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RALI GHG MRV Harmonization Framework

Agriculture, Forestry, and Other Land Use Sector Guide

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For more information on the Resources to Advance LEDS Implementation (RALI) project, please visit climatelinks.org/projects/rali.

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Amanda Valenta provided technical guidance as the contracting officer's representative for the RALI project.

Contents

Acronyms

ACR	American Carbon Registry
AFOLU	Agriculture, Forestry, and Other Land Use
CAR	Climate Action Reserve
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
GHG	Greenhouse gas
GRA	Global Research Alliance
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
kg	Kilogram
LEDS	Low Emission Development Strategies
MCF	Methane conversion factor
MMS	Manure management system
MRV	Measurement, reporting, and verification
CH_4	Methane
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
N	Nitrogen
N_2O	Nitrous oxide
Nex	Nitrogen excretion
RALI	Resources to Advance LEDS Implementation
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VCS	Verified Carbon Standard
VS	Volatile solids

Glossary

Activity Data
Data measuring human activity that results in greenhouse gas (GHG) emissions or removals. Activity data could include fossil fuel combustion, waste generation, or land-use changes.

Bottom-Up GHG Accounting
Data, methodologies, and processes used for project-level measurement, reporting, and verification (MRV) for GHG mitigation activities.

Causal Chain
A flow chart of a specific mitigation activity that identifies and maps the activity's specific actions, outcomes, and associated GHG impacts.

Carbon Pool
Reservoirs of carbon stored in aboveground biomass, belowground biomass, soil, dead wood, and litter.

Data Attribute
A characteristic of a data element (see definition below) such as the source of the data and frequency of collection.

Data Element
A variable that is used to calculate emissions in national inventory or mitigation MRV methods.

Emission Factor
The average emission rate of a GHG relative to a unit of activity. Together with activity data, emission factors are key components used to estimate emissions.

Key Category
A category of GHG emissions or removals that is prioritized due to its influence on the total absolute level of emissions, emission trends, or uncertainty associated with the emissions.

Metric
A data element that is often used to track GHG and other impacts of an activity, particularly in mitigation MRV accounting.

Inventory Pathway
The way in which mitigation activities impact GHG inventories. Inventory pathways can impact multiple Intergovernmental Panel on Climate Change (IPCC) source/sink categories or a single IPCC source/sink category in GHG inventories.

Tiers
A three-tiered classification system developed by the IPCC to distinguish different levels of methodological approaches to estimate GHG emissions. Tiers are based on data availability and the level of analytical complexity in approaches used to estimate GHG emissions. Tiers include IPCC default (Tier 1) and country-specific (Tier 2 and Tier 3) methods, which are typically more accurate.

Top-Down GHG Accounting
Data, methodologies, and processes used to measure GHG emissions as part of a country's national inventory process.

Overview

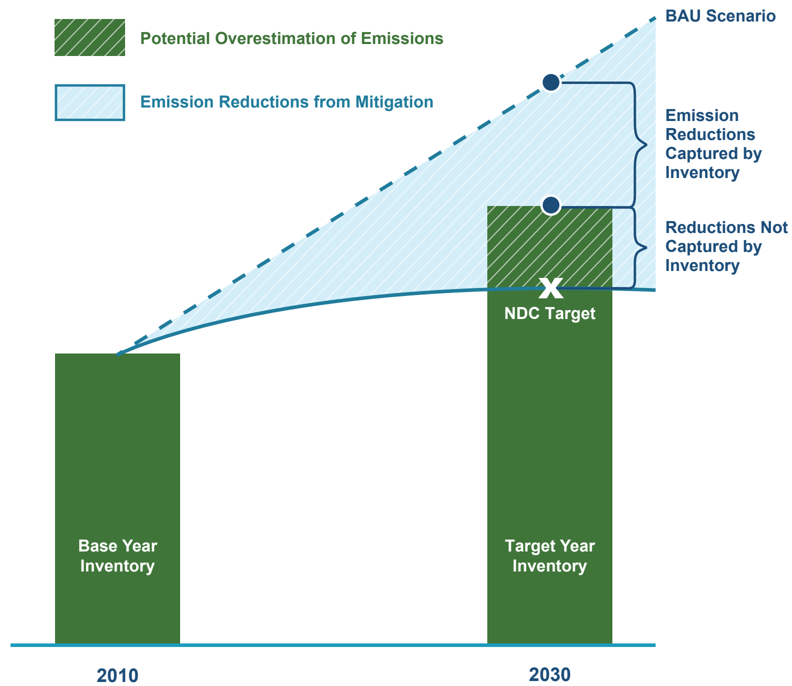
Countries around the world have set ambitious targets for reducing greenhouse gas (GHG) emissions as part of their nationally determined contributions (NDCs) under the Paris Climate Agreement. NDCs serve as a significant catalyst for mitigation actions across sectors and at all scales, from local projects to national policies. These developments enhance the need for transparent reporting on the impact of diverse mitigation actions.

The Challenge of Harmonization

As countries implement GHG mitigation activities and develop methods to measure the impact of these activities, they also need to monitor progress toward their respective NDCs.

One way to do this is to ensure that GHG effects from mitigation activities are captured in national GHG inventories. However, measurement, reporting, and verification (MRV) methods for mitigation activities vary by project and are often distinct from MRV methods for national inventories, which are typically structured to comply with international reporting requirements. This may result in over- or under-estimated national emission levels. Underestimating emission reductions achieved could indicate that countries are not meeting their reduction targets and this could affect investment in future mitigation activities if returns on climate investments are not demonstrated (see Figure 1).

Figure 1: Incorporating Mitigation into National GHG Inventories



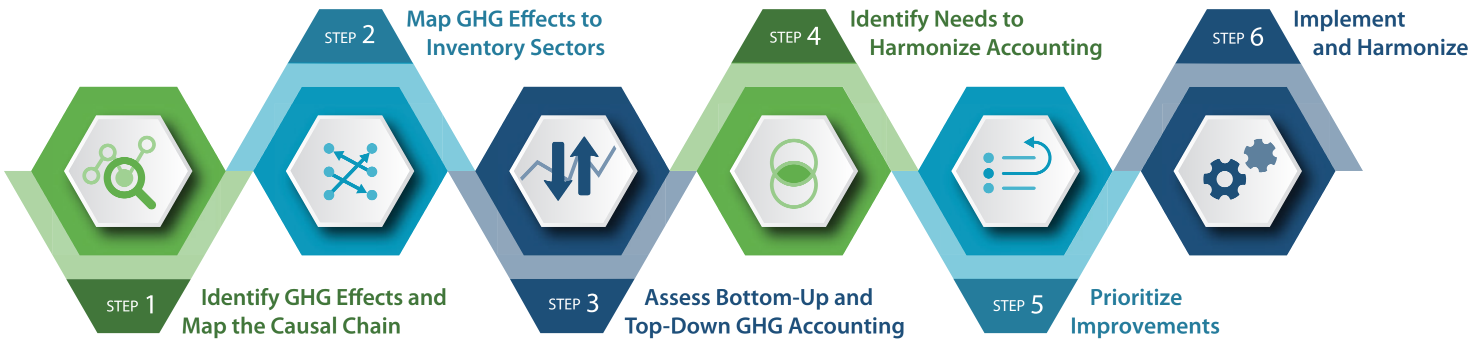
If national inventories do not reflect the full extent of mitigation activities, national emission trajectories may not demonstrate progress toward a country's NDC target.

The RALI GHG MRV Harmonization Framework

The RALI GHG MRV Harmonization Framework ("Harmonization Framework"), developed by the USAID Resources to Advance LEDS Implementation (RALI) project, is a six-step process designed to help national inventory compilers, mitigation activity implementers, and other stakeholders align MRV methods for GHG mitigation activities (i.e., "bottom-up" GHG accounting) with national GHG emission inventories (i.e., "top-down" GHG accounting) (see Figure 2).

The Harmonization Framework provides tools to improve the accuracy and transparency of GHG emissions reporting and to enhance the ability of stakeholders to use this reporting for tracking GHG effects from mitigation actions. It describes an approach for these users to identify accounting discrepancies, understand why these discrepancies are occurring, set priorities to address the most significant issues, and implement a plan to resolve these problems. Importantly, the Harmonization Framework is designed to be a sustainable, "turn-key" approach as it allows mitigation activity and emission inventory teams to continuously improve their GHG accounting.

Figure 2: RALI GHG MRV Harmonization Framework



Purpose of this Document

This document provides instructions on how to apply the Harmonization Framework to mitigation activities within the Agriculture, Forestry, and Other Land Use (AFOLU) sector. This document is part of a series of Harmonization Guidance documents, which demonstrate the harmonization technique across all inventory sectors. For more general guidance on the Harmonization Framework, and templates to apply the approach, consult the General Framework Guide.[1] The guide's intended audience includes national inventory compilers, mitigation activity implementers, and other stakeholders.

[1] See the RALI GHG MRV Harmonization Framework: A General Framework Guide. Available online at: https://www.climatelinks.org/resources/rali-ghg-mrv-harmonization-framework.

Getting Started with the Harmonization Framework

In order to apply the framework, users need to select a mitigation activity to analyze and determine who to engage at each step of the framework. Many countries have prioritized mitigation activities to meet NDC commitments. To select mitigation activities for applying this framework, consider factors such as:

- Availability of sufficient information about the activity
- Availability of established MRV methods to estimate emission reductions from the activity
- Existing MRV and stakeholder activity underway
- Mitigation potential and relative contribution to NDC goal (if applicable)
- Potential impact on emissions from key categories or priority sectors within the national GHG inventory
- Alignment with national or subnational climate change policy and initiatives

Steps 1 through 4 of the Framework are more analytical and may be appropriate for an inventory developer or mitigation activity implementer to apply, provided they have access to both mitigation MRV and national inventory information. Steps 5 and 6, however, include decisions to be made by the mitigation MRV and national inventory teams, along with governing ministries and other relevant stakeholders involved in decision-making. These steps require engaging broader stakeholder groups for implementation. Given the differences between steps, identify the appropriate stakeholders to involve throughout the process.

AFOLU Sector Introduction

The AFOLU sector can either be a net source or a net sink of GHG emissions. Globally, this sector is the second largest net source of GHG emissions behind the Energy sector.[2] However, there is significant potential for activities in the AFOLU sector to enhance land's ability to store carbon, and thus offset emissions from other sectors (e.g., Energy, Industrial Processes, and Waste). Moreover, mitigation activities in this sector have become a major focus for countries, and supporting international partners, as they make plans to realize the targets set in their NDCs under the Paris Agreement.

The significance of AFOLU-related emissions, the potential for this sector to offset GHG emissions, as well as the inclusion of AFOLU-related GHG mitigation activities in NDC commitments make mitigation activities in this sector good candidates for the Harmonization Framework.

2 See the IPCC Fifth Assessment Synthesis Report, Figure 1.7. Available online at: https://ar5-syr.ipcc.ch/topic_observedchanges.php

AFOLU mitigation activities can impact emissions of several greenhouse gases and source/sink categories. These categories are defined by the *2006 IPCC Guidelines* and primarily include those in the AFOLU, Energy, and Waste sectors. Within the AFOLU sector, GHG source/sink categories are defined by agricultural activities or land-use categories (e.g., cropland, grassland). Since agricultural mitigation activities and land use-related mitigation activities are naturally interlinked, mitigation activities focused on agriculture often have GHG impacts on land use and vice versa. The specific GHG impacts in the AFOLU sector differ depending on the type of land on which the mitigation activity occurs. However, GHG impacts are similar across many of the mitigation activities that occur on the same land-use category.

Mitigation activities in the AFOLU sector can reduce GHG emissions from agricultural production and/or offset GHG emissions by enhancing land's ability to store carbon. Some mitigation activities may also impact the Energy sector, by supplying sources of renewable energy. For example, capturing methane emissions from manure management systems for energy use mitigates GHG emissions from both the AFOLU and Energy sectors.

Applying the Harmonization Framework to the AFOLU Sector

Even with a wide variety of mitigation actions and diversity in policies or actions, this guide demonstrates that there are a limited number of ways to impact GHG emissions in the AFOLU sector of a national inventory. *Step 1* and *Step 2* of this guide define common AFOLU mitigation activities and their GHG impacts, and identify which IPCC sectors and source categories are likely to be impacted. *Step 3* describes common top-down and bottom-up accounting methods in the AFOLU sector, and identifies common areas of overlap. While recommendations for harmonization are specific to each country's circumstances and individual mitigation activities, *Step 4* discusses potential harmonization opportunities and actions that can arise in the AFOLU sector. Finally, *Step 5* and *Step 6* provide considerations for countries to prioritize and implement improvements to realize harmonization between mitigation and inventory accounting methods and processes.

The following sections of this document illustrate each step of the Harmonization Framework for seven categories of mitigation activities in the AFOLU sector: livestock management, cropland management, grassland management, forest management, wetlands management, settlements management, and bioenergy, as defined below.

- **Livestock management** activities can reduce overall emissions from livestock production or reduce the GHG intensity of livestock production (i.e., reduce GHG emissions per unit of product), impacting GHG emissions from enteric fermentation, manure management, and agricultural soil management.
- **Cropland management** activities can reduce overall emissions from crop production, reduce the GHG intensity of crop production, and enhance land's ability to store carbon, impacting GHG emissions from agricultural soil management, rice cultivation, and biomass burning.
- **Grassland management** can reduce the GHG intensity of livestock production, reduce GHG emissions from land conversion to cropland, and enhance land's ability to store carbon, impacting GHG emissions from enteric fermentation, manure management, agricultural soil management, grassland management, and land conversion.

- **Forest management** can reduce GHG emissions from deforestation and fire, and enhance land's ability to store carbon, impacting emissions and removals from forest land and land conversion.
- **Wetlands management** can reduce GHG emissions from wetlands and from land conversion to cropland or grassland, and enhance land's ability to store carbon, impacting emissions and removals from wetlands and land conversion.
- **Settlements management** can enhance land's ability to store carbon through bulk urban tree planting initiatives and improved urban forest management, impacting emissions and removals from settlements (i.e., developed land).
- **Bioenergy** can reduce fossil fuel use to meet energy needs, impacting GHG emissions from manure management, stationary fuel combustion, mobile combustion, and landfills.

The AFOLU sector also includes activities on "other land", which includes rock, ice, and other barren land. However, the scope of this sector guidance only includes mitigation activities on cropland, grassland, forest land, wetlands, and settlements.[3]

Wetlands management (left) includes activities such as rewetting lands, and settlements management (right) includes activities such as urban tree planting. Both activities increase carbon storage and removals in land.

[3] Refer to the 2006 IPCC Guidelines, Volume 4, Chapter 3 for definitions of each land use. Available online at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_03_Ch3_Representation.pdf.

Step 1: Identify GHG Effects and Map the Causal Chain

The AFOLU mitigation activities discussed in this guidance reduce GHG emissions from agricultural production, land-use changes, and fire; reduce the GHG intensity of agricultural production; and/or offset emissions by strengthening carbon sinks. While there are mitigation activities that indirectly reduce the demand for agricultural production,[4] this guidance covers activities that directly impact emissions from the AFOLU sector.

Table 1 presents categories of AFOLU mitigation activities based on their primary outcomes. A country's selected mitigation activity may fall into more than one of these categories. Throughout the process of applying this guidance, the user should review the discussion of the mitigation categories that are most relevant to the selected activity.

In addition to the AFOLU sector, some mitigation activities may also impact emissions from the Energy and Waste sectors, and thus affect which GHG impacts are considered in the harmonization process. For example, while an agroforestry activity primarily impacts GHG emissions in the AFOLU sector, a bioenergy project also impacts emissions in the Energy and Waste sectors. The GHG impacts of the mitigation activities listed in Table 1 are discussed in *Step 2*.

Installing biogas facilities to convert methane from waste to energy impacts emissions from the AFOLU, Energy, and Waste sectors.

In *Step 1*, users will:

- Identify the mitigation activity category or categories that are most similar to their selected mitigation activity.
- Map the specific outcomes of their mitigation activity and associated impacts on GHG emissions, using the simplified causal chains in this document as guidance.

[4] For more information on demand-side mitigation activities in the AFOLU sector, refer to the IPCC AR5 Climate Change 2014: Mitigation of Climate Change report, Chapter 11. Available online at: https://www.ipcc.ch/report/ar5/wg3/.

Table 1: AFOLU Mitigation Activities

Mitigation Activity Category	Description	Example Mitigation Activities
Livestock Management	Implementation of management practices to reduce emissions from livestock production and/or reduce the GHG intensity of livestock production (i.e., reduce GHG emissions per unit of product)	• Improved feed quality • Herd management • Livestock waste management
Cropland Management	Implementation of management practices to reduce emissions from crop production and/or reduce the GHG intensity of crop production, and increase carbon sequestration in cropland	• Improved nutrient management • Crop rotation • Cover crops • Reduced crop residue burning • Alternate wetting and drying fields during rice cultivation • Conservation / no tillage
Grassland Management	Implementation of management practices to improve the quality of grassland in order to increase carbon sequestration in grassland and/or reduce the GHG intensity of livestock production, and avoid conversion of grassland to cropland	• Pasture rehabilitation • Agroforestry • Rotational grazing[a] • Avoided conversion of grassland to cropland
Forest Management	Implementation of management practices to increase carbon sequestration in forest land; avoid conversion of forests to cropland, grassland, and other land uses; and reduce emissions from forest fires	• Afforestation and reforestation • Avoided deforestation • Improved forest management • Forest fire management
Wetlands Management	Implementation of management practices to reduce GHG emissions from wetlands, increase carbon sequestration in wetlands and avoid conversion of wetlands to cropland, grassland, and other land uses	• Rewetting of drained former wetlands • Restoration of undrained, but degraded/damaged wetlands • Avoided wetland conversion
Settlements Management	Planting of trees in urban areas and improved urban forest management practices to increase carbon sequestration in developed land	• Urban tree planting • Improved urban forest management
Bioenergy	Installation of technologies to collect and convert organic material (e.g., manure, crop residues) to energy	• Anaerobic digesters

[a] Rotational grazing may decrease livestock emissions per unit of product (e.g., milk), not necessarily emissions per animal. Therefore, overall emissions may continue to increase as livestock populations increase (RALI 2018a, WRI 2017).

Sources: GIZ (2014); Zeleke et al. (2016); DEA (2014).

1.1 **Map impacts of AFOLU mitigation activities using causal chains.** Each mitigation activity can be mapped to specific outcomes and associated impacts on GHG emissions. Causal chains are flow charts that illustrate this mapping.[5] Simplified causal chains for pasture rehabilitation (WRI 2017, The Greenhouse Gas Protocol 2017) and afforestation/reforestation are presented in Figure 3 and Figure 4.

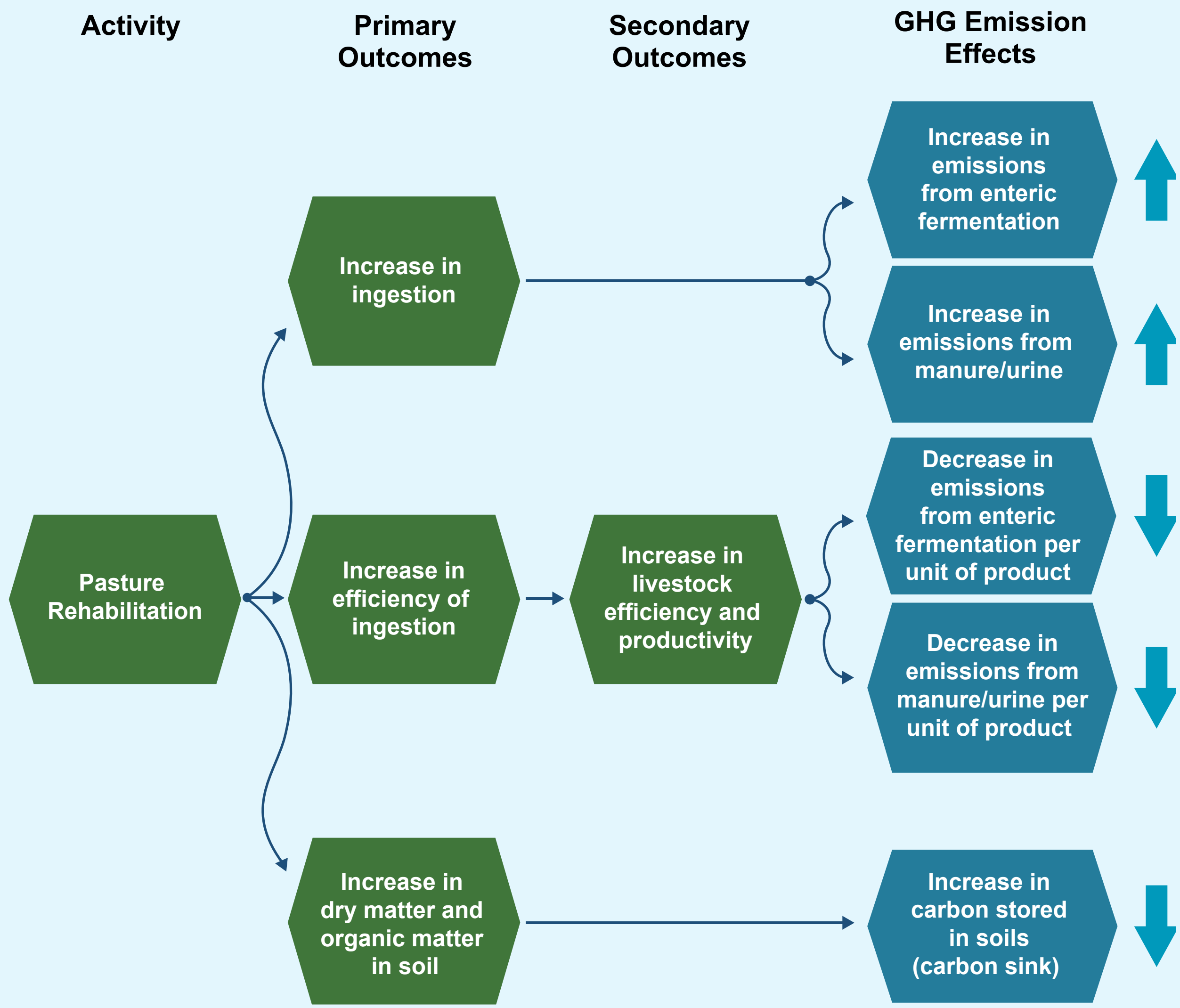
Some of the mitigation activities listed in Table 1 may not reduce emissions if climate conditions, soil quality, and the combination of management practices used are not favorable. For example, alternate wetting and drying fields can reduce methane emissions from rice cultivation; however, this activity may increase N_2O emissions from cultivation on soils where large amounts of synthetic fertilizer have been applied. Since many of the AFOLU mitigation activities may be combined on a single site (e.g., crop rotation and cover crops), activity implementers must consider climate, soil quality, management and other variations when mapping primary GHG outcomes of mitigation activities.

Furthermore, the simplified causal chains presented in this guidance are not exhaustive. They are intended to illustrate primary outcomes and associated GHG impacts. There are also potential secondary outcomes and rebound effects of AFOLU mitigation activities, which are beyond the scope of the causal chains presented in this guidance.

Pasture rehabilitation improves the quality of feed for grazing animals, which can decrease emissions from livestock production.

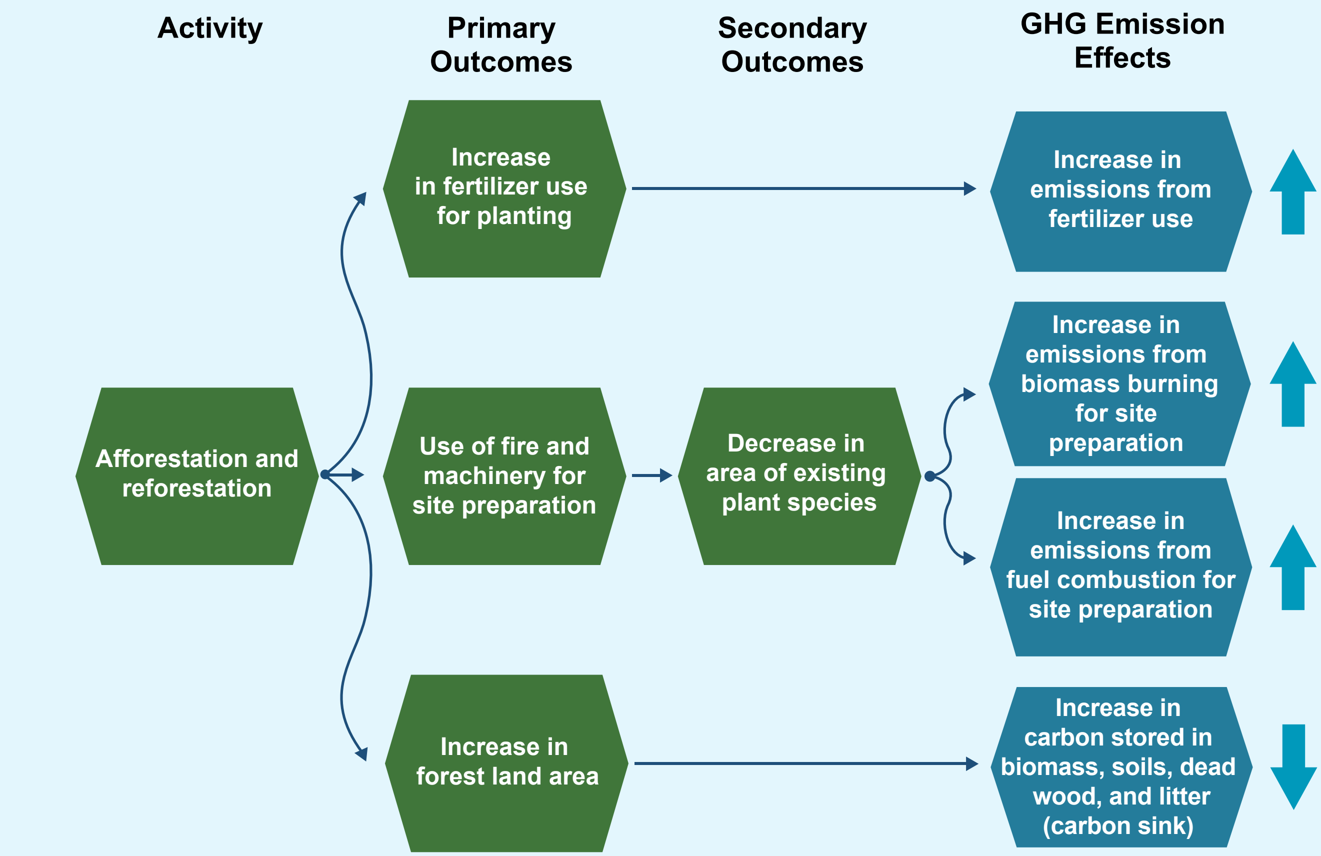
[5] For more detailed instructions on mapping causal chains, refer to Chapter 6 of the GHG Protocol *Policy and Action Standard.*

Figure 3: Causal Chain for Pasture Rehabilitation[a]



[a] Simplified causal chain adapted from WRI (2017).

Figure 4: Causal Chain for Afforestation and Reforestation[a]



[a] Kushla (2017), CDM AR-ACM0003 (2013), IPCC (2007, 2014a)

After completing *Step 1*, users have:

- Identified the mitigation activity category or categories that are most similar to their selected mitigation activity.
- Mapped the specific outcomes of their mitigation activity and associated impacts on GHG emissions, using the simplified causal chains in this document as guidance.

Step 2: Map GHG Effects to Inventory Sectors

The next step is to map the GHG impacts identified in *Step 1* to GHG inventory sectors and source/sink categories. For national inventories, these sectors and source/sink categories are defined by the *2006 IPCC Guidelines*, which detail the boundaries for categories that account for GHG emissions from different activities, and methods for how to estimate national GHG emissions and removals (IPCC 2006).

Figure 5 through Figure 11 illustrate a direct mapping of AFOLU mitigation activities to their impacted IPCC source and sink categories. The mappings in this guidance are not exhaustive; there may be indirect impacts on IPCC categories not listed, such as those in the Industrial Processes and Product Use (IPPU) sector. For instance, reducing fertilizer use might reduce the production of fertilizer, which impacts GHG emissions from the IPPU sector. This guidance includes IPCC categories that are likely to be directly impacted by the mitigation activities listed in *Step 1*.

Improved nutrient management, which reduces emissions from fertilizer consumption, is mapped to multiple IPCC source categories including 3C4 – Direct N_2O Emissions from Managed Soils and 3C5 – Indirect N_2O Emissions from Managed Soils.

In *Step 2*, users will:

- Map the GHG impacts identified in *Step 1* to GHG inventory sectors and source/sink categories.
- Identify the specific "inventory pathway" through which each mitigation activity impacts the national inventory.

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Figure 5: Livestock Management

- **Improve feed quality**: 3A1, 3A2, 3C4, 3C5, 3C6
- **Herd management**: 3A1
- **Livestock waste management**: 1A1, 1A3, 1A4, 3A2, 3C4, 3C5, 3C6, 4B

Figure 6: Cropland Management

- **Reduced crop residue burning**: 3B2a, 3B2b, 3C1b, 3C4, 3C5
- **Alternating wetting and drying**: 1A4c, 3C4, 3C5, 3C7
- **Conservation/no tillage**: 1A4c, 3B2a, 3B2b, 3C4, 3C5
- **Crop rotation**: 3B2a, 3B2b, 3C4, 3C5
- **Cover crops**: 3B2a, 3B2b, 3C4, 3C5
- **Improved nutrient management**: 1A2c, 3C4, 3C5

Figure 7: Grassland Management

- **Pasture rehabilitation**: 3A1, 3A2, 3B3a, 3B3b, 3C6
- **Agroforestry**: 3B1bii, 3C4, 3C5
- **Rotational grazing**: 3A1, 3A2, 3B3a, 3B3b, 3C4, 3C5, 3C6
- **Avoided conversion of grassland to cropland**: 1A4c, 3B3a, 3B3b, 3C4, 3C5

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- 1A2 Manufacturing Industries and Construction
- 1A3 Transport
- 1A4 Other Sectors

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- 3A2 Manure Management

4B: Biological Treatment of Solid Waste

3B: Land

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- 3B5 Settlements

3C: Aggregate Sources and Non-CO_2 Emissions Sources on Land

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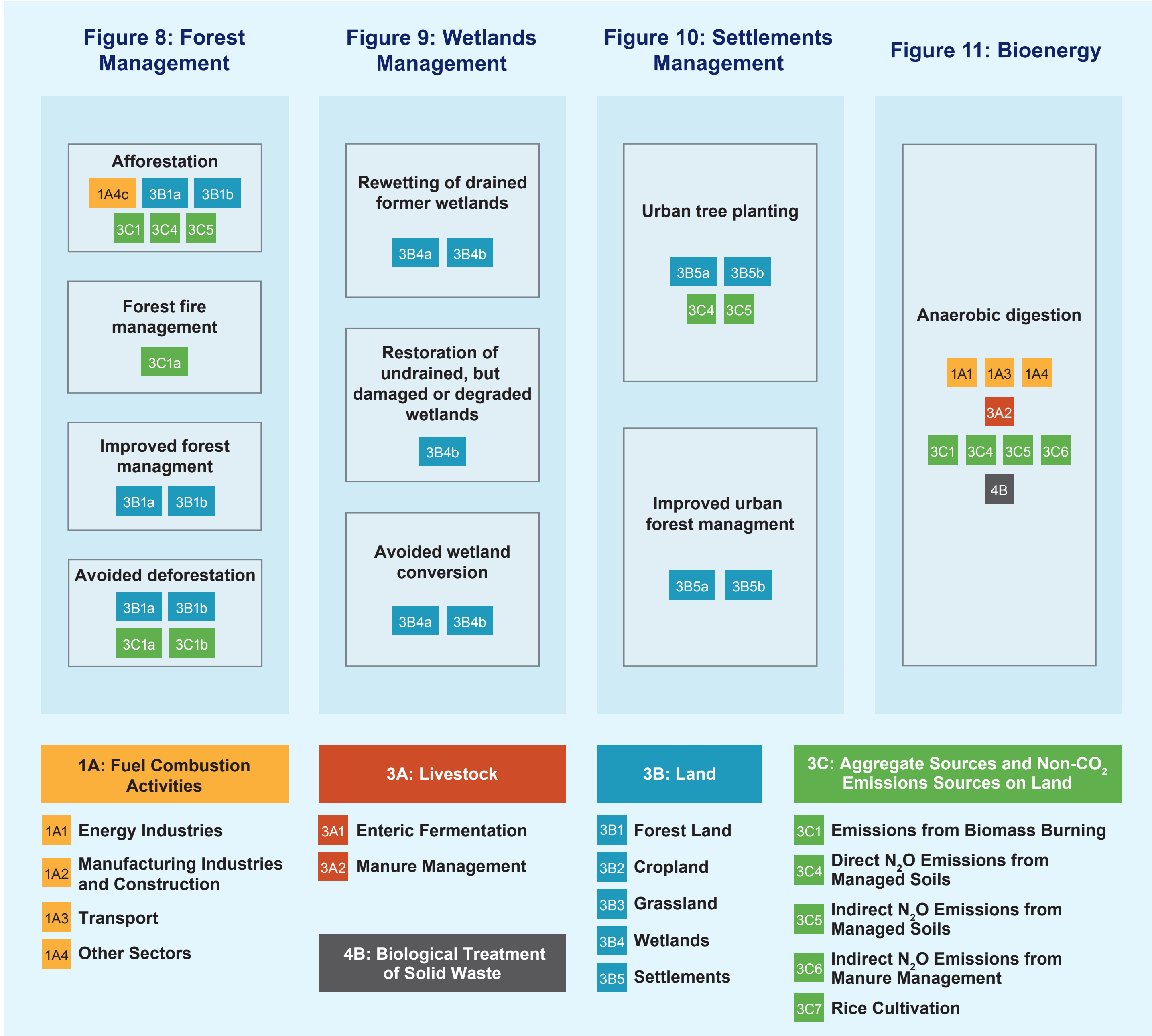
- 3C4 Direct N_2O Emissions from Managed Soils
- 3C5 Indirect N_2O Emissions from Managed Soils
- 3C6 Indirect N_2O Emissions from Manure Management
- 3C7 Rice Cultivation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2.1 **Define Inventory Pathways to Reduce GHG Emissions from Mitigation Activities in the AFOLU Sector.** Each mapping of an activity to an inventory source category represents an inventory pathway. An "**inventory pathway**" is the way in which mitigation activities impact GHG inventories. Inventory pathways can impact multiple IPCC source/sink categories or a single IPCC source/sink category in GHG inventories. For example, mitigation activities focused on livestock have primarily two pathways: reducing emissions from enteric fermentation (IPCC Source Category 3A1) or reducing emissions from manure management (IPCC Source Categories 3A2 and 3C6). Mitigation activities can impact GHG emissions through multiple pathways.[6] However, even with a wide variety of mitigation activities and diversity in policies or actions, there are a limited number of pathways to impact GHG emissions in the AFOLU sector of the national inventory, based on how GHG emissions are calculated in the national inventory.

Inventory Pathway 1. Reduce methane emissions from enteric fermentation. Mitigation activities involving livestock and grassland management can reduce methane emissions from enteric fermentation, or (as is the case in some countries' NDCs) mitigation activities can reduce the GHG intensity of livestock production by reducing GHG emissions per unit of product. Mitigation activities in livestock and grassland management reduce emissions from enteric fermentation per unit of product by improving feed quality and managing the size, composition, and health of the livestock herd. *IPCC Source Category: 3A1 – Enteric Fermentation*

Inventory Pathway 2. Reduce methane and nitrous oxide emissions from manure management. Mitigation activities focused on livestock and grassland management can also reduce methane and nitrous oxide emissions from manure management as a result of actions similar to those described above for enteric fermentation: improving feed quality, and managing the size, composition, and health of the livestock herd. In addition, changing the waste management system from more emissive systems, such as dry lot, to less emissive systems, such as solid storage or anaerobic digesters, can also reduce GHG emissions from manure management. *IPCC Source Categories: 3A2 – Direct CH_4 and N_2O Emissions from Manure Management, 3C6 – Indirect N_2O Emissions from Manure Management*

Inventory Pathway 3. Increase carbon storage and/or removals in cropland, grassland, forests, and settlements. All of the categories of AFOLU mitigation activities (excluding bioenergy) have the potential to impact carbon storage and removals in either cropland, grassland, forests, or settlements. Wetlands are covered separately in Inventory Pathway 7. Mitigation activities involving changes to livestock, cropland, and grassland management can increase carbon stored in soils through changes in management practices. These include reducing soil disturbances either through reduced tillage practices on cropland or allowing grassland to rest in between grazing periods (e.g., rotational grazing), or increasing the amount of carbon added to the soil by increasing the biomass of plants grown on the soil (e.g., growing cover crops or increasing the density of grazing plants).

[6] For example, a mitigation project in agroforestry may impact GHG emissions by increasing carbon stored in biomass and soils while also increasing emissions from fertilizer use for the initial planting of trees.

Mitigation activities focused on forest management, such as afforestation and reforestation, increase carbon stored in trees (i.e., biomass), soils and other carbon pools (i.e., reservoirs of carbon). Mitigation activities related to agroforestry and urban tree planting initiatives also increase carbon stored in biomass and soils through the planting of trees on grassland and settlements, respectively.

In addition, avoided conversion of forest land and grassland to cropland and other land uses avoids emissions that would have otherwise occurred from land-use conversion, specifically non-CO_2 emissions from forest fires or losses of carbon stored in biomass and soils. *IPCC Source Categories: 3B1 – Forest Land, 3B2 – Cropland, 3B3 – Grassland, and 3B5 – Settlements*

Inventory Pathway 4. Reduce GHG emissions from biomass burning. Biomass burning, specifically crop residue burning and forest fires, is a source of carbon dioxide, methane, and nitrous oxide emissions. Mitigation activities that either eliminate the practice of burning biomass or improve the management of fires can reduce GHG emissions from biomass burning. Carbon dioxide emissions from biomass burning are only considered in this pathway if they are not already included in Inventory Pathway 3 as changes in carbon storage based on the *2006 IPCC Guidelines*. *IPCC Source Category: 3C1 – Emissions from Biomass Burning*

Inventory Pathway 5. Reduce nitrous oxide emissions from fertilizer use. Livestock, cropland, and grassland management mitigation activities can reduce emissions from synthetic fertilizer use by increasing nutrients in soils through other means, including using livestock waste, retaining nutrients in soils through reduced tillage, or the use of “green manure”, such as growing cover crops that add nitrogen to the soil (e.g., legumes).

Mitigation activities that may decrease emissions from other aspects of livestock or land management may initially increase emissions from fertilizer use, depending on the implementing action of the mitigation activity. For example, afforestation and agroforestry may reduce GHG emissions overall, but there may be an increase in emissions from fertilizer use for initial planting. *IPCC Source Categories: 3C4 – Direct N_2O Emissions from Managed Soils and 3C5 – Indirect N_2O Emissions from Managed Soils*

Inventory Pathway 6. Reduce methane emissions from rice cultivation. Alternate wetting and drying of fields during rice cultivation is a practice that can reduce methane emissions. This activity requires draining and re-flooding lands during rice cultivation. When rice fields are continuously flooded, anaerobic conditions are sustained, resulting in increased methane emissions. By draining flooded lands, anaerobic conditions exist over shorter time periods, and therefore methane emissions are reduced. *IPCC Source Category: 3C7 – Rice Cultivation*

Inventory Pathway 7. Reduce GHG emissions from drained, damaged, or conserved wetlands and increase carbon stored. Drained wetlands are sources of carbon dioxide emissions as organic material in the previously wetted soil is exposed to oxygen. Restoration of drained or damaged wetlands is achieved through rewetting activities that restore the water saturated conditions and/or re-establish vegetation cover. Rewetting of drained wetlands decreases carbon dioxide emissions compared to the drained state, while methane emissions may increase compared to the drained state due to the restart of methanogenesis. The re-establishment of vegetation cover reinstates the carbon sink function of the wetland. Conservation maintains the carbon sink function of the wetland. *IPCC Source Category: 3B4 – Wetlands*

Inventory Pathway 8. Other sector impacts on emissions. Certain mitigation activities in the AFOLU sector also impact GHG emissions in non-AFOLU sectors, including the Energy and Waste sectors. The Energy and Waste sectors are impacted by mitigation activities that involve bioenergy and reduced fuel consumption for agricultural machinery, among other activities. Examples of pathways to non-AFOLU sectors include:

- **Reduce emissions from fossil fuel combustion (bioenergy):** Manure can be used to generate bioenergy using anaerobic digesters. This source of renewable energy can displace energy previously supplied using conventional fossil fuels, and thereby reduce GHG emissions from fossil fuel combustion. *IPCC Source Categories: 1A4 – Fuel Combustion Activities in Other Sectors, 3A2 – Manure Management*
- **Reduce emissions from fossil fuel combustion (agricultural machinery):** Mitigation activities in cropland management can also reduce fuel consumption by agricultural machinery, which reduces emissions from fossil fuel combustion. For example, fuel demands are lower for "no till" equipment compared to fuel demands for "conventional till equipment", so fossil fuel combustion emissions decrease when switching to "no till" practices. *IPCC Source Categories: 1A3 – Fuel Combustion Activities in Transportation, 1A4 – Fuel Combustion Activities in Other Sectors*
- **Reduce emissions by composting organic waste:** Composting agricultural wastes reduces emissions compared to disposing of organic waste in landfills or in lagoons. *IPCC Source Categories: 3A2 – Manure Management, 4A – Solid Waste Disposal, and 4B – Biological Treatment of Solid Waste*

After completing *Step 2*, users have:

- Mapped the GHG impacts identified in *Step 1* to GHG inventory sectors and source/sink categories.
- Identified the specific "inventory pathway" through which each mitigation activity impacts the national inventory.

Step 3: Assess Bottom-Up and Top-Down GHG Accounting

In *Step 3*, users will:

- Identify the primary "metrics" for each inventory pathway to measure the GHG impacts of the selected mitigation activity.
- Assess and compare the bottom-up and top-down GHG accounting methods and data elements by inventory pathway.

This step summarizes typical components of the national inventory GHG accounting (top-down) and mitigation activity MRV methods (bottom-up) for the AFOLU sector. For each inventory pathway defined in *Step 2*, this section summarizes primary metrics and accounting methods, and identifies common overlaps between top-down and bottom-up data elements (i.e., variables used to calculate emissions) in order to help users determine if/how mitigation activities are captured in the current inventory. This step helps establish an understanding of current accounting processes before exploring harmonization opportunities in *Step 4*. Before assessing and comparing the bottom-up and top-down GHG accounting methods for each pathway, it is important to define a consistent boundary[7] for GHG impacts of the selected mitigation activity to ensure an accurate comparison.

3.1 Identify AFOLU Metrics. The "**metrics**" are the data elements that are often used to track GHG emissions and other impacts of an activity, particularly in mitigation MRV accounting. This section defines common metrics for mitigation activities in the AFOLU sector, which can inform bottom-up accounting methods. Primary AFOLU metrics for each inventory pathway are defined in Table 2.

Table 2: Metrics for Measuring Impacts of Mitigation Activities in the AFOLU Sector

Inventory Pathway (No. and Title)		Metric	Definition
1	**Reduce methane emissions from enteric fermentation**	Animal population	Number of ruminant livestock (e.g., cattle)
		Gross energy intake	Amount of energy that an animal needs "for maintenance and for activities such as growth, lactation, and pregnancy." (IPCC 2006)
		Methane conversion factor (Y_m)	The percent of gross energy in feed converted to methane, which depends on feed and animal characteristics (IPCC 2006)

[7] For more information on defining a GHG assessment boundary, refer to Chapter 7 of the GHG Protocol *Policy and Action Standard*.

Inventory Pathway (No. and Title)		Metric	Definition
2	**Reduce methane and nitrous oxide emissions from manure management**	Animal population	Number of ruminant and non-ruminant livestock and poultry
		Excretion rates	Rate of volatile solids or nitrogen in animal manure/urine excreted per animal per day
		Fraction of manure in manure management systems	Percent of manure managed in each manure management system
		Methane conversion factor (MCF)	Methane conversion factor based on the manure management system, type of manure, temperature of the stored manure, and manure handling
3	**Increase carbon storage and/or removals in cropland, grassland, forests, and settlements**	Carbon stock change	Changes in carbon stored in each carbon pool
		Carbon pool	Reservoirs of carbon stored in aboveground biomass, belowground biomass, soil, dead wood, and litter
4	**Reduce GHG emissions from biomass burning**	Carbon density of biomass	Amount of carbon stored in forest or biomass per unit of land area
		Area burned	Area of land burned during crop residue burning, deforestation, or site preparation for afforestation/reforestation
		Crop residues remaining	Amount and type of crop residues left on the field after harvest
5	**Reduce nitrous oxide emissions from fertilizer use**	Fertilizer use	Amount of fertilizer used for agricultural purposes
		Nitrogen content of fertilizer	Type of fertilizer and amount of nitrogen in the fertilizer used for agricultural purposes
6	**Reduce methane emissions from rice cultivation**	Rice area harvested	Area of land used to harvest rice
		Water management factors	Emission factors by type of water management practice used during rice cultivation
7	**Reduce GHG emissions from drained, damaged, or conserved wetlands and increase carbon stored**	Area rewetted or conserved	Area of wetlands that are rewetted or conserved
		Area burned	Area of peatland burned
		Carbon stock change	Changes in carbon stored in wetlands
8a	**Reduce emissions from fossil fuel combustion**	Fuel consumption	Amount of fuel combusted for use in agriculture, forestry, transportation, or energy generation
8b	**Reduce emissions by composting organic waste**	Mass of waste composted	Amount of organic material composted
		Composting emission factor	Emission factor per kg of waste treated

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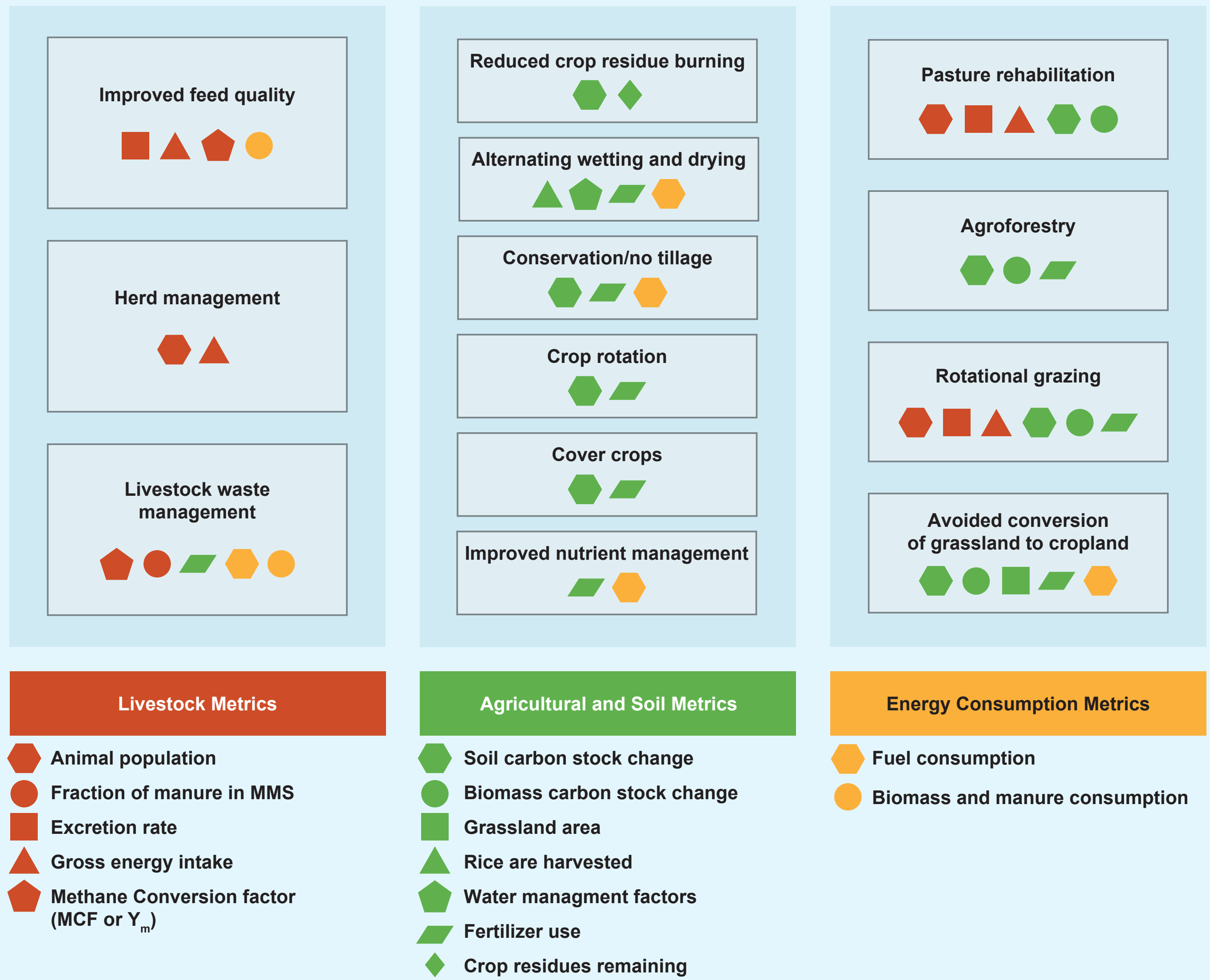
Figure 12 through Figure 18 illustrate a more detailed mapping of AFOLU mitigation activities and their metrics. Many of the mitigation activities discussed in this guidance have common metrics. For example, fertilizer use is a metric in the majority of cropland management activities shown (see Figure 13).

Figure 12: Livestock Management **Figure 13: Cropland Management** **Figure 14: Grassland Management**



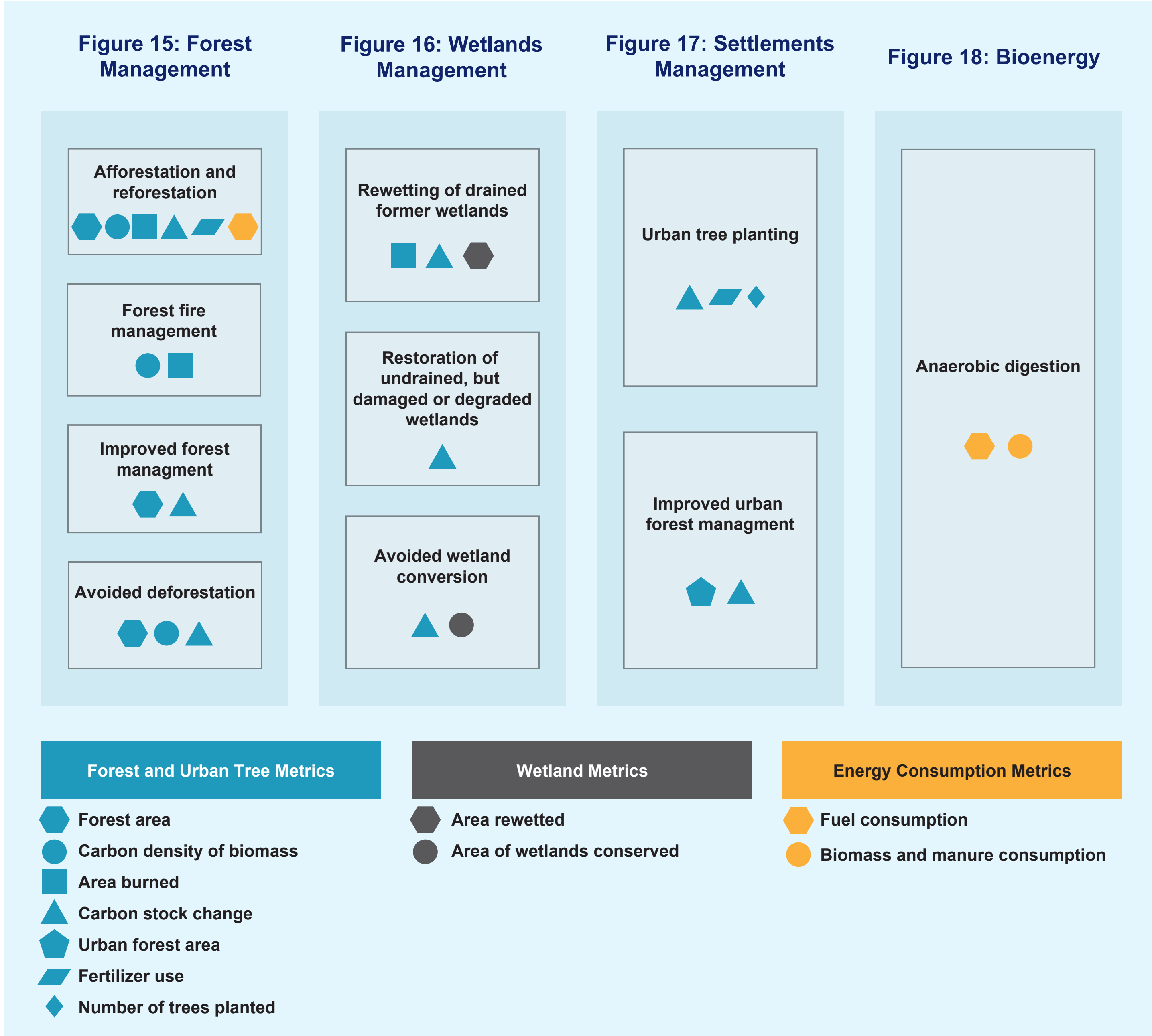


Figure 15: Forest Management
Figure 16: Wetlands Management
Figure 17: Settlements Management
Figure 18: Bioenergy
Afforestation and reforestation
Forest fire management
Improved forest managment
Avoided deforestation
Rewetting of drained former wetlands
Restoration of undrained, but damaged or degraded wetlands
Avoided wetland conversion
Urban tree planting
Improved urban forest managment
Anaerobic digestion
Forest and Urban Tree Metrics
Forest area
Carbon density of biomass
Area burned
Carbon stock change
Urban forest area
Fertilizer use
Number of trees planted
Wetland Metrics
Area rewetted
Area of wetlands conserved
Energy Consumption Metrics
Fuel consumption
Biomass and manure consumption

3.2 **Assess and Compare GHG Accounting Methods and Data Elements by Inventory Pathway.** There are many accounting methods for each of the eight inventory pathways that are impacted by mitigation activities in the AFOLU sector. The IPCC published top-down accounting methods for the AFOLU sector in the 2006 IPCC Guidelines, and other organizations have published GHG accounting methods for bottom-up mitigation activities in this sector. Annex A: Helpful Resources, Table 15 provides a summary of MRV accounting methods for each mitigation activity category for the AFOLU sector discussed in this guidance.

Methods can vary by methodology tier, data elements, data sources, frequency of data collection, and other factors. However, both top-down and bottom-up accounting methods for inventory pathways in the AFOLU sector can be distilled into the simplified equations presented in this section. The equations presented are primarily Tier 2 IPCC methodologies, although some are also considered to be Tier 1 methodologies when using default IPCC emission factors. Higher methodology tiers typically require country-specific or region-specific inputs that are more likely to capture changing trends. These equations also illustrate how the metrics presented in Table 2 are used in accounting methods.

Each inventory pathway section below presents (1) a GHG emissions methodology that is common across top-down and bottom-up methodologies, and (2) a comparison of common data elements for inventory pathways in Table 3 through Table 11, as used in a national inventory, and data elements used for bottom-up GHG accounting for mitigation activities in the AFOLU sector. These sections were developed based on a synthesis of the 2006 IPCC Guidelines and mitigation MRV methods listed in Annex A, Table 15.

The pathway sections allow users to assess and compare common data elements in both top-down and bottom-up GHG accounting, such as the same or similar activity data points or emission factors. If data elements are common across top-down and bottom-up accounting methods, they may represent an opportunity for further analysis and harmonization in Step 4.

At this stage the user should review the inventory pathway(s) that are most relevant to the selected mitigation activity:

Inventory Pathway (No. and Title)		Data Element Tables
1	*Reduce methane emissions from enteric fermentation*	*Table 3*
2	*Reduce methane and nitrous oxide emissions from manure management*	*Table 4*
3	*Increase carbon storage and/or removals in cropland, grassland, forests, and settlements*	*Table 5*
4	*Reduce GHG emissions from biomass burning*	*Table 6*
5	*Reduce nitrous oxide emissions from fertilizer use*	*Table 7*
6	*Reduce methane emissions from rice cultivation*	*Table 8*
7	*Reduce GHG emissions from drained, damaged, or conserved wetlands and increase carbon stored*	*Table 9*
8a	*Other impacts on emissions: Energy*	*Table 10*
8b	*Other impacts on emissions: Waste*	*Table 11*

Inventory Pathway 1. Reduce methane emissions from enteric fermentation. Enteric fermentation is a common category through which mitigation activities in the AFOLU sector reduce GHG emissions from livestock production. For example, when the quality of livestock feed is improved or alternative grazing practices are implemented, methane emissions from enteric fermentation will decrease. This pathway corresponds to IPCC Source Category 3A1: Enteric Fermentation. GHG emissions are calculated using a Tier 2 methodology, summarized as follows:

$$\textit{Emissions}_{CH_4} = \boldsymbol{\textit{Animal population}} \times \textit{Emission factor}_{Enteric,CH_4}$$

$$\textit{Emission factor}_{Enteric,CH_4} = \boldsymbol{\textit{Gross energy intake}} \times \boldsymbol{\textit{Methane conversion factor}} \times X$$

***Metrics are in bold**

Where “X” represents additional data elements used in calculations, including days per year and the energy content of methane.

A Tier 1 methodology uses default enteric emission factors based on region, animal type, and the country’s level of development. The Tier 2 methodology uses an emission factor for enteric fermentation that is based on gross energy intake (i.e., the amount of energy an animal needs for growth, maintenance, and/or lactation), and the methane conversion factor (Y_m) (i.e., the percent of gross energy in feed converted to methane) (IPCC 2006). Gross energy intake is estimated using data elements including live weight, weight gain, milk yield, fat content in milk, diet composition, pregnancy rate, and feeding situation. Y_m is also influenced by feed and animal properties, but many of the data elements influencing Y_m (e.g., detailed carbohydrate fraction, rates of passage and digestion) are more difficult to collect than those influencing gross energy intake (IPCC 2006). Top-down and bottom-up methodologies reviewed for this guidance reference these data elements to estimate emission factors for enteric fermentation.

The following table presents primary data elements that are used to measure GHG emissions from enteric fermentation in top-down and/or bottom-up methodologies.

Table 3: Primary Data Elements for Inventory Pathway 1–*Reduce Methane Emissions from Enteric Fermentation*

Data Element	Top-Down	Bottom-Up	Metric
Animal population	✓	✓	•
Gross energy intake	✓	✓	•
Methane conversion factor (Y_m)	✓	✓	•
Average daily weight gain	✓	✓	
Animal weight	✓	✓	
Digestibility of feed	✓	✓	
Milk production	✓		
Fat content of milk	✓		
Days on feed		✓	
Other feed characteristics		✓	
Emission factor$_{Enteric,CH4}$	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.

Sources: IPCC (2006), Alberta Carbon Offset Program (2016), Carbon Farming Initiative: Beef cattle herd management (2015), American Carbon Registry (2014), VCS-VM0026 (2014), Gold Standard (2016).

Inventory Pathway 2. Reduce methane and nitrous oxide emissions from manure management. Manure management is another common category through which mitigation activities in the AFOLU sector reduce GHG emissions from livestock production. When livestock manure is managed in a way that prevents manure run-off, maintains lower temperatures, and increases aeration, emissions from the management of livestock manure will decrease (LRG et al. 2013). This pathway corresponds with IPCC Source Categories 3A2: Manure Management and 3C6: Indirect N_2O Emissions from Manure Management.

Direct GHG emissions are calculated as follows:

$$Emissions_{CH_4 \text{ or } N_2O} = \textbf{Animal population} \times Emission\ factor_{Direct\text{–}Manure, CH_4 \text{ or } N_2O}$$

$$Emission\ factor_{Manure, CH_4 \text{ or } N_2O} = \textbf{Excretion rate}_{CH_4 \text{ or } N_2O} \times Y$$

Where "Y" represents additional data elements used in calculations, including maximum methane producing capacity, methane conversion factors for each manure management system (MMS), and fraction of nitrogen excretion in each MMS.

Indirect N_2O emissions are calculated as follows:

$$Emissions_{N_2O} = \textbf{Animal population} \times Excretion\ rate_{N_2O} \times Emission\ factor_{Indirect\ N_2O\text{–}Leaching/runoff\ or\ volatization)} \times Z$$

Where "Z" represents additional data elements used in calculations, including the fraction of nitrogen excretion in each MMS.

These direct and indirect methodologies are considered Tier 1 when using default factors or Tier 2 when using country-specific factors, except for indirect emissions from leaching and runoff, which are only considered to be part of a Tier 2 or 3 method (IPCC 2006). The emission factors for manure management are based on volatile solids (VS) and nitrogen excretion rates, which are used to estimate CH_4 and N_2O emissions, respectively. Similar to the enteric fermentation emission factor, excretion rates are based on gross energy intake, which is estimated using data elements including live weight, weight gain, milk yield, protein in diets, and other elements. The share of waste managed in various waste management systems is also used to calculate direct and indirect emissions from manure management. Top-down and bottom-up methodologies reviewed reference these data elements to estimate emission factors for manure management.

The following table presents primary data elements that are used to measure GHG emissions from manure management in top-down and/or bottom-up methodologies.

Table 4: Primary Data Elements for Inventory Pathway 2–*Reduce Methane and Nitrous Oxide Emissions from Manure Management*

Data Element	Top-Down	Bottom-Up	Metric
Animal population	✓	✓	•
VS excretion rate	✓	✓	•
Nitrogen excretion (Nex) rate	✓	✓	•
Methane conversion factor (MCF) for each MMS	✓	✓	•
Fraction of manure in manure management systems	✓	✓	•
Animal weight	✓	✓	
Maximum CH_4 producing capacity (B_0)	✓	✓	
Grazing days		✓	
Fraction of N losses due to volatilization	✓	✓	
Fraction of N losses due to leaching/runoff	✓	✓	
CH_4 emission factor	✓	✓	
Direct N_2O emission factor	✓	✓	
Indirect N_2O emission factors	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.

Sources: IPCC (2006), VCS-VM0026 (2014), Alberta Carbon Offset Program (2016), American Carbon Registry (2014).

Inventory Pathway 3. Increase carbon storage and/or removals in cropland, grassland, forests, and settlements. Increasing carbon storage and/or removals is another common pathway by which emissions from the AFOLU sector can be reduced. For example, afforestation, improving forest management, pasture rehabilitation, urban tree planting, and avoiding conversion of forests can increase the amount of carbon stored in land and lower net GHG emissions. This pathway corresponds with IPCC Source Categories 3B1: Forest Land, 3B2: Cropland, 3B3: Grassland and 3B5: Settlements.

Carbon stock change is defined as the amount of carbon accumulated or lost in each carbon pool between two distinct time periods (t_1 and t_2). Top-down and bottom-up methodologies reviewed measure carbon stock change in five carbon pools: aboveground biomass, belowground biomass, soil, dead wood, and litter. Changes in carbon stocks are calculated as follows using the "stock-difference" method, which is applicable to Tier 2 and 3 methodologies:

$$\textit{Carbon stock change}_{Pool} = \frac{\textit{Carbon stock}_{pool,t2} - \textit{Carbon stock}_{pool,t1}}{t_2 - t_1}$$

A Tier 1 methodology estimates gains and losses in carbon pools using default factors for biomass growth, as well as default carbon stock change factors in soils from the *2006 IPCC Guidelines*. A Tier 1 methodology also assumes belowground biomass carbon stocks are zero, and estimates dead wood and litter for only certain land uses using default factors (IPCC 2006).

The following table presents primary data elements that are used to measure carbon stock change in land in top-down and/or bottom-up methodologies.

Table 5: Primary Data Elements for Inventory Pathway 3–*Increase Carbon Storage and/or Removals in Cropland, Grassland, Forests, and Settlements*

Data Element	Top-Down	Bottom-Up	Metric
Carbon stock	✓	✓	•
Carbon pool (Aboveground Biomass, Belowground Biomass, Soil, Dead Wood, Litter)	✓	✓	•

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), CDM AR-TOOL14 (2015), CDM AR-ACM0003 (2013).

The bottom-up methodologies reviewed contain guidance for measuring carbon stock change or using models to estimate carbon stock change due to specific mitigation projects. For example, the CDM AR-TOOL14 contains guidance to estimate carbon stock change. If data on carbon stocks are not available, default IPCC factors and methodologies can also be used to estimate carbon stock changes, though this presents an opportunity to harmonize default top-down methodologies with bottom-up methodologies, which often use measured or modeled data.

Inventory Pathway 4. Reduce GHG emissions from biomass burning. Biomass burning, either as the result of forest fires or burning of crop residues during crop production, is a category through which AFOLU mitigation activities impact GHG emissions from fire. For example, forest fire management and reduced burning of crop residues can reduce overall GHG emissions from fire. This pathway corresponds with IPCC Source Category 3C1: Emissions from Biomass Burning. GHG emissions are calculated as follows:

$$\mathit{Emissions}_{CH_4 \text{ or } N_2O} = \textbf{Biomass burned} \times \mathit{Combustion\ factor} \times \mathit{Emission\ factor}_{Fire, CH_4 \text{ or } N_2O}$$

$$\mathit{Biomass\ Burned} = \mathit{Mass\ of\ biomass\ burned\ or}\ (\textbf{Area burned} \times \textbf{Carbon density of biomass}_{Biomass\ type})$$

This methodology is considered Tier 1 when using default factors or Tier 2 when using country-specific factors (IPCC 2006). GHG emissions depend on the carbon density of the biomass burned (i.e., amount of carbon per ton of biomass). The following table presents primary data elements that are used to measure GHG emissions from biomass burning in top-down and/or bottom-up methodologies.

Table 6: Primary Data Elements for Inventory Pathway 4–*Reduce GHG Emissions from Biomass Burning*

Data Element	Top-Down	Bottom-Up	Metric
Biomass burned	✓	✓	•
Area burned	✓	✓	•
Carbon density of biomass	✓	✓	•
Emission factor	✓	✓	
$Ratio_{C:CH4}$	✓	✓	
$Ratio_{C:N2O}$	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), VCS-VM0017 (2011), VCS-VM0026 (2014).

Inventory Pathway 5. Reduce nitrous oxide emissions from fertilizer use. Reducing fertilizer use is a common pathway for AFOLU mitigation activities on all land types considered in this guidance due to its applications to agriculture and tree planting. Improving nutrient management (e.g., aligning the amount of fertilizer applied to the needs of the plant), improves soil health and reduces the amount of excess fertilizer applied thereby also reducing GHG emissions. This pathway corresponds with IPCC Source Categories 3C4: Direct N2O Emissions from Managed Soils and 3C5: Indirect N2O Emissions from Managed Soils. GHG emissions are calculated using a Tier 2 methodology as follows:

$$Emissions_{N_2O} = Nitrogen\ applied_i \times Emission\ factor_{Direct\ \ N_2O,i} + Nitrogen\ applied_i \times Emission\ factor_{Indirect\ N_2O\text{–}Leching/runoff\ or\ volatization,i}$$

$$Nitrogen\ Applied = \boldsymbol{Fertilizer\ used} \times \boldsymbol{N\ content\ of\ fertilizer}$$

Where "i" = conditions at fertilizer application (e.g., climate, soil, land-use)

A Tier 1 methodology uses the same equations above. However, in a Tier 1 methodology, "nitrogen applied" and emission factors do not vary by conditions at fertilizer application; instead, emission factors are used for the total "nitrogen applied" regardless of conditions at application.

The nitrogen content of fertilizer depends on the type of fertilizer used. Although not shown, emissions can also depend on the method and timing of the application of fertilizer (IPCC 2006).

The following table presents primary data elements that are used to measure GHG emissions from fertilizer use in top-down and/or bottom-up methodologies.

Table 7: Primary Data Elements for Inventory Pathway 5–*Reduce Nitrous Oxide Emissions from Fertilizer Use*

Data Element	Top-Down	Bottom-Up	Metric
Synthetic fertilizer use	✓	✓	•
Organic fertilizer use	✓	✓	•
N content of fertilizer		✓	•
Fertilizer application method		✓	
Use of time release fertilizer		✓	
Fraction of N losses due to volatilization	✓	✓	
Fraction of N losses due to leaching/runoff	✓	✓	
Direct N_2O emission factors	✓	✓	
Indirect N_2O emission factors	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.

Sources: IPCC (2006), VCS-VM0017 (2011), VCS-VM0022 (2013), American Carbon Registry (2015).

Inventory Pathway 6. Reduce methane emissions from rice cultivation. This pathway is applicable to changes in flooding practices used during rice cultivation. For example, alternately wetting and drying fields during cultivation can reduce methane emissions by reducing the amount of time that rice fields are flooded. This pathway corresponds with IPCC Source Category 3C7: Rice Cultivation. GHG emissions are calculated as follows:

$$Emissions_{CH_4} = \textbf{Area harvested} \times Cultivation\ period \times Emission\ factor_{CH_4}$$

$$Emission\ Factor_{CH_4} = Emission\ factor_{Continuously\ flooded, CH_4} \times \textbf{Scaling factor}_{\textbf{Water regime}, CH_4}$$

This methodology is considered Tier 1 when using default factors or Tier 2 when using country-specific factors (IPCC 2006). The scaling factor above depends on the type of water regime used, including continuously flooded, which is the most emissive water regime, or intermittently flooded, such as during implementation of alternate wetting and drying.

The following table presents primary data elements that are used to measure GHG emissions from flooded lands during rice cultivation in top-down and/or bottom-up methodologies.

Table 8: Primary Data Elements for Inventory Pathway 6–*Reduce Methane Emissions from Rice Cultivation*

Data Element	Top-Down	Bottom-Up	Metric
Area harvested	✓	✓	•
Scaling factor$_{Water\ regime, CH_4}$	✓	✓	•
Cultivation period	✓	✓	
Emission factor$_{Continuously\ flooded, CH_4}$	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), CDM AMS-III.AU (2014).

Inventory Pathway 7. Reduce GHG emissions from drained, damaged, or conserved wetlands and increase carbon stored. This pathway is applicable to the conservation and restoration of wetlands through rewetting activities. Wetlands trap methane and have the potential to store carbon. Activities such as rewetting drained wetlands, restoration of undrained but degraded/damaged wetlands, and avoiding conversion of wetlands prevent methane from being emitted and increase carbon stored, thereby reducing GHG emissions. This pathway corresponds with IPCC Source Category 3B4: Wetlands. GHG emissions are calculated as follows using a Tier 2 methodology:

$$Emissions_{CO_2,CH_4,N_2O} = \textbf{Area rewetted} \times Emission\ factor_{CO_2,CH_4,N_2O,DOC} + \textbf{Area peat burned} \times Emission\ factor_{CH_4}$$

Mitigation activities include conserving area of wetlands, increasing the area of rewetted wetlands, and re-establishing vegetation cover to wetlands. The Tier 2 emission factors above depend on multiple factors including water table depth, nutrient status of the soil, and previous land use. Under Tier 1, default emission factors are used and emissions of nitrous oxide from rewetted soils are assumed to be negligible (IPCC 2014b). Countries where rewetted organic soils are a significant component of a key category should estimate nitrous oxide emissions using the Tier 2 methodology (IPCC 2014b). Although not shown in the accounting method above, emissions can also depend on the timing since rewetting, because the time needed for the recovery of the sink function may vary from years to several decades (IPCC 2014b). While the likelihood of fires on rewetted organic soils is considered low, fire risk may still exist (IPCC 2014b). For the GHG accounting method for increased carbon stored from re-establishment of vegetation cover see Inventory Pathway 3.

The following table presents primary data elements that are used to measure GHG emissions and sinks from wetlands in top-down and/or bottom-up methodologies.

Table 9: Primary Data Elements for Inventory Pathway 7–*Reduce GHG Emissions from Drained, Damaged, or Conserved Wetlands and Increase Carbon Stored*

Data Element	Top-Down	Bottom-Up	Metric
Area rewetted	✓	✓	•
Area peat burned	✓	✓	•
Area drained	✓	✓	
Nutrient status of the soil	✓	✓	
Water table depth	✓	✓	
Previous land use	✓	✓	
CO_2 emission factors	✓	✓	
CH_4 emission factors	✓	✓	

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), IPCC (2014b), VCS-VM0046 (2015)

Inventory Pathway 8. Other impacts on emissions.

Fuel Combustion

Fuel combustion is a common pathway by which mitigation activities in the AFOLU sector impact GHG emissions from the Energy sector. For example, using manure to generate energy can displace energy previously supplied using conventional fossil fuels, and thereby reduce emissions from fossil fuel combustion. This pathway corresponds with IPCC Source Categories 1A1: Fuel Combustion Activities in Energy Industries, 1A3: Fuel Combustion Activities in Transportation, and 1A4: Fuel Combustion Activities in Other Sectors. GHG emissions in this case are calculated as follows:

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$$Emissions_{GHG} = \textbf{Fuel consumption/sold}_{fuel} \times \textbf{Emission factor}_{GHG,fuel}$$

This methodology is considered Tier 1 when using default factors or Tier 2 when using country-specific factors (IPCC 2006). A Tier 2 methodology uses country-specific emission factors that consider information such as the carbon intensity of the grid. Bioenergy mitigation activities can not only reduce consumption of carbon-intensive fossil fuels but also the carbon content of the fuel. Using a Tier 2 methodology, CO2 emissions from fossil fuel combustion activities are calculated as follows:

$$Emissions_{CO_2} = \textbf{Fuel consumption}_{fuel} \times Carbon\ content_{fuel} \times \frac{44}{12}$$

The following table presents primary data elements that are used to measure GHG emissions from fuel combustion activities in top-down and/or bottom-up methodologies.

Table 10: Primary Data Elements for Inventory Pathway 8a–*Reduce Emissions from Fossil Fuel Combustion*

Data Element	Top-Down	Bottom-Up	Metric
Quantity of fossil fuel consumed/sold	✓	✓	•
Emission factor	✓	✓	•
Carbon content	✓		

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), CDM ACM0018 (2017).

Organic Waste Composted

Composting agricultural wastes reduces emissions compared to otherwise disposing of organic waste in landfills or in lagoons. This pathway corresponds with IPCC Source Categories 3A2: Manure Management, 4A: Solid Waste Disposal, and 4B: Biological Treatment of Waste. GHG emissions are calculated as follows:

$$Emissions_{CH_4,N_2O} = Mass\ of\ waste\ composted_{Material\ type*}\ Emission\ factor_{GHG}$$

This methodology is considered Tier 1 when using default factors or Tier 2 when using country-specific factors (IPCC 2006). The following table presents primary data elements that are used to measure GHG emissions from composting in top-down and/or bottom-up methodologies.

Table 11: Primary Data Elements for Inventory Pathway 8b–*Reduce Emissions by Composting Organic Waste*

Data Element	Top-Down	Bottom-Up	Metric
Mass of waste composted	✓	✓	•
Composting emission factor	✓	✓	•

Note: The "✓" notation indicates data elements captured by either the top-down (inventory) calculations or the bottom-up (project MRV) calculations. Metrics are noted with "•" and bold font.
Sources: IPCC (2006), CDM AMS-III.F (2009).

3.3 **Identify Data Sources and Documentation.** An understanding of current data sources and documentation helps to determine where misalignment may exist between top-down and bottom-up accounting, and subsequently helps to identify harmonization opportunities in *Step 4*. Figure 19 summarizes common data sources for top-down and bottom-up accounting, as well as where data elements are commonly documented, and is followed by a discussion of sources and documentation for top-down and bottom-up accounting.

Figure 19: Top-Down and Bottom-Up Data Sources and Documentation

	Data Sources	Documentation
Top-Down Accounting	• Statistics from ministry of agriculture or other government agency • Producer/industry organization • Peer-reviewed scientific literature • Commissioned study • IPCC default • Expert judgment • Value from other country's inventory • Equation or model	• National Inventory Report • Biennial Update Report • National Communcations report • Documentation of methods and data, including calculation spreadsheets or archiving systems where activity data and emission factors are stored • Key Category Analysis results • Quality assurance and quality control (QA/QC) procedures National inventory improvement plan
Bottom-Up Accounting	• Direct measurement • Reported value from project implementer (e.g., farmer) • Field survey (e.g., using GPS) or georeferenced spatial data (e.g., maps, GIS datasets) • Laboratory testing • Equations or models • Peer-reviewedd scientific literature • IPCC default	• Project evaluations • NAMA database • Summary reports • Training and capacity-building reports • Sectoral action palns • Mitigation registry

Top-Down Accounting

Based on national GHG inventory reports, countries use a variety of data sources and documentation to determine the values of data elements.

IPCC default values are not likely to change over time and are not country-specific, and thus may not reflect changing trends in emissions as the result of mitigation activities. Many countries may initially use IPCC default factors, but as countries improve national inventory accounting methodologies, they often substitute default values with values from country-specific data sources that reflect changing trends in AFOLU emissions and sinks (Global Research Alliance and CGIAR Research Program on Climate Change, Agriculture and Food Security [CCAFS] 2019).

For example, based on a review of national inventories using Tier 2 methodologies for GHG emissions from livestock, gross energy intake can be based on sources such as national feed tables from national statistics, surveys of livestock nutrition experts (expert judgment), updates to typical animal weights estimated based on commissioned studies, and country-specific energy balance models for feed digestibility. Table 14 in Annex A presents specific data sources commonly used by countries to gather livestock-specific data elements.

Bottom-Up Accounting

The methodologies and data used in bottom-up accounting vary from project to project. If no mitigation activity MRV method exists, internationally accepted guidelines on project GHG MRV accounting can provide the data elements needed to account for GHG emissions at the project level. The methodologies and standards in these guidelines, including those listed below, provide an overview of potential MRV methods to inform a bottom-up assessment if project-specific MRV methods do not exist.

- Clean Development Mechanism (CDM)
- GHG Protocol for Project Accounting
- Gold Standard
- The Climate Registry
- Verified Carbon Standard (VCS)
- Climate Action Reserve (CAR)
- American Carbon Registry (ACR)

AFOLU-specific GHG MRV methods that were used to inform Step 3 discussions by pathway are provided in Table 15 in Annex A by mitigation activity category.

Once accounting information has been compiled using the data sources above, users can determine whether the national inventory captures mitigation GHG impacts according to the guidance in *Step 4*.[8]

> After completing *Step 3*, users have:
>
> - Identified the primary “metrics” for each inventory pathway to measure the GHG impacts of the selected mitigation activity.
> - Assessed and compared the bottom-up and top-down GHG accounting methods and data elements by inventory pathway.

[8] For more detailed instructions on comparing data elements, see the General Framework Guide.

Step 4: Identify Opportunities to Harmonize Accounting

Opportunities to harmonize accounting are country-specific; they depend on the specific national GHG inventory methods and project MRV methods in use. However, there are several common opportunities for harmonization that arise when comparing bottom-up and top-down accounting in the AFOLU sector. These include opportunities to harmonize data elements used in the two accounting approaches, as well as improving overall inventory and mitigation activity processes.

In *Step 4*, users will:

- Determine whether the national inventory captures mitigation GHG impacts.
- Identify opportunities to harmonize top-down and bottom-up accounting methods.
- Review harmonization opportunities and examples in the AFOLU sector.

4.1 Determine if National Inventory Captures GHG Impacts from Mitigation Activities. Based on the assessment of top-down GHG accounting in *Step 3*, determine whether the national inventory does or does not currently capture the GHG impacts of the mitigation activity—for example, by incorporating activity data from mitigation projects or adjusting emission factors to incorporate the use of mitigation technologies. Understanding how the current inventory captures GHG impacts of mitigation activities helps to uncover areas where harmonization already exists or can be improved.

Analyze the information collected in *Step 3* to determine whether activity data or emission factors currently used in the inventory can capture changing trends due to mitigation activities. Questions to consider include:

- **Are mitigation project-level data used in the inventory methodology?**

  If an inventory uses older activity data, extrapolates activity data, or uses activity data from a different source than mitigation project-level data, such as a national dataset, there may be an opportunity to harmonize data sources. For example, if an inventory uses fertilizer use data that are published every five years to estimate emissions, there may be an opportunity to incorporate biennial fertilizer use data from project surveys; the result would be that changes in fertilizer use trends would be reflected in the inventory more frequently.

  Conversely, if project-level data are already being used in an inventory, then the impacts of the mitigation activity are likely captured and methods are likely harmonized. For example, in the case of an inventory that estimates animal weight using farm-level data, the inventory is likely already capturing some GHG mitigation impacts assuming the farms that are providing data are implementing livestock mitigation activities and reflecting those changes in their reported data.

- **Is the inventory methodology able to capture changing trends?**

  If the inventory methodology is unable to capture changes in trends (e.g., changes in emission factors), then this presents an opportunity to harmonize accounting methods. For example, if an inventory uses default Tier 1 emission factors from *2006 IPCC Guidelines* to estimate emissions from livestock manure, the inventory is not capturing changes resulting from mitigation activities that directly impact emission factors over time (such as improving livestock feed quality); these changes can be reflected in Tier 2 or 3 methodologies. There may be opportunities to obtain specific Tier 2 emission factors, such as gross energy intake or excretion rates from projects or by region, and the inventory team can then use these for geographic areas where mitigation activities are being implemented. This results in an emissions inventory that better tracks the GHG impacts of livestock mitigation activities.

- **In the inventory methodology, are data collected frequently enough to capture changing trends?**

  Increasing the frequency of collection is also important to capture GHG impacts from mitigation activities. For example, if forest area data are collected every five years, the inventory does not capture changes in forest area or deforestation rates in the interim years, nor does it capture any potential emission reductions from mitigation efforts to reduce deforestation. Any increased frequency of data collection on forest area will allow the inventory to capture GHG trends, and to more accurately track the impact of mitigation activities on emissions.

4.2 **Identify Harmonization Opportunities.** In this part of *Step 4*, users identify harmonization opportunities by comparing bottom-up and top-down data elements. Documenting, prioritizing, and implementing identified opportunities are covered in *Step 5* and *Step 6*.

In this discussion, "**data element**" refers to any variable that is used to calculate emissions in a national inventory or mitigation MRV methods. A "**data attribut**e" is a characteristic of the data element. Harmonization actions might involve changing one or more of these data attributes. Table 12 provides the definition and examples of data elements and data attributes.

Table 12: Data Element and Data Attribute Definitions and Examples

	Data Element	Data Attribute
Definition	Any variable that is used to calculate emissions	Characteristic of the data element
Examples	• Animal population • Gross energy intake • Excretion rates • Carbon stock change • Carbon density of biomass • Fertilizer use • Rice area harvested • Wetlands area • Fossil fuel consumption A full list of data elements is provided in Table 2	• Source of the data • Frequency of data collection or publication • Unit of measurement • Level of data granularity (e.g., project-level, regional, national) • Level of uncertainty (qualitative and/or quantitative) • IPCC methodology tier (if applicable) • Key assumptions • Reporting status • Data quality

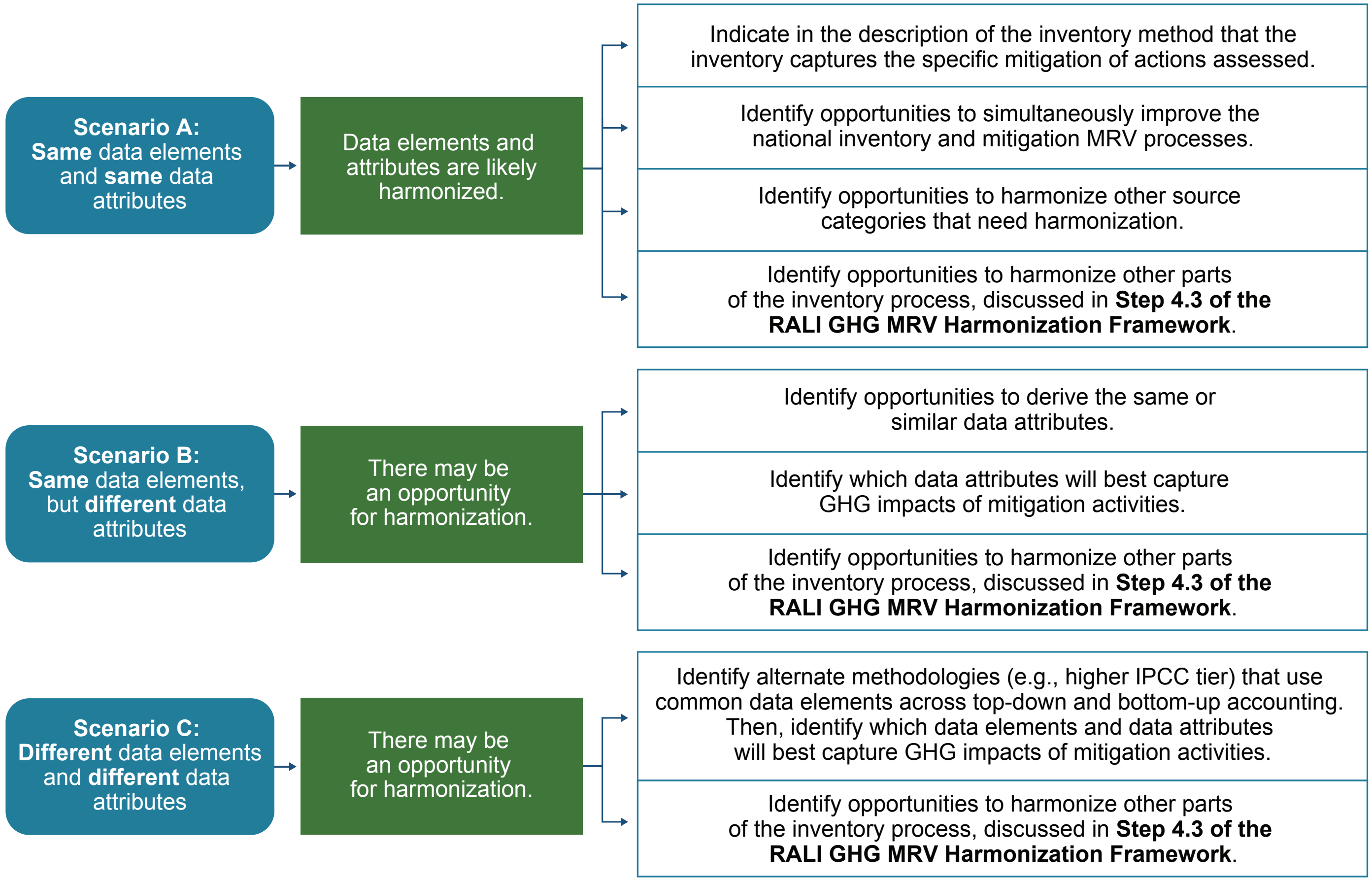
The template table below can be used to compare data elements and their attributes in top-down and bottom-up methodologies in order to identify alignment issues, which are also potential harmonization opportunities.

Table 13: Template Table of Alignment Issues for Data Elements

Data Element	Type of Alignment Issue	Top-Down Methodology	Bottom-Up Methodology
Example: Forest area	**Frequency of collection**	**Updated every five years**	**Updated every two years**
[Data Element 1]	[Data Attributes:Data source/ Granularity/Frequency of collection]	[Description]	[Description]

Figure 20 shows three likely scenarios that can arise as bottom-up and top-down data elements are compared, and how to identify harmonization opportunities within this scenario. This framework can be used to understand common harmonization opportunities in the AFOLU sector.

Figure 20: Harmonization Opportunity Flow Chart



For more detailed instructions on identifying opportunities to harmonize other components of the inventory process, such as institutional arrangements, data documentation and reporting, uncertainty analyses and discussion, and improvement planning, see the General Framework Guide.

4.3 **Review Potential Harmonization Actions.** The actions that an inventory team can take to harmonize accounting methods vary by available resources, mitigation activity, inventory source category, and other factors. Opportunities for harmonization uncovered in Steps 1 through 4 could include low- or no-cost options, such as documentation of findings, or could require extensive investments in new projects; the choice of which actions to implement depends on the relative priority of each improvement on the inventory and trends. Some examples of harmonization actions include:

- Define new data sources and incorporate new institutional arrangements
- Create new data templates for mitigation activity implementers
- Align schedules of inventory and MRV data collection
- Increase the frequency of data collection
- Move to a higher IPCC tier of the inventory methodology
- Develop more specific emission factors (e.g., country-, region-, or project-specific)
- Splice (i.e., join) subnational data into national data in order to compensate for incomplete or missing data
- Form new institutional arrangements or strengthen current ones
- Update or create new reporting procedures
- Document qualitative or quantitative uncertainties uncovered through the harmonization process
- Document harmonization opportunities as planned improvements to the inventory
- Update the Inventory Improvement Plan to include harmonization opportunities

Example: Harmonization Actions for Improved Feed Quality Mitigation Activity

Below are examples of harmonization actions for Scenarios A, B, and C, described in Figure 20, for the improved feed quality mitigation activity, which can reduce methane emissions from enteric fermentation in the livestock sector. Gross energy intake is a metric for the improved feed quality mitigation activity, as explained in the Inventory Pathway 1 section of Step 3.

Scenario A: Same data elements and same data attributes

Gross energy intake is used in both the top-down and bottom-up methodologies to estimate emissions from enteric fermentation (same data element). Gross energy intake is updated every five years based on national statistics in both the top-down and bottom-up methodologies (same data attribute).

Top-Down Methodology	Bottom-Up Methodology	Type of Alignment Issue
Gross energy intake is updated every five years from national statistics	Gross energy intake is updated every five years based on livestock characteristics and reported annually to national statistics	No alignment need identified

Harmonization action: Likely harmonized, focus on improvements. Gross energy intake values in the top-down and bottom-up methodologies have the same data source and update frequency. As a result, the mitigation activity is likely captured in the national inventory, so it is likely that no alignment issue exists. In this case, national inventory compilers and project mitigation stakeholders can seek to simultaneously improve the gross energy intake value by coordinating to improve estimates, increase update frequency, or reduce uncertainty. Alternately, they might decide to devote limited resources to other data elements, mitigation actions, or source categories that are not in alignment. When an analysis is conducted and the findings indicate that the inventory and mitigation action are likely harmonized, the transparency of the inventory will be strengthened by documenting that such mitigation actions are reflected in the inventory and emission trends.

Scenario B: Same data elements, but different data attributes

Gross energy intake is used for both the top-down and bottom-up methodology (same data element). Gross energy intake is updated every five years based on national statistics in the top-down methodology, but is updated biennially based on livestock characteristics in the project area and used in the bottom-up methodology (different data attribute). The bottom-up mitigation activity does not report project data to national statistics.

Top-Down Methodology	Bottom-Up Methodology	Type of Alignment Issue
Gross energy intake is updated every five years based on national statistics.	Gross energy intake is updated biennially based on livestock characteristics in the project area but is not reported to national statistics.	Frequency of Collection and Data Source

Harmonization action: Create new reporting structure. The harmonization actions in this scenario are to initiate bottom-up reporting of annual livestock characteristics and gross energy intake values into national statistics and the inventory team, and to splice such data into the dataset. This will yield an increased accuracy of the gross energy intake values for any given inventory reporting year.

Scenario C: Different data elements and different data attributes

A default Tier 1 enteric fermentation emission factor is used for the top-down methodology, while the bottom-up methodology uses gross energy intake data updated every five years to update enteric fermentation emission factors (different data elements). While the data source for the top-down methodology is IPCC (2006), the bottom-up mitigation activity updates and reports to national statistics compilers (different data attributes).

Top-Down Methodology	Bottom-Up Methodology	Type of Alignment Issue
A default and static Tier 1 enteric emission factor is used from IPCC (2006).	Gross energy intake is updated every five years based on livestock characteristics and reported into national statistics.	Data Element, Frequency of Collection, and Data Source

Harmonization action: Move to a higher IPCC tier of the inventory methodology. The harmonization action in this scenario is for the national inventory to move from Tier 1 to a higher IPCC tier by transitioning from using an IPCC default emission factor to a country-specific emission factor based on gross energy intake values from national statistics, which include bottom-up mitigation activity updates.

Denmark Harmonization Example

Denmark's inventory developers collect data from dairy farm monitoring systems four to eight times each year. Specifically, inventory developers collect data elements used to develop gross energy intake, including animal weight and livestock populations from participating farms. Participating farms represent 10 percent of Danish farms (GRA and CCAFS 2019). As a result, the inventory captures changing trends in gross energy intake more accurately than default emission factors from IPCC (2006).

After completing *Step 4*, users have:

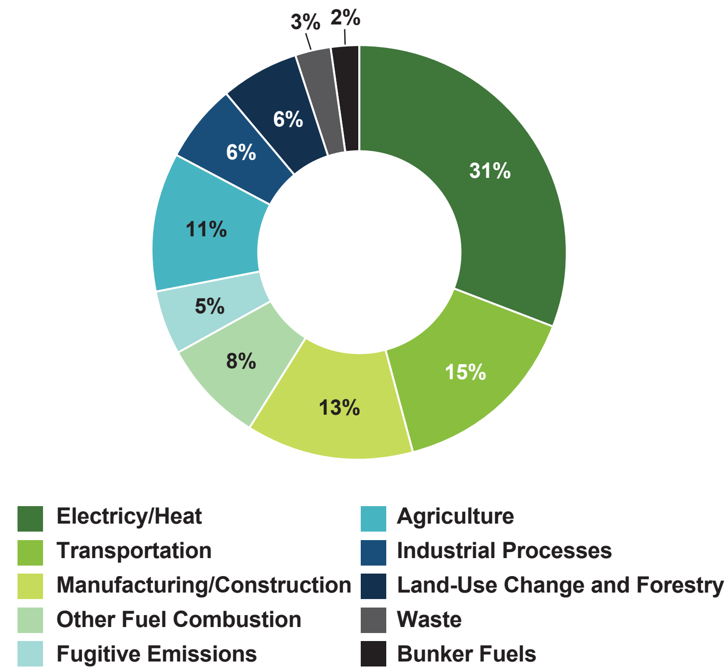
- Determined whether the national inventory captures mitigation GHG impacts.
- Identified opportunities to harmonize top-down and bottom-up accounting methods.
- Reviewed harmonization opportunities and examples in the AFOLU sector.

Step 5: Prioritize Improvements to GHG Accounting

Several factors will influence which recommendations identified in *Step 4* should be adopted by countries. Country stakeholders need to define which criteria to consider when prioritizing improvements, and then prioritize recommendations to maximize the impact on GHG accounting transparency, accuracy, completeness, comparability, and consistency. For example, one factor to consider is whether the potential improvement significantly impacts emissions from a key category, which would imply that the improvement is a higher priority.

Country stakeholders also need to consider AFOLU harmonization actions in the context of other sectors. This AFOLU Harmonization Guidance document is part of the Harmonization Guidance series, which demonstrates the harmonization technique across all inventory sectors. Any inventory improvements should be prioritized within the context of country emissions, emission reduction ambitions and targets, co-benefits of inventory or data improvements, and more.

Figure 21: Global GHG Emissions (2014)



In *Step 5*, users will:

- Develop a framework for prioritizing impacts by defining criteria to consider when prioritizing improvements.
- Prioritize improvements to maximize the impact on GHG accounting transparency, accuracy, completeness, comparability, and consistency.

Globally, the AFOLU sector accounted for about 17 percent of all emissions in 2014 (see Figure 21) (WRI CAIT 2017), making AFOLU the second most emissive sector, after energy. On average from 2010 to 2016, the largest sources of emissions in the Agriculture sub-sector were Enteric Fermentation (39%), Manure Left of Pasture (16%), Synthetic Fertilizers (13%), Rice Cultivation (10%) and Manure Management (7%) (FAOSTAT 2019). Over the same time period, the largest source of net emissions in the Land Use sub-sector were Biomass Burning (46%), Forest Land (32%), and Cropland (23%) (FAOSTAT 2018). While the specific breakdown of emissions within each country will vary, countries are likely to have key categories within the AFOLU sector. Therefore, improvements to this sector will have a relatively large impact on overall inventory harmonization.

5.1 **Develop a Framework for Prioritizing Impacts.** The prioritization process for inventory improvements involves defining country-specific evaluation criteria, and this will be impacted by existing national priorities. Country stakeholders need to assess the impact of harmonization improvements in specific sectors based on their relative importance to various criteria, including:

- Status as a key category
- Mitigation potential
- Emission trends
- Uncertainty levels
- Contribution to mitigation commitments.[9]

These criteria can also complement other evaluation criteria, such as existing GHG accounting approaches, institutional resources, and overall institutional dynamics.

After completing *Step 5*, users have:

- Developed a framework for prioritizing impacts by defining criteria to consider when prioritizing improvements.
- Prioritized improvements to maximize the impact on GHG accounting transparency, accuracy, completeness, comparability, and consistency.

To prioritize harmonization opportunities, it is important to identify which criteria to use, their relative importance, and their target outcome (e.g., increase mitigation potential, reduce uncertainty levels). This selection process can be done by any of the key stakeholders considering harmonization improvement priorities. This selection process can also be used to prioritize harmonization opportunities for multiple mitigation activities simultaneously, including non-AFOLU sector mitigation projects that might be occurring as well.

[9] For example, if a country commits to reducing GHG emissions from deforestation as the primary means by which they are to meet their NDC target, harmonization activities in this area may be a higher priority.

Step 6: Implement and Harmonize

The implementation of harmonization improvements in the AFOLU sector may take many forms, and may require other stakeholders than those engaged in Steps 1 through 5. This process will ultimately be country-specific, and will require implementers to:

- Determine resources, roles, and responsibilities for implementing improvements.
- Work with national inventory compilers, source category leads, and other inventory stakeholders throughout the inventory development process to incorporate the identified priority harmonization opportunities into a future national inventory cycle or into the Inventory Improvement Plan.
- Create or modify existing mitigation activity MRV requirements to better align mitigation reporting with national inventories.

After harmonization opportunities have been identified, inventory teams will have additional information that can be used to improve the transparency of their inventory. A low-cost option for applying the findings of the harmonization exercise is to document the findings by describing the methodology, data sources, uncertainty, or planned improvements for the source categories examined.

Step 6 is not unique to the AFOLU sector, but it is essential to the success of the Harmonization Framework. As with other sectors, developing a sustainable approach to implement the harmonization opportunities in previous steps can help stakeholders to continuously enhance the transparency of GHG accounting for and between national GHG inventories and mitigation accounting.

After completing *Step 6*, users have:

- Engaged stakeholders and determined resources, roles, and responsibilities for implementing harmonization improvements that align MRV methods with national emission inventories.
- Implemented prioritized harmonization improvements.

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Annex A: Helpful Resources

Table 14: Top-Down Documentation and Associated Data Elements for Livestock Mitigation Activities

Documentation	Activity Data/Data Source	Data Element	Country Example
National statistics and other information from the ministries of agriculture	Agricultural or livestock census	Animal population/sub-populations	
	Number of young females (to determine proportion pregnant)	Gross energy intake	
	National breed registry	Animal population/sub-populations	
	Slaughter data (to estimate live weight values and trends)	Gross energy intake	
	Milk yield data, either national or sub-national	Gross energy intake	
	Proportion of cows pregnant	Gross energy intake	
	National feed tables	Gross energy intake	
	Surveys on manure management systems or incorporating question into regular surveys	Fraction of manure in manure management systems	
Expert judgment	Changes to breed composition of herd	Animal population/sub-populations	Hungary
	Updates to weight estimates over time	Gross energy intake	
	Milk yield by breed over time	Gross energy intake	
	Annual surveys of nutrition experts to determine feed digestibility	Gross energy intake	
	Structured surveys to experts on manure management systems	Fraction of manure in manure management systems	
	Manure management systems, to supplement surveys (e.g., align manure management categories collected in surveys to IPCC categories)	Fraction of manure in manure management systems	

Documentation	Activity Data/Data Source	Data Element	Country Example
Commissioned Studies	Updates to weight estimates over time	Gross energy intake	
	Feed digestibility study combined with expert judgment on typical diets	Gross energy intake	
	Direct measurement studies of Y_m to validate value determined by models	Y_m	Belgium, France
	Direct measurement of methane emission factors from manure management	B_0 and MCF	Japan
	Commissioned study on manure management systems		
Literature	Average weight for each breed within the herd, then combine with population data from national breed registry	Gross energy intake	Estonia
	Scientific publications on feed digestibility	Gross energy intake	
	Published literature on Y_m	Y_m	
	Published literature on B_0 and MCF	B_0 and MCF	
Equations or models[a]	Relationship between milk yield and live weight	Gross energy intake	Slovenia
	Country-specific energy balance model for feed digestibility	Gross energy intake	
	Model of herd dynamics	Animal population/sub-populations	Georgia
	Equation relating Y_m to milk yield and type of diet; data available from cattle recording database	Y_m	Norway
	Model based on feed chemical composition	Y_m	Denmark, Colombia, United States
	Model of rumen processes	Y_m	Netherlands
	IPCC model for estimating Bo and MCF	B_0 and MCF	

[a] While some models were developed specifically for GHG inventories, most were developed for feed evaluation and provision of farm advisory services.

Source: GRA and CCAFS (2019). MRV Platform for Agriculture.

Table 15: Bottom-Up Standards and Organizations Providing Emission Reduction and MRV Guidance

Organization	Specific Standards for AFOLU Projects	Applicable Mitigation Activities
Livestock Management		
Alberta Carbon Offset Program	Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle	• Improved diets
American Carbon Registry	Methodology for Grazing Land and Livestock Management, Version 1.0	• Improved diets • Livestock waste management • Rotational grazing • Agroforestry
Carbon Farming Initiative	Beef Cattle Herd Management, Methodology Determination 2015	• Improved diets • Herd composition management
Clean Development Mechanism	ACM0010: GHG Emission Reductions from Manure Management Systems, Version 8.0	• Livestock waste management
The Gold Standard	Smallholder Dairy Methodology, Version 0.9	• Improved diets
The Gold Standard	Reducing Methane Emissions from Enteric Fermentation in Dairy Cows Through Application of Feed Supplements, Version 0.9	• Improved diets
Cropland Management		
American Carbon Registry	Methodology for Quantifying Nitrous Oxide (N2O) Emissions Reductions from Reduced Use of Nitrogen Fertilizer on Agricultural Crops, Version 1.0	• Improved nutrient management • Crop rotation • Cover crops
American Carbon Registry	Changes in Fertilizer Management (Version 2.0)	• Improved nutrient management
American Carbon Registry	Emission Reductions in Rice Management Systems, Version 1.0	• Alternate wetting and drying fields during rice cultivation
Climate Action Reserve	Nitrogen Management Project Protocol, Version 2.0	• Improved nutrient management
Climate Action Reserve	Rice Cultivation Project Protocol, Version 1.1	• Water and residue management in rice cultivation
Clean Development Mechanism	AMS-III.AU.: Methane Emission Reduction by Adjusted Water Management Practice in Rice Cultivation, Version 4.0	• Alternate wetting and drying fields during rice cultivation
The Gold Standard	Increasing Soil Carbon Through Improved Tillage Practices, Version 0.9	• Conservation/no tillage
Verified Carbon Standard	VM0017: Adoption of Sustainable Agricultural Land Management, Version 1	• Improved nutrient management • Cover crops • Reduced crop residue burning
Verified Carbon Standard	VM0022: Quantifying N2O Emissions Reductions in U.S. Agricultural Crops through N Fertilizer Rate Reduction	• Improved nutrient management

Organization	Specific Standards for AFOLU Projects	Applicable Mitigation Activities
Grassland Management		
American Carbon Registry	Avoided Conversion of Grasslands and Shrublands to Crop Production, Version 1.0	Alternate wetting and drying fields during rice cultivation
Climate Action Reserve	Grassland Project Protocol, Version 2.0	Conservation/no tillage
Clean Development Mechanism	AR-ACM0003: Afforestation and Reforestation of Lands except Wetlands, Version 2.0	Improved nutrient management Cover crops Reduced crop residue burning
Verified Carbon Standard	VM0026: Sustainable Grassland Management, Version 1.0	Improved nutrient management
Forest Management		
Climate Action Reserve	Forest Project Protocol, Version 4.0	Improved forest management
Clean Development Mechanism	AR-ACM0003: Afforestation and Reforestation of Lands except Wetlands, Version 2.0	Afforestation and reforestation
Clean Development Mechanism	A/R Tool08: Estimation of Non-CO2 GHG Emissions Resulting from Burning of Biomass Attributable to an A/R CDM Project Activity, Version 4.0.0	Forest fire management
Wetlands Management		
Verified Carbon Standard	VMD0046: Methods for monitoring of soil carbon stock changes and GHGs and removals in peatland rewetting and conservation project activities	Wetlands restoration
IPCC 2013 Supplement	Chapter 3: Rewetting inland organic soils; Chapter 4: Restoration of coastal wetlands; Chapter 5: Restoration and creation of wetlands on mineral soils	Wetlands restoration
Verified Carbon Standard	Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions in Tidal Wetland Restoration and Conservation Project Activities	Avoided wetlands conversion
Settlements Management		
Climate Action Reserve	Urban Tree Planting Project Protocol, Version 2.0	Urban tree planting
Climate Action Reserve	Urban Forest Management Project Protocol, Version 1.0	Improved urban forest management
Clean Development Mechanism	AR-ACM0003: Afforestation and Reforestation of Lands except Wetlands, Version 2.0	Urban tree planting
Bioenergy		
Clean Development Mechanism	ACM0010: GHG Emission Reductions from Manure Management Systems, Version 8.0	Anaerobic digesters
Clean Development Mechanism	AMS-III.D.: Methane Recovery in Animal Manure Management Systems, Version 21.0	Anaerobic digesters
Climate Action Reserve	U.S. Livestock Project Protocol (biogas/methane digesters), Version 4.0	Anaerobic digesters

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