the effects of climate or environmental change on GHG fluxes. Instead, they only pick up changes in activity data (e.g., number of hectares farmed, number of cattle raised, amount of fertilizer used, etc.). As a result, if management practices in an individual year are representative, it may be appropriate to select that year as the base period.

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 company and that cause the base period inventory to depart significantly from typical GHG flux profiles	During a single growing season, a heat wave increases irrigation and therefore fuel use requirements
Atypical or episodic changes in farming practices	Coppiced woodland is returned to crop production
	Forest is cleared for agricultural production
Agricultural activities vary cyclically over a set period of years, such that 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

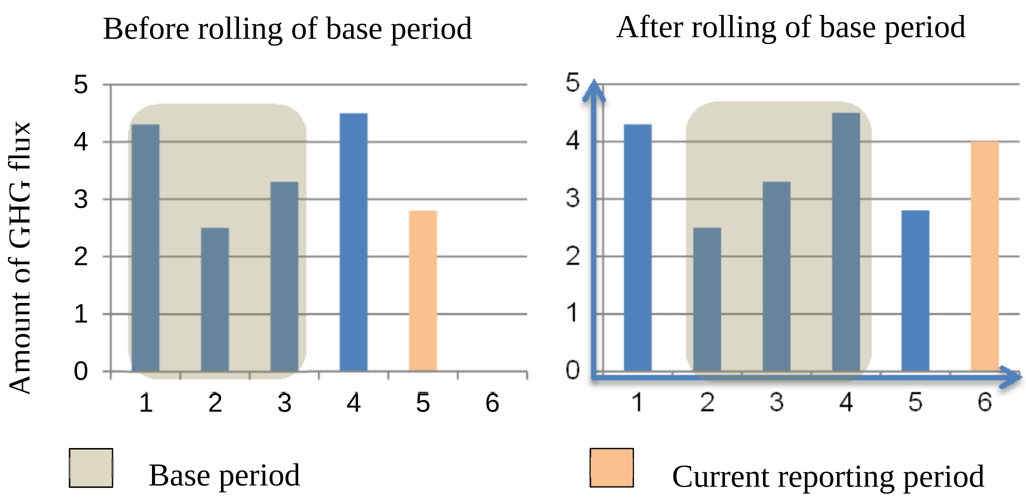
Rolling base periods may be useful

Rolling base periods are base periods that move forward in time with each reporting period. They are useful because long-term environmental trends, such as changes in precipitation and temperature that accompany climate change, can affect agricultural GHG fluxes. As a result, the more widely separated the current reporting period is from a fixed base 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. Therefore, companies may 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 (Figure 6-1).

One disadvantage to rolling base periods is that they 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.

Figure 6-1. The concept of rolling base periods



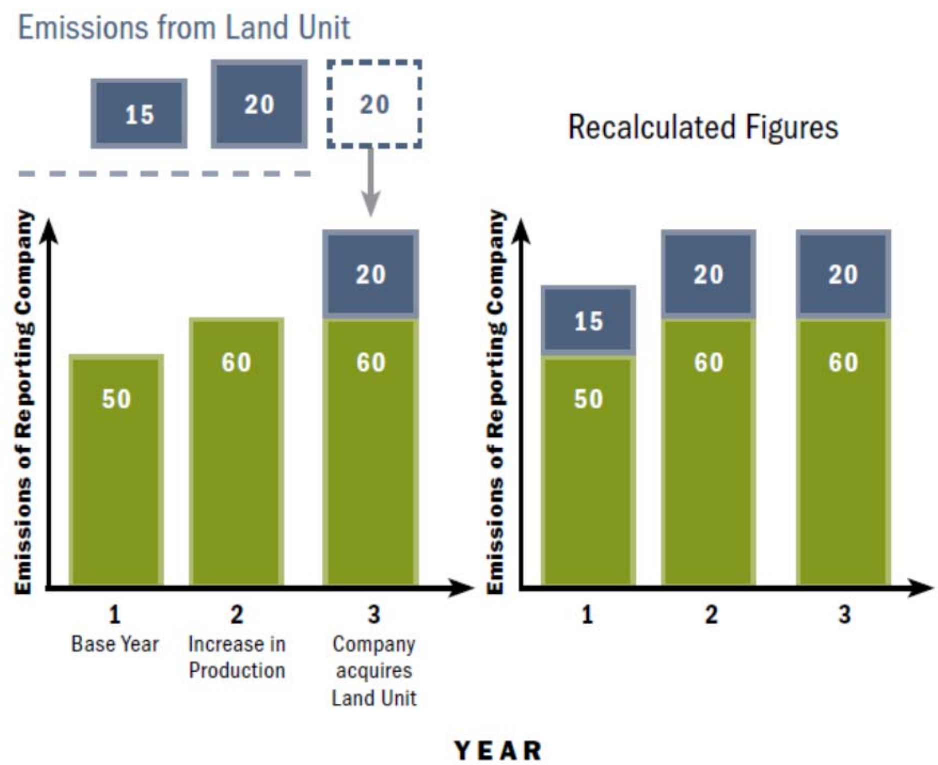
6.2 Recalculating base period inventories.

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

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

In determining whether changes are significant, companies 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 provide recommended thresholds. Once defined, a significance threshold should be applied consistently over time.

Figure 6-2. Recalculating base period inventories for structural changes. Here, the reporting company acquires a business at the beginning of year 3. The emissions from that business during year 3 are reflected in the reporting company's inventory for that year, but the inventories for the base period and year 2 are recalculated to include the acquired business's emissions during those two years.



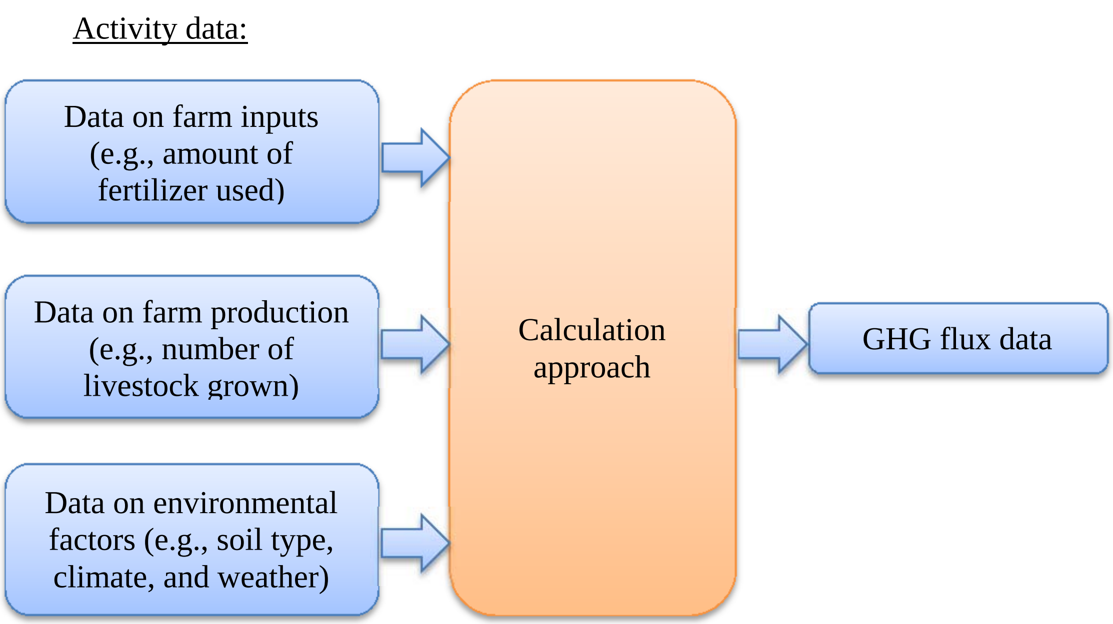
Changes that do not trigger recalculations

- Organic growth or decline. Organic growth and decline is defined as increases or decreases in production output, changes in product mix, or 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 a company are also considered organic change and do not trigger recalculations, even if that action substantially increases production levels.
- The acquisition (or insourcing) of an operation that did not exist in the base period of the reporting company.
- Operational changes, such as switching from a feedlot to a rotational grazing operation, assuming both operations are owned or controlled by the reporting company.

Chapter 7: Calculating GHG Fluxes

Calculating GHG fluxes can be the most challenging part of developing GHG inventories in the agricultural sector. Companies 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. This selection is a key step, because the likely accuracy of GHG flux data and the types of activity data needed vary widely amongst approaches. Figure 7-1 shows the general process for calculating GHG fluxes.

Figure 7-1. General process for calculating GHG flux data.



This chapter:

- Describes the types of activity data typically needed to calculate GHG fluxes.
- Provides guidance on prioritizing emissions sources for data collection.
- Describes the general approaches for calculating the GHG fluxes to/from agricultural, especially non-mechanical, sources.
- Describes criteria that are useful in selecting specific calculation tools.
- Describes common sources of uncertainty in calculating GHG data that offer opportunities for improving inventory quality.

Summary of requirements and main recommendations:

- When high-quality activity data are not available for all of the emissions sources that need to be included in an inventory, companies should prioritize their data collection efforts based on source magnitude.
- Companies should select a calculation approach that best meets their objectives for compiling an inventory and the GHG accounting and reporting principles.
- When managing inventory quality, companies should focus on reducing parameter uncertainty.
- Information on GHG data uncertainty should be reported in inventories.

Note: Prior to calculating GHG fluxes, companies should also consult Chapter 8, which details the specific types of C stock changes that should be included in an inventory and for which calculations are therefore recommended.

7.1 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 LUC can be more difficult to obtain. Table 7-1 summarizes common types of required activity data. Companies 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 7-2). Companies should be mindful of these challenges when designing inventories and inventory quality management plans.

Table 7-1. Types of activity 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 activity data may be required for a given source.

Source	Common types of activity data needed
General	• Soil texture, moisture, drainage and pH • Temperature • Area of different types of crops harvested and crop yield by crop • Location (e.g., state or biome)
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, type and digestibility of feed • 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 • Amount 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 (including from crop rotations) • 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
Open burning of crop residues	• Acres burnt • Amount of crop residue left on field per acre
Land use change	• 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, or • Starting and ending volumes of different fuel stocks, and • 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 • Starting and ending volumes of different refrigerant stocks • Amounts of different types of refrigerants purchased

Table 7-2. Common challenges in collecting activity data for agricultural emissions sources

Challenge	Solution
Determining 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
Obtaining data for calculating the emissions from contractor fuel use on farms, when only the contracted area is recorded	Make assumptions about the amount of fuel needed per area serviced, as well as the machinery employed
Understanding the energy consumption of individual facilities or sources (e.g., an irrigation pump)	Install meters or provide a use log that tabulates the number of hours per day of operation
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).

7.2 Guidance for prioritizing data collection efforts

It may not always be possible to collect high quality activity data for all of the emissions sources that need to be included in an inventory. As a result, data collection efforts should be prioritized.

Companies should prioritize data collection efforts for key sources
Key sources are those that are expected to have the highest GHG fluxes, offer the most emissions reduction potential, and are most relevant to the company's business goals (Table 7-3). The identification of key sources should take into account the range of different GHGs emitted from individual sources, because of the potential for trade-offs in GHG fluxes (see Chapter 7.3) and also because companies might have different amounts of control over the different sources. Collecting higher quality data for key sources will allow companies to more effectively set reduction targets and track and demonstrate progress over time, while making the most efficient use of available resources. For the same reasons, the key sources should also be subject to the most accurate quantification methods and the focus of quality analysis/quality control procedures.

Table 7-3. 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 uncertainty of the GHG fluxes is (or is believed to be) large
Degree of control	There are potential emissions reductions that could be undertaken or influenced by the reporting 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 sector

Identifying key sources based on the magnitude of GHG fluxes is preferred
The most rigorous approach to identifying key sources is to use quantitative data to rank the size of different sources (and sinks). This approach has three steps:

1. Obtain 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, companies may use initial GHG estimation (or screening) methods to estimate the fluxes for each source (e.g., by

using industry-average data, LCA studies of different food or biofuel products, or rough estimates).

2. Rank 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. Apply a pre-determined, percentage cumulative threshold. Key sources are then those that together add up to a certain percentage of the overall emissions (e.g., key sources are cumulatively responsible for 70% of GHG fluxes).

Trends in magnitude are also useful for identifying key sources 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.

$$\text{Percentage change in GHG flux} = \frac{\text{latest inventory estimate} - \text{base period estimate}}{\text{absolute value of base period estimate}} x100\%$$

This analysis is helpful because it can identify sources whose trend is different from that of the overall inventory. Companies 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. Companies may likewise chose to invest more in categories whose fluxes show large increases.

Companies should not exclude small or highly uncertain emissions sources
In general, companies should not exclude required emissions sources from their inventories as a result of uncertainty. 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). For instance, while fuel use will often comprise a small share of the inventory of a ranching operation, it should still be included in the inventory, but may be estimated based on simplified assumptions.

Can ‘materiality thresholds’ be used? These are minimum GHG accounting thresholds that state that when a given source is smaller than the threshold size it can be omitted from the inventory. Although it appears useful in theory, the practical implementation of such a threshold is not compatible with the completeness principle of this 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.

7.3 Selecting a calculation approach

GHG fluxes can be determined in different ways, ranging from the use of highly specialized, field-scale measurement equipment to global emission factors. This Guidance does not require or recommend the use of a specific calculation approach or tool. Instead companies should select an approach that best meets their objectives for compiling an inventory and that meets the GHG accounting and reporting principles (see Chapter 3 and below).

The distinction between mechanical and non-mechanical sources becomes paramount when calculating GHG fluxes and the associated levels of uncertainty. In general, GHG fluxes for mechanical sources can be calculated with higher accuracy. 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. In contrast, the GHG fluxes to/from non-mechanical sources depend on complex interactions between management practices and variable environmental conditions. As a result, GHG flux data for these sources are likely to have much higher uncertainty, regardless of the calculation approach chosen. This difference has important implications for how these data should be reported in inventories (see Chapter 9).

Because calculation tools for mechanical tools are widely available (e.g., from GHG reporting programs), this section will focus on non-mechanical sources.

How are GHG fluxes calculated for non-mechanical sources?

Broadly, four different types of calculation approaches can be used for non-mechanical sources (Table 7-4):

- Field measurements
- *Emission factors*
- Empirical models and process-based models

Field measurements

Many, but not all, GHG emission sources in agriculture can be measured using either direct or indirect measurement techniques. Direct techniques include controlled livestock chambers that measure the CH_4 emissions from enteric fermentation, flux chambers that measure the N_2O and CO_2 emissions from plots of land, and gas flux meters that measure the CH_4 emissions from certain livestock waste management systems (e.g., covered anaerobic lagoons). Indirect techniques include the measurement of carbon stocks before and after a change in management practices or land use. Indirect techniques are often much simpler and easier, but may require additional planning ahead of time to capture the 'before' scenario. While useful for research, both direct and indirect techniques are often far too costly for developing corporate inventories.

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 by an emission factor that specifies how much CH_4 is emitted per head of dairy cattle. The accuracy of this approach depends not only on the accuracy of the activity data, but also on how specific the factor is to the specific combination of environmental factors and management activities concerned. Default emission factors are largely either based on field measurements at individual research sites or represent average values across a range of sites.

Empirical and process-based models
Empirical models use field measurements to develop statistical relationships between GHG fluxes and agricultural management factors. In turn, 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 have extensive data requirements that span 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 may not be reliable.

GHG fluxes can also be calculated using any combination of the above approaches. For instance, empirical or process models could be used to derive more specific emission factors. The resulting hybrid approaches can increase the accuracy and practicability of calculating emissions.

No one approach is ideal
The calculation approaches differ in how they map onto the various tiers defined by the Intergovernmental Panel on Climate Change (IPCC) for the purposes of national inventory 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 are not very effective in capturing the geographical variation in the biophysical processes that underpin GHG fluxes and they may not be sensitive to many changes in farm management practices. As a result, they tend to become less accurate as spatial resolution increases from a regional or national level to a local or farm-level. And their use may mask much of the variation in performance that exists amongst farms.

Emission factors and empirical models also tend to focus on individual emission sources and management practices one at a time. This is a problem because non-mechanical sources are often connected by complex flows of N and C through farms, such that management activities have non-additive GHG effects. For example, soil N_2O emissions are affected not only by fertilizer application regimes, but also by tillage, soil pH management, irrigation, and drainage practices. As a result, the GHG impact of different agricultural practices is best evaluated simultaneously and at the whole 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 GHG fluxes. They are therefore 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.

Companies may choose to use different approaches for different activities.

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 inventories. Many of the tools listed in Appendix III 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. The choice of tier depends, 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 (mostly temperate) 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. In general, Tier 3 methods are considered most accurate and Tier 1 methods least accurate.

* http://www.ipcc-nggip.iges.or.jp/public/2006gl/

Table 7-4. Summary of approaches for calculating the GHG fluxes to / from non-mechanical sources

Approach	Advantages	Disadvantages
Field measurements. This category includes lab measurements of soil C	• 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 and environmental factors
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 regimes (e.g., new animal genotype, different method of 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 regimes, 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 environmental 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 background data are not available at the farm level (as is the case in many developing countries)	• Require vast background datasets (e.g., multi-decadal weather 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 expensive to run and develop/calibrate

Box 7-2. GHG trade-offs and the value of a whole-farm approach to calculating GHG fluxes

Mitigation options or best management practices (BMPs) introduced to reduce the emissions of one GHG can sometimes increase those of others. Some examples include:

- Measures taken to enhance soil C sequestration (e.g., no till-practices, the recovery of degraded pasture, or increased irrigation) can increase 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 C sequestration but lead to increased soil N_2O emissions, compared to field margins.
- Constructed wetlands can sequester C 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 C 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 examples demonstrate the need to identify trade-offs and consider multiple emissions 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.

What tools are available for calculating GHG fluxes?

There are an increasing number of publicly available tools - spreadsheets, software and protocols - for calculating GHG fluxes based on emission factors, models or a combination of these approaches. Appendix III 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 GHG fluxes, at least in regions for which background, calibrating datasets are available.

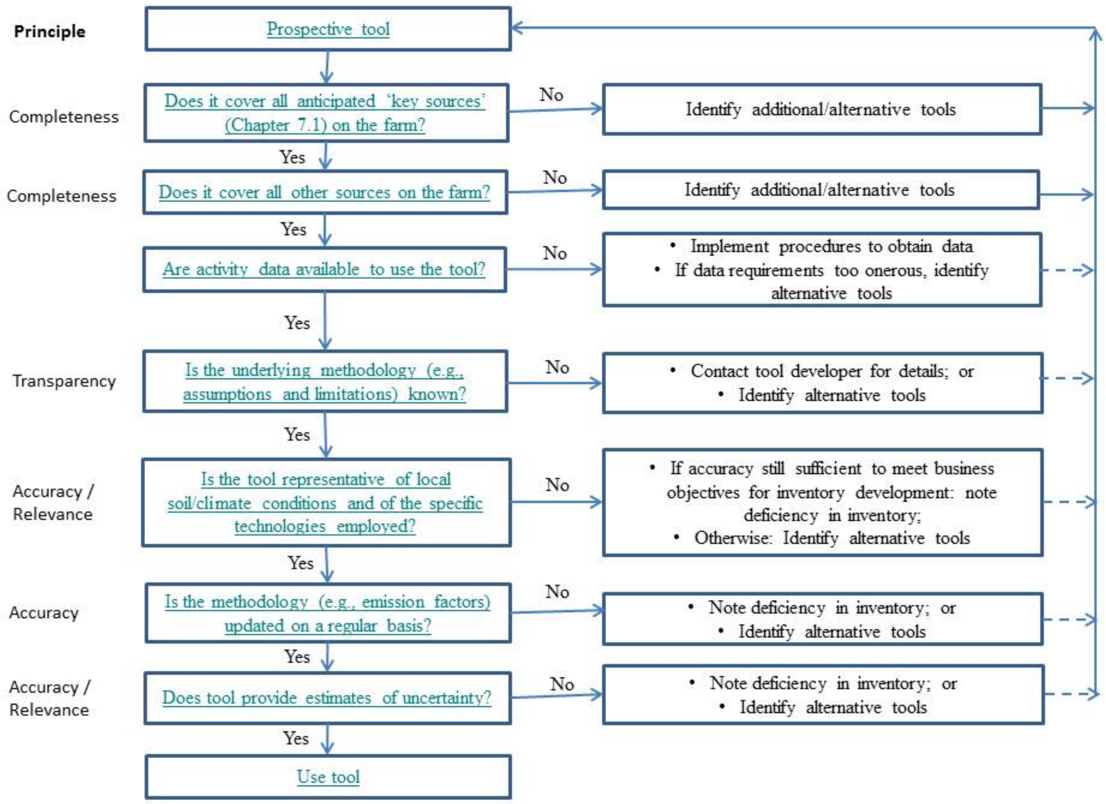
Tools should be evaluated against a range of criteria

This Guidance does not recommend specific tools for calculating GHG fluxes – companies should instead select tools that best allow them to meet their objectives for compiling an inventory and the GHG accounting and reporting principles. In evaluating individual tools, companies should consider a range of questions, including:

- 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?
- 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 methodology, including limitations and assumptions?
- Is the tool geographically representative? Is it tailored to the region/area of interest?
- Is the tool accurate enough to help meet the business objectives for compiling an inventory?
- Is the tool up-to-date (e.g., are emissions factors updated on an annual basis)?
- Does the tool provide estimates of uncertainty?
- Does the tool have verifications functions (e.g., are ranges enforced for the values of activity data)?
- Can the tool quantify environmental impacts other than GHG fluxes (e.g., nitrate or phosphorus pollution)?
- Can the tool quantify GHG performance metrics?
- Is the tool otherwise consistent with the GHG accounting principles?

Figure 7-2 outlines a decision tree for choosing a tool based on core questions.

Figure 7-2. Decision tree for choosing a GHG emissions calculation tool.



7.4 Uncertainty in activity and GHG flux data

The GHG fluxes to/from agricultural sources – and especially non-mechanical sources - are inevitably estimated with some degree of uncertainty. 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 both the inventory results and any estimates of emissions reductions from changes in farming practices.

Two types of uncertainty affect GHG flux estimations

1. Model uncertainty. This refers to intrinsic limitations in the ability of the calculation approach to reflect real world conditions. Such uncertainty is particularly important for non-mechanical sources whose GHG fluxes 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 actual and calculated values. 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. This is a measure of how close the data used to calculate the inventory results (e.g., activity data and emission factors) are to the true (though unknown) actual data and GHG fluxes. Parameter uncertainties can be evaluated through statistical analysis, measurement equipment, precision determinations, and expert judgment.

Together, these sources of uncertainty affect whether GHG data are accurate enough to meet the business goals that are driving inventory development or to determine if changes in GHG fluxes are the result of management changes.

Companies should focus on parameter uncertainty

In general, understanding parameter uncertainty will be the primary focus of companies in managing inventory quality. This is because most companies will lack the technical capacity to estimate model uncertainty, while most companies should be able to estimate parameter uncertainty. As far as is possible, companies should identify and track key uncertainty sources throughout the inventory process and iteratively check whether the uncertainty of the results is adequate for the company's business goals. The GHG Protocol does not define acceptable uncertainty levels. However, if the uncertainty bounds are asymmetrical, the larger uncertainty should be used to remain conservative.

Parameter uncertainty can be quantified based on one or more the following:

- Measured uncertainty (represented by standard deviations)
- The pedigree matrix approach, based on data quality indicators (DQIs)[8]
- Default uncertainties for specific activities or sector data (reported in various literature)
- Probability distributions from commercial databases
- Uncertainty factors reported in literature
- Other approaches reported by literature

Uncertainty data for emission factors will often be available. For instance, the IPCC typically provides uncertainty bounds for its Tier 1 emission factors.

The GHG Protocol's Quantitative Inventory Uncertainty tool[9] provides more information on assessing the overall uncertainty of an inventory and the contribution of each data element to this uncertainty.

Information on uncertainty should be reported

Uncertainty can be reported in many ways, including through qualitative descriptions of uncertainty sources, and quantitative representations, such as error bars, histograms, probability density functions, etc. It is useful to provide as complete a disclosure of uncertainty information as is possible. Users of the information may then weigh the total set of information provided in judging their confidence in the information.

[8] The use of DQIs involves rating individual data points against a range of quality criteria, such as precision and geographical representativeness.

[9] http://www.ghgprotocol.org/calculation-tools/all-tools

Chapter 8: Accounting for Carbon Stocks

Agricultural systems contain C in above-ground and below-ground biomass, dead organic matter (DOM), soil organic matter, and harvested products (Chapter 4.2). These C stocks are reversible - any C sequestered in C stocks will eventually be emitted to the atmosphere. Also, changes in C stocks can take decades to reach equilibrium following a change in farm management or land use. These special features of agriculture have important implications for whether and how C stocks should be included within GHG inventories.

This chapter:

- Describes how changes in C stocks should be reported in terms of CO_2 fluxes.
- Describes the types of CO_2 fluxes that should / should not be included in inventories.
- Describes how the CO_2 fluxes from long-term changes in C stocks can be spread over multiple reporting periods.

Summary of requirements and main recommendations:

- Companies should report the net CO_2 fluxes (in tonnes CO_2) to/from organic C stocks in mineral/organic soils and above-ground and below-ground woody biomass, as well as the CO_2 emissions from DOM and biomass combustion.
- Natural disturbances, Payments for Environmental Services (PESs), and conservation areas should be accounted for equivalently to other agricultural activities.
- Companies should use peer-reviewed methods for CO_2 flux calculations.
- When relevant, companies should amortize changes in C stocks evenly over time using a fixed-rate approach.
- Companies should account for historical changes in land use or management occurring on or after the base period.

8.1 Including flux and stock data in inventories

Companies should report net CO_2 flux data

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

- Stock size, when measured in units of mass of C (e.g., metric tonnes C/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 mass of CO_2.

Both approaches are equally valid. Under either, companies should take care to use methods that treat soil depth consistently, particularly in the context of LUC. For instance, reference stock values might be available for soil C stocks in forest and cropland - if these are not defined to a consistent depth[10], some of the estimated stock difference will reflect methodological differences rather than actual variation.

While companies should report net CO_2 flux data, they may also report data on stock size (when available) to provide useful context for interpreting inventory results. Stock size data can be converted to net flux data by multiplying the mass of stock change by $\frac{44}{12}$, which is the ratio of the molecular weights of CO_2 and elemental carbon.

Companies should use peer-reviewed methods for CO_2 flux calculations
This Guidance does not prescribe specific methodologies for calculating the CO_2 fluxes to/from C stocks. Any of the general approaches detailed in Chapter 7.3 may be used, as long as the underlying methodology has been scientifically vetted (i.e., has undergone peer review). Appendix III lists many, scientifically published and well established calculation tools for estimating CO_2 fluxes.

8.2 Reporting recommendations for different C stocks

Recommended CO_2 fluxes

The following CO_2 fluxes should be included in inventories:

1. CO_2 emissions from, and atmospheric removals by, organic C stocks in mineral and organic soils
2. CO_2 emissions from, and atmospheric removals by, below-ground and above-ground woody biomass (e.g., woody vegetation in orchards, vineyards and agroforestry systems)
3. CO_2 emissions from the combustion of herbaceous biomass (e.g., open burning of crop residues)
4. CO_2 emissions from DOM

These fluxes should be reported within a special ‘Biogenic Carbon’ category that is outside of the scopes. The one exception concerns the CO_2 emissions from soils and woody biomass that result from LUC. These LUC CO_2 emissions should be reported within the scopes because they effectively constitute permanent losses of C to the atmosphere (see Chapter 9.1).

The CH_4 and N_2O emissions from all C stocks (e.g., from biomass or DOM combustion) shall always be reported in the scopes.

Additional CO_2 fluxes that may be reported

1. Fluxes to/from inorganic soil carbon stocks

[10] This Guidance does not recommend a minimum soil depth for measuring soil C stocks.

In contrast to soil organic C stocks, inorganic C 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, companies can exclude the net fluxes to/from inorganic soil C stocks.

However, certain management practices can be expected to significantly affect inorganic C stocks by changing soil chemistry and inducing the breakdown of carbonates, leading to CO_2 emissions. For instance, use of ammonium sulfate fertilizer to lower soil pH will tend to promote CO_2 emissions from inorganic C. In such cases, companies should consider quantifying the CO_2 emissions.

2. Sequestration in organic soils.
In wetland environments with organic soils, the rates of C sequestration are relatively slow and can be assumed to be negligible. They therefore can be excluded.

CO_2 fluxes that should not be reported

1. Sequestration in harvested woody products (HWPs) and herbaceous vegetation
The C contained in HWPs should not be included in any reported values for the amount of sequestration in above-ground woody biomass stocks. Depending on how these values have been calculated, this may mean that the amount of C in HWPs will have to be subtracted from estimates of the total amount of sequestration. This subtraction is necessary to ensure that inventories do not over-estimate the net GHG benefits of woody crop production.

The biomass associated with annual and perennial herbaceous vegetation 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, companies should also not report any sequestration in herbaceous biomass stocks.

2. CO_2 fluxes to/from livestock
The carbon incorporated into animal tissues or lost through animal respiration should not be reported in an inventory.

Special note: Accounting for natural disturbances, conservation areas, and payments for environmental services

Natural disturbances are varied and include fires, windstorms, landslides, droughts, and pest outbreaks. *Conservation areas* are lands where agricultural production has been limited or halted so as to provide environmental benefits, such as maintaining or improving water quality or wildlife habitat. Such areas may be established mandatorily, to meet legal requirements for resource protection, or voluntarily, to contribute to the public good and/or take advantage of financial incentives. *Payments for Environmental Services* (PESs) are incentives offered to farmers or landowners in exchange for managing their land to provide some sort of ecological service. Box 8-1 shows some examples of conservation areas and PESs.

Box 8-1. Examples of conservation areas and PESs in agriculture

Conservation easements: A legal agreement voluntarily entered into by a property owner and a qualified conservation organization such as a

Natural disturbances, conservation areas, and PESs are treated identically to other sources and activities

The CO_2 fluxes associated with natural disturbances, conservation areas and PESs should be treated the same way as other CO_2 fluxes, following the recommendations outlined above. The reason is that companies often have some measure of control over these fluxes - they are often be able to influence the frequency or intensity of disturbances and the corresponding amount of emissions, while operational decisions frequently lead directly to the formation of conservation areas. For instance, many forest management practices can reduce the risk of disturbances - forest thinning can increase resilience to droughts and insect/diseases outbreaks, while fuel hazard reduction and the use of prescribed fires can reduce the risk of uncontrolled fires. Another reason for not excluding natural disturbances is that it is often challenging to identify whether an event actually constitutes a disturbance. For instance, there are no universally accepted criteria for defining droughts.

GHG fluxes attributable to disturbances may also be reported in a separate line item

Companies may separately estimate the amount of GHG fluxes that they consider attributable to natural disturbances and report this amount outside of the scopes in a line item that is separate from the scopes and the Biogenic Carbon category. This reporting is additional to the reporting of these same fluxes within the scopes or the Biogenic Carbon category. Estimating the specific GHG effects of individual disturbances is challenging because:

1. Ambiguity often exists around whether an event is a 'disturbance' or simply within the bounds of 'normal' environmental variation. Companies might therefore have to establish criteria for consistently recognizing disturbances.
2. Natural disturbances may be rare events, in which case the effects on estimated CO_2 fluxes may be small when averaged over large areas or long periods of time and therefore difficult to accurately quantify. For instance, the effects of a one-year period of insect defoliation might be difficult to distinguish from background fluxes over a three-year period. In contrast, catastrophic disturbances such as wind storms may cause obvious and easily estimated changes in C stocks.

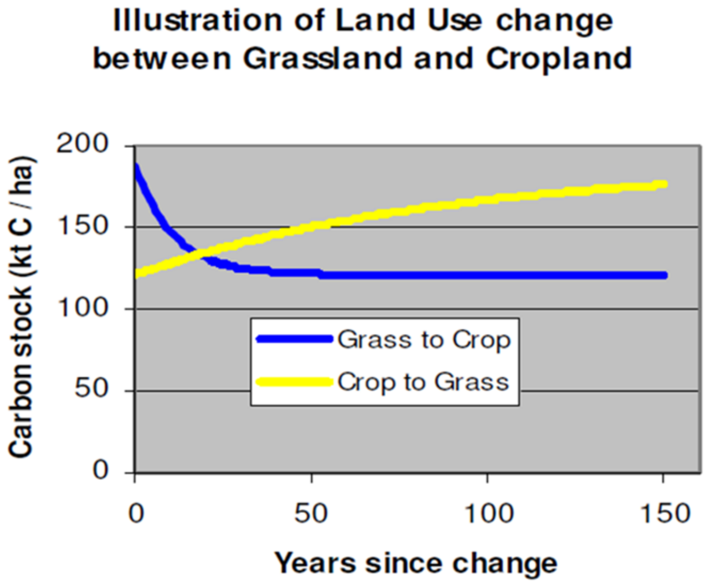
Because of these challenges, companies should evaluate the likely size of a disturbance before committing the resources to quantifying it. For the sake of practicality, if companies do choose to report disturbance emissions, they may assume that all post-disturbance emissions occur in the year of the disturbance event. That is, the CO_2 emissions from the long-term decay of DOM created during an event (e.g., downed trees from a windstorm) can be reported in the year of the event. Alternatively, these emissions can be amortized (see Chapter 8.3).

8.3 Amortizing changes in carbon stocks over time

What is 'amortizing' and when is it necessary?

Shifts in management practices during the reporting period will often have long-lasting effects on C stocks that may persist for decades. For instance, following a change in management practices (e.g., adoption of no-till practices) soil C stocks may take 15 - 60 years to reach equilibrium, depending on the type of tillage and crop rotation regimes. Following LUC (e.g., conversion of cropland to grassland), the transition period will often exceed 100 years (e.g., Figure 8-1). Also, as Figure 8-1 demonstrates, the rate of change in C stocks will vary over time. Amortizing the CO_2 fluxes from changes in C stocks involves allocating these fluxes across time (and therefore multiple inventories) to ensure the more consistent accounting of C stock impacts.

Figure 8-1. Illustration of land use change between grassland and cropland



Source: To be provided

Whether amortization is needed depends on the calculation approach
As discussed in Chapter 7.3, a variety of methods can be used to quantify CO_2 fluxes. If a method is used that directly estimates the amount of GHG flux (or stock change) within the reporting period, amortization is not needed. Conversely, if the estimated data are generated for the transition period as a whole, rather than just for the reporting period, amortization is needed (Table 8-1).

Table 8-1. Examples of calculation approaches that will and will not require amortization of the calculated CO_2 fluxes.

Calculation approach	**Examples**	**Is amortization required?**
Directly provides an estimate of the amount of CO_2 flux or stock change that occurred in the reporting period, rather than in the transition period as a whole	• A process model that estimates the cumulative net CO_2 flux over the reporting period • An emission factor that has a time dependence of only one year (e.g., tonnes C sequestered per hectare per year of practice)	No
Estimates the total amount of CO_2 flux or stock change over the entire transition period, under permanent adoption of the practice concerned	Reference stock sizes for the amount of carbon stored in the biomass of grassland and woodland that are used to quantify the stock change associated with LUC	Yes

Certain CO_2 fluxes should never be amortized
Irrespective of the quantification approach, certain CO_2 fluxes should never be amortized and should always be reported in the year of the management practice. These are:

- The CO_2 emissions from biomass and DOM combustion
- The CO_2 emissions from the organic carbon stocks of organic soils.

Amortizing the CO_2 emissions from DOM stocks is optional
Some management practices may move C 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, companies may either assume that the total CO_2 emissions from DOM stocks occur in the year of the intervention, or, should capacity and data exist, they may amortize these emissions over time.

Table 8-2 summarizes when it is and is not appropriate to amortize CO_2 fluxes.

Table 8-2. When CO_2 fluxes can be amortized

CO_2 flux	Time reporting requirement
• Sequestration in woody biomass stocks • Sequestration in organic C stocks of mineral soils	• Amortize if the time interval of the quantification approach exceeds one year • Otherwise, report all the estimated sequestration in the reporting period
Emissions from woody biomass stocks	Biomass combustion emissions should be reported in the year of the intervention
Emissions from dead organic matter (DOM)	From the decomposition of DOM: • Amortize, should capacity and data exist; or • Report in the year of intervention From the combustion of DOM: • Report in the year of intervention
Emissions from organic C stocks of mineral soils	• Amortize if the time interval of the quantification approach exceeds one year • Otherwise, report all the estimated emissions in the year of the intervention
Emissions from organic soils	Do not amortize – report losses as they occur
Sequestration in organic soils	Do not amortize - report sequestration as it occurs

How should CO_2 fluxes be amortized?

Companies should amortize fluxes evenly over time

When amortization is necessary, companies should use a linear-rate approach, wherein the total amount of CO_2 flux is amortized evenly over multiple inventories. This involves dividing the total flux by the number of years in the amortization period and then reporting the quotient in each year of the amortization period. This 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 is context specific

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 emission factor; or
- For woody biomass stocks, the length of the nominal harvest/maturity cycle.

The second condition assumes that woody vegetation accumulates biomass for a finite period until it is removed through harvest or reaches a steady state where there is no net accumulation of C 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, companies may assume an amortization period of 20 years for DOM stocks and the organic C 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) [11]. This value may be too long for certain stocks (e.g., soil stock changes in tropical biomes) and too short for others (soil stock changes in boreal biomes). Companies may alternatively assume more specific values used by individual countries in their national inventories[12].

Companies should account for historical LUC

Companies should account for historical changes in land use that occur within a certain ‘look back’ period prior to the base period. This look back period should be equal in length to the amortization period for the stock concerned (e.g., 20 years if the default IPCC amortization period for mineral soil organic stocks is used). Thus, if LUC happened within the 5 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. Equivalently, if the shift occurred more than 20 years before the base period, it should not be reflected in the base period inventory.

As discussed in Chapter 6.2, the acquisition (or divestment) of business units that own land can trigger base period recalculations. C stocks may be changing on the newly-transferred land as a result of land use changes introduced by the prior land-owner.

[11] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4.

[12] See http://unfccc.int/national_reports/annex_i_ghg_inventories/items/2715.php.

Therefore, when recalculating the base period inventory, new landowners should assess whether these changes occurred within the relevant look back period from their base periods. If so, the associated changes in C stocks should be included in the recalculated base year inventory. For instance, if a company acquired land that had been deforested by the prior land-owner five years before the new land-owner's base period, the associated changes in C stocks should be included in the recalculated base period inventory. Appendix II provides an example.

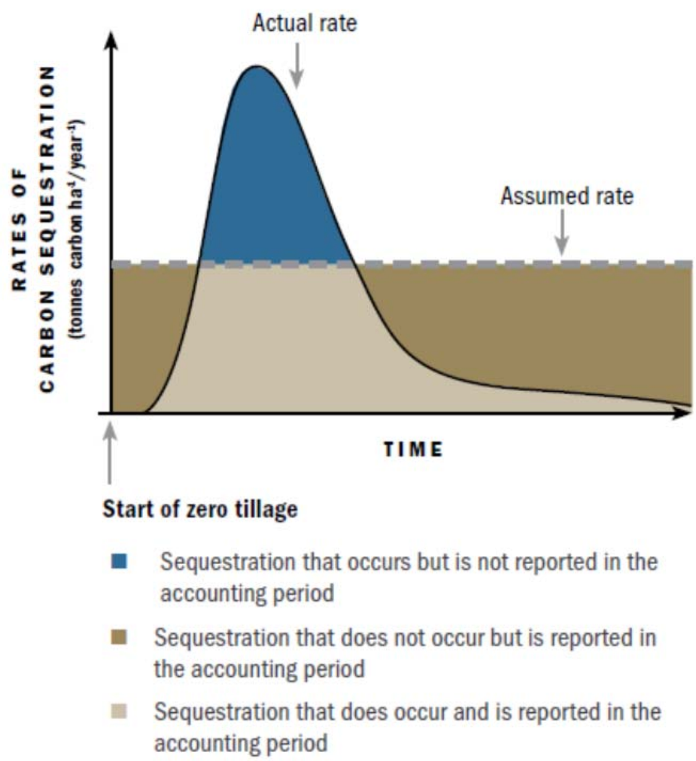
Proxy data on historical LUC should be used in the absence of actual data
Companies, and especially new landowners, may find it difficult to obtain information on historical LUC. What should they do in such cases? This Guidance recommends that companies identify and estimate historical LUC using regional or local trends in, for example, 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.

Additional reporting recommendations

1. To maintain the transparency of reported data, companies should report when they have not been able to collect historical data and estimate historical effects.
2. Companies should carefully document all assumptions made in amortizing CO_2 fluxes (see Chapter 9.1). This is because the amortization schedule chosen by a company will not match actual patterns of change, and a given period's inventory will most likely under- or over-estimate the actual fluxes (for instance, see Fig. 8-2).
3. If management shifts occur that would reverse any soil C sequestration that has previously been amortized, companies should account for these losses in the inventory period in which the shift occurred. For instance, if no till practices were to cease at any point and be replaced by conventional till, C sequestration will be rapidly lost, and companies should record the cumulative gains up to that point as CO_2 emissions in the inventory period in which conventional till started.

Appendix II provides simplified case studies that illustrate how amortization is carried out, including for historical LUC.

Figure 8-2. Amortization schedules chosen by companies will not match actual patterns of change. In this example C sequesters in soil at a non-linear rate following the adoption of reduced-tillage. But the CO_2 emissions are amortized at a fixed rate, causing actual fluxes to be either under- or over-estimated in any one reporting period. Note that the sequestration rates rise due to reduced soil disturbance but slow down as the C stock becomes saturated due to inherent physiochemical processes.



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.
- Outlines additional, sector-specific recommendations for reporting agricultural GHG fluxes.
- Provides guidance on reporting offset and renewable energy projects on farms.

Summary of requirements and main recommendations:

- Companies shall report descriptive information on inventory boundaries and base periods.
- Companies shall report quantitative information on GHG fluxes following requirements in the Corporate Standard (and repeated here).
- Companies should follow a set of additional 'best practice' recommendations for reporting agricultural GHG fluxes.
- Any offset credits or renewable energy that are generated on farmland but sold off-site shall not be reflected in inventory totals.

9.1 Required information

Companies shall publicly report the following information:

General information on inventory boundaries and base periods

- The approach used to set the organizational boundaries
- 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
- Information on the base period, including:
  - The period chosen as the base period
  - The rationale for choosing this period
  - The base period recalculation policy
  - Base period inventory totals by category (see below and Figure 9-1)
  - Appropriate context for any changes that trigger recalculation of the base period inventory
- Any specific exclusion of sources and/or operations from the inventory

General GHG flux data

- 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)
- Total scope 1 and 2 emissions without subtractions for trades in offsets
- Data disaggregated by scope
- A reference or link to the calculation methodologies used

9.2 *Minimum, best practice, recommendations for reporting agricultural GHG fluxes*

Companies should publicly report the following information:

- For non-mechanical sources: A description of whether the calculation methodologies are IPCC Tier 1, 2, or 3, and a description of how those methodologies were chosen based on the quality criteria in Chapter 7.3
- Scope 1 emissions disaggregated by mechanical sources, LUC (biogenic CO_2 only), and all other non-mechanical sources
- Net CO_2 flux data for the C stocks in above-ground and below-ground biomass, DOM and soils (in tonnes CO_2), to the extent relevant and required, as defined in Chapter 8.2
- Where LUC results in a reduction in the size of C stocks, the CO_2 emissions are reported in Scope 1 (LUC is further defined in Box 9-1)
- Otherwise, all CO_2 fluxes are reported outside of the scopes in a separate category ('Biogenic Carbon') that has three components: (1) CO_2 fluxes (emissions or removals) during land use management; (2) Sequestration during LUC; and (3) CO_2 emissions from biofuel combustion
- A description of the methodology used (where relevant) to amortize the CO_2 fluxes to/from C stocks
- Assumptions regarding any use of proxy data in calculating the impacts of historical changes in management on C stocks
- Any exclusions of the impacts of historical management practices on C stocks

Figure 9-1 summarizes how GHG data should be separated within an inventory following these requirements and best practice recommendations.

Fig. 9-1. Schematic illustrating the requirements and minimum, best practice recommendations for disaggregating GHG flux data in inventories

Category of source or sink	Subcategory	Examples
Scopes		
Scope 1	Mechanical sources	Mobile equipment, stationary combustion, and refrigeration and air-conditioning systems
	Non-mechanical sources	Enteric fermentation, soil N_2O emissions, and manure management.
	CO_2 emissions from land use change	CO_2 emissions from the conversion of forests into ranchland or the conversion of wetlands into croplands
Scope 2	Purchased energy	Purchased electricity
Scope 3 (optional)	All other indirect sources	Production of agrichemicals and purchased feed
Biogenic Carbon	Land use management	CO_2 fluxes to/from C stocks in soils, above- and below-ground woody biomass, and DOM stocks, and the combustion of crop residues for non-energy purposes
	C sequestration due to land use change	CO_2 removals by soils and biomass following afforestation or reforestation
	Biofuel combustion	Combustion of biodiesel in farm machinery
Additional information	• A reference or link to the calculation methodologies used • Description of whether these methodologies are IPCC Tier 1, 2, or 3 • Description of the methodology used to amortize the CO_2 fluxes • Assumptions regarding the use of proxy data in calculating the impacts of historical LUC on C stocks	

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.

LUC occurs when land is converted from one land use category to another[13]; for instance, when cropland is converted to grassland or when forests are converted to cropland. 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	An area of high concentration of woody biomass. Typically defined on the basis of a minimum tree height and canopy cover. Forests lands include plantations, primary forests, and naturally regenerated forests with evidence of human intervention
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.).

9.3 Additional information that may be reported

Besides the required and best practice reporting elements, companies may wish to report other information to enhance the transparency and relevance of their inventories. This information includes:

- Data on the size of C stocks (in metric tonnes C per unit land area)
- Biogenic CO_2 flux data further subdivided by the type of C stock (e.g., DOM versus biomass stocks)
- Other GHG flux data further subdivided by the type of non-mechanical source (e.g., enteric fermentation versus manure management)

[13] This Guidance follows the 'land-based' approach for recognizing LUC, as opposed to an 'activities-based' approach. Land-based approaches assess the net emissions of select land-use categories while activity-based approaches assess the net emissions of select land-use activities. Both approaches can be used for developing national GHG inventories for the UNFCCC.

- Emissions of other GHGs (e.g., those of CFCs)
- Performance metrics and a description of any allocation approach used in deriving these (see Appendix I)
- A description of performance measured against internal or external benchmarks
- An outline of current management practices and any GHG management strategies
- GHG flux data for relevant scope 3 sources for which reliable data can be obtained
- Information on the uncertainty of GHG flux data

The reporting of scope 3 sources is optional, but encouraged
Scope 3 sources are many and diverse. The Scope 3 Standard identifies 15 distinct categories. These include the activities of the reporting company's direct suppliers, cradle-to-gate impacts further upstream, as well as downstream activities, such as the customer use and disposal of products the company has manufactured and sold. Which scope 3 sources should be included in an inventory? Companies 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 companies, scope 3 emissions will represent a significant component of overall GHG impacts. For instance, the manufacture of fertilizer and livestock feed will be important scope 3 sources for crop and livestock operations, respectively. Moreover, companies 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, specific scope 3 sources should be reported where those sources are considered 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. In general, the scope 3 emissions from fertilizer and feed production should be included in inventories, where possible.

9.4 Agricultural offset and renewable energy projects

Companies 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

Such 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 impact of many of these projects on a company's inventory will depend on whether any of the energy that is generated is consumed on-site by the company 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, it shall not be used to lower scope 1 or scope 2 emissions. This is necessary to prevent double counting of the emissions benefits of that energy. This requirement extends to the calculation of performance metrics, which should not include the emissions benefits of sold energy. The GHG Protocol *Guidelines for Grid-Connected Electricity Projects* – a supplement to the Project Protocol (Chapter 1.2) - provide guidance on quantifying the emissions reductions from sold energy.

Accounting for 'avoided' emissions

Many renewable energy projects may 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 company – means avoided emissions do not necessarily occur. As a result, avoided emissions shall not be reported within the scopes and they shall not be used to 'net' emissions[14]. However, estimates of avoided emissions may be reported as a memo item, as long as the underlying assumptions and appropriate calculation methodologies are also described. The Project Protocol provides guidance relevant for calculating avoided emissions.

Accounting for transactions in offset credits

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

[14] Avoided emissions are also not quantified as part of product life cycle inventories under the GHG Protocol Product Standard.

Appendices

Appendix I: Performance metrics

The Corporate Standard and this Guidance only require the reporting of absolute GHG flux data. GHG performance metrics do not have to be reported. However, they can provide important insights into a company's GHG performance and are generally recommended as part of an effective GHG reporting and management system. For instance, they can be used 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).

This Appendix:

- Summarizes the various types of GHG performance metrics that exist.
- Provides general recommendations for the calculation, use, and reporting of metrics.

Types and usage of performance metrics

Many types of performance metrics exist
Some examples of performance metrics are:

<u>Productivity and efficiency ratios:</u> These express the value or achievement of a company 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).

<u>Intensity ratios:</u> 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 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 companies may have to *allocate* GHG fluxes amongst different product streams (see below).

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

In selecting a performance metric, companies should consider which metrics 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.

The use of multiple performance metrics is recommended

Companies might find it useful to track performance using more than one metric. This is because individual metrics might exclude certain sources, 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, performance metrics should always be reported alongside data on the absolute GHG fluxes to/from a farm. The following scenarios show the importance of using additional ratio indicators (in addition to reporting absolute GHG flux 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 hectare 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 I-1 describes various trade-offs associated with different types of metrics commonly used in the agricultural sector.

Contextual information should be provided

Importantly, the inherent diversity of agricultural practices, as well as the influence of environmental factors on GHG fluxes, will affect the comparability of metrics, 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. (Note: in such cases, companies 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, performance metrics are not useful for assessing performance. Such context should be provided in reports to aid the reliable interpretation of performance metrics.

Table I-1. Advantages and disadvantages of common performance metrics

Metric	Advantages	Disadvantages
GHG flux per unit land area (e.g., flux / ha)	• Useful to companies 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
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 • 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 type and amount 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 GHG data for calculating performance metrics

Agricultural production frequently results in the generation of by-products or co-products, especially if farms have on-site *product processing* facilities. In addition, certain agricultural activities will contribute to multiple streams of products (and their co/by-products), especially on mixed farms (Figure I-1). 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. *Allocation* is the process of partitioning GHG flux data from a farm to the different product streams from that farm. Allocation may be needed when computing intensity ratios for individual products. Allocation may also be needed when:

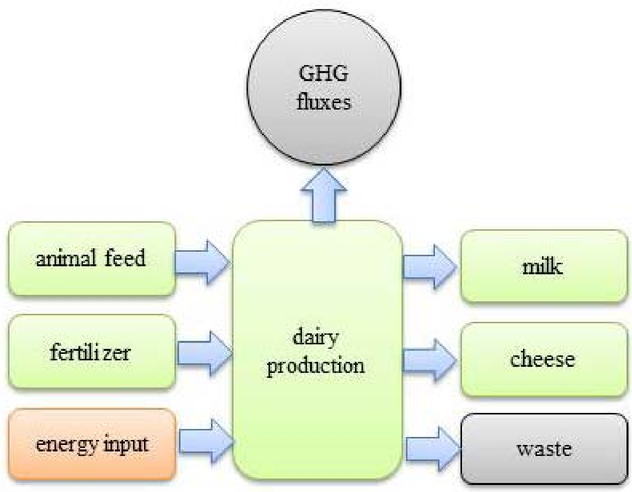
- Reporting GHG data to customers that are accounting for their scope 3 emissions and that therefore only require information on the specific GHG fluxes attributable to the products they purchased.

- Allocating GHG fluxes between scope 1 and scope 3.

Allocations will not be necessary when a farm produces only one output. **They should not be done to calculate the GHG fluxes that are to be reported in a corporate inventory**, except to allocate between scope 1 and scope 3. Also, this Guidance is not concerned with allocations for product-level GHG accounting – for guidance on this topic, see the GHG Protocol Product Standard, sectoral life cycle accounting guidance, or product category rules.

Should allocations be performed, note that co-products without economic value are considered wastes and should have no GHG fluxes allocated to them. Also, if GHG fluxes are allocated, they should sum to the total flux initially calculated.

Figure I-1. Illustration of a common process requiring allocation



Allocation should be avoided where possible
If possible, companies should avoid allocation because allocation adds uncertainty to performance metrics. Companies may be able to avoid allocation in a number of ways:

- By dividing the common GHG emitting process into sub-processes that separately produce the various products. This approach 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 fuel consumption or the number of field passes by field and date.
- By redefining the scope of analysis for the performance metric so that the fluxes attributable to the various products no longer have to be separated. For instance, by expressing GHG emissions on a kg sheep-raised basis as opposed to a kg lamb meat basis, it is no longer necessary to separate out the emissions attributable to wool production.

Different allocation approaches exist
Should allocation be unavoidable, the following approaches may be used:

Physical allocation: Allocations are based on an underlying physical relationship between the multiple inputs/outputs and the GHG fluxes. For example, if mass is the main causal factor driving differences between products, allocations can be based on the mass of farm outputs:

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

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 products and 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 product leaving the process, as follows:

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

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, if prices for the outputs vary over the reporting period, it may be necessary to develop averages for the market values of the outputs over this period.

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

Selecting an allocation approach

A single approach should be used to consistently allocate the GHG data for all of the products of a farm. Otherwise, the use of multiple allocation methods might result in the over- or under-counting of total farm-wide fluxes.

Different allocation methods can yield significantly different results. For example, in cheese manufacturing, 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.

Companies 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 drives their relative GHG impacts.
- Prices change significantly or frequently over time. Example: fluctuation in commodity crop prices (note: averaging prices over three to five years can help avoid this problem).
- Prices are not well-correlated with underlying physical properties and GHG fluxes.
- Companies pay different prices for the same product (due to different negotiated prices).

Economic allocation is preferred when:

- A physical relationship amongst the products cannot be established or does not adequately reflect their GHG impacts.
- 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).

Appendix II: Amortizing CO_2 Fluxes to / from Carbon Stocks

Introduction

Shifts in the management of farmland or the conversion of one land-use category into another can change C stocks over long time periods. Chapter 8 describes methodologies for accounting for the associated CO_2 fluxes. Depending on how these fluxes have been calculated, they may have to be amortized over a defined time period, with an equal amount of flux allocated to each year over that period. Consistent with Intergovernmental Panel on Climate Change (IPCC) methodologies, the length of this period can be assumed to be 20 years, unless more specific information is available (see Chapter 8.3).

The amortization approach is illustrated here using a common land use pattern in central Brazil - the conversion of native vegetation (cerrado) into pasture and subsequently into an annual crop rotation (soybean-corn). Two cases are presented:

- Case A: All soil stock changes are amortized before any further changes occur in the ownership or management of stocks
- Case B:
- Case C: Purchase of land undergoing changes in C stocks

While these cases are hypothetical, they use representative data on soil C stocks that are derived from published studies. To facilitate ease of understanding, only soil C stocks are considered, while all fluxes are amortized before any further shifts occur in management practices. The management practices and land-use types considered, along with the corresponding C stocks, are shown in Table II-1.

Table II-1. Soil C stocks of different management practices and land use types.

Land use	Soil stock (tonnes C/ha)*
Cerrado	75
Pasture	72
Full-tillage annual crop rotation (soybean-corn)	69
No-till annual crop rotation (soybean-corn)	79

* Measured in the top 30 cm layer of soils. Data based on a synthesis of several dozen studies of the central region of Brazil and provided by Marcelo Galdos, University of Sao Paulo (private communication, September 15, 2010).

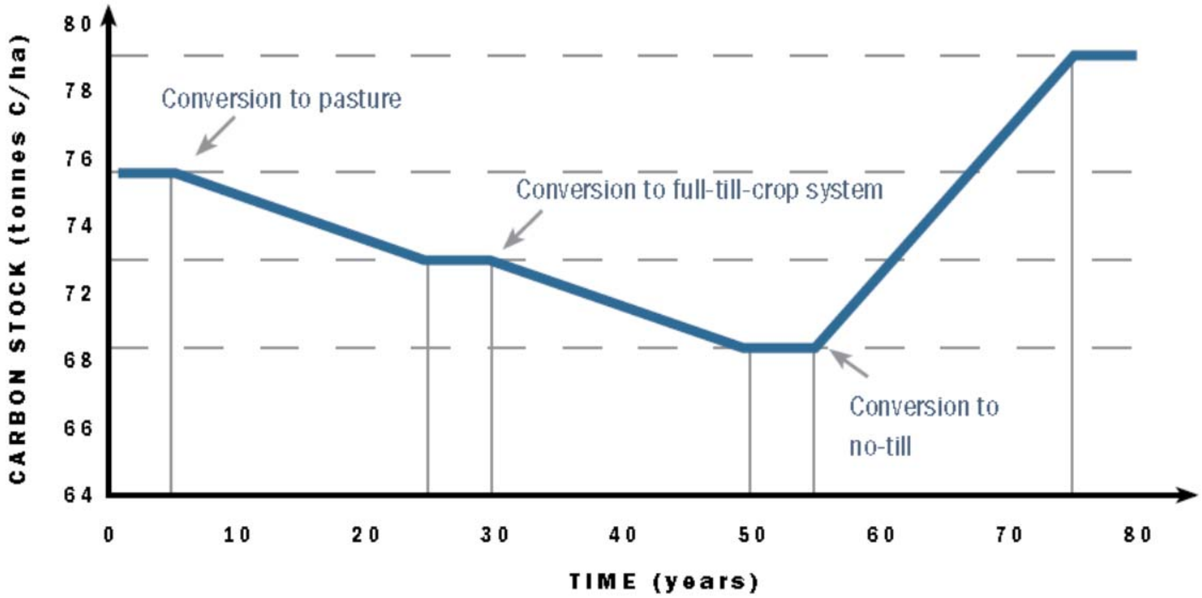
Case A: All soil stock changes are amortized before any further changes occur in the ownership or management of stocks

Cerrado is converted into a no-till crop system over the course of 75 years. While multiple shifts in land use and farming practices occur over this period, the resulting CO_2 fluxes are fully amortized before any further shifts occur. Table II-2 describes the time series of shifts in land use and management practices, as well as how the corresponding CO_2 fluxes are amortized. GHG emissions inventories are prepared annually. Figure II-1 shows how the C stocks change over time with amortization.

Table II-2. The amortization schedule for case A

Year	Commentary	Amount of carbon stock amortized per year (tonnes C/ha/year)
1-5	Land is undisturbed cerrado	0
6	Cerrado is converted into pasture. This is estimated to reduce carbon stocks by 3 tonnes C/ha (75–72 tonnes C/ha)	–
6–25	The 3-tonne C/ha change is amortized over 20 years, while land continues to be managed as pasture	-0.15
26–30	Land remains pasture	0
31	Pasture is converted into full-till crop system. This is estimated to decrease carbon stocks by a further 3 tonnes C/ha (72–69 tonnes C/ha)	–
31-50	The 3-tonne C/ha change is amortized over 20 years, while land continues to be managed as full-till crop system	-0.15
51-55	Land remains as full-till crop system	0
56	No-till is adopted. This is estimated to increase carbon stocks by 10 tonnes C/ha (79–69 tonnes C/ha)	–
56–75	The 10-tonne C/ha change is amortized over 20 years, while land continues to be managed as no-till crop system	0.5
76 +	Land remains as no-till crop system	0

Figure II-1: Changes in C stocks are fully amortized before any further shifts in management practices or management occur (Case A)



Case B: Not all soil stock changes are amortized before a further change occurs in stock management

Same as Case A, except that the pasture is converted into a full-till crop system only 10 years after the cerrado was first converted into pasture (i.e., when only half of the change in carbon stocks has been amortized). Table II-3 describes the time series of shifts in land use and management practices, as well as how the ensuing changes in carbon stocks are amortized.

Table II-3. The amortization schedule for case B.

Year	Commentary	Amount of stock change amortized per year (tonnes C/ha/year)
1-5	Land is undisturbed Cerrado	0
6	Cerrado is converted into pasture. This is estimated to reduce carbon stocks by 3 tonnes C/ha (75-72 tonnes C/ha)	–
6-15	The change in carbon stock is amortized for 10 years. The carbon stock after 10 years is calculated as: carbon stock of cerrado (75) - stock change amortized so far (10 x 0.15) = 73.5 tonnes C/ha	-0.15
16	The pasture is converted into a full-till crop system. The total change that now needs to be amortized is calculated as: carbon stock at end of year 15 (73.5) - carbon stock of full-till system (69) = 4.5 tonnes C/ha	–
17-36	The 4.5-tonne C/ha change is amortized over 20 years, while land continues to be managed as a full-till crop system	-0.225
37-40	Land remains as full-till crop system	0
41	No-till is adopted. This is estimated to increase carbon stocks by 10 tonnes C/ha (79-69 tonnes C/ha)	–
41-60	The 10-tonne C/ha change is amortized over 20 years, while land continues to be managed as a no-till crop system	0.5
61 +	Land remains as no-till crop system	0

Case C: Purchase of land undergoing changes in C stocks

Same as Case A, but the land is acquired by the reporting company (at year 28) after its conversion into pasture (Figure II-2). The reporting company amortizes the CO_2 fluxes from this conversion over a 20 year period (ending year 25), but does not include all of these fluxes in its inventories. Instead, it only revises its inventories to report the CO_2 fluxes that occurred during years 20–25. This is because year 20 was established as its base period. Table II-4 describes how the changes in C stocks are amortized by the reporting company.

Figure II-2. The reporting company purchases land that is undergoing changes in C stocks because of a shift in land use made by a prior owner (Case C)

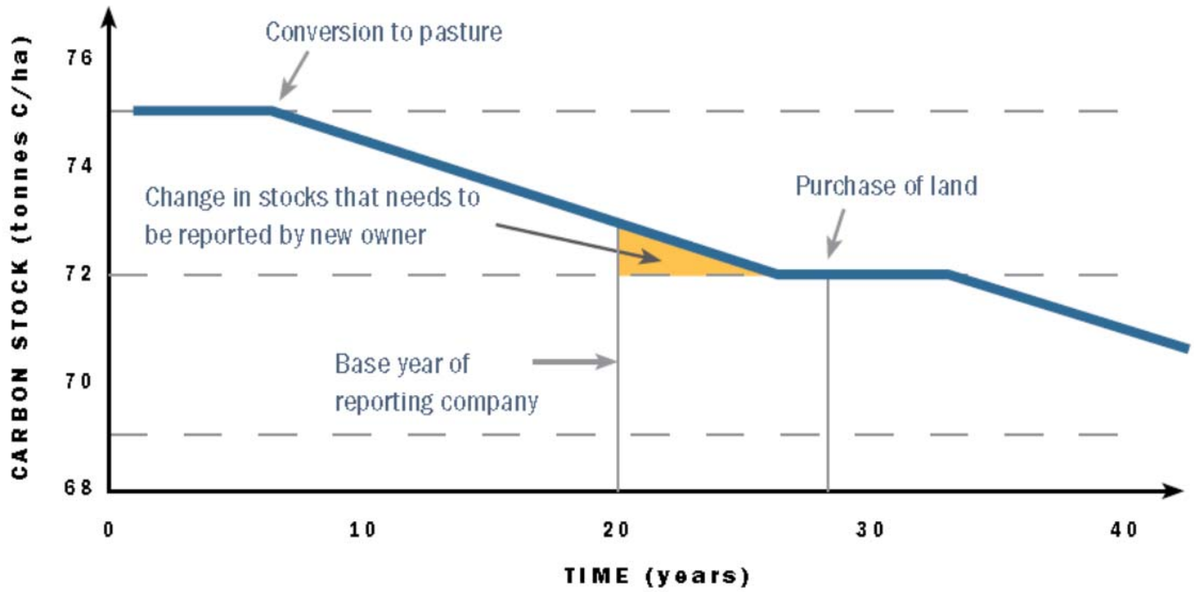


Table II-4. The amortization schedule for Case C.

Year	Commentary	Amount of carbon stock amortized and reported by the new owner (tonnes C/ha/year)
1-5	Land is undisturbed cerrado	0
6	Cerrado is converted into pasture. This is estimated to reduce carbon stocks by 3 tonnes C/ha (75-72 tonnes C/ha) and this change is amortized over the next 20 years, while the land continues to be owned and managed as pasture by the original owner	–
6-19	Change in carbon stocks occurs before base period of reporting company	0
20	Base period of reporting company. Land is not owned by the reporting company, but the base period inventory is adjusted to reflect the carbon losses amortized this year	-0.15
21-25	Land is not owned by the reporting company, but the reporting company's inventories for this period are adjusted to reflect the ongoing carbon losses	-0.15
26-27	Land remains pasture	0
28	Land remains pasture and is purchased by the reporting company	0
29 +	As in Case A	–

Appendix III: Tools for calculating agricultural GHG fluxes

Overview

This Appendix lists some of the most widely used tools (spreadsheets, software and protocols) for calculating GHG fluxes in agriculture. 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 7-1; 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 flux data for an extensive range of emissions sources. They do not provide an interface for performing calculations.
- 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 III-1 lists the GHGs and operations covered by each tool, while Table III-2 provides further information on each tool, such as its geographic focus and type of interface.

Notes and Caveats

- These tools typically generate GHG flux data in a format that is not automatically in conformance with this Guidance. Users will often therefore need to reformat these data (e.g., to divide them by scopes) for the purpose of developing a corporate GHG inventory.
- This Appendix does not attempt to provide an exhaustive list of tools, but is merely intended as an illustrative guide. The tools 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 agricultural GHG fluxes. For example, even if a tool is relevant to, say, ‘cropland’ or ‘livestock’ operations, as indicated in Table III-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.
- The tools may employ different definitions for the same management practices and land use categories. Companies should ensure that consistent definitions are applied when using multiple tools for a single inventory.
- This Appendix focuses on non-mechanical sources, although many of the tools listed will also cover mechanical sources, mostly fuel use and fertilizer production.
- Tools for product-, project- and national-level assessments are excluded.

Table III-1. Publicly available tools for calculating agricultural GHG fluxes[1]

Tool	GHG			Operation											
	CO_2	N_2O	CH_4	Cropland	Horticulture	Grazing land	Grassland	Agroforestry	Wineyards / Orchards	Livestock	Forest	Land use change	Rice production	Wetlands	Energy use
Tools suitable for farm managers															
Brazil GHG Protocol Program calculation tool	✓	✓	✓	✓		✓				✓		✓	✓		✓
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	✓										✓				
COMET-Farm: CarbOn Management Evaluation Tool for whole FARM GHG accounting	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓

Tool	GHG			Operation											
	CO_2	N_2O	CH_4	Cropland	Horticulture	Grazing land	Grassland	Agroforestry	Wineyards / Orchards	Livestock	Forest	Land use change	Rice production	Wetlands	Energy use
COMET-VR: CarbOn Management Evaluation Tool for Voluntary Reporting of greenhouse gases V2.0	✓	✓		✓		✓	✓	✓	✓						✓
Cool Farm Tool	✓	✓	✓	✓			✓			✓	✓	✓	✓		✓
C-PLAN	✓	✓	✓	✓						✓	✓	✓			✓
CQuest Lite	✓			✓											
Dairy Greenhouse Gas Model (DairyGHG)		✓	✓							✓					
Dia'terre	✓	✓	✓	✓	✓		✓		✓	✓	✓				✓
DNDC NUGGET	✓	✓	✓	✓						✓		✓			
FarmGas	✓	✓	✓	✓	✓	✓				✓	✓				
Farming enterprise Greenhouse Gas Emissions Calculator	✓	✓	✓	✓		✓				✓					
Field to Market Fieldprint Calculator	✓	✓	✓	✓									✓		✓
Full Carbon Accounting Model (FullCAM)	✓			✓			✓				✓				

Tool	GHG			Operation											
	CO_2	N_2O	CH_4	Cropland	Horticulture	Grazing land	Grassland	Agroforestry	Wineyards / Orchards	Livestock	Forest	Land use change	Rice production	Wetlands	Energy use
Greenhouse in Agriculture tools for Dairy, Sheep, Beef or Grain Farms	✓	✓	✓	✓						✓					✓
Holos	✓	✓	✓	✓			✓			✓	✓				✓
Illinois Farm Sustainability Calculator	✓	✓	✓	✓					✓	✓				✓	✓
International Wine Carbon Calculator	✓	✓							✓						
Live Swine Carbon Footprint Calculator	✓	✓	✓							✓					✓
Livestock Analysis Model			✓							✓					
Manure and Nutrient Reduction Estimator (MANURE) TOOL		✓	✓							✓					
OVERSEER	✓	✓	✓	✓	✓	✓			✓	✓					✓
US Cropland Greenhouse Gas Calculator For Farm Systems	✓	✓		✓											✓
General catalogues of calculation methodologies															

Tool	GHG			Operation											
	CO_2	N_2O	CH_4	Cropland	Horticulture	Grazing land	Grassland	Agroforestry	Wineyards / Orchards	Livestock	Forest	Land use change	Rice production	Wetlands	Energy use
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	✓	✓	✓	✓			✓				✓				

Tool	GHG			Operation											
	CO_2	N_2O	CH_4	Cropland	Horticulture	Grazing land	Grassland	Agroforestry	Wineyards / Orchards	Livestock	Forest	Land use change	Rice production	Wetlands	Energy use
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	✓			✓			✓				✓				

1, Based on Colomb et al. (2013), Denef et al. (2012) and additional research.

Table III-2. Additional features of emissions calculators[1]

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
Tools suitable for farm managers				
Brazil GHG Protocol Program calculation tool	Brazil	Methodologies and emission factors from Brazils national inventory and IPCC Tier 1 emission factors	Excel-based	
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	Global	Online interface to NASA-CASA model	Web-based	
Dairy Greenhouse Gas Model (DairyGHG)	US	Unknown	Software application	

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
Dia'terre	France	Unknown	Unknown	Unknown
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	Based on Australian national inventory - combination of country-specific and IPCC methodologies and emission factors.	Software application	
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	✓
Illinois Farm Sustainability Calculator	US - Illinois		Excel-based	
International Wine Carbon Calculator	International	Tier 1 emission factors and academic literature	Excel-based	
Live Swine Carbon Footprint Calculator	US	Unknown	Software application	
Livestock Analysis Model	US	Specific to cattle and buffalo	Software application	
Manure and Nutrient Reduction Estimator (MANURE) TOOL	US	IPCC methodology and emission factors from IPCC, EPA, and USDA	Web-based	
OVERSEER	New Zealand	Emission factors from New Zealand's national inventory practices	Web-based and software	

Tool	Geographic focus	Methodology	Interface	Uncertainty analysis
			applications	
US Cropland Greenhouse Gas Calculator For Farm Systems	US (but applicable to temperate region soils worldwide)	Limited to corn, soybean, switchgrass, alfalfa and corn silage. Based on SOCRATES (for soil carbon) and IPCC emission factors (for other sources)	Web-based	
General catalogues of 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)		✓

1, Based on Colomb et al. (2013), Denef et al. (2012), and additional research.
2, The 2006 IPCC Guidelines are implemented in software available at: http://www.ipcc-nggip.iges.or.jp/software/index.html. This software is not recommended for use by farm managers.

Abbreviations

C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
DOM	Dead organic matter
GHG	Greenhouse gas
HFCs	Hydrofluorocarbons
HWPs	Harvested woody products
LUC	Land use change
N	Nitrogen
N_2O	Nitrous oxide
SF_6	Sulfur hexaflouride
PFCs	Perfluorocarbons

Glossary

Accounting (GHG accounting)	Quantification and organization of information about *GHG fluxes* based on common procedures, and correct attribution of the same to specific companies.
Agistment	An arrangement between a stock owner and the owner of a short-term supplier of feed to use that feed.
Agriculture	The cultivation of animals, plants, fungi, and other life forms for food, fiber, biofuel, drugs and other products used to sustain and enhance human life
Agroforestry	Integrated agricultural practices that exploit the interactive benefits from combining trees and shrubs with crops and/or livestock.
Allocation	The process of partitioning *GHG flux* data from a farming system to the different product streams from that system
Amortization	The allocation of CO_2 fluxes from changes in *carbon stocks* over a period of time.
Base period	A historic period against which a company's *GHG fluxes* 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 an agricultural process with a minor market value, rather than the primary product being produced or a *co-product*.
Carbon pools	Natural stores of carbon in biomass, dead organic matter, soils, 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 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.
Conservation area	Land where agricultural production has been limited or halted so as to provide environmental benefits, such as maintaining or improving water quality or wildlife habitat.
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 an agricultural system with a significant market value in another system.
Corporate GHG emissions inventory	A quantified list of the *GHG fluxes* from across the entire operations of the reporting company. Such inventories include the emissions of all seven *Kyoto GHGs* (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3).

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.
Cultivar	A cultivar is an assemblage of plants that (a) has been selected for a particular character or combination of characters, (b) is distinct, uniform and stable in those characters, and (c) when propagated by appropriate means, retains those characters.
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.
Dead organic matter	A *carbon pool* that includes non-living biomass in: (1) dead wood that is either standing, lying on the ground, or in the soil; and (2) litter located on or within the mineral or organic soil.
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 fluxes* 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 a company 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 a company 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.
Forestry	The theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources.
Greenhouse gas (GHG)	A gas absorbs and emits radiation within the thermal infrared range in the atmosphere.
GHG Flux	Emissions to or removals from the atmosphere of GHGs.
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 CO_2.
Harvested wood products (HWPs)	A *carbon pool* that includes all wood material (including bark) that leaves the boundary of the reporting company.
Indirect GHG emissions	Emissions from sources that are owned or controlled by another company, but are nonetheless a consequence of the activities of the reporting company.

Indirect N_2O emissions from soils	Emissions of N_2O from soils as a result of leaching and *volatilization* processes that lead to the emissions being physically displaced.
Indirect land use change (iLUC)	A pattern of land use wherein an existing crop is diverted for another purpose and replacement crops are then grown on formerly non-agricultural lands.
Kyoto GHGs	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.*
Manure	Effluent and bedding material collected from housed animals.
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*.
Natural disturbance	An environmental and destructive event that disturbs landscape health, structure, and/or changes resources at any given spatial or temporal scale. Disturbance agents include pathogens, insects, fires, drought, flooding, and acid rainfall.
Nitrification	During nitrification, bacteria and other microorganisms oxidize the nitrogen within ammonia (NH_3) to create nitrites, which are further oxidized into nitrates.
Nitrogen mineralization	The process by which organic nitrogen is converted to inorganic forms that are available to plants.
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 a company accounts for 100% of the emissions from an operation over which it has the authority to introduce and implement its own operating policies.
Payments for Environmental Services (PESs)	Incentives offered to farmers or landowners in exchange for managing their land to provide some sort of ecological service.
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.
Rolling base period	Base periods that move forward in time with each reporting period.
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 company's own consumption.
Scope 3	*Indirect* emissions other than those covered in *scope 2*.
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.
Volatilization of soil nitrogen	The vaporization of soil NH_3 and NO_X and their subsequent release into the atmosphere.

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