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Measurement, reporting and verification of livestock GHG emissions by developing countries in the UNFCCC: current practices and opportunities for improvement

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Front cover photo

Neil Palmer (CIAT). Improved forages in Dak Lak province, in the central highlands of Vietnam.

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Abbreviations and acronyms

AFD	Agence Française de Développement
AFOLU	agriculture, forestry and other land use
APA	Ad Hoc Working Group on the Paris Agreement
BAU	business as usual
BUR	biennial update report
CCAFS	Climate Change, Agriculture and Food Security Program of the CGIAR
CDM	Clean Development Mechanism
CGE	Consultative Group of Experts
CH_4	methane
CO_2e	carbon dioxide equivalent
COP	Conference of Parties to the UNFCCC
CSC	Climate Science Centre, Ethiopia
DCC	Department of Climate Change, Chile
DMI	dry matter intake
DMP	Dairy Master Plan, Kenya
EBRD	European Bank for Reconstruction and Development
ETF	Enhanced Transparency Framework (agreed under the Paris Agreement, 2015)
FAO	Food and Agriculture Organization of the UN
FREL	forest reference emission level
FSV	facilitative sharing of views
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GLEAM	Global Livestock Environment Assessment Model
GPG	good practice guidance
GRA	Global Research Alliance on Agricultural Greenhouse Gases
IAE	Institute for Agricultural Environment of the Vietnam Academy of Agricultural Sciences
ICA	International Consultation and Analysis
IFI	international finance institutions
INDC	intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change
KPI	key performance indicator
LCA	life cycle analysis
LDCs	least developed countries
LULUCF	land use, land use change and forestry
M&E	monitoring and evaluation
MCF	methane conversion factor

MEFCC	Ministry of Environment, Forest and Climate Change, Ethiopia
MIS	management information system
MRV	measurement, reporting and verification
N_2O	nitrous oxide
NAMA	nationally appropriate mitigation action
NC	national communication
NDC	nationally determined contribution
NGO	non-government organization
NIR	national inventory report
NSP	NAMA support project
REDD+	reducing emissions from deforestation and degradation
SBI	Subsidiary Body for Implementation
SDG	sustainable development goals
SEEA	System of Economic-Environmental Accounting
SIDS	small island developing states
SINAMECC	National Metrics System for Climate Change, Costa Rica
SINIA	National Environmental Information System, Costa Rica
TTE	Team of Technical Experts
UK	United Kingdom
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Summary

This report gives an overview of current practices, challenges and opportunities in the measurement, reporting and verification (MRV) of livestock greenhouse gas (GHG) emissions and emission reductions by developing countries in the context of the United Nations Framework Convention on Climate Change (UNFCCC). MRV of livestock GHG emissions is relevant because (i) livestock production makes a significant contribution to global GHG emissions; (ii) livestock GHG emissions have been contributing an increasing share of agricultural emissions over time; and (iii) better characterization of livestock GHG emissions can assist policy makers to target and design efforts to mitigate GHG emissions. As national climate change mitigation policies increasingly focus on GHG reduction targets in Nationally Determined Contributions (NDCs), this report assesses the extent to which current MRV practices are able to meet the evolving policy needs. The report describes MRV obligations under the UNFCCC (Chapter 2), current practices in compiling and reporting livestock GHG emissions through national GHG inventories (Chapter 3) and MRV of mitigation actions (Chapter 4), and highlights opportunities for improvement (Chapter 5).

MRV in the UNFCCC

Developing countries are currently required to submit national GHG inventory reports to the UNFCCC. This is mostly done through the inventory section of National Communications (every four years, with flexibility for countries that need it) and Biennial Update Reports (every two years, with flexibility). Inventory reports should be compiled using methods set out in the *Revised IPCC 1996 Guidelines for National GHG Inventories*, but may also be compiled using methods set out in the I*PCC 2006 Guidelines*. Countries should also report on mitigation actions, giving information on methodologies "to the extent possible". The Paris Agreement adds the obligation to maintain, update and account for NDCs. Specific modalities and procedures for this are still being negotiated.

While the UNFCCC requirements and IPCC guidance on MRV provide an overarching framework, they leave considerable flexibility for countries to decide how to meet these reporting requirements. While this creates the opportunity for MRV practices to serve not only UNFCCC requirements, but also national policy objectives, it also presents challenges for compatibility between different components of national and sub-national MRV systems.

Current MRV practices

Livestock GHG inventories: National GHG inventories are a key MRV tool for all countries. Many countries are also seeking to link MRV of specific mitigation actions with national GHG inventories to measure and report on progress in relation to NDCs. The diversity of current practices used to maintain the completeness, consistency, accuracy and transparency of national GHG inventories for livestock GHG emissions is described. A key finding is that 119 out of 140 developing countries assessed use a Tier 1 approach – which uses regionally determined fixed values for GHG emissions per head of livestock – to estimate all livestock GHG emissions and only 21 countries used a Tier 2 approach – which use national or sub-national data – to estimate some or all livestock GHG emissions. Only five of the countries using Tier 2 approaches regularly update emission factors based on changes in management or productivity, or have updated emission factors between submissions. Yet, Tier 1 approaches do not reflect changes in animal production and productivity, and thus are not suitable for measuring the effects of change in the livestock sector or specific mitigation actions on GHG emissions. Even Tier 2 emission factors only capture these changes if they are updated regularly. Although some countries have adopted country- or system-specific Tier 2 emission factors, these are often not updated and therefore cannot reflect changes in livestock production and productivity and associated GHG emissions over time. Reports by 10 developing countries suggest that the uncertainty associated with emission factors is higher than that associated with activity data, but compared to developed countries, reducing the uncertainty of activity data provides a bigger opportunity to reduce overall uncertainty of livestock emission estimates.

MRV of mitigation actions: In communications to the UNFCCC, more than half of developing countries recognized the potential for mitigation of livestock-related GHG emissions, with 55 mentioning manure management and 43 mentioning enteric fermentation emissions. However, few countries have developed specific

policies or plans. Forty-eight developing countries included livestock-related emissions in the scope of their INDC, with 35 mentioning enteric fermentation, 19 mentioning manure emissions or biogas mitigation measures, and 24 mentioning grasslands, pastures or silvopastoral systems. Only 11 of these identified policies and measures to implement these intentions.

Most countries are still developing potential livestock-related mitigation actions, and MRV systems are still under development. Rather than highlight specific 'good practices', this report maps the policy, institutional and technical issues that stakeholders are considering in the design of MRV systems:

Policy and institutional issues:

- Linking the design of MRV systems to policy goals and mechanisms.
- Whether and how to align MRV of mitigation actions with national GHG inventories, including the relationship between inventories and baselines, integrating higher resolution data from MRV of mitigation actions with existing inventory data, aligning with other accounting standards and donor needs, needs for conservativeness, and how to reflect change in multiple sinks and sources in the inventory. Not all countries have decided to link MRV of mitigation actions with the national GHG inventory.
- How to integrate information management systems among government agencies, between governments and the private sector (including finance sector), between project-level and national-level MRV, and between international and national institutions, including building on existing statistical surveys and data sources.
- Measuring and reporting non-GHG benefits of mitigation actions.
- How to improve MRV over time based on country resources and capabilities.

Technical issues:

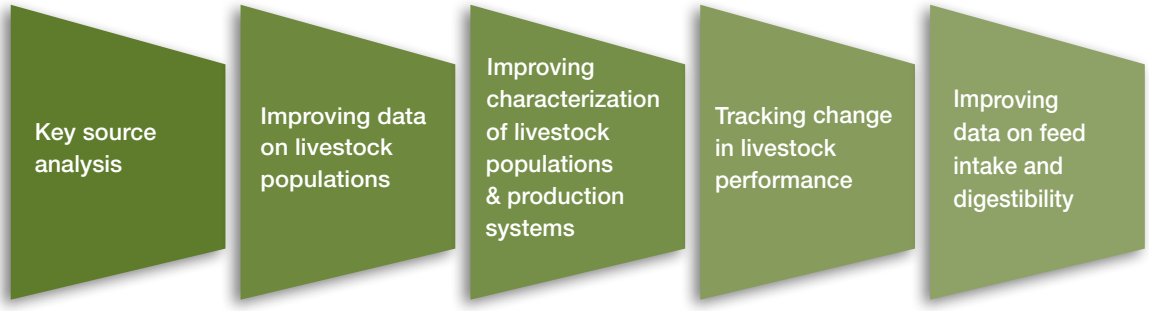
- Determining the scope of GHG sinks and sources affected by livestock mitigation actions.
- Setting baselines for mitigation actions.
- Improving emission factors and activity data, and the relative importance of inventory improvements to make more accurate estimates of emissions in a given year versus improving the accuracy of the trend in emissions over time, especially if productivity in the sector is changing.
- Levels of feasible accuracy and acceptable uncertainty, and their change over time.
- Other features of MRV systems that give credibility to emission-reduction claims (e.g. quality assurance and quality control, links with carbon offset standards).

There are no uniform institutional and technical requirements for MRV systems. Each country, according to its specific context, is considering suitable solutions out of a range of options defined by these policy, institutional and technical issues. Future harmonization of MRV between countries would increase comparability and opportunities for mutual learning, but would leave less room for countries to respond to national conditions.

Opportunities for improvement

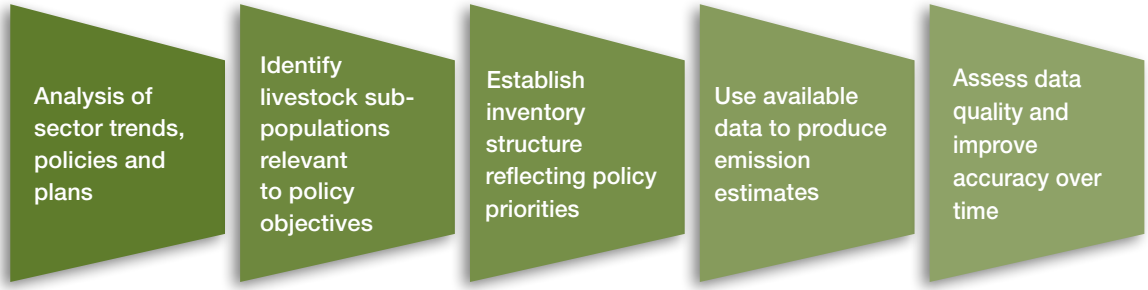
GHG inventory improvement: Priorities and options for inventory improvement vary depending on a country's policy objectives. Where countries see the national inventory mainly serving UNFCCC reporting obligations and value accuracy of reporting, moving to a Tier 2 approach can improve the accuracy of livestock emission estimates, including emissions trends, especially where productivity changes over time. Priorities for inventory improvement are likely to be analysis of which livestock emission sources are significant in the national inventory (i.e. key source analysis), followed (in order of priority) by improvements in data on livestock populations, improved characterization of production systems and livestock sub-populations, livestock productivity, and feed intake and digestibility estimates for key emission sources in the inventory.

Stylized strategy for improving the accuracy of livestock GHG estimates for national GHG inventory reporting



Where GHG inventories serve primarily the function of measurement and reporting on the effects of mitigation actions, and seek to capture the impacts of mitigation, Tier 2 approaches that are able to capture on-going changes in livestock productivity will be necessary to measure the reductions in livestock GHG emissions or emission intensity. The ability to estimate trends in GHG emissions will be the most important characteristic of such improved GHG inventories, as the priority is to capture changes in emissions, not an accurate level of emissions in any given year. Inventory improvements could focus on livestock sub-populations relevant to mitigation practices, establishing an inventory structure that uses livestock productivity data to enable tracking of trends in emissions, with improvements in data quality and accuracy over time.

Stylized strategy for improving the accuracy of livestock GHG emission trends through national GHG inventories



Both of these inventory improvement strategies can be implemented in a manner consistent with the IPCC Guidelines. While policy objectives may determine the fit between inventory methods and users' needs, weak linkages between different policy agencies and between inventory compilation processes and national data providers, and lack of funding for inventory improvement are key practical constraints. Involving key stakeholders in discussions on inventory improvements may increase their awareness of the value of inventory improvements, and enable better targeting of resources to improvements that serve policy goals.

Improving MRV of mitigation actions: For those countries that have decided to measure and report the GHG effects of mitigation actions through the national GHG inventory, improvements to enable the national GHG inventory to reflect trends in livestock-related GHG emissions will be the key focus. Most countries actively developing livestock mitigation actions are still designing their MRV systems. Each country has made progress on different aspects of MRV design, and there will be no 'one size fits all' solution applicable to all situations. There is strong demand for learning from other countries' experience, including in some cases from developed countries where livestock systems and management practices may be relevant, by documenting and making available case studies on specific topics and through regional and inter-regional networking.

Recommendations for supporting MRV improvement

In addition to specific recommendations to assist developing countries to identify initial steps on the path to continuous improvement of their MRV systems (see Chapter 6), developing countries and their international partners can support improvements in MRV through the following actions:

- **Improving national GHG inventories**

(a) Policies, institutions and supporting conditions:

- Analyse how improvements in inventories and other MRV systems can help (and may be necessary for) countries (and stakeholders within those countries) to meet their climate and sustainable development policy goals.
- Share examples of how countries are improving national MRV system, especially how improvements in components support overall performance.
- Enable regional sharing of experiences on MRV improvement.
- Assess whether enhanced reporting formats (either as voluntary guidance or within the Enhanced Transparency Framework) could increase the transparency of developing country inventory reporting while providing flexibility in the light of capacities and resources.
- Provide resources to build countries' capacities for inventory compilation, including institutional arrangements that facilitate collaboration and information flows, political and scientific engagement, human resources and technical capacities, and financial resources in line with the needs for increased transparency.

(b) Methods:

- Review current Tier 2 approaches adopted by developed and developing countries to clarify how different methodological approaches have evolved over time and to understand the interaction between policy goals, MRV design and specific data needs.
- Compare methods for data collection on livestock populations, herd structure, feed intake, livestock performance and other parameters to guide the choice of reliable and cost-effective methods, including alternative methods to 'gold standard' methods.
- Assess the potential for countries to use research results from similar production systems in other countries, so that not all countries need to undertake original research for all parameters in the Tier 2 approach.
- Provide guidance on uncertainty analysis, transparency and QA/QC, including how to deal with data gaps and mixed data sources, and their relevance for different policy objectives.
- Document and share case studies of the approaches, including institutional arrangements, used by different countries to compile and improve their national GHG inventories.

- **Improving MRV of mitigation actions**
  - Provide guidance on good practices in baseline and mitigation scenario analysis for NDCs and specific mitigation actions.
  - Provide guidelines with principles, practical advice and best practices for MRV of livestock-related mitigation actions, acknowledging the need for countries to have flexibility to design systems best suited to their contexts and capabilities.
  - Further develop available assessment tools for estimating emissions to improve software capabilities and transparency for use in national decision-making.
  - Provide guidance on uncertainty analysis in the estimation of emission reductions.
  - Develop principles for credible MRV practices based on input from country experts and users of MRV information about what is considered widely acceptable.
  - Support piloting and testing of MRV systems at the national and sub-national levels.
  - Share case studies and examples of approaches (including institutional arrangements) and methods used in MRV at different levels (national, sub-national, project).
  - Enable regional and inter-regional exchange on MRV of livestock-related mitigation actions.

1. Introduction

Key messages

- Livestock GHG emissions account for a significant proportion of total GHG emissions in many developing countries, and are expected to increase in the coming decades.
- Capturing the effects of mitigation actions related to productivity improvements in the livestock sector requires adoption of more complex methodologies to estimate GHG emissions.
- Policy attention to livestock sector GHG mitigation – as reflected in NDCs, NAMAs and other mitigation policies and actions – is creating political demand for credible measurement, reporting and verification (MRV) of livestock GHG emissions and emission reductions.

Data from 137 developing countries suggest that enteric fermentation and manure management together account for about 9.2% of their total GHG emissions.

The focus of this report is on the measurement, reporting and verification (MRV) of livestock greenhouse gas (GHG) emissions and emission reductions by developing countries and countries with economies in transition[1] in the context of the United Nations Framework Convention on Climate Change (UNFCCC). There are several reasons why a better understanding is needed of MRV of livestock GHG emissions and emission reductions.

First, livestock production contributes significantly to anthropogenic GHG emissions (Text Box 1). Given the relatively greater importance of the agriculture sector in many developing countries, livestock-related emissions account for a greater proportion of total GHG emissions in many developing countries. The main livestock emission sources are enteric fermentation, manure management and deposit of dung and urine on pasture. Further livestock-related emissions include emissions in feed production, emissions and removals from grassland vegetation and soils and from vegetation in silvopastoral systems, and energy emissions affected by bioenergy production from livestock-related waste. Data from 137 developing countries suggest that enteric fermentation and manure management together[2] account for about 9.2% of their total GHG emissions. However, these two emission sources exceed 20% of total GHG emissions in 48 countries (i.e. 35% of 137 countries), and exceed 5% of total GHG emissions in 95 countries (i.e. 69% of 137 countries) (see Appendix 1 for details).

Text Box 1

The contribution of livestock to global GHG emissions

Based on a life-cycle analysis, livestock production has been estimated to have emitted 7.1 gigatonnes of carbon dioxide equivalent (CO_2e) in 2005, equivalent to about 14.5% of anthropogenic GHG emissions. Of this, about 39% is emitted in the form of methane from enteric fermentation by ruminant livestock, 9.5% in the form of methane and nitrous oxide from manure management, and 16.4% in the form of nitrous oxide from manure applied to cropland and dung and urine deposited on pasture. Other emissions related to livestock include energy use in livestock supply chains, GHG emissions in feed production, and emissions from land use change attributable to livestock production. Among different livestock species, cattle are responsible for about 65% of total livestock sector emissions.

Source: Gerber et al. (2013)

[1] In the remainder of this report, we use the term 'developing countries' to cover both developing countries and countries with economies in transition. This report refers to 'countries' rather than 'parties', while recognizing that some parties to the UNFCCC (e.g. the European Union) are not countries. Prior to the Paris Agreement of 2015, developing countries were referred to as 'non-Annex 1' parties, and developed countries as 'Annex 1' parties. Except where quoting from UNFCCC documents, this report refers to 'developing' and 'developed' countries.

[2] But excluding dung and urine deposited on pasture, which is reported together with other activities causing N_2O emissions from agricultural soils.

Second, livestock GHG emissions have been contributing an increasing share of agricultural emissions over time.[3] While total GHG emissions from livestock production in developed countries as a whole have declined in recent decades, emissions from cattle, pigs and small ruminants in developing countries have increased significantly.[4] Further growth in production and consumption of livestock products is projected in developing countries in the coming decades, with the highest increase in total and per capita consumption projected to occur in low and lower middle income countries.[5] Although some increase in demand will be met by trade with developed countries, GHG emissions from livestock production in developing countries can be expected to continue to increase. Despite the increase in total emissions from livestock production in developing countries, GHG emission intensity (tCO_2e per tonne of livestock product) has been decreasing.[6] Increases in the efficiency of livestock production – whether through transformation of livestock production systems or through incremental improvements within production systems – are therefore an important way to meet increasing demand for livestock products while limiting impact on the global climate system.[7]

Tier 2 methodologies are better able to capture the effects of changes in livestock management, but only 21 out of 140 developing countries have adopted a Tier 2 approach to some or all livestock emission sources.

From a technical perspective, measuring the effects of changes in livestock management practices on GHG emissions requires adoption of more complex methodologies to estimate emissions. Guidance from the Intergovernmental Panel on Climate Change (IPCC) for national GHG inventory compilation and reporting provides several methodological options for estimating livestock GHG emissions. Tier 1 methodologies use fixed values for GHG emissions per head of livestock, so changes in total emissions are responsive only to changes in livestock populations. Tier 2 methodologies, which require enhanced classification of different types of livestock and data on livestock weight, weight gain, feed digestibility and other factors, are better able to capture the effects of changes in management on GHG emissions. However, as is shown in Chapter 3 of this report, only 21 out of 140 developing countries reporting livestock emissions to the UNFCCC have applied Tier 2 methodologies to some or all livestock GHG emission sources. And only five countries report using a Tier 2 approach that can capture changes over time in productivity and efficiency of livestock systems in their reporting to the UNFCCC. A better understanding of barriers to adopting Tier 2 methodologies, enabling factors, and data management practices that are suited to developing countries' national conditions while adhering to IPCC good practice guidance can contribute to targeting support and capacity building activities. However, accurate measurement is only one aspect of MRV requirements under the UNFCCC. Chapter 3 also addresses other aspects of MRV through national GHG inventories reported to the UNFCCC, including completeness, consistency, comparability and transparency. Methods for adhering to these principles are likely to become more important as the Enhanced Transparency Framework (ETF) agreed in the Paris Agreement (2015) develops.

Only 5 countries report using a Tier 2 approach that can capture changes over time in productivity and efficiency of livestock systems in their reporting to the UNFCCC.

From a policy perspective, better characterization of livestock GHG emissions can assist policy makers to target and design efforts to mitigate GHG emissions. As discussed in Chapter 4 of this report, a number of developing countries have identified the relevance of the livestock sector for mitigation of national GHG emissions, and have included livestock emissions in the scope of their Intended Nationally Determined Contributions (NDCs) to mitigate climate change in response to the Paris Agreement.[9] Some have developed or are in the process of developing specific mitigation policies and measures, such as Nationally Appropriate Mitigation Actions (NAMAs),[10] often motivated by the potential for securing domestic and international climate finance. While this policy attention provides opportunities to address livestock GHG emissions, it also presents challenges for the MRV of the resulting emission reductions. Emission reduction targets presented in INDCs take a variety of forms. Few countries have established national GHG inventory processes capable of reflecting the effects of livestock GHG mitigation actions over time. Beyond climate

[3] Tubiello et al. (2015), Caro et al. (2014).
[4] Caro et al. (2014).
[5] Robinson and Pozzi (2011).
[6] Caro et al. (2014).
[7] Gerber et al. (2013), Havlík et al. (2014).
[8] IPCC (1996), IPCC (2006)
[9] At the time of research for this study, most countries had submitted INDCs, but not subsequent NDCs.
[10] Van Dijk et al. (2015).

policy and finance, improved MRV systems may also bring benefits for decision-making and reporting in other policy domains, such as agriculture, rural development and environment. How improved MRV of mitigation actions in the livestock sector relates to these multiple policy goals varies significantly between countries. For example, Uruguay's investment in improving MRV of emissions from the national beef herd is driven in part by the sector's important role in national agricultural and trade policy.[11]

MRV of livestock emissions supports policy goals beyond meeting UNFCCC obligations.

One key issue is whether current livestock GHG emission MRV practices are appropriate in a context of rising livestock productivity and concern about food security on the one hand, and countries' commitment to measure progress in reducing GHG emissions through NDCs and specific mitigation actions, on the other. Rising livestock productivity has been a global trend.[12] In developing countries, average slaughter yield for cattle has increased by more than 15% between 1974 and 2014, while in developed countries it has increased by about 28%.[13] Average milk yields have increased by about 70% and 100% in developing and developed countries, respectively, over this period. Among 48 developing countries that included livestock in the scope of their INDCs, average annual growth rates in cattle slaughter yield and milk yield in the last decade were almost twice as high as for developing countries as a whole (i.e. 0.55% per year compared to 0.28% for slaughter yield and 0.20% per year compared to 0.11% for milk yield). Considering also that specific mitigation actions are more likely to target sub-sectors and regions where GHG mitigation has strong synergies with profitability for producers, the relevance of MRV systems that capture the effects of productivity gains on GHG emissions and mitigation objectives is clear.

The purpose of this report is to give an overview of the current (2016) state of MRV systems for livestock GHG emissions, and to highlight opportunities for improved implementation of MRV systems to support low-income countries to meet their national and sub-national goals for mitigation in the livestock sector. While the focus is on identifying improvements that are immediately feasible in developing countries, lessons are also drawn from MRV practices in developed countries, many of which have moved towards improved MRV systems in recent years. The report is structured as follows. Chapter 2 summarizes the main internationally agreed obligations for developing countries under the UNFCCC with respect to MRV, and key features of existing guidance on the conduct of MRV. Chapter 3 gives an overview of current practices in MRV through national GHG inventories, and assesses the quality of livestock GHG emission reporting by developing countries to the UNFCCC. It highlights strategies and options for improving livestock GHG measurement and reporting through national GHG inventories. Chapter 4 gives an overview of current practices in MRV of livestock sector mitigation actions. Most ongoing livestock MRV initiatives are still under development. The chapter highlights key dimensions that countries are considering as they move forward. The final chapter summarizes the main issues faced in improving current practices and progressing in the development of further approaches to MRV of livestock GHG emissions. It presents recommendations both for developing countries and for international actors working to support capacity development for MRV of livestock GHG emissions and mitigation actions. The analysis presented in this report is intended to assist developing countries to identify strategies and practices for improved MRV of livestock GHG emissions and emission reductions and to highlight key entry points for support from international partners.

[11] Oyhantçabal (2016).
[12] Thornton (2010).
[13] FAOSTAT, data not shown.

2. The framework and requirements for MRV by developing countries in the UNFCCC

Key messages

- Guidelines for reporting of livestock GHG emissions have been agreed under the UNFCCC. Developing countries report these emissions through national GHG inventories, and summary reports in national communications (NCs) and biennial update reports (BURs).
- NCs are not subject to international verification. BURs are subject to technical analysis.
- Measurement of livestock GHG emissions in developing countries' national GHG inventories should follow *IPCC 1996 Revised Guidelines*. Use of more recent IPCC (2006) guidelines is optional.
- Mitigation actions are reported in NCs and BURs. Agreed guidance on the measurement and reporting of mitigation actions through NCs and BURs is limited and of a general nature, and provides considerable flexibility to developing countries in the design of measurement methodologies.
- The Paris Agreement agreed to establish an Enhanced Transparency Framework. This will largely be built on existing MRV mechanisms (e.g. national inventory reports, NCs, BURs). The most significant departure from the existing MRV framework will be the need to report progress on implementation and achievement of Nationally Determined Contributions (NDCs). Methods and procedures for this are still under development.
- UNFCCC and IPCC guidance gives considerable flexibility to developing countries. Flexibility is reflected in the use of terminology such as 'encourage', 'should' or 'may'; in the provision of tiered options for approaches to GHG quantification; and in the recognition that decisions affecting MRV should consider national circumstances (e.g. data availability, available resources, and capacities).

Agreements under the UNFCCC relating to MRV have evolved over time, and continue to be a focus of ongoing negotiations. This chapter summarizes the main internationally agreed obligations for developing countries with respect to MRV, and key features of existing guidance on the conduct of MRV. The scope of MRV refers not only to MRV of GHG emissions and the effects of mitigation actions, but also to adaptation and support received by developing countries (Text Box 2). While recognizing that these topics are of high importance to developing countries, the focus of this report is on MRV of GHG emissions and mitigation actions.

The Paris Agreement (2015) commits to establish an enhanced transparency framework for climate action and support in order to provide a clear understanding of mitigation actions, track progress towards NDCs and inform a global stocktake to be undertaken every five years. While the ETF will build on existing transparency mechanisms under the UNFCCC, specific modalities, procedures and guidelines are being developed by the Ad Hoc Working Group on the Paris Agreement (APA) for presentation at COP 24 (2018). Section 2.1 outlines existing agreements on reporting and verification under the UNFCCC. The main implications of the Paris Agreement for MRV are discussed in Section 2.2. Section 2.3 describes UNFCCC requirements for measurement of GHG emissions and emission reductions.

2.1 Reporting and verification requirements for developing countries prior to the Paris Agreement

2.1.1 Reporting on GHG emissions

The UNFCCC obliges all Parties to report information on their GHG emissions to the Conference of the Parties (COP), and on the steps taken to implement the Convention.[14] This is done through National Communications (NCs). COP 8 (2002) adopted revised guidelines for the preparation of NCs.[15] COP 16 (2010) agreed that developing countries should submit NCs every four years, and that a Biennial Update Report (BUR) should be submitted every two years.[16] By contrast, developed countries are required to submit NCs every four years, a biennial report every two years and a national GHG inventory annually (Table 1).[17]

Guidelines for NCs[18] indicate that NCs should report information on a number of topics, including the national GHG inventory and information on policies, programmes or other steps implemented or planned to mitigate climate change. Developing countries are also encouraged to report information on institutions and procedures for the establishment of a regular national GHG inventory process, and on efforts undertaken to develop emission factors and activity data.

Biennial Update Reports (BURs)[19] should include updates to the most recent NC in areas including the national GHG inventory, mitigation actions and their effects, and domestic arrangements for MRV (Text Box 4). The national GHG inventory section of the BUR should consist of a national inventory report "as a summary or as an update", including two overview tables required in the NC guidelines. Additional or supporting information, including sector-specific information, may be supplied in a technical annex.

Text Box 2

The Overview of MRV for developing countries prior to the Paris Agreement

Measurement (M) for developing countries applies both to efforts to address climate change and to the impacts of these efforts. It occurs at the national level and refers to GHG emissions, mitigation actions and their effects, and the support needed and received.

Reporting (R) for developing countries is implemented through the national communications and Biennial Update Reports (BURs), where countries report on their actions to address climate change in their national communications.

Verification (V) is addressed at the international level, through International Consultation and Analysis of BURs. It can also occur at the national level, but this is voluntary.

Source: http://unfccc.int/national_reports/non-annex_i_natcom/items/2716.php

Table 1: Overview of reporting requirements for developed and developing countries

Developed countries	Developing countries
National Communication every 4 years	National Communication every 4 years, with flexibility
Biennial Report every 2 years	Biennial Update Report, every 2 years, with flexibility
National GHG Inventory annually	

[14] UNFCCC Article 4, paragraph 1, and Article 12, paragraph 1.
[15] Decision 17/CP.8.
[16] Annex III of Decision 2/CP.17.
[17] Decision 4/CP.5, decision 2/CP.17 (Annex I) and Decision 24/CP.19.
[18] Decision 17/CP.8.
[19] Annex III of Decision 2/CP.17.

2.1.2 Reporting on mitigation actions

Reflecting in part the evolution of the UNFCCC negotiations, there are some differences in reporting requirements for mitigation actions between the requirements and guidelines for NCs and for BURs. The NC guidelines provide general guidance on reporting relating to mitigation actions:

Based on national circumstances, non-Annex I Parties are encouraged to provide, to the extent their capacities allow, information on programmes and measures implemented or planned which contribute to mitigating climate change…including, as appropriate, relevant information by key sectors on methodologies, scenarios, results, measures and institutional arrangements.[20]

The BUR guidelines are more explicit on the information that must be reported for mitigation actions (Text Box 5).

Text Box 3

The main contents of National Communications

Guidelines highlight that national communications shall include:

"(f) A national inventory of anthropogenic emissions by sources and removal by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties;

(g) A general description of steps taken or envisaged by the non-Annex I Party to implement the Convention;

(h) Any other information that the non-Annex I Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends."

Source: Annex to Decision 17/CP.8.

Text Box 4

The main contents of Biennial Update Reports

Biennial update reports provide an update to the most recently submitted national communication in the following areas:

(a) Information on national circumstances and institutional arrangements relevant to the preparation of the national communications on a continuous basis;

(b) The national inventory of anthropogenic emissions by sources and removal by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol, including a national inventory report;

(c) Information on mitigation actions and their effects, including associated methodologies and assumptions;

(d) Constraints and gaps, and related financial, technical and capacity needs, including a description of support needed and received;

(e) Information on the level of support received to enable the preparation and submission of biennial update reports;

(f) Information on domestic measurement reporting and verification;

(g) Any other information that the non-Annex I Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its biennial update report.

Source: Annex III of Decision 2/CP.17.

[20] Decision 17/CP.8.

2.1.3 Verification processes

Verification of information in both NCs and BURs may be conducted domestically at national level before submission to the UNFCCC. NCs are not subject to international verification, but information from the NCs submitted by developing countries is compiled and synthesized by the UNFCCC Secretariat. The Consultative Group of Experts (CGE) provides technical support and advice to developing countries on the preparation of their NCs. This work involves analysis of NCs and recommendations for the improvement of NCs. These tasks are not, however, part of the formal verification framework under the UNFCCC.[21]

With regard to BURs, however, a verification framework has been agreed, which is referred to as International Consultation and Analysis (ICA). The aim of ICA is to increase the transparency of information reported in BURs, including information on mitigation actions and their effects. ICA is conducted through technical analysis of BURs by teams of technical experts (TTEs), followed by facilitative sharing of views (FSV) in a workshop convened by the Subsidiary Body for Implementation (SBI).[22]

2.2 Evolving MRV arrangements under the Paris Agreement[23]

Under the Paris Agreement (COP 21, 2015), both developed and developing countries agree to undertake and communicate their efforts to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.[24] Parties to the Agreement must submit Nationally Determined Contributions (NDCs), which are statements of intended reductions in GHG emissions that are to be updated every 5 years and that should reflect progressive ambition.

The Paris Agreement also commits to establish "an enhanced transparency framework (ETF) for action and support, with built-in flexibility which takes into account countries' different capacities."[25] The decision to establish the ETF represents a significant step in the further evolution of the MRV framework under the UNFCCC. The ETF will eventually supersede the existing modalities, procedures and guidelines for MRV.[26] In terms of GHG mitigation, the purpose of the ETF is to provide a clear understanding of

Text Box 5

Reporting on mitigation actions in BURs

"Developing country Parties shall provide the following information to the extent possible:

(a) Name and description of the mitigation action, including information on the nature of the action, coverage (i.e. sectors and gases), quantitative goals and progress indicators;

(b) Information on methodologies and assumptions;

(c) Objectives of the action and steps taken or envisaged to achieve that action;

(d) Information on the progress of implementation of the mitigation actions and the underlying steps taken or envisaged, and the results achieved, such as estimated outcomes (metrics depending on type of action) and estimated emission reductions, to the extent possible;

(e) Information on international market mechanisms.

13. Parties should provide information on the description of domestic measurement, reporting and verification arrangements."

Source: Annex III of Decision 2/CP.17.

[21] However, the mandate of the CGE will be reviewed in 2018 and may be revised in the light of the modalities and procedures decided under the ETF. See http://unfccc.int/files/meetings/marrakech_nov_2016/application/pdf/auv_cop22_i12_cge.pdf
[22] Annex IV of decision 2/CP.17 and the annex to decision 20/CP.19.
[23] This section draws on the Paris Agreement, Decision 2/CP.21, and Briner and Maorif (2016).
[24] UN (2015) Paris Agreement.
[25] Paris Agreement, Article 13.
[26] 1/CP.21, paragraph 98.

mitigation actions, to track progress towards NDCs, and to inform a global stocktake to be undertaken every 5 years to assess collective progress towards the objectives of the Paris Agreement. Modalities, procedures and guidelines for the ETF will be developed by the Ad Hoc Working Group on the Paris Agreement (APA) and presented for consideration at COP 24 (2018).

The Paris Agreement makes a new requirement for countries to maintain, update and account for their Nationally Determined Contributions.

In terms of reporting on GHGs and GHG mitigation for developing countries, the key provisions of the Paris Agreement are that:

- all Parties shall regularly submit national inventory reports and information on implementation and achievement of NDCs;[27]
- all Parties shall account for their NDCs;
- developing country parties should regularly communicate progress made on implementing capacity building plans, policies, actions or measures.[28]

Paragraph 2 of Article 4 of the Paris Agreement states that:

Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

These NDCs are currently communicated through a registry maintained by the UNFCCC Secretariat,[29] and the Subsidiary Body for Implementation (SBI) is undertaking work to develop modalities and procedures for operation and use of the registry. NDCs are to be updated every five years with the expectation that the level of ambition will increase over time.

There is a significant diversity among existing NDCs. For example, some specify targeted reductions in absolute emission levels, while others target reductions in GHG emission intensity (e.g. GHG per unit GDP); some are economy-wide targets, while others specify certain sectors only; baseline and target years also vary between countries.
There is little existing agreement on methods for measurement and reporting of progress in implementing these diverse forms of NDC.

In terms of verification, information on GHG inventories and on implementation and achievement of NDCs will be subject to technical expert review. While ICA of BURs submitted by developing countries only considers transparency, under the ETF implementation and achievement of NDCs by all countries will be subject to "facilitative, multilateral consideration", the modalities, procedures and guidelines for which have still to be developed under the APA. For those developing countries that need it in the light of their capacities, the review process shall include assistance in identifying capacity-building needs.[30]

The ETF will build on and enhance existing transparency arrangements under the UNFCCC, including NCs, BURs, and related verification processes. As with the current MRV framework, the ETF will contain some flexibility for developing countries "that need it in the light of their capacities".[31] While some provisions state what all countries are required to do, some provisions for developing countries indicate what they "should" or are "encouraged" to do, indicating flexibility in the stringency of requirements.

Table 2 summarizes the potential differences between the current MRV system for developing countries and the possible requirements of the ETF, bearing in mind that the APA has yet to present its recommendations. The most significant departure from the current MRV framework will be the need to report progress on implementation and achievement of NDCs. There is a significant diversity among existing NDCs. For example, some specify targeted reductions in absolute emission levels, while others target reductions in GHG emission intensity (e.g. GHG per unit GDP); some are economy-wide targets, while others specify certain sectors only; baseline and target years also vary between countries. There is little existing agreement on methods for measurement and reporting of progress in implementing these diverse forms of NDC. The Paris Agreement calls for "methodological consistency, including on baselines, between the communication and implementation of" NDCs and refers to "consistency between the methodology communicated in the NDCs and the methodology for reporting on progress made towards achieving NDCs". However, no further definition has been given of what consistency means.[32]

[27] Paris Agreement, Article 13.
[28] Paris Agreement, Article 11.4.
[29] http://unfccc.int/focus/ndc_registry/items/9433.php
[30] Paris Agreement, Article 13, paragraph 11.
[31] Paris Agreement, Article 13, paragraph 2.
[32] Briner and Maorif (2016)

Table 2: Summary of potential differences between the current MRV system for developing countries and possible requirements under the ETF

	Existing MRV system	Possible requirements under the ETF
GHG inventories	Biennially in BURs IPCC 1996 Revised guidelines No verification for developing countries	Developing countries to submit biennially (with flexibility for LDCs and SIDS) Same methodologies to be used by all countries
National Communications	Developing countries encouraged to submit every 4 years Guidelines for NCs Support from CGE	No specific provisions in Paris Agreement, but NC submission every 4 years may continue
Biennial reports	Guidelines for BURs BURs submitted biennially consistent with the level of support	BUR submissions with flexibility in scope, frequency and level of detail of reporting for developing countries that need it in the light of their capacities
Nationally determined contributions	-	All countries shall prepare, communicate, maintain and account for NDCs
Review or analysis	Analysis of BURs ICA, FSV for developing countries	All countries to participate in review and multilateral consideration of progress, with flexibility in scope for developing countries that need it

Source: adapted from Briner and Maorif (2016)

2.3 Measurement under the UNFCCC

While it is possible that there will be some evolution of GHG measurement requirements for developing countries under the ETF, there have been no substantive negotiations on this issue to date. This section therefore focuses on measurement requirements and guidelines under the current (2016) UNFCCC MRV system.[33]

2.3.1 Requirements for measurement of GHG emissions

UNFCCC MRV guidelines allow flexibility for countries in view of their capacities, data availability and support provided.

Guidelines for NCs for developing countries were agreed "to encourage the presentation of information in a consistent, transparent and comparable, as well as flexible, manner, taking into account specific national circumstances".[34] Guidelines for the preparation of NCs recommend that developing countries should use the *Revised 1996 IPCC Guidelines for National GHG Inventories* (IPCC 1996) for estimating and reporting their national GHG inventories, and *IPCC GPG and Uncertainty Management in National GHG Inventories* (IPCC 2000), "taking into account the need to improve transparency, consistency, comparability, completeness and accuracy in inventories".[35] The *Revised 1996 IPCC Guidelines* provide detailed instructions for the application of various methods for the estimation of GHG removals and emissions from sinks and sources across all sectors, and on reporting to the COP. The *IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories* (IPCC 2000) was issued to support "the development of inventories that are transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and assurance, efficient in the use of the resources available to inventory agencies, and in which uncertainties are gradually reduced as better information becomes

[33] Current guidelines for non-Annex 1 Parties' NCs mandates the use of *Revised IPCC 1996 Guidelines and IPCC (2000) GPG and Uncertainty Management in National GHG Inventories*. Future guidance may mandate the use of the 2006 IPCC Guidelines, which have already been adopted for use by Annex 1 Parties, but there have been no formal discussions to date on this.
[34] Decision 17/CP.8.
[35] Decision 17/CP.8.

available".[36] It provides detailed guidance for procedures that may be used in characterizing activity data and selecting emission factors, in the quantification of uncertainty in GHG inventories and in the analysis of key GHG sources, and provides guidance on quality control and quality assurance in GHG inventories.

BURs are intended as an update to NCs, providing more recent information than in the latest NC or a summary of parts of the NC if submitted in the same year as an NC.[37] Guidelines for preparation of BURs have considerable overlaps with the guidelines for NCs, and explicitly reference the NC guidelines related to measurement in national GHG inventories. Some requirements for BURs represent updates to the NC reporting requirements (e.g. developing countries are encouraged to use reporting tables from the *IPCC Good Practice Guidance for Land Use, Land Use Chance and Forestry* (IPCC 2003) in addition to other sectoral tables specified in the *1996 Revised Guidelines*), and some requirements are emphasized given the specific purpose of BURs (e.g. countries are encouraged to provide a consistent time series back to the years reported in the previous NCs). As with the guidance for NCs, guidance for BURs allows flexibility so as to appropriately reflect the "capacities, time constraints, data availabilities and the level of support provided by developed country Parties for biennial update reporting".[38]

2.3.2 Requirements for measurement of mitigation actions

For measurement of the effects of mitigation actions, there is limited agreed methodological guidance under the UNFCCC.[39] Guidance on the preparation of NCs requires developing countries to provide information on steps taken in the implementation of the UNFCCC, including mitigation actions. The guidance, agreed in 2003, states that: "based on national circumstances, non-Annex I Parties [i.e. developing countries] are encouraged to use whatever methods are available and appropriate in order to formulate and prioritize programmes containing measures to mitigate climate change".[40] BURs should also include inter alia reporting on mitigation actions, such as Nationally Appropriate Mitigation Actions (NAMAs). Guidance requires that "information on methodologies and assumptions" is given "to the extent possible" and that domestic measurement, reporting and verification arrangements are described.[41]

Guidance on GHG quantification for domestic MRV of domestically supported NAMAs respects the principles that MRV should be:

"voluntary, pragmatic, non-prescriptive, non-intrusive and country-driven, take into account national circumstances and national priorities, respect the diversity of nationally appropriate mitigation actions (NAMAs), build on existing domestic systems and capacities, recognize existing domestic measurement, reporting and verification systems and promote a cost-effective approach."[42]

When the Paris Agreement states that all Parties shall account for their NDCs, it refers to existing guidance adopted under the UNFCCC (Text Box 6).

Text Box 6

Requirements for accounting for NDCs

"Parties shall account for their nationally determined contributions. In accounting for anthropogenic emissions and removals corresponding to their nationally determined contributions, Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement…In the context of their nationally determined contributions, when recognizing and implementing mitigation actions with respect to anthropogenic emissions and removals, Parties should take into account, as appropriate, existing methods and guidance under the Convention, in the light of the provisions of paragraph 13 of this Article."

Source: Paris Agreement, Article 4, paragraphs 13-14

[36] IPCC (2000: 1.3).
[37] UNFCCC (2014).
[38] Annex III of Decision 2/CP.17.
[39] With the exception of REDD, upon which more detailed methodological guidance has been agreed. See http://unfccc.int/land_use_and_climate_change/redd/items/8180.php
[40] http://unfccc.int/resource/docs/cop8/07a02.pdf
[41] Annex III of Decision 2/CP.17.
[42] Decision 21/CP.19.

In accounting for NDCs, Parties should take into account existing methods and guidance under the UNFCCC.

For internationally supported NAMAs or other forms of mitigation action, there is no agreed methodological guidance. In general, it is expected that quantification methodologies will be consistent with guidance from the IPCC and other organizations.[43] International climate funds (e.g. Global Environment Fund (GEF), Green Climate Fund (GCF)) and international financial institutions (IFIs) are likely to be among the main financial supporters of mitigation actions in many developing countries. In recent years, these institutions have been developing their internal policies and procedures to account for GHG emissions and emission reductions from projects they support. These policies and procedures, including agreements among a number of IFIs to harmonize their GHG accounting policies, are not within the scope of the UNFCCC, but are discussed in Chapter 4 below.[44] The GCF, which is one of the main financing vehicles for climate action under the UNFCCC, has issued documents specifying performance indicators for projects and programmes funded by the GCF, but further guidance on baseline setting and performance measurement is still to be developed (see Text Box 30).[45]

2.3.3 Guidelines for measurement under the UNFCCC

Under current UNFCCC agreements, developing countries should use the *Revised 1996 IPCC Guidelines for National GHG Inventories, IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* and the *IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories* for estimating and reporting their national GHG inventories. These documents are intended to assist countries in providing estimates of GHG emissions that are in line with principles for credible MRV. Several UNFCCC texts refer to general principles for measurement of GHG emissions.[46] These principles (Table 3) were further elaborated in the *2006 IPCC Guidelines*, which were adopted in 2013 for use in reporting by developed countries,[47] but which have so far not been mandatory for developing countries.[48] In general, the IPCC guidelines promote the credibility of GHG estimations by providing technical guidance, and recommending procedures and institutional arrangements.

The IPCC Guidelines provide guidance on the identification of GHG sinks and sources. For livestock management activities, methane (CH_4) emissions from enteric fermentation, CH_4 and (direct and indirect) nitrous oxide (N_2O) emissions from manure management, and (direct and indirect) N_2O emissions from

Table 3: Principles for credible MRV under the UNFCCC

Principle	Interpretation
Transparency	Assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information.
Consistency	An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks, or if different methodologies for different years were used, the inventory should be recalculated in a transparent manner.
Comparability	Estimates of emissions should be comparable among countries, for which methodologies and reporting formats have been agreed by the COP.
Completeness	All GHG sinks and sources, and all gases included in the IPCC Guidelines and any other source/sink categories are covered; the inventory provides full geographic coverage of sources and sinks of country.
Accuracy	Estimates of GHGs should neither systematically over- nor under-estimate true emissions or removals, as far as can be judged, and uncertainties are reduced as far as practicable.

Source: FCCC/SBSTA/2006/9

[43] UNFCCC (2014), page 16.
[44] Climate Investment Funds (2014).
[45] GCF (2016).
[46] E.g. FCCC/SBSTA/2006/9
[47] Decision 24/CP.19
[48] The Paris Agreement refers also to "environmental integrity" and avoiding "double counting", but it remains to be seen how these terms may be translated to future procedural requirements.

deposit of urine and dung on pastures are the main GHG sources identified.[49] Regarding livestock emission sources, guidance is provided on the characterization of livestock populations (Text Box 7) and on the selection and estimation of emission factors (Text Box 8, Figures 1 and 2). General procedures are also set out for estimation of uncertainty (Text Box 9).

Text Box 7

IPCC guidance on characterization of livestock populations

Estimations of emissions from enteric fermentation and manure management require multiplying livestock numbers by an emission factor (GHG emissions per head per year). Using a Tier 1 approach, average annual livestock numbers should be estimated for each type of livestock (e.g. sheep, goats, camels, horses, swine, poultry) and distinguishing between dairy cattle and non-dairy cattle. For dairy cattle, average annual milk yields should be estimated so that the appropriate Tier 1 emission factor can be applied. The distribution of livestock by climate zone (i.e. cool, temperate or warm) should be estimated to apply the appropriate Tier 1 emission factor for CH_4 emissions from manure management. A Tier 2 approach is recommended for countries with large populations of cattle, buffalo and swine, and is only recommended for other livestock types where they make significant contributions to total methane emissions in the country. Using a Tier 2 approach, to develop more accurate emission factors for each type of livestock, livestock populations should be divided into sub-groups. For cattle, the guidelines recommend at a minimum separately enumerating mature dairy cattle, mature non-dairy cattle and young cattle, but countries are encouraged to use more detailed characterization of sub-groups when the sub-group emissions are a large portion of total methane emissions for a country (e.g. distinguishing between cattle used for different purposes or raised under different production systems).

Source: IPCC (1996) Volume 3 Reference Manual.

Text Box 8

IPCC guidance on selection and estimation of emission factors

The *Revised 1996 IPCC Guidelines* suggest that a Tier 2 approach for estimation of livestock emissions should be used for estimation of enteric fermentation in countries with large populations of dairy or non-dairy cattle, and for estimation of manure management emissions from countries with large populations or cattle, buffalo or swine. The *Guidelines* also provide formal procedures for determining key source categories (i.e. emission sources that cumulatively contribute to 95% of the total emissions in an inventory), and recommend that higher methodological tiers should be followed for key source categories where collection of the data required is possible without jeopardizing resources for other key source categories.

Estimation of Tier 2 emission factors for enteric fermentation and manure management require significantly more data than the use of Tier 1 emission factors. The *Guidelines* set out the data required to estimate emissions using the IPCC models, but countries may also use country-specific methodologies. For enteric fermentation, in the IPCC model data is required for each sub-group on average daily feed intake and the percentage of feed energy converted to methane. These can be estimated from data on animal reproduction (e.g. percentage of cows pregnant), animal performance (e.g. weight, daily weight gain, daily milk yield) and feed characteristics (e.g. digestibility) (Figure 1).

For methane emissions from manure management, data on feed intake and digestibility are used to estimate manure production, and data on methane producing potential, the proportion of methane produced, and the portion of manure managed under different systems is required (Figure 2).

The *Guidelines* state that the data should be from national sources, but default values are provided in the *Guidelines* for parameters for which data is rarely available (e.g. methane conversion factors). The *2006 IPCC Guidelines* further develops the IPCC model for enteric fermentation, and provides additional (but generally non-prescriptive) guidance on appropriate data sources, as well as default values for some parameters if national data is not available. While not mentioned in the *1996 Guidelines*, the *2006 Guidelines* state that "emission factors should be updated periodically to account for changes in manure characteristics and management practices" and that "frequent monitoring is desirable to verify key model parameters and to track changing trends in the livestock industry."

Sources: IPCC (1996) Workbook Ch. 4; IPCC (2000) Ch. 7; IPCC (2006) Vol. 4 Ch. 10.

[49] Application of animal manure to croplands is livestock-related but is attributed to cropland management activities and is not considered in this report.

Step 1a: Divide the livestock population into sub-groups

Categorize selected livestock types by key factors affecting average emissions or expected trends in average emissions (e.g. by region, production system, breed). Define sub-groups (e.g. by age, sex, physiological state, productive use)

Step 1b: Characterize each sub-group

Characterize each sub-group by animal performance (e.g. pregnancy rates, weight, daily weight gain, milk yield) and diet (e.g. feeding situation, feed digestibility)

Step 2: Estimate emission factors (kg CH_4 per animal per year) for each sub-group

Estimate gross energy based on net energy requirements for maintenance, activity, growth, pregnancy and other functions. Multiply gross energy by an appropriate methane conversion factor.

Step 3: Multiply sub-group emission factors by sub-group populations to estimate sub-group emissions and sum across sub-groups to estimate total emissions.

Figure 1: Generic framework for Tier 2 estimation of enteric fermentation emissions

Source: Adapted from IPCC (1996) and Kouazounde et al. (2014)

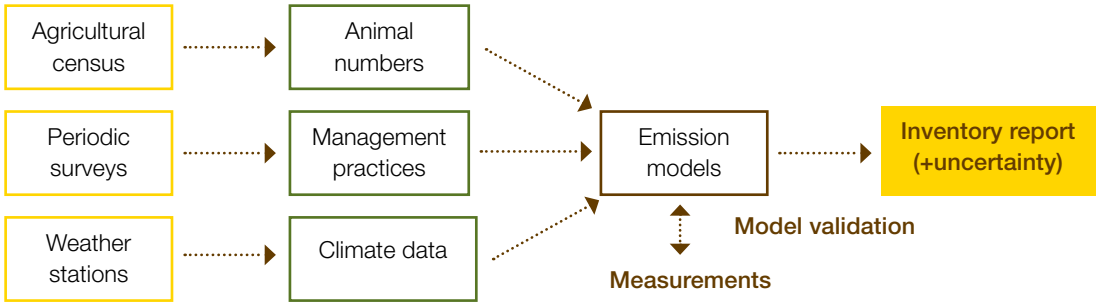


Figure 2: A general framework of data sources, models and measurements for estimation of manure management emissions

Source: VanderZaag et al (2013)

Text Box 9

IPCC guidance on management of uncertainties

Uncertainty is lack of knowledge of the true value of emissions or the trend in emissions, which may be due to a number of factors causing bias or variation in estimates, such as lack of representative data, measurement error, or model errors. In the IPCC guidance, the purpose of uncertainty assessment is not to dispute the validity of inventory estimates, but to help prioritise efforts to improve the accuracy of inventories over time. The *Guidelines* do not require that uncertainty is measured for all data used in inventory compilation, but proposes a pragmatic approach that uses a combination of the available measured data and expert judgement. For livestock emission sources, default values are provided for the uncertainty associated with emission factors and some other parameters required in estimations. For example, Tier 1 emission factors have an estimated uncertainty of ±20% (IPCC 1996), which was later revised to between ±30% and ±50% (IPCC 2006). IPCC 2006 (Vol 4, Ch 10) provides an estimate that the uncertainty of Tier 2 emission factors "is likely to be in the order of +20%". The uncertainty of activity data varies considerably between countries depending on the quality of statistical reporting systems used in estimates of animal populations. The guidance encourages the use of uncertainty assessment for prioritizing resources for inventory improvement. As improvements are made over time, revisions to activity data and emission factors should be used to recalculate the time series of a country's emission estimates, so as to ensure that emissions are reported consistently. IPCC (2000) also provides guidance on quantifying the contribution of livestock emission sources to estimates of the level and trend in inventory emissions. As at the source level, the primary purpose of uncertainty assessment is to target resources for improvement of accuracy and reduction of uncertainty in the inventory.

It is also worth noting, however, that the uncertainty of inventory estimates has not been used in determining whether developed countries with emission reduction commitments under the Kyoto Protocol have met their targets or not. In this context, therefore, the accuracy of estimated trends over time is given higher priority than the accuracy of estimates for any given year. The approach to uncertainty within the UNFCCC is thus quite different from its treatment in other fields, such as scientific research or carbon markets.

Sources: IPCC (1996), IPCC (2006), IPCC (2000)

The purpose of the IPCC guidelines is to ensure that national GHG inventory estimates are unbiased and to reduce uncertainties "as far as is practicable, given national circumstances".[50] In general, the IPCC guidelines recognize a number of limitations on the quality of GHG inventories and encourage users to take measures to improve the quality of inventories over time. As with UNFCCC guidelines, IPCC guidelines provide for flexibility in the measurement of GHG emissions. In particular, the guidelines recognize that resources for inventory compilation and reporting are limited, and encourage the cost-effective allocation of inventory resources. National circumstances (including inter alia data availability and available resources) should be taken into account when applying the IPCC guidelines. The guidelines themselves set out tiered methodologies and decision trees to enable decisions over which tier of estimation approach to adopt given national circumstances, and use terminology such as "recommend", "may" or "should", reflecting the flexibility available. General guidance is given on data collection, including data collection through measurements, surveys, and expert judgment. While procedures for estimation of emission factors are set out in the IPCC guidelines, there is little prescriptive guidance on data sources to be used for each parameter. Furthermore, countries may use alternative approaches where it is believed this results in a more accurate representation of national circumstances.[51]

While procedures for estimation of emission factors are set out in the IPCC guidelines, there is little prescriptive guidance on data sources to be used for each parameter. Furthermore, countries may use alternative approaches where it is believed this results in a more accurate representation of national circumstances.

2.4 Discussion

The UNFCCC has agreed guidelines for MRV of GHG emissions. For measurement and reporting of GHGs, including livestock GHG emissions, the UNFCCC mandates the use of IPCC guidelines. Both the UNFCCC and IPCC guidance contain considerable flexibility, particularly for developing countries and for countries that need it in the light of national circumstances, considering issues such as data availability, capacities and available resources. On the one hand, the provision of guidance together with flexibility allows countries to improve their national GHG inventory reporting over time. On the other hand, it leaves open the questions of what are acceptable MRV practices in any particular country context, and when, how and over what time frames a country can transition from more basic to more advanced MRV approaches while continuing to meet the agreed requirements. That the guidelines provide flexibility is not necessarily due to a lack of knowledge of best scientific practices, but represents also the need for political agreement among countries with vastly differing interests and capabilities, and can be seen as reflecting the best effort that countries can make together.

On the one hand, the provision of guidance together with flexibility allows countries to improve their national GHG inventory reporting over time. On the other hand, it leaves open questions of what are acceptable MRV practices in any particular country context, and when, how and over what time frames a country can transition from more basic to more advanced MRV approaches while continuing to meet the agreed requirements.

For the estimation of livestock GHG emissions, the flexibility in current guidance, and the pragmatic treatment of uncertainty within the UNFCCC, raise a number of questions as well as opportunities. Above all, how can MRV practices best serve national policy objectives, including objectives relating to UNFCCC obligations as well as objectives in livestock and other sectors? Where resources for MRV are limited, how to prioritize and balance possible trade-offs among transparency, accuracy, completeness, comparability and consistency? Where moving to Tier 2 approaches can help meet national policy objectives, but data and resources are limited, what data sources and estimation methods are acceptable to overcome data constraints? The following chapter presents a survey of current practices used in national GHG inventory compilation and reporting, and identifies both challenges and opportunities faced by countries as they undertake efforts to improve reporting of livestock GHG emissions in the rapidly evolving policy context.

Guidance agreed under the UNFCCC on reporting of mitigation actions and GHG emission reductions is quite general. Again, this flexibility enables countries to fully consider national circumstances, but leaves the definition of minimum acceptable practices undefined. With the agreement at COP 21 in 2015 to establish an enhanced transparency framework, the UNFCCC's requirements for MRV continue to evolve. In particular, while the Paris Agreement invites countries to submit NDCs and calls for "methodological consistency, including on baselines, between the communication and implementation of" NDCs, work to define modalities and procedures is ongoing. These issues affect the choice of methodologies for MRV in all sectors. In the livestock sector, experience with MRV of mitigation actions is relatively more limited than in some other sectors (e.g. energy). Chapter 4 highlights elements of existing experience and some key challenges that policy makers, scientists and other stakeholders are facing as they develop systems for the MRV of mitigation actions.

With flexible guidance from the UNFCCC and IPCC, a key question is: What MRV practices best serve countries' own policy objectives?

[50] IPCC (2006) Overview Chapter.
[51] IPCC (1996) Vol. 1.

3. MRV through livestock GHG inventory compilation and reporting

Key messages

A review of current practices by 140 developing countries in the reporting of livestock GHG emissions in national communications, BURs and GHG inventory reports finds that:

Key source category analysis: Less than half of developing countries conducted key source category analysis. The vast majority of those that did found that at least one livestock emission source was a key source category.

Completeness: Of the 140 countries, 139 reported CH_4 emissions from enteric fermentation, 134 reported CH_4 emissions from manure management and 115 reported N_2O emissions from manure management. 116 countries reported N_2O emissions from application of animal manure to agricultural soils or dung and urine deposit on pasture. In some cases, misunderstanding of the IPCC Guidelines on reporting of manure and dung contributed to omission of one or more of these emission sources.

Consistency: Of the 119 countries that reported emissions for more than one year, 37 presented inconsistent time series, mostly due to a change in the inclusion or omission of one or more manure or dung emission sources.

Accuracy: Twenty-one out of 140 countries used a Tier 2 approach to estimate some or all livestock GHG emissions. Only five of these countries have a Tier 2 approach that reflects changes over time in management or productivity, or have updated emission factors between submissions. Out of 140 countries, 89 made no analysis of the uncertainty of livestock emissions. Of 29 countries that reported livestock-related inventory improvement plans: 13 reported a need to improve both emission factors and activity data; 11 reported a need to improve activity data only; five reported a need to improve emission factors only. Just one of these countries is considering moving to a Tier 2 approach that uses regularly updated data to automatically reflect changes in productivity in the way emissions are calculated for any given year.

Transparency: Most countries submitted a summary of the GHG inventory as part of an NC or BUR. The extent to which full information is provided in the summary varies significantly: 41 countries neither explained the source of livestock population data nor presented population data; 23 countries did not mention the tier approach used in estimation of emissions; of the 32 countries omitting one or more livestock emission source, 20 gave no explanation for this omission.

Quality assessment: The quality of livestock GHG emission reporting by 140 countries was assessed using a scoring approach. The scoring indicated considerable variation in the quality of reporting. For the average country assessed, low scores were mainly due to poor practices contributing to inventory accuracy, but there were also often shortcomings in relation to inventory consistency and transparency. Within accuracy, the use of Tier 1 approaches was the main reason for poor inventory accuracy, but lack of uncertainty analysis also contributed to low accuracy scores for many countries.

Options for inventory improvement: The function of GHG inventories in national policy varies. Where policy objectives prioritize improvements in the accuracy of emission estimates in a given year, priorities for improvement are key source analysis, followed by improvements in data on livestock populations, improved characterization of production systems and livestock sub-populations, and feed intake and digestibility estimates. Where policy objectives prioritize presenting an accurate trend in livestock emissions (e.g. in response to changing productivity or specific mitigation actions), the priority is to structure a Tier 2 approach so that changes in productivity can be reflected in the inventory. Practical options and specific inventory compilation practices matched to these policy objectives may vary. Sources of data and methods that support improved accuracy for a given inventory year may not contribute to increased accuracy in tracking emission trends, while pragmatic methods used to improve the accuracy of trends may not all achieve high accuracy in a given year. In the light of these varying policy objectives, stakeholders in different national contexts may wish to further consider what constitute acceptable inventory compilation practices.

This chapter describes current practices in national MRV of livestock GHG emissions, with a focus on national inventories and other national reporting tools under the UNFCCC. Section 3.1, based on a review of national communications, inventory reports and biennial update reports submitted to the UNFCCC, provides an overview of common practices by developing countries, highlighting methods that specific countries have used to measure and report livestock GHG emissions in their national inventories. It also provides an overall assessment of the quality of livestock emission reporting by developing countries, and identifies common areas where improvements can be made. Section 3.2 discusses different perspectives on livestock GHG inventory improvement considering the different functions that GHG inventories serve in national policy context. It proposes that some types of policy objectives prioritize improvements in the accuracy of estimates for a given inventory year, while other policy goals prioritize accuracy in the trend in livestock GHG emissions. Priorities for inventory improvement may thus vary. Section 3.3 discusses a range of practical options for inventory improvement considering these varying priorities. Section 3.4 presents four interrelated questions than can help guide countries in defining strategies and options for inventory improvement.

3.1 Current practices in livestock GHG emission reporting

Developing countries' livestock GHG emissions are reported in national GHG inventories, sometimes communicated through national inventory reports, but more often through an inventory summary NCs and more recently in BURs. NCs and BURs from developing are available on the UNFCCC website.[52] Of the 153 developing countries, submissions by 149 were selected. Of these 149 countries, two had made submissions that were not available on the UNFCCC website, three had not made any submission, and submissions by four countries did not include livestock emissions in their latest submission.[53] Submissions reporting livestock emissions by 140 countries were reviewed to understand how livestock emissions are measured and reported in national inventories.

The long duration between each submission for many countries presents challenges for the development of institutionalized procedures for inventory compilation and reporting.

3.1.1 Reports submitted

Figure 3 shows the number of countries making submissions in different years. The sample reflects the 140 countries that made at least one submission with livestock emissions to the UNFCCC. One hundred and seventeen countries had submitted two national communications, and 21 countries had submitted three. In addition, 29 countries had submitted a BUR, and three had submitted more than one BUR. For countries submitting a second NC, the average NC2 was submitted ten years after NC1. For those countries submitting a third NC, this was on average submitted 5.5 years after NC2. The 29 countries that submitted BURs did so on average three years after their previous NC submission. This suggests that for a small, but growing number of developing countries, reporting to the UNFCCC is becoming more frequent.

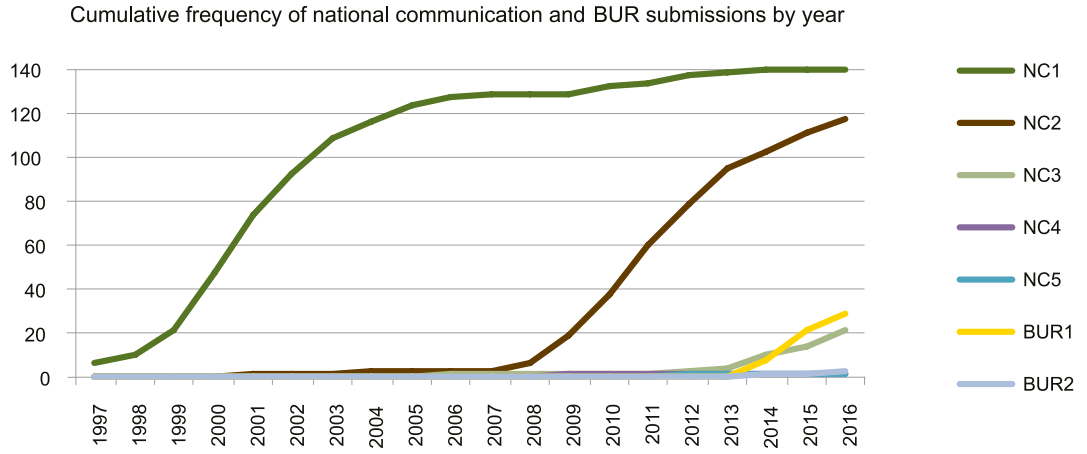


Figure 3: Cumulative frequency of national communication and BUR submissions by year

Data sources: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php and http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

52 http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php; http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

53 The Maldives, Singapore and the Solomon Islands did not report livestock emissions. The Kingdom of Bahrain reported livestock emissions in its first national communication, but these were insignificant, and were not included in its second national communication.

However, the long duration between each submission for many countries presents challenges for the development of institutionalized procedures for inventory compilation and reporting, which are required for efficient compilation of BURs. Submission of a full national inventory report (NIR) is not mandatory for developing countries, and only nine countries have submitted a full NIR to the UNFCCC. However, some countries' NCs referenced an NIR available on a country-hosted website. Since NCs and BURs often present a summary of a GHG inventory, rather than the complete report, detailed elaboration of methods and data was often not presented, which affects the transparency of inventory reporting.

3.1.2 Comparability

Use of the IPCC Guidelines and common reporting formats is intended to facilitate comparability among countries' submissions. The UNFCCC Guidelines for developing countries mandate use of the *IPCC 1996 Guidelines*, but countries may use subsequent updates if this enables improved reporting. Of the 140 countries, 112 used the *IPCC 1996 Guidelines*, 11 used the *1996 Guidelines*, but referred to emission factors in the *2006 IPCC Guidelines* for livestock emissions, and 17 countries used the *IPCC 2006 Guidelines*, including the new structure of agriculture, forestry and other land use (AFOLU) emission categories and other changes therein. Several countries' NCs noted the positive contribution that national inventory software products have made to facilitating inventory compilation and analysis (Text Box 10).

3.1.3 Completeness and identification of key sources

Of the 140 countries, 139 reported methane emissions from enteric fermentation, 134 reported methane emissions from manure management and 115 reported nitrous oxide emissions from manure management. 116 countries reported N_2O emissions from application of animal manure to agricultural soils or dung and urine deposit on pasture, but not all countries' submissions clearly specified whether deposit of dung and urine on pastures was included in N_2O emissions from agricultural soils.

Most countries that did not report all of these livestock emission sources did not provide a clear explanation for the exclusion of one or more sources. Among those that did, one common explanation for omitting reporting of N_2O emissions from manure management and dung and urine deposit on pasture was the lack of activity data on the use of different manure management systems. Several countries assumed that direct N_2O emissions from grazing animals was equal to zero due to the lack of activity data; one country noted that dung deposited on pasture is unmanaged and therefore decided not to report related emissions; another reported that all dung stays in the paddock, but omitted to report this under either manure management or emissions from agricultural soils. The *IPCC 1996 Revised Guidelines* provide a range of default factors required for estimation of emissions from manure management and agricultural soils. However, it appears that in some cases misunderstanding of the reporting guidelines (Text Box 11) may have contributed to omission of these livestock emission sources.

Among the 140 countries whose submissions were assessed, 65 (i.e. 46%) reported having conducted key source category analysis. This was done in different ways. Eleven countries reported key source categories only at sector level or by gas. Fifty-three countries conducted key source category analysis at the inventory level. All but one of these used the IPCC-recommended method of adding emissions from different source categories until 95% of the total inventoried emissions were accounted for. Most countries applied this analysis to the level of emissions reported in the inventory (with and without the LULUCF sector), while some

Text Box 10

Software tools to assist in inventory preparation

Preparation of national inventories often used dedicated software produced by the IPCC for the purpose. Software is available for use together with the 1996 IPCC Guidelines and the IPCC 2006 Guidelines (http://www.ipcc-nggip.iges.or.jp/software/). This software was commonly used for inventory compilation as well as analysis of key sources and uncertainty. Some countries reported using other software for estimating livestock emissions, such as the Agriculture and Land Use (ALU) Greenhouse Gas emissions software produced by Colorado State University (http://www.nrel.colostate.edu/projects/ALUsoftware/index.html), which users commented greatly facilitated the ease of data entry to produce Tier 2 emission factors.

also applied the analysis to the trend in emissions. One country also assessed the contribution of uncertainties of different source categories to total inventory uncertainty to identify the main sources of uncertainty in the inventory. Among the 53 countries reporting key source category analysis at the inventory level, 52 reported at least one livestock-related emission source to be a key source in the national inventory (Table 4).

3.1.4 Consistency

Guidelines for reporting by developing countries encourage the use of consistent methods.[54] Guidelines for BURs adopted in 2011 encouraged countries to submit a national inventory time series back to the years reported in previous NCs.[55] Twenty-one countries' latest NC, NIR or BUR submission reported livestock emissions for a single year only. Of the remaining 119 countries, 37 presented inconsistent time series for livestock emissions, either due to a change in the GHG sources included in different inventory reports or to a change in methodology that had been made without recalculation of earlier inventory submissions. Changes in reporting of manure management emission sources were a common cause of inconsistent reporting (see Section 3.1.3). In many cases, explanation in the NC referred to the significant time lag since preparation of NC1 (see Section 3.1.1), and changes in institutional arrangements, staffing and methodological approaches in the preparation of subsequent NCs as factors contributing to inconsistency. Eighty-two countries (59%) presented a consistent time series for all years reported.

3.1.5 Accuracy

(a) Tiered approaches to estimation of GHG emissions

For the different GHG sources reported, the vast majority of countries used a Tier 1 approach to estimate all GHG emissions from all types of livestock (Table 5).[56] Seven countries used a Tier 1 approach, but used different default emission factors for different climate regions within the country (referred to here as a 'Tier 1b' approach; see Text Box 15). Appropriate to the tiered approach adopted, most countries used and presented livestock populations in a basic characterization by type of livestock only (e.g. 'cattle', 'sheep' etc.).[57] Only countries using a Tier 2 approach for some or all livestock types categorized livestock sub-groups in a detailed way.

Text Box 11

Categorization of manure management emissions

In the *1996 Revised Guidelines*, methane and nitrous oxide emissions from manure management both fall within inventory category "4B manure management". The estimation of these emissions requires characterization of manure management systems (anaerobic, liquid systems, solid storage and drylot, or 'other' system). In the *Workbook* that forms part of the guidelines, the calculation of N_2O emissions from grazing are explained along with explanation of estimation of other manure emission sources, but emissions from deposit of dung and urine on pasture and application of animal manure to other agricultural soils are reported under category "4D agricultural soils". Emissions from agricultural soils (category 4D) also include indirect emissions from atmospheric deposition of NH_3 and NO_x, part of which is due to livestock nitrogen excretion. The focus is on anthropogenic emissions, so emissions from wildlife and termites are excluded. Default factors are provided in the guidelines for estimating proportions of livestock manure managed under different management systems (including pasture deposit of dung and urine) in each continent, and for emission factors.

In the *IPCC 2006 Guidelines*, livestock emissions, including manure management, are reported in the scope of AFOLU sector reporting, where manure management methane and nitrous oxide emissions are reported under category 3A2, while indirect emissions from manure management are reported under category 3C6, and direct and indirect emissions from application of animal manure to croplands and urine and dung deposited on pasture, range and paddock are included under categories 3C4 (direct N_2O emissions from managed soils) and 3C5 (indirect N_2O emissions from managed soils).

Sources: IPCC (1996), IPCC (2006)

[54] Decision 17/CP.8.
[55] Annex III of Decision 2/CP.17.
[56] Including 23 Parties that did not state the Tier approach used, but which are assumed to have used a Tier 1 approach.
[57] On IPCC guidance on characterization of livestock populations, see Text Box 7.

Table 4: Number of countries identifying livestock related GHG sources as key source categories in the national inventory (n=53)

Enteric fermentation	Manure management	Agricultural soils
49	28	44*

** Note: In 37 of these cases, the level of detail reported was insufficient to distinguish whether livestock-related emissions from agricultural soils (i.e. deposit of dung and urine on pastures) were a key source.*

Table 5: Use of tiered approaches in estimation of livestock emissions by 140 developing countries

	Tier 1 for all livestock types	Tier 1b for all livestock types	Tier 2 for some livestock types	Tier 2 for all livestock types
Enteric fermentation	118	0	19	2
Manure management	120	6	10	0
Agricultural soils	110	2	2	2

Most developing countries use fixed Tier 1 emission factors or fixed country-specific Tier 2 factors. Only 5 countries have updated emission factors to reflect changes in production practices or productivity.

Use of a Tier 2 approach for enteric fermentation: Twenty-one countries have reported some or all livestock emissions using a Tier 2 approach. Most often this was applied only to cattle populations or certain types of cattle, while other livestock were reported using a Tier 1 approach. In some cases, a Tier 2 approach was also applied to some other livestock types (e.g. small ruminants in South Africa), and two countries (Mongolia, Republic of Korea) reported applying a Tier 2 approach to estimate enteric fermentation emissions from all types of livestock.

The Tier 2 approach was implemented in different ways, depending on national circumstances, including the availability of data. These approaches included:

(a) IPCC model: The most commonly used approach was to populate the IPCC enteric fermentation model with available data. Countries structured this in different ways (Text Box 12). For example, Bolivia stratified the livestock population by agro-ecological zone; Argentina stratified the population by agro-ecological zone and production system; and Georgia stratified the cattle population by breed. Within each stratum, specific emission factors were developed for sub-groups of cattle.

(b) Use of other models: Considering the similarities between agro-ecological conditions and production systems in Australia and South Africa, South Africa developed Tier 2 emission factors for livestock based on equations produced under Australian conditions. India's national inventory uses Tier 2 emission factors for cattle developed through a country-specific methodology that relates the total digestible nutrients of national feeding standards to gross energy.[58]

(c) Use of the dry matter intake method: Bangladesh developed Tier 2 emission factors for cattle produced using a dry matter intake estimation method reported in an Indian research paper (Text Box 13).

Most countries have applied the IPCC Tier 2 methodology to produce 'static' emission factors that are used to calculate livestock emissions in the current and subsequent inventories. In this sense, these emission factors are similar to Tier 1 emission factors, but specific to a country or livestock production system, but they do not capture changes in absolute emissions and emission intensity that result from changes in productivity over time (see Text Box 14). Of the 20 developing countries that described the methodology

[58] Swamy and Bhattacharya (2006).

used in deriving a Tier 2 approach for enteric fermentation, 15 used a 'static' emission factor, while five have updated the emission factor on the basis of subsequent statistical data or expert judgment:

- Armenia regularly updates dairy cattle emission estimates using statistical data on milk yield;
- Brazil updated emission factors considering change in pregnancy rates and feed digestibility in some regions;
- Georgia applies its Tier 2 emission factor within a model of herd reproduction and off-take (i.e. where different breeds reproduce at different rates and are culled at different ages), resulting in a changing average emission factor over time;
- the Republic of Moldova updates cattle emission factors using statistical data on live weight, daily weight gain, milk yield and pregnancy rates and expert judgment on feed digestibility in different historical periods;
- Uruguay updated its cattle emission factors on the basis of recent data on cattle live weight.

Text Box 12

Different ways used by selected countries to structure application of the IPCC Tier 2 equations

Argentina:[59] The country was divided into eight regions, based on agro-ecological and climatic factors. In each region, a number of breeding and fattening systems was identified. Data to characterize production systems in terms of activity, diet, reproduction and production in each system were then procured from literature, and entered into a model structured around regions and production systems. The resulting preliminary model was then refined using other data sources, and the aggregate results cross-checked against regional, census and agricultural production data.

Bolivia:[60] Cattle populations in three climatic regions (altiplano, valles and tropics) were identified according to the agro-ecological zonation of different departments (sub-regions) in the country. For cattle and sheep, the population was stratified into sub-groups (e.g. dairy cattle, non-dairy cattle, young cattle and oxen) based on consultations with livestock production experts in each region. In each region, data on feed rations and apparent digestibility of forage and feed was obtained from publications, and other production data (e.g. milk yields, live weights) were obtained from publications or government agencies.

Georgia:[61] Common cattle breeds in Georgia include late maturing breeds (the Georgian Mountain and Red Mingrelian) characterized by low weight, low productivity and high milk fat content, as well as several high-productive early maturing breeds that were imported in the previous century. The IPCC equations were populated separately for early and late maturing breeds at different life stages using published data and expert opinion. Expert opinion was used to estimate the proportion of each breed in the total cattle population.

Mongolia:[62] Although Mongolia has diverse indigenous breeds of livestock, a small number of breeds dominate the total population of each livestock type. Published breed characterization studies were referred to, and used along with expert judgement of livestock experts and IPCC default factors to develop a single Tier 2 emission factor for each type of livestock in the country. Results were compared with Tier 2 emission factors from China.

Text Box 13

A dry matter intake method to estimate methane emissions

Singhal et al. (2005) present a method for estimating methane emissions from enteric fermentation based on estimated dry matter intake (DMI). The approach estimates DMI using data on the population of livestock of different sub-groups (as defined by sex, age, breed), the weight of animals in each sub-group and estimates of DMI for animals of each sub-group. Published methane conversion factors developed on the basis of studies of *in vitro* dry matter digestibility are then applied to different types of feed. The national inventory of Bangladesh adjusted the published emission factors based on the difference in weight between cattle in India and Bangladesh.

Source: Singhal et al. (2005)

[59] Argentina, National Inventory Report 2012, Vol 3
[60] Bolivia, National Inventory Report 1999-2000
[61] Georgia, National Inventory Report 2010-2013
[62] Prof. B. Namkhainyam, Mongolian University of Science and Technology, pers. comm.

From available descriptions of data sources and methodologies used, some other countries' Tier 2 emission factors could also be updated using subsequent data on livestock performance, but updating has not been reported. For example, Chile has reviewed its Tier 2 emission factors, but decided that no update was needed as the emission factors still reflect prevailing management practices (Text Box 15).[63] South Africa's national GHG inventory report recommends that "if sufficient data is available, annual emission factors incorporating changes in feed quality and milk production" should be used.[64]

The IPCC Tier 1 default emission factors are given for mature animals in a limited number of sub-groups (e.g. dairy cattle, non-dairy cattle). When implementing a Tier 2 estimation approach, most countries develop a more refined categorization of the livestock population, with a larger number of sub-groups of each type of livestock, or sub-groups identified in different regions or by breed. The range of emission factors identified in each country is large, so the weighted average implied Tier 2 emission factor will depend on the structure of the livestock population. Table 6 compares the IPCC regional default emission factors with recent implied Tier 2 emission factors for mature cattle categories reported in national inventories. In several cases, the Tier 2 emission factors are significantly higher than the Tier 1 default factor, due to differences in factors such as assumed productivity, pregnancy rates and digestible energy.[65] Some countries attempted to quantify the uncertainty associated with Tier 2 emission factors (Table 6). They mostly referred to an IPCC (2006) estimate that Tier 2 emission factors are likely to be associated with an uncertainty of ±20%, compared to a generic assumption of between ±30% and ±50% for the Tier 1 emission factor (although the accuracy of this uncertainty estimate for any particular country cannot be independently verified). Other countries produced their own estimates of uncertainty on the basis of expert judgment. The uncertainty of resulting Tier 2 estimates of emissions from enteric fermentation will be highly dependent on the quality of activity data used. This is further discussed in Section 3.1.6 on uncertainty assessment.

Text Box 14

Tier 1 and Tier 2 approaches

The IPCC approach estimates enteric fermentation emissions (E, kg CH_4 per year) by multiplying the population (N) of each category of livestock by an emission factor (EF):

$$E = N * EF$$

In the Tier 1 approach, the population derives from national data while the emission factor is a default value estimated at continental level. The emission factor does not change over time. Most developing countries moving to a Tier 2 approach have used the same equation, replacing the IPCC default value for the emission factor with country- or system-specific values. This approach also results in a 'static' emission factor that does not change over time, unless input values are re-estimated.

When implementing a Tier 2 approach, most developed countries use regularly updated information on productivity (e.g. weight gain, milk yield, fertility) to estimate feed energy intake per animal in each inventory year. Because productivity changes over time, an inventory structured in this way is better able to track changes in gross energy intake. Emissions per animal are then calculated by multiplying the estimated energy intake per animal (I) by the amount of methane emissions per unit of intake (i.e., 'methane yield' or 'Y_m'), which is generally relatively stable over time:

$$E = N * I * Y_m$$

Thus, the focus is on regularly updating activity data that contributes to the energy intake term, 'I', so that change in emissions is tracked over time.

Source: GRA, CCAFS and FAO (2016)

[63] Chile BUR
[64] GHG inventory for South Africa 2000-2010
[65] See, e.g. http://unfccc.int/resource/docs/natc/zafnir1.pdf

Text Box 15

Constraints to developing a regularly updated Tier 2 approach for enteric fermentation in Chile

Chile has relatively abundant data for the different regions of the country on livestock production systems, including livestock populations, type of cattle (dairy/beef), breed, age, feeds used and grass composition, and manure management. However, data is not regularly collected, and mainly derives from an agricultural census conducted every 10 years. This survey is undertaken by the National Institute of Statistics, but there is little coordination with the Institute for Agricultural Research, which is responsible for compiling the agriculture component of the national inventory. A key need is therefore for the Ministry of Environment to engage the National Statistics Institute to improve the utility of the agricultural survey for the national inventory. Improved funding for data collection to serve the national inventory would require stronger political support from the ministries of agriculture and environment. In the absence of nationally representative data, information is collected through a variety of informal approaches, and assessed using expert judgment.

Source: Interview with Dr. F. Salazar (INIA, Chile)

Table 6: The range and uncertainty of Tier 2 enteric fermentation emission factors (EF) for mature cattle used in national GHG inventories by selected countries

Country (year estimated)	Tier 1 EF (kg CH_4 per head per year)	Implied Tier 2 EF for mature animals (kg CH_4 per head per year)	Estimated uncertainty of Tier 2 EF
Argentina (2012)	Dairy: 57 Non-dairy: 49	Dairy: 87-126 Non-dairy: 50 – 61 (range by region)	20%
Armenia (2000-2010)	Dairy: 56 Non-dairy: 44	74 – 79 (range by year)	-
Bangladesh (2000, 2004)	Dairy: 56 Non-dairy: 44	19-23 (range by physiological state)	-
Bolivia (1999-2000)	Dairy: 57	50-59 (range by climatic region)	10%
Brazil ('90-'95, '96-'01, '02-'06)	"Tier 2 EFs consistently higher than IPCC defaults"		-
Colombia (2000, 2004)	Non-dairy: 49	Non-dairy: 50 – 61 (range by region)	20%
Georgia (2006-2011)	Total cattle emissions 2.4%-3.3% higher using Tier 2 compared to Tier 1 emission factors		40%
India (2007)	Dairy: 56	28 – 43 (range by breed type)	23-35%
Mongolia (1990-2006)	Dairy: 56 Non-dairy: 44	Dairy: 48-65 Non-dairy 32 – 44 (range by breed type)	-
South Africa (2000-2010)	Dairy 40 Non-dairy: 31	Dairy: 80-132 Non-Dairy: 73-112 (range by production system and physiological state)	-

Sources: NCs, BURs and NIRs available at http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php and http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

Use of higher tier approaches for manure management: Sixteen countries used more advanced methods to estimate emissions of CH_4 or N_2O from manure management. Methane conversion factors (MCF) used in estimating methane emissions from manure management are sensitive to temperature, and the IPCC guidelines provide default values for methane emissions per head of livestock by temperature zone. Six countries applied different Tier 1 default emission factors to livestock in different climate zones in the country, i.e. a T1b approach (Text Box 16). Ten countries applied a Tier 2 approach to the estimation of methane emissions from manure management for some types of livestock. Most countries did this using the IPCC Tier 2 equations. In all cases, input data on gross energy intake and feed digestibility from Tier 2 estimates of enteric fermentation were used to estimate volatile solids produced. Most countries used national data on the distribution of livestock between different manure management systems, although some used IPCC default estimates. Most countries used IPCC default values for all other parameters in the IPCC calculations, although some used national data for parameters such as the ash content of dry matter feed intake. Very few countries used a Tier 2 approach in estimating N_2O emissions from manure management. Those that did referred to national studies on nitrogen excretion and crude protein content of diets.

(b) Uncertainty assessment

Uncertainty is lack of knowledge of the true value of emissions or the trend in emissions. The IPCC guidelines identify different sources of error in estimates, such as biased estimation methods, lack of representative data, measurement error, or model errors.[66] Developing countries are encouraged to provide information on the level of uncertainty associated with inventory data and their underlying assumptions, and to describe the methodologies used for estimating these uncertainties.[67] Of the 140 countries, 89 (i.e. 64%) made no analysis of the uncertainty of livestock emissions in their latest submission. These countries included those that had used a Tier 1 approach to estimate emissions from all GHG sources from all types of livestock as well as some countries that had adopted a Tier 2 approach for some or all livestock emission sources. In fact, of these 89 countries, 71 (i.e. 80%) made no analysis of uncertainty in the whole inventory report or national communication.

For those countries that did assess uncertainty, various approaches were used. Fifteen countries used qualitative approaches to assess uncertainty. In some cases, this involved narrative commentary on the quality of the data used for estimation of different emission sources. In other cases, a tabular format was used, with activity data and emission factors being assessed as of 'low', 'moderate' or 'high' uncertainty on the basis of expert judgment.

Thirty-eight countries used quantitative methods to assess uncertainty. In some cases, an overall quantitative estimate of the uncertainty in the whole inventory or agriculture sector was reported, with no further explanation of the method used. In a number of cases, however, the methods used to assess uncertainty were described. At least one country developed country-specific 'default values' for the uncertainty of different sources of activity data (Text Box 17), together with IPCC values for uncertainty of emission factors. Few countries using Tier 2 emission factors used error propagation methods to estimate the uncertainty associated with emission factors. A common comment was that official livestock population data provided by government agencies came with no estimate of error, making quantitative uncertainty assessment impossible. Table 6 shows that Tier 2 emission factors used by developing countries had estimated uncertainty ranges of 10-40%. Further analysis of uncertainty is given in section 3.2.3.5 below.

3.1.6 Transparency

Transparency refers to the clear presentation and explanation of assumptions and methodologies used in inventory compilation so as to enable assessment of the inventory by users of the reported information. Some developing countries have submitted a full inventory report to complement submitted NCs or BURs, but most countries submitted a summary of the inventory reported in the NC or BUR. A few countries' submissions referenced a separate, publicly available national inventory report. The extent to which full information is provided in summary inventory reports varies significantly among countries. For example, 41 countries neither explained the source of livestock population data nor presented population data; 23 countries did not mention the tier approach used in estimation of enteric fermentation or other emissions; and of the 32 countries omitting one or more livestock emission source, 20 gave no explanation for this

[66] IPCC (2006), Volume 1, Chapter 3.
[67] Decision 17/CP.8, paragraph 24.

Text Box 16

Tier 1b approaches to estimating methane emissions from manure management

Sri Lanka was one of six countries that used a 'Tier 1b' approach to estimating methane emissions from manure management, in which different default values are applied to livestock in different climate zones. Within Sri Lanka, one region located at high elevation is characterized as a temperate region (i.e., average annual temperatures 15-25°C), while others are characterized as warm regions (i.e., average annual temperatures >25°C). Numbers of each type of animal located in each region were estimated based on census data, to produce a more accurate estimate of national methane emissions from manure management.

Source: Sri Lanka (2012) Second National Communication on Climate Change

Text Box 17

Country-specific estimates for the uncertainty of activity data

A common challenge is that data sources report point estimates (e.g. total head of livestock in a year) or mean values, but do not report the error or uncertainty ranges associated with these estimates. Statistics on livestock populations from official sources as well as literature values and expert judgments mostly only give a single figure. Facing the challenge of characterizing uncertainty in the national inventory in order to prioritize improvements, Ghana developed a quantitative approach in which expert judgment was used to assign uncertainty ranges to data depending on the level of verifiability and perceived reliability of the source of data. The purpose of this was to ensure the application of a consistent and transparent approach to uncertainty estimation. Table 7 presents some of the estimates derived. It should be noted, however, that the estimated uncertainty ranges are country specific and differ from ranges assumed in other countries.

Table 7: Country-specific estimates of uncertainty ranges for activity data sources in Ghana's national GHG inventory report for 2014

Activity data source	Uncertainty range		Comments
	Plus	Minus	
Peer reviewed literature	5%	5%	
Enumeration	4%	2%	
Industry archive	6.5%	6%	
International sources	6%	5.5%	
National project reports	5%	5.5%	Including strategies, action plans
National census	5%	5%	
Expert judgment	15%	12%	

Source: Adapted from Republic of Ghana (2015) National GHG inventory report: 2014 national carbon accounting.

omission. The current verification process for BURs involves technical analysis of BURs by teams of technical experts (TTEs), who focus largely on assessing the transparency of information. As more countries move towards BUR submission, the importance of transparency is likely to increase.

3.1.7 The quality of national inventory reporting of livestock emissions

Appendix 2 describes the application of a scoring method to assess the quality of livestock GHG emission reporting in submissions to the UNFCCC of 140 developing countries.[68] Indicators were developed to assess the quality of reporting in relation to the UNFCCC MRV principles of completeness, accuracy, consistency and transparency (Table 8).[69] Since all 140 countries used either the *Revised 1996 IPCC Guidelines* or *IPCC 2006 Guidelines*, the use of comparable methodologies was not assessed. Scoring was applied to information obtained from the latest NCs, NIRs and BURs available on the UNFCCC website.[70] The scores were then weighted by the relative importance of these four IPCC principles as indicated by participants at an international workshop.[71]

Figure 4 shows the distribution of weighted scores among all countries. The scoring system used allowed for a minimum score of -7 and a maximum score of 27.[72] The resulting scores for the 140 countries ranged between -3 and 24, indicating considerable variation in the quality of livestock emission reporting. The mean score was 13.6, with a standard deviation of 6.1. Figure 5 compares the average weighted scores for each criterion with the maximum possible score. It visually illustrates that the largest gap in livestock inventory reporting quality is in relation to accuracy, with some gaps in consistency and transparency. For most countries, use of Tier 1 approaches was the main contributor to this gap, but lack of uncertainty analysis also contributed. However, as with all scoring systems, certain assumptions are embedded in the selection and weighting of indicators. If, for example, the most important function of national GHG inventories is to report the effects of mitigation actions, completeness might only matter for those GHG sources that are affected by mitigation actions. Similarly, indicators of accuracy would give greater weight to the ability of the GHG inventory to reflect trends in key GHG sources. Thus, appropriate methods for assessing the quality of GHG inventories depend on the policy objectives to which they are applied.

The assessment of reporting quality suggests that for developing countries, on average, the aspects of livestock GHG emission reporting most requiring improvement relate to accuracy.

Data sources described in Appendix 1 suggests that livestock GHG emissions contribute more than 5% of total national GHG emissions in about 70% of developing countries. Moreover, of the 40% of countries that reported key source category analysis at the inventory level, almost all reported that at least one livestock emission source to be a key source category in the national inventory (Section 3.1.3). Improving inventory quality for key source categories can improve the accuracy and confidence in the overall inventory estimates.[73] The assessment of reporting quality presented here suggests that for developing countries, on average, the aspects of livestock GHG emission reporting most requiring improvement relate to accuracy. Of 29 countries that reported inventory improvement plans related to livestock emissions in their NCs, BURs or NIRs, 13 reported a need to improve both emission factors and activity data, 12 reported a need to improve activity data only, and 4 reported a need to improve emission factors only. Figure 6 shows the inventory quality scores of these countries. The distribution shown in the figure indicates that most (i.e. 24 out of 29) countries proposing specific improvements had an inventory quality above the average for all 140 countries. Countries only proposing improvements in emission factors tended to have a much higher score than average. However, countries proposing improvements in emission factors and activity data include both countries with a high-quality inventory and countries with a lower-quality inventory. The specific gaps and needs faced by these countries are therefore likely to vary significantly. Suggestions for improvements in emission factors mainly related to development of country-specific Tier 2 emission factors. Only South Africa has reported interest in developing Tier 2 approach that can be updated periodically on the basis of statistical data.

[68] Submissions by developed countries were not included because they are required to follow different UNFCCC guidelines. In general, because of more explicit requirements and higher capacities, completeness, consistency and transparency scores would be higher, and since many developed countries use Tier 2 approaches for some livestock types, accuracy scores would also be higher.
[69] Comparability was not assessed as all countries used either IPCC (1996) or some or all components of IPCC (2006) Guidelines.
[70] http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php and http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php
[71] See Appendix 2 for further explanation.
[72] Because only GHG inventories reporting livestock emissions were assessed, at least one livestock-related emission source would be recorded, which would give a score of 2, so the minimum possible score is -7, not -9 as suggested by the description of the scoring system in Table A.2.
[73] IPCC (2000).

Table 8: Scoring criteria for the quality of national reporting of livestock emissions

Criteria	Indicators	Scoring	Weighting (% of total possible score)
Completeness	1. The main livestock emission sources were included in the latest inventory	0 – 9	20%
Accuracy	2. IPCC tier approach used for livestock emission sources	0 – 3	26%
	3. National data on livestock population is available	0 – 3	
	4. Efforts are being made to identify and reduce uncertainty	0 – 3	
Consistency	5. Consistency of methods used in time series reporting	0 – 9	24%
Transparency	6. Justification is given for any GHG source excluded	-3 – 0	31%
	7. Tier level used is stated or a Tier 2 emission factor was used and was referenced or explained	-3 – 0	
	8. Reference to livestock population data source was given and livestock population data was presented	-3 – 0	

Note: positive scores were given for indicators of adherence to complete, accurate and consistent reporting, while negative scores were given for non-adherence to indicators of transparency. The maximum and minimum possible scores remain the same for all countries assessed.

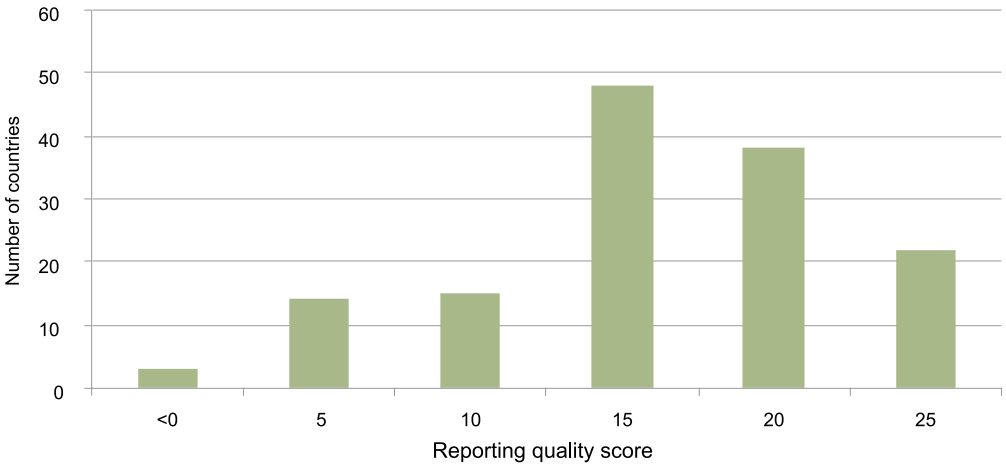


Figure 4: Distribution of scores for the quality of national reporting of livestock emissions (n=140)

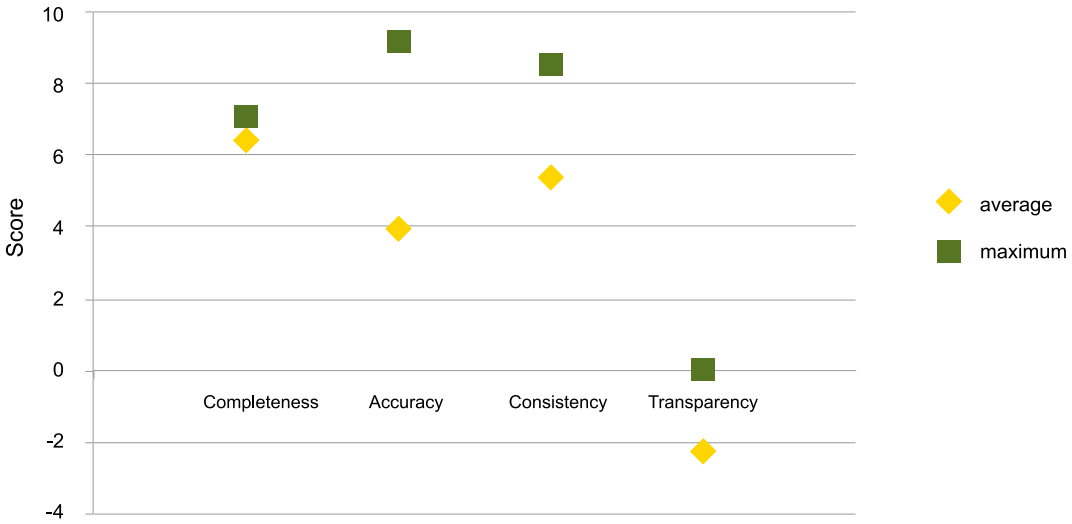


Figure 5: Comparison of average with maximum possible scores for each criterion for all countries assessed (n=140)*

**The scoring methodology provided scoring options from 0 to 9 for completeness, accuracy and consistency and between -9 and 0 for lack of transparency. Each principle was then weighted based on expert opinion by 32 experts from developing and developed countries.*

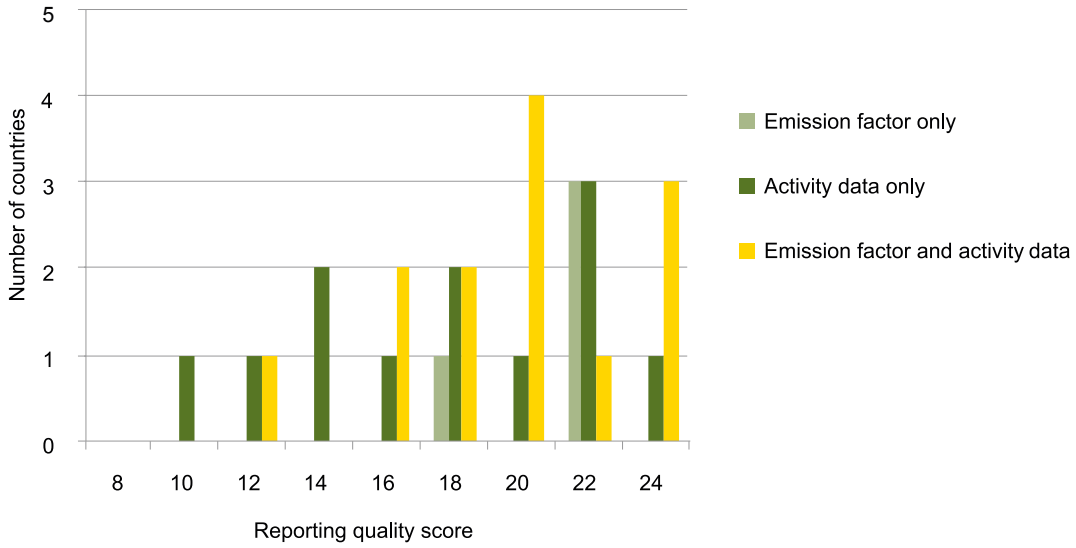


Figure 6: Livestock GHG emission inventory quality scores of countries proposing inventory improvements related to livestock GHG emissions

3.2 Challenges and opportunities for inventory improvement

Reviews and studies of national GHG inventory processes and inventory processes in related fields (e.g. REDD+) indicate that critical underlying capacities for inventory compilation include institutional arrangements that facilitate collaboration and information flows; political engagement; human resources and technical capacities; and financial resources (Text Box 18).[74] These needs and constraints faced by developing countries in relation to general inventory processes are also relevant to inventory compilation and reporting for livestock GHG emissions. Table 9 highlights some key practical constraints mentioned in interviews by people involved in compilation of livestock emission inventories in selected developing countries.[75] The interviews also suggested that the way these various practical constraints are perceived, and how countries could approach inventory improvement in the face of these constraints, may be determined in part by the policy objectives to which the national GHG inventory contributes. The following sections explore the varying policy drivers of inventory improvement (Section 3.2.1), strategies for improvement that match different policy objectives (Section 3.2.2) and key practical options for inventory improvement (Section 3.2.3).

Critical underlying capacities for inventory compilation include institutional arrangements that facilitate collaboration and information flows; political engagement; human resources and technical capacities; and financial resources.

3.2.1 Policy drivers of inventory improvement

The national policy context has a major influence on the policy uses of national GHG inventories and the motivating factors for inventory improvement. In some countries, such as Ethiopia, Indonesia and Vietnam, national mitigation strategies and INDCs provide the main impetus for improved quantification of livestock emissions (Text Box 19). In all of these countries, the potential for securing climate finance investments from outside sources is also a key motivating factor. The politics of developing country commitments and obligations in the UNFCCC also have an influence on approaches to inventory improvement (Text Box 20). For example, in Chile, which in international discussions has stressed the relevance of mitigation as a co-benefit of adaptation,[76] national mitigation strategy is not prioritizing NAMAs in the agriculture sector, so in the absence of specific MRV systems for NAMAs, the national GHG inventory is the main tool for MRV of GHG emission trends in the sector. Inventory improvement efforts in Chile have focused on improving the accuracy of estimated emission levels. In China, agricultural policies with GHG mitigation effects are included in its INDC, and these effects are also reflected in the national GHG inventory. Interviews with Chinese inventory compilers indicated that inventory improvements are made not only considering national policies and capacities but also agreements on developing countries' reporting obligations under the UNFCCC and the level of international support provided.

[74] IGES (2016); Neeff et al. (2015); Tulyasuwan et al. (2012); Romijn et al. (2012)
[75] Countries were selected for interview based on existing contacts of CCAFS, GRA, FAO and UNIQUE forestry and land use, and the willingness of inventory compilers to participate in the interviews.
[76] See, e.g. Chile's submission to SBSTA 39 workshop on agriculture: http://unfccc.int/resource/docs/2013/sbsta/eng/misc17a01.pdf

Text Box 18

Needs and constraints for inventory compilation and reporting identified in the Sixth compilation and synthesis of developing countries' national communications

By 2005, 122 countries had submitted their initial national communications to the UNFCCC. Synthesis by the Subsidiary Body for Implementation (SBI) identified the following needs and constraints in relation to national inventories:

- Inadequate technical and institutional capacities for meeting reporting obligations;
- Lack of activity data for estimation of emissions;
- IPCC default emission factors not applicable to national circumstances, and thus a need to develop appropriate emission factors;
- Need for financial and technological support for the continuous collection and archiving of inventory data, along with the establishment and maintenance of stable national institutions, inventory teams and a reliable and effective GHG inventory database system;
- Financial and technical assistance is needed for improving the quality (availability, accuracy and reliability) of sectoral data by establishing systematic mechanisms to collect data, undertaking field studies and validation of emission factors and carrying out further surveys in order to reduce uncertainties in activity data;
- The need to improve the availability and reliability of data through active cooperation with relevant government departments and agencies, industry, NGOs and other institutions that provide, collect and maintain relevant data;
- The need for adequate training to enhance local technical capacity and expertise in data collection, management and dissemination;
- The need to strengthen the capacity of institutions involved in the preparation of the GHG inventory, including the training of personnel.

Source: SBI (2005).

Table 9: Practical constraints mentioned in relation to livestock inventory compilation in selected countries

	Chile	Colombia	Ethiopia	Indonesia	Philippines	Vietnam
Human resource allocation to inventory work	✓	✓				
Institutional structures for inventory related research	✓		✓			
Limited data from / low priority on activity data collection in national agencies	✓		✓	✓		✓
Lack of data on diverse farm conditions			✓			✓
Limited capacities for Tier 2 research			✓			✓
Sustainability of finance for inventory agencies		✓				
Finance for activity data collection or emission research			✓	✓	✓	✓

Source: this study.

Text Box 19

National mitigation strategies, INDCs and climate finance opportunities as drivers of livestock GHG emission inventory improvement efforts

Ethiopia:[77] Ethiopia's first NC was compiled by the Meteorology Institute, its second by a consultant, and the third will be prepared by the Climate Science Centre (CSC), a cross-departmental centre aiming to improve research and build capacity on climate issues related to GHG accounting and adaptation. The CSC closely partners with different ministries, including the Ministry of Environment, Forest and Climate Change (MEFCC), and aims to build capacity and strengthen regional GHG data collection through agricultural and livestock research institutes and the Bureau of Agriculture. Ethiopia's second NC specifically proposes to improve future GHG inventories by developing Tier 2 emission factors for livestock emissions. Initially, the key planned activity is to produce a more detailed stratification of the country by agro-ecological zone and production system.

This initiative has been driven by a combination of factors. With the communication of Ethiopia's INDC in 2015, the Ministry of Livestock and Fishery Development is tasked with delivering a mitigation target. This target is based on analysis conducted for the development of the country's Climate Resilience Green Economy strategy. The MEFCC has a strong interest in validated, credible and internationally recognized research to support emission estimates in relation to the INDC. A number of international donors are also interested to support Ethiopia in this field. While donors are not interested in supporting basic research, they are interested in small-scale surveys to support the development of emission factors. It is hoped that by conducting a number of such studies in the context of a nationally appropriate stratification of the country's livestock production systems, Tier 2 emission factors can gradually be developed.

Vietnam:[78] The Institute for Agricultural Environment (IAE) of the Vietnam Academy of Agricultural Sciences has begun research to provide improved activity data on manure management and to develop Tier 2 emission factors for livestock enteric fermentation. In doing so, IAE is primarily responding to two sources of demand. On the one hand, Vietnam's Green Growth Strategy includes a goal to reduce GHG emissions through sustainable agriculture and improved agricultural competitiveness. In response to the strategy, each province needs to identify mitigation actions, and provinces have approached IAE asking for related advice. There is also strong awareness of the potential for climate finance, if effective mitigation actions can be identified. There is thus strong demand for the institute to undertake research on mitigation options. This requires better data, including Tier 2 emission factors that can reflect the effects of changes in livestock and manure management practices. In addition, mitigation of livestock emissions has not been deeply analysed in previous national communications and is not highlighted in the country's INDC. Therefore, there is also demand from the agriculture ministry and from members of national communication working groups for better representation of the livestock sector in national mitigation policies.

These preceding examples relate to domestic and international climate policy domains. However, the selection of mitigation priorities is often not driven by climate policies or GHG mitigation considerations alone. For example, GHG mitigation can be a co-benefit of a national policy focus on enhancing the competitiveness of the national livestock industry (e.g. as in Chile, Namibia or South Africa), improving food security and rural incomes (e.g. as in Ethiopia or Kenya), addressing degradation of land and forest resources (e.g. as in Ecuador, Colombia, Mongolia) and combating the contribution of livestock waste to pollution of the environment (e.g. in China). In many countries, several policy objectives are present at the same time.[79]

The role of national GHG inventories in these policy contexts varies. In many countries, it appears that national GHG inventories are perceived primarily as an element of countries' international obligations under the UNFCCC, and are not referred to as a basis for decision-making or progress assessment in the livestock sector, even where climate and livestock policy linkages are explicitly made. However, the preparation of national mitigation strategies, and the preparation and communication of INDCs to the UNFCCC have in some countries strengthened linkages between domestic agricultural and climate policy fields, which may alter perceptions of the policy functions of national GHG inventories, and thus the priorities for inventory improvement.

[77] Based on an interview with Dr Zewdu Eshetu, Director of the Climate Science Centre at Addis Ababa University.
[78] Based on an interview with Dr Mai Van Trinh, Institute for Agricultural Environment of the Vietnam Academy of Agricultural Sciences.
[79] Wilkes et al. (2013).

Text Box 20

Effects of international obligations and negotiations on approaches to GHG emission inventory improvement

Chile:[80] Chile has submitted four inventory reports to the UNFCCC since its first in 2000. Since 2012, The Department of Climate Change (DCC) in the Ministry of Environment has developed and put in place a National GHG Inventory System, which sets out the institutional, legal and procedural steps required for regular updating of the national GHG inventory. This includes the work of sectoral technical teams. The establishment of this system has primarily been driven by a pro-active team within the DCC, who are engaged at the international level and enthusiastic in delivering on Chile's national responsibilities. Agreements between the Ministries of Environment and Agriculture are in place, which ensure the willingness of the latter to play an active role, including INIA the agricultural research institute of the Ministry of Agriculture which leads technical work on compilation of the livestock emissions inventory. In the UNFCCC negotiations, Chile has been concerned to avoid mitigation targets in the agriculture sector. As an open economy with significant livestock product exports, mitigation targets might be restrictive on the one hand, but on the other hand carbon footprints are relevant to product differentiation and competitiveness and to the efficiency of livestock production. Chile has not considered including agriculture in the scope of its planned carbon tax and emission trading schemes, and has not proposed NAMAs directly relating to livestock production. In terms of MRV, therefore, the national GHG inventory is the main tool through which trends in livestock GHG emissions will be tracked.

China:[81] Following announcement of its voluntary commitment to reducing the carbon intensity of the economy in 2009, China has mainstreamed climate change mitigation into its national development planning, including related activities also in sectoral development plans and policies. More recently, the achievement of targets for emission intensity have been included in the system for assessing officials' work performance. Since 2011, successive national development plans for the agriculture sector have included related targets, such as decreases in agricultural pollution sources and increases in adoption of improved manure management practices. In recent years, the ministries of agriculture and environment have worked closely to issue regulations requiring large-scale livestock farms to install waste management facilities. To assess the effects of these and other policies on livestock waste management practices, the Ministry of Agriculture entrusts researchers from the Chinese Academy of Agricultural Sciences to undertake an annual survey. The scientists involved are also responsible for preparation of the livestock component of the national GHG inventory. Thus, annual data is available to track changes in manure management in the national GHG inventory. However, the inventory compilation process closely follows UNFCCC and IPCC requirements, which at present only require submission of the inventory as part of the national communication every 4 years, with an interim update through BURs. National policy makers' information needs are met through the annual survey, but more frequent updating and reporting of activity data or emission factors in the national GHG inventory is not currently required under the UNFCCC, and the international community does not fund more frequent inventory improvement activities.

3.2.2 Matching inventory improvement strategies with policy objectives

It appears that in many countries, the national GHG inventory is mainly perceived as a tool for meeting reporting obligations under the UNFCCC. Inventory improvement plans are often made in consideration of the challenges faced in inventory compilation, or assessment of data gaps and uncertainties. In line with IPCC guidance, such efforts aim primarily to improve confidence in inventory estimates.[82] In such a policy environment, the priorities in inventory improvement are likely to be improvements in data acquisition and increasing the accuracy of inventory estimates. Even in some countries where national livestock and climate policies are well aligned, inventory improvements may be driven more by the dynamics of the inventory process than by the demands from stakeholders in the livestock sector.

If a key function of national GHG inventories is to reflect the effects of mitigation actions, the precision of the trend in livestock emissions may be more important than accuracy for any given year.

By contrast, where the national GHG inventory is seen as a tool to inform policy making or to measure progress against policy goals, such as climate change mitigation, the priorities for inventory improvement can also reflect these other objectives. Where the livestock sector is expected to contribute to reductions in national GHG emissions (e.g. in the context of NDCs) or where countries are developing livestock mitigation actions, whether for international or domestic financing, an important characteristic of the national inventory

[80] Based on an interview with Dr Marta Alfaro, INIA.
[81] Based on an interview with Professor Dong Hongmin, Chinese Academy of Agricultural Sciences.
[82] IPCC (2000).

is its ability to track change in emissions and emission intensity over time. In this policy context, it could be that accuracy for any given single year is less important than the accuracy of the trend in livestock emissions or emissions intensity.

This stylized depiction of the role of GHG inventories in the broader policy context may not accurately represent policy dynamics in any one country, but it brings to focus a number of issues underlying some practical considerations regarding improvement of livestock inventories. In particular, Section 3.1.8 highlighted that the limited adoption of Tier 2 approaches that reflect changes over time is a major gap in livestock GHG inventory quality. Depending on how the priorities for inventory improvement are determined, countries' strategies for moving to or improving a Tier 2 approach could differ:

Inventory improvement to improve accuracy and reduce uncertainties: Section 3.1.3 reported that very few countries have conducted key source analysis, but compilation of data from submissions to the UNFCCC suggests that livestock emission sources are likely to be key source categories for the majority of developing countries (see Appendix 1). IPCC guidance suggests that where livestock emission sources are a key category, further assessment of whether particular livestock types are key sources can aid in identifying the livestock types for which a Tier 2 approach would improve the accuracy of the inventory or at least produce emission factors that are more reflective of a country's key production systems.[83] Once key livestock types have been identified, key factors influencing total emission estimates, in order of importance, are likely to be: livestock numbers > distribution of the livestock population by agro-ecological zone or production system > livestock reproduction and performance parameters over time > characterization of feed intake and digestibility (Figure 7).

For some countries, therefore, the key area for improvement is activity data on livestock populations. For other countries, livestock population data is available, but the accuracy of emission estimates can be improved by adopting a Tier 2 approach. Improving the characterization of livestock populations by agro-ecological zone or production system, and increasing the availability and accuracy of data on feed intake and feed digestibility for livestock sub-populations, would be the priorities for developing a Tier 2 approach.

Inventory improvement to improve estimation of an accurate trend in livestock emissions: If a country starts from the premise that the key function of the national GHG inventory is to measure GHG reductions over time, the priority is to be able to show as accurately as possible a trend in emissions over time. Inventory improvement priorities may be identified considering that even if annual estimates are biased, if consistent methods are used, the errors are likely to be highly correlated, so the trend in emissions may still be accurate. Unless fluctuations in livestock populations are the major driver of emissions,[84] only moving to a regularly updated Tier 2 approach that captures changes in productivity or movements between production systems can enable inventories to play this function. Key steps, in order of importance, could be: Prioritize livestock sub-sectors or sub-populations based on planned mitigation interventions or expected trends in the sector affecting emissions > use available data to populate the IPCC Tier 2 model > assess data quality and uncertainty to prioritize inventory improvements over time.

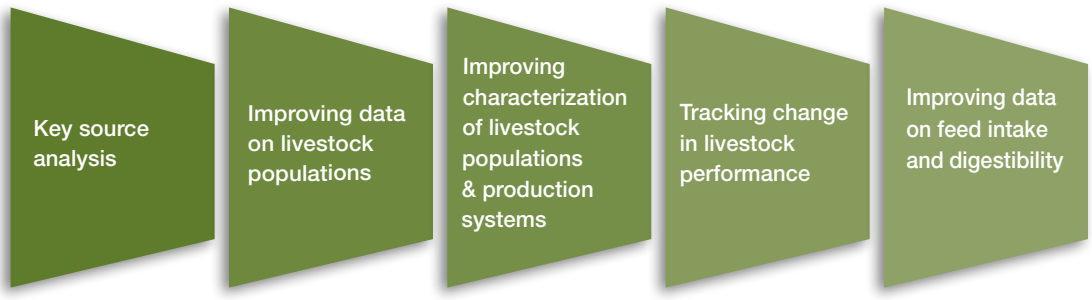


Figure 7: Stylized strategy for improving the accuracy of estimated livestock GHG emissions for a given year in a national GHG inventory

[83] Note that is somewhat artificial and potentially misleading to compare the generic uncertainty of Tier 1 emission factors with the uncertainty of emission factors derived using a Tier 2 approach for a specific production system. In the latter case, uncertainty can be estimated using statistical analysis and expert judgement, whereas in the former case any individual country or production system could deviate from the default Tier 1 emission factor by much more than the assumed generic uncertainty factor.

[84] E.g. in countries frequently subject to natural disasters.

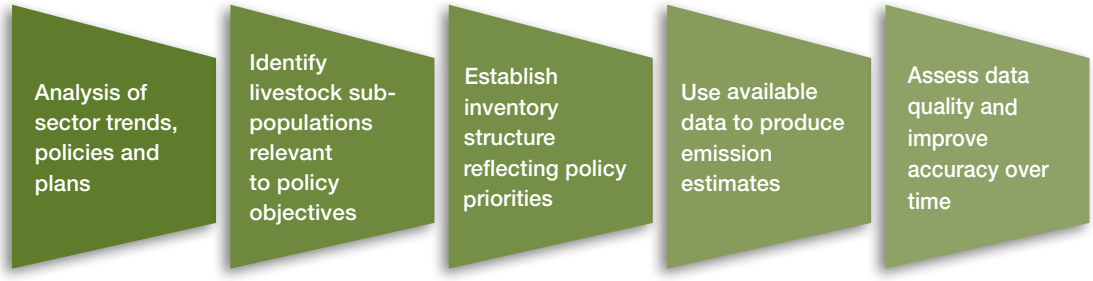


Figure 8: Stylized strategy for improved estimation of livestock GHG emission trends through national GHG inventories

Because of the flexibility in the IPCC Guidelines, particularly regarding data sources, both of the strategies outlined above could be implemented in a manner consistent with the Guidelines. However, the underlying approach to data quality may vary. With a focus on improving accuracy of inventory estimates for a given year, available resources should be allocated over time to increasing the availability and validity of data required to implement a Tier 2 approach for key sources of livestock emissions. A risk, however, is that the costs of achieving a given level of accuracy (or range of uncertainty) slows down or prevents progress in inventory improvement. From a decision-maker's point of view, the cost-benefit ratio of making inventory improvements may be too high to justify investment unless incremental improvements and low-cost data collection methods can be identified. With a focus on tracking the trend in livestock emissions, the initial emphasis is on being able to describe an accurate trend in livestock emissions over time, rather than on minimizing error in the initial estimates. Available data may be used as long as data quality is deemed acceptable for estimation of the trend in emissions over time, data sources are transparently documented, and plans for improvement are put in place. These features would need to be balanced against the use of consistent methods over time (including recalculation when improvements are made). With either approach, improvements can be made incrementally using the resources available at different times and targeted to improvements that increase the policy utility of the inventory, thus making investment in inventory improvement more attractive and sustainable over time.

How these strategies work in practice will depend not only on the domestic and international policy context as characterized above, but also on the awareness and understanding of participants and stakeholders in the process, including officials in different ministries, scientists supporting inventory compilation and review and industry stakeholders, as well as donors. The understanding and views of these groups will determine what can be agreed upon as acceptable practices. How different stakeholders understand the priorities, potentials and acceptable practices in Tier 2 approaches are further explored in Section 5.3.2 and Appendix 4.

3.2.3 Practical options for inventory improvement

The survey of current practices in livestock GHG inventory compilation and reporting (Section 3.1) showed that specific practices vary considerably, reflecting the flexibility in IPCC guidelines as well as national conditions, including the national situation and policy, capacities and resources. Focusing on potential priority areas for improvement, the following sections highlight key options for improvement in activity data (3.2.3.1), characterization of livestock sub-groups (3.2.3.2) and feed intake (3.2.3.3), emission factors and livestock performance (3.2.3.4), uncertainty analysis and improvement over time (3.2.3.5), and transparency (3.2.3.6).

Priorities for inventory improvement depend on how GHG inventories serve national policy goal.

3.2.3.1 Improving accuracy through better activity data

A number of countries' submissions to the UNFCCC reported difficulties in compiling data on the basic characterization of livestock populations in their country. These included countries in arid climate areas with transhumant livestock populations, some small island states, and countries afflicted by conflict. Common issues reported in NCs and BURs included:

- Timing of data collection: irregular periodicity of livestock surveys, lack of annual time series data from national data providers, and data from surveys taken at different times of the year;
- Lack of data in needed categories: national data does not report livestock populations in IPCC categories (e.g. no distinction between dairy and non-dairy cattle, transhumance prevents enumeration or characterization of livestock by climate zone);
- Discrepancies: discrepancies in data reported by different data-providing institutions.

Countries used a variety of methods to fill data gaps on an ad hoc basis for the purpose of national GHG inventory compilation. These methods included interpolation of FAO livestock population data for years or livestock types with missing data; calculation of the average population in years with data, and interpolation into years with missing data; consultation with sectoral experts; and extrapolation of data on herd composition from sample surveys to the national livestock population. Other countries report having assessed the reliability of livestock population data by cross-checking between alternative data sources.

Several countries have proposed including data needed for the GHG inventory in forthcoming agricultural censuses (Text Box 21). Since agricultural and livestock censuses are expensive, most countries do not conduct them frequently. Between censuses, some countries use livestock vaccination records or undertake sample-based surveys. However, there are often problems with the reliability and representativeness of these data sources.[85] For example, free government vaccinations have been withdrawn in some countries, so the coverage of vaccinations may be limited. Transhumant herds may be underrepresented in sample-based surveys. In the years between national censuses, many countries use fixed population growth rate coefficients to estimate growth in the population of different livestock types. Fixed coefficients for population growth, livestock product outputs and off-take are commonly used by national agencies to estimate the contribution of livestock to GDP on a quarterly and annual basis. However, the reliability of the coefficients used in some countries may be questionable, especially if changes in demand, trade, or production models occurs. Models incorporating population growth, livestock product outputs and off-take have also been used to estimate livestock population and structure in some countries' GHG inventories. Models incorporating population growth, livestock product outputs and off-take have also been used to estimate livestock population and structure in some countries' GHG inventories. If model coefficients are inaccurate, this will influence the accuracy of national GHG emission estimates over short timeframes (e.g. 2-4 years between BUR or NC submissions), but if good census data is available to update model estimates, the accuracy of estimates can be improved over time.

Improved availability of activity data relating to manure management systems is particularly relevant in a number of countries, because the lack of activity data was often given as a reason for omitting manure management or dung and urine deposit on pastures from national inventories. This highlights the importance of linking national GHG inventory compilation processes to the work of statistical and census agencies. Institutional arrangements for inter-ministerial cooperation in inventory processes have frequently been stressed as a key capacity in national GHG inventory compilation (see also Text Box 22).[86]

3.2.3.2 Characterization of livestock sub-groups

No matter whether a Tier 1 or Tier 2 approach is used, where emissions from manure management are important, *IPCC 1996 Guidance* suggests that livestock populations should be characterized by climate zone, so that appropriate emission factors for CH_4 emissions from manure management can be used. With Tier 2 approaches, a more detailed characterization of livestock sub-groups is required. This means distinguishing different sub-groups of animal by age, sex, productive use or other factor likely to be associated with significant differences in average feed energy demand and hence emissions. A critical issue is to link categorization of animal sub-groups with the collection of activity data on livestock populations (see 3.2.3.1 above).

It also means identifying agro-ecosystems, production systems, breeds or other dimensions associated with differences in feed and animal performance that determine variation in emissions. Text Box 12 provides examples of different ways countries have stratified data to estimate livestock emissions when developing a Tier 2 approach. More detailed characterization of livestock populations can contribute to more accurate emission estimates. It also provides an opportunity for better understanding of potentials and priorities for GHG mitigation (Text Box 23). This could also inform decisions on the prioritization of limited resources for GHG inventory improvement for key sub-groups.

[85] See IBRD (2014).
[86] See IGES (2016); Neeff et al. (2015); Tulyasuwan et al. (2012); Romijn et al. (2012).

Text Box 21

Resources for improving livestock data availability through national censuses

In the absence of regularly reported livestock population data, agricultural or livestock censuses provide a good opportunity to collect data on herd parameters (e.g. birth, survival and mortality rates), with which to develop or update coefficients for use in modelling national livestock populations. The FAO operates the World Programme on Agricultural Censuses, which supports countries to carry out census and provides methodological guidance (http://www.fao.org/world-census-agriculture/en/). National agricultural and livestock census questionnaires and reports from many countries can be viewed at http://www.fao.org/world-census-agriculture/wca2020/countries2010/en/ The World Bank and FAO have recently produced a guidebook for designing the livestock component of household survey questionnaires (Zezza et al. 2016a).

Sources: Zezza et al. (2016a); Ugo Pica-Ciamarra, pers. comm.

Text Box 22

Institutional arrangements for improving data availability

Vietnam:[87] Researchers in Vietnam are undertaking research to develop Tier 2 emission factors for enteric fermentation and manure management. Applying the emission factors in the national GHG inventory will require that nationally representative data on a number of parameters are available. Every 5 years, the General Statistics Office consults other ministries on updates required to its data collection form for annually reported data. This provides a potential opportunity for data needs to implement a Tier 2 approach to be incorporated within the national statistics system.

Chile:[88] Chile's statistics agency implements an agricultural census every 10 years. In the interim, there is a livestock production survey every 2 years. Researchers responsible for the livestock component of the national GHG inventory can use this data to check against other sources of data used in the national inventory, and also have the opportunity to add questions into the survey to ensure that the data needs of the inventory are met.

Text Box 23

An approach to improved livestock characterization and mitigation analysis

UN FAO, the Climate Science Centre (Ethiopia) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) recently completed an assessment of GHG mitigation potential in Ethiopia's dairy sector. The assessment characterized dairy production systems in Ethiopia into 4 main types, and several sub-types:

- Rural mixed crop-livestock systems, including traditional crop-livestock farms and crop-livestock farms with intensive cropping
- Pastoral and agropastoral system
- Small commercial dairy, including intensified crop-livestock farms in rural areas and peri-urban farms
- Medium commercial dairy systems, including urban farms, intra-urban dairy farms and specialized dairy farms

For each sub-type, national experts collated information from existing national databases, literature reports and other sources to estimate data on populations (including herd composition), performance parameters, feeding systems and manure management. The data was entered into the Global Livestock Environment Assessment Model (GLEAM), developed by FAO, to estimate average emissions per head and per litre of milk produced in each sub-type of production system, and to characterize the spatial distribution of dairy emissions across the country. Analysis identified key drivers of variability in GHG emission intensity as inadequate and poor-quality feed, animal health, reproductive efficiency and breeds.

Literature reports were also used to collate data on the effects on milk yields and implementation costs of feed, disease control and breeding interventions in each of the production systems, the GHG effects of which were estimated using GLEAM. This enabled cost-effective mitigation options and packages of interventions to be identified for different production systems.

Source: FAO (2017)

[87] Interview with Dr Mai Van Trinh, Institute for Agricultural Environment of the Vietnam Academy of Agricultural Sciences.
[88] Interview with Dr M. Alfaro, INIA.

3.2.3.3 Improving estimates of feed intake

Feed energy intake and feed digestibility are key drivers of enteric fermentation emissions. There are a number of methods for direct measurement of feed intake, as well as indirect estimation methods based on energy requirements. Studies comparing the accuracy and reliability of these methods commonly find that indirect methods perform relatively well.[89] Hence, the IPCC Guidelines recommend estimation of feed energy intake using indirect methods, namely data on animal reproduction (e.g. percentage of cows pregnant) and animal performance (e.g. weight, daily weight gain, daily milk yield).[90] Given the diversity of breeds and production conditions in many countries, collecting representative data on these parameters is likely to be prohibitively expensive. It is likely that these perceived costs are one reason why many countries have not moved towards a Tier 2 approach.

However, alternative data collection methods are commonly used in developing and developed countries that have moved towards a Tier 2 approach. Some countries, such as India, use existing national feeding standards as the basis for estimating feed intake. More commonly, a combination of literature reports, industry data on live weight or milk yields, and expert judgment are used to provide data on these parameters. Most countries should be able to estimate these parameters for key livestock types using these data sources, including breed characterization studies (see Text Box 24), although the accuracy of the data sources may not always be known.

Similarly, although seasonal variations in feed digestibility will have major impacts on methane emissions, it can be costly to accurately inventory diverse feedstuffs. Where countries lack national data, literature reports and international databases[91] can be used, along with comparison with the IPCC default values, to produce initial values for use in the Tier 2 model.

3.2.3.4 Improving emission factors

The vast majority of developing countries use a Tier 1 approach to estimate livestock GHG emissions. Moving to a Tier 2 approach could significantly improve the quality of livestock GHG emission reporting in national inventories by more accurately reflecting methane and nitrous oxide production. Adopting a Tier 2 approach is one way to therefore improve the accuracy of trends of emission estimates for inventories, where this is the priority.

Where precision of emission trends is the priority, emission factors should be updated to reflect changes in livestock production and performance.

The accuracy of Tier 2 emission estimates is likely to be most strongly influenced by characterization of livestock population groups, and the accuracy of feed digestibility and productivity data, including reproduction parameters, which collectively determine energy demand and feed intake. In addition, feed digestibility is a key determinant of the methane conversion factor, Y_m. While some countries have undertaken sensitivity analysis, this has rarely been reported. It is likely that change in livestock performance parameters over short periods (e.g. 2-4 years) has a smaller impact on the accuracy of emission factors than improved information on feed intake, digestibility and reproduction. Over longer time periods, changes in livestock performance can make significant contributions to changes in absolute emissions and emission intensity.[92]

Where increasing the ability of inventories to describe trends in emissions is the priority, it is critical that inventory databases and data collection activities are structured to enable updating of livestock productivity and performance data that determine energy/feed demand of animals (Text Box 14). As noted in Section

[89] Most studies, however, have been conducted in temperate areas where the equations used in the indirect method were developed. Little research has been conducted to validate or revise the equations for developing countries in tropical areas.

[90] IPCC (2016) indicates that the IPCC is considering further elaboration of guidance on description of feeding systems in a future updating of the 2006 IPCC Guidelines.

[91] See http://www.feedipedia.org/content/feed-databases. In addition, some countries maintain national feed databases and the private sector may also hold some relevant information on feed quality.

[92] It is not possible on the basis of currently available evidence to give well-substantiated advice on the frequency with which productivity parameters should be updated. FAO data suggest that in the last 10 years, about a quarter of developing countries have experienced annual rates of change in cattle carcass yields greater than 1%; more than 50% have experienced annual rates of change in milk yields per cow greater than 1%, with 9 countries having average annual growth rates over 5%. Productivity changes may be even greater for specific regions or sub-sectors (e.g. commercial dairy) in each country. The effect of these productivity changes on emission factors will vary depending on the sensitivity of the parameterized model, and the significance for total livestock emissions will depend on the proportion of animals in regions or systems undergoing change.

3.1.5, only a few developing countries have updated Tier 2 emission factors. The experience of developed countries – many of which have also only recently moved to Tier 2 approaches – can be instructive. Table 10 indicates the parameters and data sources that are updated in Tier 2 approaches for cattle by a selection of developed countries. For dairy cattle, most of the sampled countries updated their emission estimates using data on milk yields and the fat content of milk, and around half also updated data on live weight, diet composition, reproduction rates and feeding situation. For 'other cattle', data is updated by most countries for live weight, and by some countries for diet composition and reproduction rates. In terms of data sources, statistical data were the most common data source. In some countries, this was regularly reported data from agriculture or statistics agencies, which in some cases was facilitated by registration of the whole cattle (or dairy cattle) population. However, in some countries, statistical data were collected on a portion of the national herd (e.g. cattle registered with an industry association) and results were extrapolated to the remaining herd, or used in combination with literature values (e.g. from breed characterization studies) to estimate changing trends.

Text Box 24

The availability of breed characterization studies

Breed characterization studies are one potential source of data for estimating animal performance parameters. For preparation of the Second Report on the State of the World's Animal Genetic Resources, 91 developing countries responded to a questionnaire about their related capacities. One question asked for information about the proportion of breeds (indigenous and exotic) for which breed characterization studies had been conducted. The results were scored as 'none', 'low' (i.e.<33% of breeds), 'medium' (33–67% of breeds) and 'high' (>67% of breeds). Of the 91 countries, about a third reported that no characterization studies had been done for different types of cattle breed; 20-25% reported 'low' levels of characterization; 25-30% reported medium levels and about 16% reported a high level of breed characterization (Figure 9). This provides suggestive evidence that 40-50% of developing countries may have a reasonable amount of information with which to elaborate at least an initial characterization of cattle breeds as part of a Tier 2 approach.

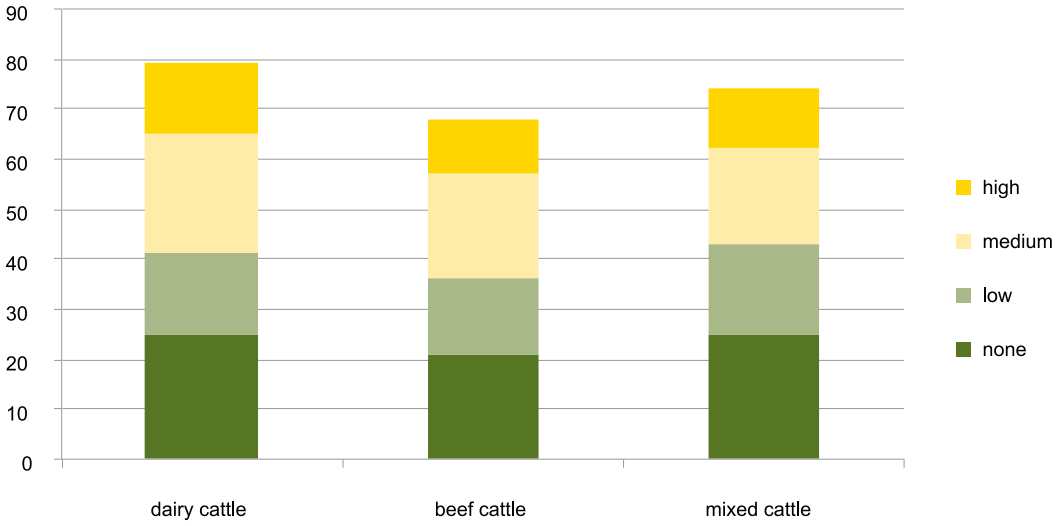


Figure 9: Number of countries reporting different levels of breed characterization for three types of cattle

Source: Compiled by this study from country reports available at http://www.fao.org/3/a-i4787e/i4787e01.htm

Expert judgment was also used by some countries to estimate trends in key parameters.

Table 10: Practical constraints mentioned in relation to livestock inventory compilation in selected countries

Country	Livestock type	Parameters						
		Live weight	Weight gain	Milk yield	Fat content in milk	Diet composition	Pregnancy rate	Feeding situation*
Belgium	Cattle	S		S	S	E		
Cyprus	Dairy cattle			S			S	
Czech	Cattle	E	E	S	S			E
Denmark	Dairy cattle	S	S	S	S	S		S
Estonia	Dairy cattle	L&S		S	S		S	
Hungary	Dairy cattle	L&S		S	S	S		S
	Other cattle	L&S				S		S
Latvia	Dairy cattle	E or L		S	X		S	
Norway	Dairy cattle			S		S		
	Other cattle	S	S			S		
Poland	Dairy cattle			S	S	E	S	
Portugal	Dairy cattle			S	S		S&X	L&S
	Other cattle	S						
Slovakia	Cattle	L&S		S		E	E	
Slovenia	Dairy cattle			S	S		S	S
	Other cattle	S&X	S&X					

** i.e. % of days feeding on pasture or in stalls. S=official statistics; E = expert judgment; L=literature data; X: extrapolated from limited existing data. (Source: this study)*

Enteric fermentation emissions are sensitive to value of the methane conversion factor (Y_m). Of the countries listed in Table 10, only Denmark and Norway used national measurements or models to characterize this parameter. Two countries used expert judgment, two used literature values from studies in another country, and the remainder use the appropriate IPCC default value. While measurements of Y_m can increase accuracy, lack of direct measurements of Y_m under national conditions is clearly not a barrier to adoption of a Tier 2 approach where an accurate trend in emissions is the priority. Some countries that are beginning to develop data for Tier 2 emission factors have begun by focusing on measurement of emissions associated with different diets to estimate methane conversion factors. However, researchers have become aware that a measurement approach requires longer-term experiments – considering also the need to build researchers' capacities – and repeated experiments for animals of different ages and physiological states, all of which requires funding.[93] The key enabler of moving to a Tier 2 approach in the near future at low cost is thus the availability and routine update of data on animal production systems, rather than data on methane conversion factors.

The availability of data on livestock performance in developing countries may be a key issue in the feasibility of implementing a regularly updated Tier 2 approach. Studies have found that the availability of data

[93] Interviews with Dwi Yulistiani (Indonesia), Francisco Salazar (Chile).

on livestock productivity in developing countries is often limited or if available, of low quality.[94] National capacities for management of agricultural statistics is related to institutional infrastructure, resources, methods, and accessibility. A study of African countries has suggested that the continent is quite weak in resources, but strong in institutional infrastructure and availability of statistical information – with considerable variation among countries – while limited data accessibility is a common issue.[95] Similar studies conducted in the Asia-Pacific region also highlight considerable variation among countries.[96]

Livestock productivity parameters are among the 'core' data requirements defined in the Global Strategy to Improve Agricultural Statistics, and are the focus of some initiatives to improve data collection and management (Text Box 25). However, the availability and quality of data on these parameters varies considerably. For example, assessment in Botswana, Indonesia and Tanzania show that while data on milk yields is perceived to be widely available, data on live weight, growth rates and reproduction are much less widely available.[97] From a GHG perspective, part of the challenge in improving data availability is that data collection for the purpose of the GHG inventory is rarely a priority. However, livestock productivity data align much more closely with issues of interest to industry stakeholders and farmers than GHG estimates *per se*. Assessments show that livestock sector stakeholders perceive priorities for improvement in data availability differently, but investments in improved data availability, quality and accessibility can be targeted to areas of common interest among sector stakeholders.[98] Furthermore, no single survey tool is likely to be sufficient to collect the fundamental data required to estimate livestock production (including herd dynamics), productivity and management practices.[99] Integrating data from different sources (e.g. administrative data and surveys by government agencies, and data from the private sector) is therefore likely to be important. For countries interested to integrate statistical systems with GHG inventory compilation, it will be critical to assess the availability of data, gaps between available data and demand for data, and the efficient functioning of livestock data management systems.

Investments in improved data availability, quality and accessibility can be targeted to areas of common interest among sector stakeholders.

For countries interested to integrate statistical systems with GHG inventory compilation, it will be critical to assess the availability of data, gaps between available data and demand for data, and the efficient functioning of livestock data management systems.

Text Box 25

International initiatives to improve the availability and quality of livestock statistics

The Global Strategy to Improve Agricultural and Rural Statistics is an initiative of the UN, FAO and the World Bank, working with national statistical institutes, ministries of agriculture and regional and international organisations to improve national statistical systems. The Global Strategy has three pillars:

- Establishment of a minimum set of core data that all countries will collect;
- Integration of agriculture into national statistical systems;
- Governance and statistical capacity building to improve the sustainability of the agricultural statistics systems.

The Global Strategy, coordinated by the FAO Statistics Division, is implemented through a Global Action Plan, on the basis of which each region develops its own regional action plan.

Improvement in livestock statistics has been one focal area. Specific studies on gaps in data availability in selected pilot countries, and comparisons of the practicality, reliability and cost of implementing alternative data collection methods have been conducted.

The UN Statistical Commission has also been promoting the System of Economic-Environmental Accounting (SEEA), which includes also information on the interrelation between agricultural activities and the environment, including GHG emissions. Within the SEEA framework, countries can prioritize information needed to support decision-making and reporting (e.g. in relation to the UN Sustainable Development Goals). In countries with significant livestock populations, this prioritization process may give additional impetus to improved data collection and statistical reporting.

Sources: http://gsars.org/en/tag/Livestock/; GSARS (2015).

[94] Morgan and Ring (2012).
[95] AfDB (2014).
[96] APCAS (2012); Fink (2014).
[97] GSARS (2016).
[98] GARS (2016).
[99] IBRD (2014).

3.2.3.5 Uncertainty analysis and improvements over time

The purpose of the IPCC guidelines is to ensure that national GHG inventory estimates are unbiased and to reduce uncertainties "as far as is practicable, given national circumstances".[100] Assessment of the sources of uncertainty plays a key role in achieving this, yet most developing countries did not assess uncertainty of livestock emission estimates in their latest submission (see Section 3.1.6). The combined uncertainty of livestock emission estimates depends on the uncertainty of activity data and emission factors.[101] Figure 10 and Table 11 compare uncertainty levels of livestock emissions reported by developed countries and by the small number of developing that have reported quantitative estimates. However, it should be borne in mind that generic estimates of the uncertainty associated with either Tier 1 or Tier 2 emission factors, such as the IPCC default uncertainty values, are qualitatively different from those derived on the basis assessing country- or system-specific Tier 2 emission factors, since there is no way to assess the extent to which a default uncertainty value applies to a specific context.

Table 11 and Figure 10 indicate that: (i) on average the combined uncertainty for developing countries is slightly higher than for developed countries; (ii) there is a greater gap in the uncertainty associated with activity data than with emission factors; and (iii) the range of uncertainties does not necessarily decrease when moving to a Tier 2 approach (most likely reflecting a greater awareness and appreciation of the sources of uncertainty when a Tier 2 approach is adopted). With combined uncertainty levels of 11-50%, for the average of these countries, livestock emissions would have to decrease by 14%-67% in order to be statistically significantly different from emissions in the base year. Even for developed countries, with average combined uncertainty of 24%, on average emissions would have to decrease by about 32% before a statistically significant difference can be observed. This highlights the importance of reducing uncertainties, and the utility of uncertainty assessment for identifying areas for improvement (see also Box 24). However, the uncertainty of emission estimates is not considered in assessing the compliance of developed countries with their commitments under the Kyoto Protocol. This suggests that from a political perspective, improving the ability of inventories to describe trends in emissions is more important than reducing the uncertainty in emission estimates in any given year.[102]

Reducing uncertainty in activity data is a key opportunity for many developing countries.

While uncertainty associated with the emission factors in developing countries is generally higher than that associated with activity data (Table 11), the biggest gap between developing and developed countries is in activity data uncertainty. Activity data (i.e. data on livestock populations and sub-populations) are critical data to support decision-making and investment in the livestock sector.[103] The benefits to improved decision-making would be the most important benefit of improved activity data. It would also increase the accuracy of developed countries' livestock emission estimates, and if the priority is to improve estimates of emission trends, reducing uncertainty associated with livestock populations may also be of increased importance (Text Box 26).

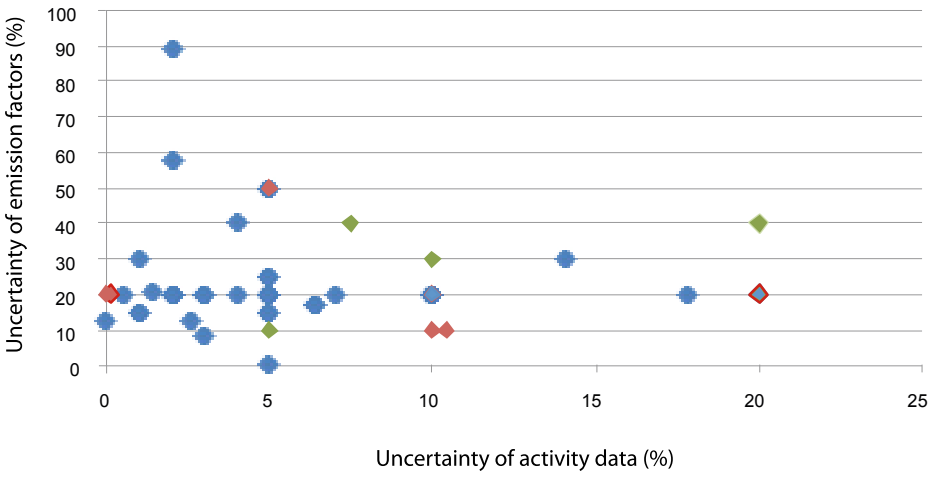


Figure 10: Uncertainty of emission factors and activity data in enteric fermentation estimates reported by selected developed and developing countries

Blue data points = developed countries; Red data points = developing countries Tier 2; light green = developing countries Tier 1

[100] IPCC (2006), Overview chapter.
[101] IPCC (1996) Vol. 1 Annex 1.
[102] That is, assuming livestock emissions are normally distributed, the mean estimate of emissions in year t would only be lower than the lower bound of the 95% confidence interval for livestock emissions in the base year if the estimated mean in year t is 14%-67% lower than the estimated mean in the base year.
[103] IBRD (2014).

Table 11: Mean and range (min, max) of uncertainty estimates for enteric fermentation by those developing countries that reported uncertainty estimates (n=12) and for selected developed countries (n=35)

	Mean and range for uncertainty of activity data (%)	Mean and range for uncertainty of emission factor (%)	Mean and range for combined uncertainty (%)
Selected developing countries (n=12)	11.49 (0-40)	25.83 (10 - 50)	28.27 (14.14 – 58.30)
Selected developed countries (n=35)*	5.20 (0-20)	23.46 (0 – 89)	24.03 (5.00 – 89.02)

** Submissions in Russian language could not be assessed for this report*

Sources: Party's submissions accessed at http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php; http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php and http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

Text Box 26

Uncertainty of emission estimates and emission reduction targets

Milne et al. (2014) report the methods and results of uncertainty analysis of CH_4 and N_2O emissions in the United Kingdom (UK) national GHG inventory. Using Monte Carlo analysis implemented in a specialist software, uncertainty of estimated emissions was quantified, and model inputs were identified that contributed most to the uncertainty of the estimated emissions. Sensitivity analysis was used to achieve this, whereby the effect on total uncertainty of halving the standard deviation of each input parameter in turn was compared. Quantifying the uncertainty also enabled an assessment of the statistical significance of trends in emissions. In this case, the downward trend in N_2O emissions in three out of four of the UK's constituent countries was found to be significant, while the downward trend in the fourth was insignificant.

Uncertainty analysis has also been applied to livestock emission sources in the national inventory of the Netherlands (Olsthoorn and Pielaat 2003). In that case, analysis identified different key sources of uncertainty in annual estimates and in trends. For example, while emission factors contributed most significantly to uncertainty of enteric fermentation emission estimates for an individual year, activity data on livestock population numbers was the main contributor to uncertainty of the trend in emissions on a decadal scale. For manure methane emissions, the main contributor to uncertainty of the trend was the assumed mass of manure produced per animal.

When transitioning to a Tier 2 approach, few countries are able to immediately access all the required data. This has been the case for both developing and developed countries, many of which have also made the transition to a Tier 2 approach in recent years. Text Box 27 illustrates the process of gradual improvement over time, with examples from New Zealand and Namibia, but several other countries' successive submissions to the UNFCCC also clearly show how improvements have been made over time.

3.2.3.6 Improvements in the transparency of livestock emission reporting

The assessment of inventory reporting quality produced for this report (Section 3.1.8) identified lack of transparency as a constraint on inventory quality in some countries. Inventory compilers, users and other stakeholders surveyed by this study also rank transparency as the most important of the five UNFCCC principles for inventory quality (see Appendix 2). Awareness of the importance of transparency is likely to increase with the transition to biennial reporting and associated technical analysis. As outlined in UNFCCC decisions,[104] teams of technical experts (TTE) identify the extent to which information listed in guidelines for

[104] Decision 2/CP.17, annex IV; 20/CP.19

BURs are submitted, and undertake a technical analysis of information contained in the BUR. The technical analysis assesses, inter alia, whether procedures and arrangements undertaken to collect and archive data for the preparation of national GHG inventories are described, and whether information on methodologies used for GHG emission estimates (including a brief explanation of the sources of emission factors and activity data) have been presented (Text Box 28). Irrespective of whether increased accuracy of estimates in a given year or of the estimated trend in livestock emissions is pursued, improving the documentation of data sources and assumptions used in compiling livestock inventories can have multiple benefits, including improving information availability about methods and data for subsequent inventories, documenting improvements made over time and enabling improved understanding by other countries.

Text Box 27

Gradual improvement of data over time

New Zealand: Clark et al. (2003) describes the development of a model for estimation of enteric fermentation from ruminants in New Zealand. Rather than estimate fixed Tier 2 emission factors, the model enables annually updated estimation of emissions for livestock sub-groups based on annually updated productivity data. Thus, changes in management practices or livestock performance are reflected automatically in the national inventory. After dividing the livestock population into sub-groups of each livestock type, data were unavailable for some sub-groups in some years when the improved inventory was first implemented. Missing values were estimated using linear regression, linear interpolation between known data points or average values based upon the known data points, depending on the number of data points, the distance between data points and the presence or absence of a trend. As in many other countries, there was limited data on livestock performance. The best available data were used, but despite uncertainty with some data sources, the same data source was used in different years to ensure consistency. For some parameters (e.g. milk fat and protein content, feed energy content), data from a single published source was used, while for others where no data sources exist, expert judgement was used (e.g. carcass weights), or simplifying assumptions were applied to specific parameters for all livestock in a given sub-group (e.g. birthing and slaughter dates during the year, linear body weight growth rates). The Australian Feeding Standard was used to infer total dry matter intake for a given level of animal performance. Methane emissions were then estimated per unit of feed intake, initially based a simple average of reported SF6 tracer measurements, which was later updated through more systematic analysis of available measurements.

A subsequent review of the model (Muir et al. 2011) highlighted assumptions that could be improved and areas where better data was needed. The review highlighted animal sub-classes for which improvements in model assumptions for mortality and culling could be made to improve accuracy of livestock population estimates; animal production parameters (e.g. live weight, weight gain, milk production) for which improved assumptions should be incorporated; and data sources and assumptions affecting methane conversion rates.

Namibia: Namibia's first NC (2002) used a Tier 1 approach to estimate enteric fermentation emissions. Expert judgment assessed that uncertainty in livestock emission estimates was particularly high. In preparation for the subsequent inventory (2011), a review of emission factors produced Tier 2 emission factors based on the IPCC model. Due to lack of data on herd structure, the Tier 2 emission factor was applied to each livestock type. The third NC (2015) re-estimated Tier 2 emission factors for cattle, but Tier 1 emission factors were used for other livestock types. Expert judgment was used to characterize manure management systems and cattle workload, IPCC default values were used for feed digestibility estimations for grazing cattle, and data from a private company used for feed digestibility for dairy cattle. The inventory improvement plan highlighted the need for better data on live weights of specific livestock types and feed digestibility. In Namibia's BUR1 (2014) dairy and non-dairy cattle were further subdivided into sub-groups based on age, sex and physiological state using the herd structure reported in a study conducted in communal areas, which given the lack of other data was also assumed to apply to cattle in the country's commercial sector. Average live weight and live weight gain estimates for each sub-group were based on data from slaughterhouse and auction data. The inventory improvement plan continues to highlight the need for better data on live weights of specific livestock types and feed digestibility. This data will be easily absorbed into the existing inventory framework.

Text Box 28

Key criteria used to assess the transparency of BUR submissions

Teams of technical experts assess BURs using pre-set criteria, which include the following:

- Does the BUR cover at a minimum, the inventory for the calendar year no more than 4 years prior to the date of submission?
- Does the national inventory update contain updated activity data based on best information available following the required IPCC guidelines?
- Does the summary of update of the inventory section include the mandatory and recommended reporting tables?
- Is a consistent time series back to years reported in previous NCs provided?
- Are summary information tables for previous submission years provided?
- Is additional or supporting information, including sector-specific information, provided in a technical annex?
- Were procedures and arrangements for collecting and archiving data, and for making this a continuous process described?
- Is information on methodologies used, sources of emission factors and sources of activity data provided?
- Is the level of uncertainty associated with inventory data, underlying assumptions and methodologies used for estimating these uncertainties described?

Source: http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

The transparency of livestock GHG emission reporting was higher for countries whose national inventory report was submitted to the UNFCCC or made available on national website, and for countries whose inventory report within a NC or BUR was structured in a way similar to the inventory report structure required for developed countries.[105] For many developing countries, the level of detail submitted to the UNFCCC is most likely influenced by factors such as political decisions, editorial considerations and financial constraints.[106] Many developing countries have depended on GEF or UNFCCC grants for assistance in preparation of national inventories and national communications.[107] At least one country omitted description of inventory methodologies and procedures and some inventory analysis results (e.g. key source analysis) from their national communication because of limited funding, which restricts the total length of the NC that could be translated and printed within the available budget.[108] With increasing emphasis on transparency in the Paris Agreement, revised reporting formats could enhance transparency, while funding agencies may need to increase finance of national inventory reporting in line with expectations for transparency.

With increasing emphasis on transparency in the Paris Agreement, revised reporting formats could enhance transparency, while funding agencies may need to increase finance of national inventory reporting in line with expectations for transparency.

3.3 Discussion

This chapter has provided an overview of the methods used by developing countries to present livestock GHG emissions in their national GHG inventory submissions to the UNFCCC, and assessed the extent to which challenges are faced in transparent, complete, consistent and accurate reporting. While gaps between current practice and UNFCCC good practice guidance exist in all these areas, the use of Tier 1 approaches by most developing countries contributes significantly to poor accuracy. However, the relative priority given to these dimensions depends on the functions of national GHG inventories in view of national policy goals, especially whether detecting changes or trends is more important than capturing absolute numbers. For example, where the national GHG inventory is seen as playing a key role in tracking the trend in livestock GHG emissions – such as where livestock are included within the scope of an NDC, or the effects of mitigation actions are to be reflected in national GHG inventories – an accurate trend in emissions

[105] http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf
[106] Developing countries, by contrast, must report inventories using a different common reporting format, which both requires and facilities greater transparency. See http://unfccc.int/national_reports/annex_i_ghg_inventories/reporting_requirements/items/2759.php
[107] See http://unfccc.int/capacitybuilding/core/activities.html; https://www.thegef.org/projects?search_api_views_fulltext=GHG+inventory&=Apply
[108] S. Ilyasov, Climate Change Centre of the Kyrgyz Republic, pers. comm.

may be the priority for inventory improvement. Criteria for assessing inventory quality, and strategies, key information needs, and appropriate methods and data sources used in inventory improvement will vary depending on how these priorities are set. When developing national GHG inventory improvement plans, countries may find it useful to consider the following key questions:

- What are the climate change, livestock and other policy goals that national GHG inventory compilation should serve?
- What are the functions of the national GHG inventory in relation to these policy goals?
- What are the key inventory improvements needed to better fulfil these functions?
- Considering current data availability, capacities and resources, what are practical, acceptable methods, data sources and inventory management processes for making the identified key inventory improvements?

While the degree of fit between policy objectives and inventory methods has been the focus of much of this chapter, policy objectives are not always the main factor determining the practical opportunities for inventory improvement. Table 9 highlighted two common constraints to inventory compilation and improvement: weak linkages between inventory compilation and national data providers, and lack of funding for inventory improvement. These factors may be interrelated. This suggests that involving key stakeholders in discussion on inventory improvements may increase awareness of the value of inventory improvements to key decision-makers. This may enable better targeting of resources to improvements in livestock GHG emission inventories and support sustainability of inventory processes.

4. MRV of livestock mitigation actions

Key messages

- While many countries have expressed interest in GHG mitigation in the livestock sector, few countries have begun to implement mitigation actions. The practice of MRV is thus just emerging. In addition to livestock and manure emissions, grassland management and silvopastoral systems are livestock-related mitigation actions proposed by several countries that will also require MRV.
- NCs and BURs are the main ways in which mitigation actions are reported in the UNFCCC. Progress in implementation and results achieved should be reported to the extent possible. Most current BURs describe existing or proposed mitigation actions and outline proposals for MRV. Lack of a fully elaborated MRV system is thus not a barrier to reporting on mitigation actions to the UNFCCC.
- Countries have different objectives with regard to MRV of mitigation actions: (i) Aligning mitigation actions with NDCs is seen as critical, and most countries are aiming to link MRV of livestock and agriculture emission reductions to the national GHG inventory. However, there are a number of constraints – above all, the limited ability of existing GHG inventories to track changes in livestock productivity described in Chapter 3 – and some countries are therefore focusing on developing MRV systems specifically for livestock sector interventions. (ii) For some countries, high importance is given to MRV of non-GHG benefits of mitigation actions. (iii) In addition to UNFCCC reporting, meeting other stakeholders' information needs is sometimes also considered. These policy objectives have major implications for institutional and technical issues in MRV system design.
- Key institutional issues concern linking data management systems among government agencies, between government and the private sector (including financial institutions), between project-level and national-level MRV, and between international and national institutions.
- Technical issues relate to defining GHG sinks and sources affected by livestock mitigation actions, characterizing baseline scenarios, linking estimates of reductions in emission intensity with land-based mitigation measures, collaboration between government agencies, levels of accuracy and uncertainty, and quality aspects of MRV systems that give credibility to emission reduction claims.
- Given countries' diverse objectives and conditions, the UNFCCC makes no uniform institutional and technical requirements of MRV systems. Rather, each country, according to its specific context, is considering suitable solutions out of a range of options defined by these policy, institutional and technical issues.

Obligations for developing countries to undertake mitigation actions are a more recent development under the UNFCCC,[109] and GHG mitigation in the livestock sector has received less attention in most countries compared to some other sectors (e.g. energy). Some countries nonetheless have begun to consider the design of MRV systems with the development of livestock mitigation policies and actions, but progress to date is limited in all countries. Rather than highlight specific 'good practices', therefore, this chapter maps the key issues that policy makers and other stakeholders are considering in the design of MRV systems for livestock mitigation actions. Section 4.1 illustrates the extent of interest in livestock mitigation in developing countries and the general types of mitigation action being considered. Section 4.2 summarizes current practices in reporting on mitigation actions to the UNFCCC through NCs and BURs. Section 4.3 presents key policy, institutional and technical issues in the design of MRV systems for mitigation actions, which are then summarized in Section 4.4.

[109] See http://unfccc.int/essential_background/items/6031.php.

4.1 Developing country interest in GHG mitigation in the livestock sector

In addition to livestock emissions (enteric fermentation, manure management and deposit of dung and urine on pasture), livestock-related emissions include emissions in feed production, emissions and removals from grassland vegetation and soils and from vegetation in silvopastoral systems, and energy emissions affected by bioenergy production from livestock-related waste. National communications include assessment of mitigation options and descriptions of plans and policies. Many developing countries have expressed interest in GHG mitigation related to the livestock sector (Figure 11; see Appendix 5 for the full list of countries). Of 140 national communications assessed, 76 mention the potential for mitigation of livestock-related GHG emissions (including 55 that mention manure management and 43 that mention mitigation of enteric fermentation emissions). However, of these 76 national communications, only 19 provide any analysis of the identified mitigation options, and only 13 mention related plans or policies.

A number of countries have also communicated their intention to implement nationally appropriate mitigation actions (NAMAs) in the livestock sector. Currently available information[110] has identified 20 NAMAs relating to livestock that have been proposed by 17 countries. Most have been proposed by Latin American countries, and most are still under development or seeking support (Figures 12a and 12c). While livestock and manure management emissions are two areas of interest, some countries have also expressed interest in mitigation related to livestock production systems through improved land and vegetation management or biogas (see Figure 12b).

Countries were invited at COP 20 (2014) to submit INDCs. By December 2016, 189 countries to the UNFCCC had submitted INDCs, including 150 developing countries.[111] Of these 150 countries, 48 countries explicitly mention that livestock-related emissions are included in the scope of the mitigation objectives of their INDC, including 35 mentioning livestock emissions, 19 mentioning manure emissions or biogas mitigation measures, 20 mentioning grasslands or pastures and four mentioning mitigation through silvopastoral systems. While INDCs state policy intention to promote mitigation in the livestock sector, only 11 INDCs identified policies and measures to implement these intentions.

These stated policy intentions imply growing demand for appropriate methods to measure, report and verify (MRV) livestock emission reductions, but the relatively small number of policies or mitigation actions identified, and the even smaller number of NAMAs under implementation, suggests that the practice of MRV of mitigation actions in the livestock sector is still in its early stages.

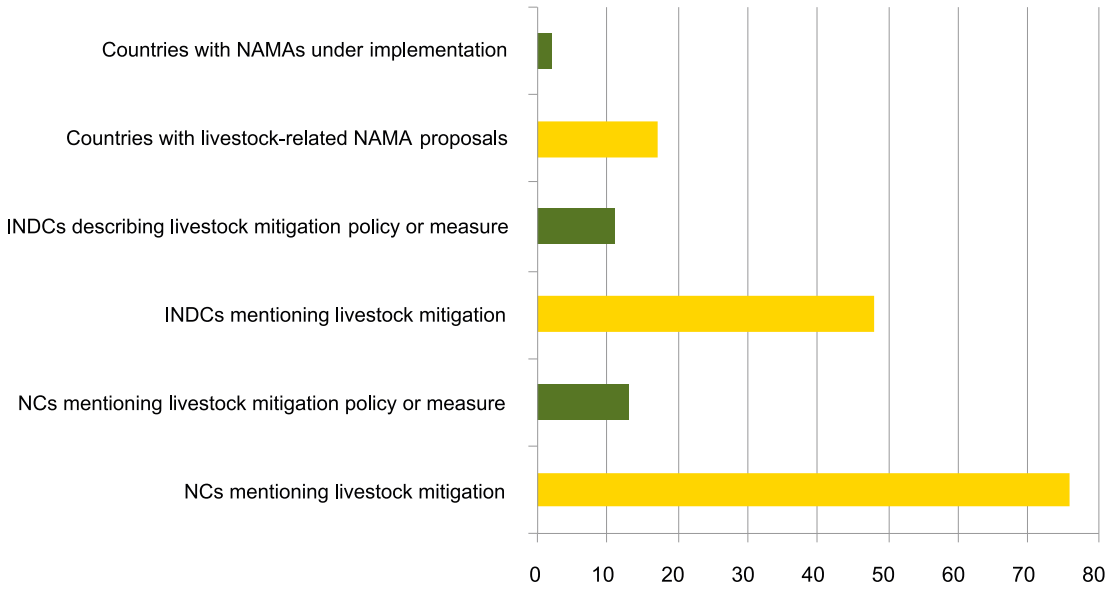
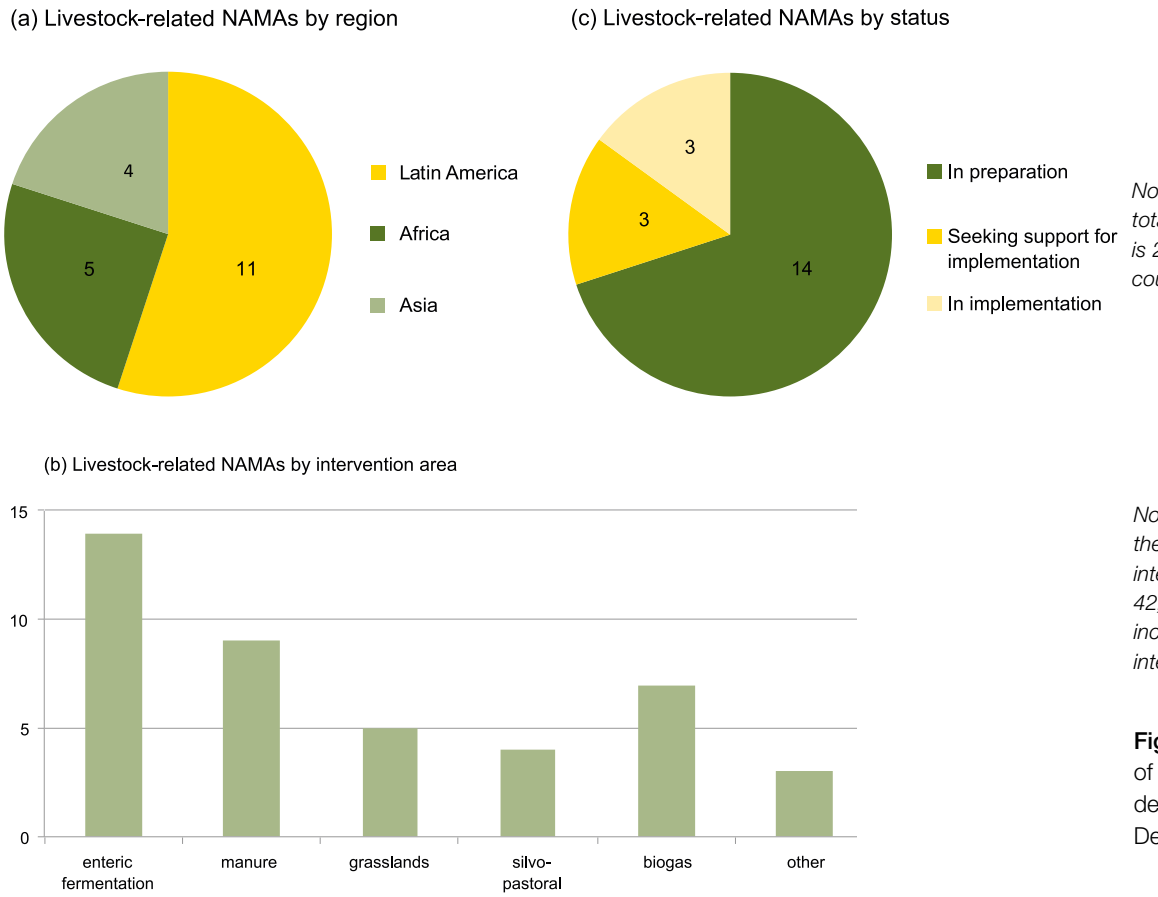


Figure 11: Number of developing countries expressing intention to or engaging in livestock mitigation actions

Notes: NAMA: nationally appropriate mitigation action; INDC: intended nationally determined contribution; NC: national communication.

[110] http://www4.unfccc.int/sites/nama/SitePages/Home.aspx, http://www.nama-database.org/index.php/Main_Page, http://www.namapipeline.org/

[111] http://unfccc.int/focus/indc_portal/items/8766.php. INDCs were analysed as many countries have yet to submit formal NDCs.



Note: In panel (a), the total number of NAMAs is 20 proposed by 17 countries.

Note: In panel (b) the total number of intervention areas is 42, as several NAMAs include more than one intervention area.

Figure 12: Status of livestock NAMA development (as of December 2016)

4.2 Current practices in reporting on mitigation actions to the UNFCCC

Compared with guidelines for NCs, guidelines for BURs specify in more detail the information required for reporting on mitigation actions (see Text Box 5). Text Box 29 gives two examples of how countries have been reporting on mitigation actions to date and notes the results of technical analysis of reporting on mitigation actions in BURs. These examples from current practice illustrate that countries can report on mitigation actions without having fully elaborated and implemented GHG quantification methodologies or MRV systems. BURs submitted by some other countries (e.g. Georgia, Namibia) also list proposed mitigation actions in the livestock sector, describing their current state of implementation and presenting estimates of mitigation potential but without fully elaborating MRV systems.

4.3 Issues in the development of MRV systems for mitigation actions

In contrast to the near universal reporting of livestock GHG emissions through national inventory reports (Chapter 3), the practice of MRV of livestock mitigation actions is still at an early stage. With the exception of policies whose effects are reflected in national GHG inventories, there are few operational practical examples of systems for MRV of emission reductions due to specific mitigation actions. However, a number of countries have begun the process of designing MRV systems to capture the impacts of mitigation. Given this limited progress, rather than identifying 'good practice', the focus here is on describing the key factors and issues that countries are considering as they progress in MRV system design. The following sections focus on the policy and institutional issues (4.3.1) and technical issues (4.3.2) that the design of MRV systems poses. The information in these sections draws on interviews with people involved in MRV system development in eight countries,[112] supplemented by reference to other experiences in the available literature.

[112] Interviews were held with individuals from Brazil, China, Costa Rica, Colombia, Ecuador, Ethiopia, Kenya and Uganda.

Text Box 29

Reporting on mitigation actions to the UNFCCC

Brazil: Brazil's first BUR describes 8 NAMAs, including the National Plan for Low Carbon Emission in Agriculture (ABC Plan). The BUR lists the GHGs targeted, provides a general description of the NAMA and the agronomic activities promoted, and reports the state of completion of two objectives. The first objective is the establishment of a sectoral plan, which was completed in 2011. The second objective is to transform 35.5 million hectares of land to sustainable agricultural production by 2020. The BUR reports the finance invested and the capacity building activities conducted, and notes that a monitoring system is under development. In the BUR section on domestic MRV arrangements, the envisaged development of the 'SMMARE' system for MRV is outlined, in which it is proposed that GHG emission reductions are measured in accordance with IPCC guidelines. Technical analysis of the BUR assessed that this met the requirements for reporting on methodologies, assumptions and results achieved.

Republic of Korea: Korea's BUR describes the country's emission reduction roadmap, and presents summary information on mitigation actions by sector. These include the actions summarized in Table 13. Technical analysis assessed that the BUR requirements had been partly met, and noted that further information on methodologies and assumptions had been provided during the technical analysis. The performance indicators proposed relate to physical outputs of each mitigation action (i.e. number of treatment facilities, tonnes of forage). Critical issues would be whether data on the performance indicator for the manure management policy is reflected in Korea's GHG inventory, and whether the inventory is able to track changes in animal diets and productivity to reflect the effects of the forage development policy.

Table 12: Livestock mitigation actions listed in Republic of Korea's First BUR

Name of mitigation action	GHG(s) affected	Objectives and description	Type of instrument	Implementing ministry	State of implementation	Start year	Performance indicators
Expansion of livestock manure treatment facility	CH_4	GHG reduction by using livestock manure as resource	Policy	Ministry of Ag., Food and Rural Affairs	Implemented	2007	The number of livestock manure treatment facilities launched
Expansion of high quality forage cultivation	CH_4	GHG reduction by increasing provision of high quality forage to livestock	Policy	Ministry of Ag., Food and Rural Affairs	Implemented	1998	The supply rate of high quality forage (1000 t)

Source: Republic of Korea (2014) First Biennial Update of the Republic of Korea.

4.3.1 Policy and institutional issues in MRV design

Countries have different objectives with regards to MRV of mitigation actions. From a GHG perspective, for some countries, the priority is to reflect the effects of mitigation actions in national GHG inventories, while in others the priority is to develop MRV systems that reflect the effects of specific actions. Some countries are concerned also to measure and report non-GHG effects. These different objectives have diverse implications for institutional issues in MRV design. Countries are considering effective ways to integrate data management systems between government agencies, between government and the private sector, between project-level and national-level MRV, and between international and national institutions.

4.3.1.1 Policy objectives and implications for MRV design

In all countries interviewed, developing mitigation actions to meet NDC goals is seen as critical. MRV of GHG emission reductions planned in the NDCs is therefore a common concern. Most countries' NDCs also include targets and actions for adaptation, and livestock-related mitigation actions are not promoted solely for the effects on GHGs. For example:

- Ecuador is developing NAMAs as a mechanism to promote climate-smart livestock production. The adaptation benefits of climate-smart practices are an expected benefit, and MRV system development is focusing initially on measurement of change in adaptive capacity, with GHG MRV system design planned to follow at a later date.
- Costa Rica's livestock NAMA design is considering the strong interest of stakeholders in the benefits of mitigation actions for productivity and socio-economic development. The government itself is keen to link MRV of these multiple benefits to its system for reporting on progress in relation to the Sustainable Development Goals (SDGs).
- Many countries' interest in manure management is driven by concerns with rural energy or environmental pollution which may be linked with ammonia emissions and nutrient leaching (e.g. as in the case of China's manure management policies described in Text Box 18).
- Brazil's Low Carbon Agriculture Plan, which includes investment in sustainable cattle ranching, is motivated also by a concern to improve the economic profitability of cattle ranching. Some stakeholders interested in the MRV of this programme are also considering the potential to link with future markets for ecosystem services in the country.

These countries are working on development of MRV systems that can reflect multiple effects of policies and actions in the livestock sector. Reporting on non-GHG benefits is also central to the MRV requirements of some international sources of climate finance (Text Box 30).

In most – but not all – countries pursuing mitigation actions in their NDCs, the plan is to conduct MRV of mitigation actions using national GHG inventories.

In most – but not all – countries pursuing mitigation actions in their NDCs, the plan is to conduct MRV of mitigation actions using national GHG inventories. Text Box 19 described, for example, the institutional arrangements and processes through which China reflects the effects of its manure management policies in the national GHG inventory. Text Box 31 describes ongoing innovation in Uruguay to accomplish MRV of mitigation actions in the beef sector through the national GHG inventory. Earlier progress in improving Uruguay's national GHG inventory and existing high-quality data infrastructure are clearly enabling factors for making this linkage in Uruguay. In other countries, however, the most significant barrier to integrating MRV of mitigation with national GHG inventories is the lack of regularly updated Tier 2 emission factors in national inventories, as was extensively discussed in Chapter 3. This means that most national GHG inventories are not capable of capturing the effects of changes in production practices and productivity on GHG emissions. Even where national inventories are able to track change over time, linking MRV of policies, programmes or projects with national GHG inventories is not always straightforward. Particular challenges are faced in aligning baseline and mitigation scenarios for the livestock sector with scenarios underlying NDCs, and data integration issues.

Particular challenges are aligning baseline and mitigation scenarios for the livestock sector with scenarios underlying NDCs, and data integration issues.

Forms of NDC target and accounting vary among countries actively developing livestock mitigation actions (Table 13). For example, Costa Rica has proposed a mitigation target based on the balance of GHG emissions and removals, while Uruguay has proposed a reduction in emission intensity. Other countries have proposed to achieve emission reductions relative to a business-as-usual (BAU) baseline scenario (see Table 13). This baseline is not always reflected in the national GHG inventory. In several countries, efforts to describe BAU and mitigation scenarios for the livestock sector are still ongoing, and linking GHG inventories with national and sectoral emission scenarios may require additional efforts (Text Box 32). In addition, while there is increasing interest in quantifying reductions in livestock emissions in terms of reduced emission intensity (i.e. tCO_2e / t livestock product), there may be technical challenges in linking this with estimations of reductions from land-based mitigation actions (i.e. tCO_2e / ha).

Text Box 30

MRV requirements of selected climate finance sources

The NAMA Facility: The NAMA Facility, a fund established by the UK and German governments, provides finance for the implementation of NAMA Support Projects (NSP). These are projects that have a catalytic role in the implementation of a NAMA objective of a developing country. Within the NAMA Facility, monitoring and evaluation (M&E) serves two main functions: (a) promoting accountability for results, including GHG effects, and (b) supporting learning and knowledge sharing as a basis for decision-making. The NAMA Facility has a system for M&E of the facility itself, and M&E is a mandatory component of all NSPs financed by the facility, with project-level M&E contributing to performance monitoring and evaluation of the facility itself. The NAMA Facility was designed with a theory of change that specifies 6 outputs. Two of these outputs ('establishment of the Facility' and 'preparation of project pipeline') are the responsibility of the management unit. The other four outputs (leverage of finance, good practice examples, national capacities and development co-benefits) are delivered through NSPs. Therefore, at the project level, there are 5 mandatory monitoring indicators that all NSPs must monitor and report on:

- M1: Reduced GHG emissions
- M2: Number of people directly benefitting from NSPs
- M3: Degree to which the supported activities catalyse impact beyond the NSP
- M4: Volume of public finance mobilized for low-carbon investment
- M5: Volume of private finance mobilized for low-carbon investment

Each NSP must report on these indicators, but is also required to develop its own indicators and system to monitor project specific indicators at the output or outcome levels to describe the results and effects of the project. These indicators can include indicators of implementation progress, direct outputs or outcomes attributed to project implementation, such as sustainable development benefits of the NSP. In some cases, M&E of NSPs will contribute to building national systems for MRV of low carbon development.

The Green Climate Fund (GCF): The Board of the GCF approved performance measurement frameworks for support to mitigation and adaptation projects in different sectors. Performance indicators are divided into core indicators, which shall be measured for all supported projects, and other indicators that shall be reported on according to their relevance to a project. For mitigation, the Fund's core indicators are tonnes of carbon dioxide equivalent (t CO_2e) reduced, to be estimated ex-ante and verified ex-post; cost per tCO_2e decreased; and volume of finance leveraged. Core indicators are then set for each sector. Core indicators set for forestry and land use (tCO_2e reduced or avoided from forestry and land use activities and total area of land under improved management) are aligned with UNFCCC decisions on MRV for REDD+, and may not be suitable for all projects focusing on the livestock sector. In general, mitigation projects that also generate adaptation results should also report on adaptation indicators, and vice-versa. For adaptation, core indicators include the "total number of direct and indirect beneficiaries" and "percentage of beneficiaries relative to total population". Other indicators are then set for adaptation effects on livelihoods, health, ecosystems and infrastructure. Perhaps the most relevant to livestock is "percentage of population (and relative disaggregation of women and men) adopting climate-resilient livelihood practices / options by sector (fisheries, agriculture, tourism, etc.)". Further technical guidance on performance monitoring is still under development. Gender disaggregation should be applied to data were possible.

Accredited entities of the GCF will submit annual performance reports to report on progress made towards targets of the core indicators and additional indicators identified at project level. On the basis of these annual performance reports, the GCF will then produce an annual portfolio performance report.

Sources: http://www.nama-facility.org/concept-and-approach/monitoring-evaluation/ and GCF (2016)

Table 13: Forms of mitigation target of developing country INDCs that include the livestock sector

Form of mitigation target	Number of countries
reduction in emission intensity	3
reduction in emissions per capita	1
reduction from business-as-usual (BAU) baseline*	28
peak emission by a given date	1
absolute emission reduction	9
emissions < removals	2
Other	2
no quantitative target	2

**which may be expressed terms of absolute emissions or reductions in emission intensity per unit of output.*

Text Box 31

Linking MRV of beef sector mitigation with the national GHG inventory in Uruguay

Uruguay's INDC has proposed reductions in the emission intensity (kg CH_4/kg beef) of beef production. Uruguay's national inventory has adopted regional Tier 2 emission factors for beef cattle based on data on herd structure and diet quality and composition in different production systems in each region. Since grazing practices are a key determinant of animal diets, data on grazing and land use can be used to re-estimate emission factors for each region. Farmers make an annual electronic report of livestock numbers, herd structure and grazing practices, which is submitted to the Ministry of Agriculture. This activity data is also spatially disaggregated so it can be matched with sub-national emission factors. All beef cattle in the country are registered, so beef output data are also readily available. Together, these data sources can enable an annual estimate of the trend in emission intensity from beef production.

Key factors enabling these improvements include strong recognition of the importance of sustainable intensification of the cattle sector in political agendas; strong personal leadership from the Minister of Agriculture; active involvement of the Ministry of Agriculture's Climate Change Unit in the inventory; and coordination with the *Ministry of Environment at cabinet level.*

Source: Oyhantçabal (2016).

Text Box 32

National scenarios and scenario development in Kenya's dairy NAMA

Preparation of Kenya's National Climate Change Action Plan (2013-2017) involved setting a 'reference case', or BAU scenario for national GHG emissions to 2030. Analysis of mitigation potentials then informed Kenya's INDC target for mitigation. For livestock emissions, the trend in emissions was estimated assuming a continuation of historical trends in livestock population and a constant Tier 1 emission factor. Analysis of mitigation potential in the livestock sector was not available at that time to inform the priorities set out in the Action Plan, and in any case, would not have been possible using a fixed Tier 1 emission factor.

Kenya's dairy NAMA began to be developed after the release of the Action Plan. Scenarios for the dairy sector were developed taking Kenya's Dairy Master Plan (DMP) as a guide, in which per capita milk demand is forecast to double by 2030. A BAU scenario (i.e. the DMP's target is met with no change in emission intensity), and several mitigation scenarios (i.e. the DMP's target is met with different trends in emission intensity over time) were produced using the GLEAM model to estimate potential changes in emission factors and yield.

The MRV methodology proposed for Kenya's dairy NAMA will involve establishing a baseline through regional surveys of smallholder dairy farms to collect data needed to estimate emission intensity in each region. Emission reductions due to changes in emission intensity and yield will be calculated in comparison to this baseline.

There will clearly be a need to update the BAU and mitigation scenarios informing Kenya's NDC, and also to align the national scenario development approach with advances in analysis of the dairy sector.

In some countries, data integration between MRV systems for livestock mitigation actions and national inventories is a challenge arising from the policy decision to align MRV systems at different levels. For example, national GHG inventories in Colombia and Kenya use a single Tier 1 or Tier 2 emission factor for cattle throughout the whole country, but the effects of mitigation actions can better be reflected using separate emission factors developed for different sub-classes of livestock in different production systems or regions in a country. MRV of specific mitigation actions may also generate higher resolution data in parts of the country than are used in the national GHG inventory. Revising the national inventory to incorporate higher resolution activity data or emission factors might be desirable, but the feasibility and costs of doing so while maintaining consistency would need to be assessed. Some stakeholders consider that inaccuracy in the national inventory and limited linkages between MRV of sub-national mitigation actions and national GHG inventories should not constitute a barrier to proceeding with the implementation and MRV of mitigation actions. Thus, in Kenya for example, design of MRV systems for livestock mitigation actions is being pursued with limited links to the national GHG inventory. Links with national reporting through NCs and BURs is, however, being considered.

A third issue arising from a policy objective to link MRV with national inventories is that mitigation actions in the livestock sector may affect a range of GHG sinks and sources, but these GHG sinks and sources may be allocated to different sectors in national inventories. Section 4.1 showed that a number of countries are proposing NAMAs that relate not only to livestock but also to energy, grassland management and forestry as emissions sources affected in the supply chain. Improvements in feed will relate to cropland management. The related sinks and sources are identified as different emission categories in national inventories. Compilation of inventories in each category is accomplished through existing data sources, each of which has their own sampling frame and processes for collection of activity data and estimation of emission factors. It will be challenging to align data on all the GHG sinks and sources affected by a mitigation action with existing inventory data management. While integrated agriculture, forestry and other land use (AFOLU) data management systems may be one way forward, complexity, completeness, and links with other sectors while avoiding double counting would all have to be addressed.

4.3.1.2 Institutional issues in MRV design

Diverse institutions need to be involved in MRV, including those that implement mitigation actions, those that need information about the impacts of mitigation, and those enabling coordination and collaboration of MRV. Governments need to coordinate the operation of MRV and enable collaboration among government agencies and subnational and national institutions. The private sector may also require the acquisition, provision and use of data to guide decision-making in the sector. Text Box 33 indicates how some of these elements are being addressed in the development of Costa Rica's livestock NAMA. In some countries, the private sector and NGOs are active in delivering mitigation actions, such as national biogas programmes. While effective arrangements for programme implementation and monitoring may exist, data from programme monitoring are not always linked to information systems of national GHG inventories. For example, large-scale biogas programmes implemented for some years in Vietnam have installed more than 150,000 biogas units. However, data on manure management systems are not collected by the relevant government agency involved in providing data for national inventory compilation.[113] In Brazil, Colombia, Costa Rica and Kenya, livestock mitigation actions are planned to be supported through finance delivered via the banking sector, but financial institutions have generally not incorporated GHG accounting in their management information systems, so linking financial institutions' management information systems to GHG MRV systems is a new area requiring innovation (Text Box 34).

The potential for livestock mitigation actions to attract investment from climate finance or other international sources is a common motivation for stakeholders' interest in GHG mitigation in the livestock sector, and in many developing countries livestock mitigation actions are likely to be implemented with support from multilateral agencies, international development banks or other donors. Different international finance institutions and development agencies have their own GHG quantification policies, procedures and guidelines (Text Box 35). It is increasingly common for these agencies to require *ex ante* estimation of a project's GHG effects. Integrating GHG emissions in results frameworks and monitoring plans for ex post estimation is less common. The World Bank has recently begun to do so in some livestock-related 'climate

[113] Minh Van Trinh, IEA VAAS, pers. comm.

Text Box 33

Towards a National Metrics System for Climate Change in Costa Rica

Costa Rica's INDC focuses on exploiting synergies between adaptation and mitigation, and creating an integrated strategy in these areas. Alongside its long-term decarbonisation plan, the country is also developing a National Adaptation Plan. In agriculture, NAMAs are being developed in the coffee and livestock sectors. These plans require an integrated monitoring and evaluation infrastructure to support decision-making and reporting.

Costa Rica already has a National Environmental Information System (SINIA). The country is now working on integrating a National Metrics System for Climate Change (SINAMECC) within SINIA. This will collate data on related finance, mitigation and adaptation benefits and other co-benefits. For the MRV of GHG and non-GHG benefits of mitigation actions, such as the livestock NAMA, key performance indicators (KPIs) are being defined through consultation with sector stakeholders. The national metrics system will collect data on these KPIs, which will form the basis for national reporting. This system will also link with the national GHG inventory compilation process, currently coordinated by the National Meteorological Institute. Some data on non-GHG KPIs is already collected by the private sector (e.g. farmer associations), so consultations are also focusing on identifying private sector needs for improved information. It is also intended that the system will enhance the accessibility to the public of this information, so that MRV of the NAMA also contributes to improved decision-making in the sector as well as transparency of the actions implemented.

Sources: Interview with Mauricio Chacon Navarro, Agripina Jenkins and Karla Mena, and Jenkins (2016)

Text Box 34

Tracking the mitigation and adaptation effects of credit supplied through financial institutions

Credit to livestock keepers for climate-smart investments is a main measure employed in implementing Brazil's Low Carbon Agriculture Plan, and is planned also in livestock NAMAs in Colombia, Costa Rica and Kenya. Some national development banks and commercial banks have begun to develop or implement 'green credit' policies, and have a strong interest in improving their understanding of social and environmental impacts. However, incorporating GHG accounting in management information systems (MIS) is new to many financial institutions. In addition, financial institutions are generally subject to client privacy regulations that will need to be addressed in linking the MIS to public reporting.

FAO and the French Development Agency (AFD) have been working with selected national development banks in Latin America to understand how GHG accounting can be incorprated in their internal procedures. Discussions with staff of Agrobanco (Peru) identified that simple GHG calculator tools could be used to provide clients with GHG emission reduction estimates for use in receiving payments for environmental services, while aggregation of the results could help the bank build a picture of the carbon footprint of its agricultural lending activities. Staff at FIRA (Mexico) have been looking into how to incorporate assessment of GHG effects as well as effects on ecosystem services and resilience in their System of Environmental and Social Risks Analysis. The limited experience gained to date stresses the importance of assessing quantification tools in the context of each bank's own green planning framework.

Other experience suggests that appropriate approaches to GHG estimation depend also on the users of the information generated. For example, in many public schemes involving payment for ecosystem services, changes in practice are taken as a proxy for the changes in carbon stocks or GHG emissions achieved. Simple models linking credit proposals to GHG effects using default factors could be applied. But other sources of performance-based finance (e.g. carbon markets) often require greater accuracy. One suggestion under discussion in relation to Brazil's Low Carbon Agriculture Plan is to link credit proposal assessment to modelling using a biogeochemical model that has been parameterized for the regions targeted by the credit line. The level of accuracy of model input data and model outputs could vary depending on the sources of finance and the requirements of information users. It is generally expected, for example, that many sources of public funds would tolerate greater uncertainty in GHG estimates than investors in carbon offsets.

Sources: Bockel et al. (2016); D. Reed and W. Salas (C-AGG), pers. comm.

smart agriculture' projects under development in Niger, Kenya, Bangladesh and Ethiopia.[114] However, project monitoring largely plays accountability functions, and projects are implemented by especially established project management units, so even where projects collect data relevant to quantifying GHG emission reductions, project M&E data may not link with national MRV systems. Either dedicated efforts to make these linkages would have to be made both by donor institutions and by national governments with whom they negotiate, or national MRV systems should consider how to report donor project results separately from the national GHG inventory, as is currently done for Clean Development Mechanism (CDM) projects in some countries' UNFCCC submissions. However, there are examples of international projects that have been designed explicitly to support the development of national MRV systems (Text Box 36).

Either dedicated efforts to integrate GHG frameworks would have to be made both by donor institutions and by national governments with whom they negotiate, or national MRV systems should consider how to report donor project results separately from the national GHG inventory, as is currently done for Clean Development Mechanism (CDM) projects in some countries' UNFCCC submissions.

4.3.2 Technical issues in MRV design

Technical guidance under the UNFCCC on MRV of mitigation actions is limited (see Chapter 2). In general, it is expected that quantification methodologies will be consistent with guidance from the IPCC and other organizations.[115] However, existing IPCC guidance is designed for compilation and reporting of national GHG inventories, and gives incomplete guidance on estimation of emission reductions from mitigation actions. Other approaches adopted under the UNFCCC include guidance related to Joint Implementation and the Clean Development Mechanism. Outside the UNFCCC, the World Resources Institute's *Policy and Action Standard*[116] is frequently referred to as a reference source for guidance on MRV, and voluntary carbon market methodologies may also be relevant. Annex 3 summarizes a number of GHG quantification and monitoring methodologies related to livestock GHG from different carbon market standards. Methodologies relating to manure management (e.g. biogas, composting) have been widely used for some years. In some cases, biogas programmes operating at national scale have used these methodologies to generate carbon credits through which to co-finance implementation. Methodologies focusing on enteric fermentation as the main source of GHG emission reductions are more recent, and have not been used so widely. Several methodologies are applicable to mitigation actions that also affect land use and vegetation, including methodologies for afforestation in silvopastoral systems, for improved management of grasslands and for avoided conversion of grassland to croplands.

Some aspects of these sources of guidance are broadly relevant to livestock mitigation actions, while other aspects are particular to certain uses or contexts (e.g. generating tradeable carbon credits). The following sections summarize considerations in defining approaches to common technical issues, including the definition of GHG sinks and sources (4.3.2.1), characterizing baselines (4.3.2.2), levels of accuracy and uncertainty (4.3.2.3) and other features of MRV systems that give credibility to emission reduction claims (4.3.2.4).

4.3.2.1 Definition of sinks and sources affected by the mitigation action

IPCC guidance focuses on the preparation of national GHG inventories and is often insufficient to determine the GHG sinks and sources affected by specific mitigation actions. For example, promotion of improved livestock feeding practices will not only affect enteric fermentation, but may also change the use of inputs in the production of animal feed, and may even affect land use on a larger scale. Guidance on MRV of mitigation actions developed by other institutions highlights the importance of identifying the full range of GHG sinks and sources that are likely to be significantly affected by a mitigation action.[117] This is useful not only for increased completeness of GHG accounting, but can also inform the design of mitigation actions by drawing attention to GHG emission sources throughout livestock supply chains and landscapes (Text Box 37). This is relevant not only in large-scale livestock operations that depend on purchased animals and feeds, but also in smallholder contexts in developing countries where livestock are often raised in mixed farming enterprises with diverse land uses. The summary of carbon market methodologies in Annex 3 indicates the range of sinks and sources considered in each.

[114] P. Gerber, FAO / World Bank, pers. comm.
[115] UNFCCC (2014), page 16.
[116] WRI (2014)
[117] E.g. WRI (2014). Many standards do not require that insignificant GHG sinks or sources are considered, although there are variations in how "insignificance" is defined, and may allow exceptions for sinks and sources that are difficult to quantify.

Text Box 35

GHG mitigation benefit calculation and reporting requirements of selected institutions

Global Environment Facility (GEF): Since 2011, full- and medium-size GEF projects have been required to use a climate change mitigation tracking tool to report on the GHG mitigation benefits of GEF projects. Manuals for calculating GHG mitigation benefits of projects in the energy and transport sectors have been issued. In 2014-15, a review was conducted of the GEF's policies and guidance, which made recommendations for GHG quantification in the AFOLU sector. This review recommended use of methodologies consistent with the WRI's *GHG Protocol Policy and Action Standard*, but does not require that these methodologies are consistent with national GHG inventories.

International Finance Institutions (IFIs): In 2012, nine IFIs committed to engage in harmonizing their reporting on GHG mitigation benefits. General principles were agreed, and guidance notes specific to the energy sector are under development. Specific policies vary, for example:

World Bank: The World Bank's environment strategy, issued in 2012, commits to analyse the GHG emissions of investment projects financed by IDA/IBRD. *Ex ante* quantification of emissions and emission reductions for energy and forestry projects began in 2013 and for agriculture in 2014. Internal guidance notes on how to meet calculation and reporting requirements in these sectors have been adopted. Guidance for the agriculture sector mandates the use of the EX-ACT tool for ex ante estimation. Ongoing experiences with integrating GHG benefit calculation in some livestock projects suggests that other tools that are capable of estimating changes in Tier 2 emission factors (e.g. GLEAM) may be more suitable if ex post assessment is required.

The European Bank for Reconstruction and Development (EBRD): EBRD's Environmental and Social Policy mandates that clients provide the data necessary for GHG assessment for projects with expected emissions exceeding 100,000 tCO_2e per annum. Reportedly, almost all projects are screened for their GHG impact during the project assessment phase. A set of Guidance Notes have been produced to assist consultants and staff in completing these requirements.

Some international development institutions have also developed related policies. For example:

United Nations Development Programme (UNDP): Since 2015, the *Social and Environmental Standards* of UNDP requires screening of all projects above US$ 500,000, and projects with emissions of more than 25,000 tCO_2e per annum are deemed 'high risk' and may require in-depth social and environmental impact assessment. Emissions must be tracked and reported in accordance with IPCC estimation methodologies.

Source: Wilkes et al. (2016) Guidance for standardized GHG assessment of agriculture, forestry and other land use (AFOLU) projects. FAO, Rome

Text Box 36

Supporting national MRV through internationally funded projects

"Promotion of climate-smart livestock management integrating reversion of land degradation and reduction of desertification risks in vulnerable provinces" is a GEF-FAO project in Ecuador that aims to reduce soil degradation and mitigate GHG emissions in the livestock sector of Ecuador. It contains components focusing on strengthening institutional capacities and designing livestock sector policies (including NAMAs), developing strategies for promotion of climate smart livestock management practices, and a component focused on developing MRV systems for monitoring GHG emissions as well as adaptation impacts. The project, which began implementation in 2016, intends to support the strengthening of national systems for MRV such that the effects of the NAMA's activities can be reflected in the national inventory. Although the project has to date accumulated limited experience in this regard, the design of a project component dedicated to strengthening national MRV systems indicates one way in which projects financed or implemented by international agencies can support national MRV processes.

Source: Pamela Sangoluisa and David Salvador, FAO Ecuador, pers. comm.

Text Box 37

Life-cycle approaches to GHG quantification of livestock mitigation actions

The effects of mitigation actions throughout livestock supply chains can be captured by life cycle analysis approaches. For example, improving feed is a commonly mentioned measure that can reduce methane emissions due to higher digestibility of improved feeds. But increasing consumption of new feed types will change GHG emissions in feed production processes, and may also change emissions from land use (e.g. if cropland expansion occurs).

GLEAM is a model based on life cycle analysis (LCA) of livestock production systems that is increasingly frequently being used to assess mitigation options in livestock production systems. The model can be used to estimate upstream emissions (i.e. due to feed production, processing and transportation activities, including induced land use change), animal production emissions (i.e. emissions from enteric fermentation, manure management and on-farm energy use), and downstream emissions (i.e. due to processing and post-farm transport of livestock products). A common feature of LCA approaches is that they enable quantification of the emission intensity of livestock products (e.g. GHG emissions per kg milk or meat), although the scope of which stages of the life cycle are included for emissions accounting can vary depending on the aim of the analysis and available tools and information. Emissions intensity metrics are well suited to the livestock sector, where total absolute emissions may increase to meet growing demand for livestock products, but mitigation actions can reduce the total climate impact by reducing emissions per unit of product.

The LCA approach has also been used in Argentina to inform policy-making in relation to beef sector GHG emissions, where the GHG footprint of beef products is relevant to international trade competitiveness. Their model proposes to consider on-farm production, cattle transportation and livestock product transportation. The model estimates GHG emission intensity using an IPCC Tier 2 approach for different beef production systems in different regions of the country. The model has then been used to assess the GHG effects of different policy scenarios. The model could also be used to track changes in the GHG intensity of beef production.

Sources: GLEAM http://www.fao.org/gleam/en/; Idigoras et al. (2016).

4.3.2.2 Characterization of baselines and baseline scenarios

Many INDCs set a target of reducing GHG emissions in relation to a business-as-usual (BAU) scenario (see Table 13). When mitigation actions are planned in a specific context (e.g. a specific region, sub-sector or individual farm), it will be necessary to further specify the BAU scenario for that context. GHG quantification guidance[118] and carbon market standards[119] provide general rules governing baseline setting. Existing livestock-related GHG quantification methodologies illustrate a range of approaches to determination of the baseline scenario (see Annex 3). These include:

- Determining the baseline on the basis of recent (e.g. average over past 3 years) activity data from participating farms: This approach assumes that recent performance would continue in the absence of the mitigation action. It may be suitable in contexts where livestock production systems are not changing rapidly.
- Determining the baseline on the basis of data from participating farms measured in one year at the start of the mitigation action: This approach assumes that conditions at the start of the mitigation action would prevail in the absence of the mitigation action. It may be suitable in contexts where there is limited farm documentation to establish historical trends or model future ones.
- Determining the baseline on the basis of projected changes in farming practices: In some methodologies, data that substantiates a likely trend in livestock management practices and related GHG emissions can be used to characterize a dynamic business-as-usual scenario. This approach is most relevant where sufficient data is available to support projected scenarios.
- Determining the baseline on the basis of prevailing practices in a region: This approach characterizes conditions in the absence of the mitigation action in terms of average performance of producers in a sub-sector or in a region. It may be suitable for reducing the costs of baseline data collection on each individual farm.

[118] WRI (2014).
[119] CDM (2008), VCS (2012).

Some methodologies require that baselines are re-assessed periodically (e.g. every 5 years) to take account of factors influencing performance other than the project implemented. Each of these baseline-setting options is compatible with measurement of GHGs in absolute terms, in terms of GHG emission intensity of livestock production, or in terms of GHG emissions per capita. Other methodological guidance adopted within the UNFCCC context is broadly consistent with these options. For example, agreed methodological guidance on MRV for reducing deforestation and forest degradation (REDD+) mandates the use of historical trends as the basis for determining the Forest Reference Emission Level (FREL) to serve as a benchmark against which to assess country performance.[120] FRELs should be consistent with the national GHG inventory and can be updated to account for improvements in data or methodologies over time. Countries may use subnational FRELs as an interim measure, before transitioning over time to a national FREL. Baseline and monitoring methodologies have also been approved under the Clean Development Mechanism (CDM) and guidance on baseline setting has been agreed for Joint Implementation mechanism projects, which is also consistent with the options identified above.[121] In addition, the CDM allows the development of country- or sector-specific standardized baselines. One example of a standardized baseline approach has recently been approved by the Gold Standard, a voluntary carbon standard, and is intended for use in Kenya's dairy sector NAMA (Text Box 38).

Text Box 38

A standardized baseline approach for GHG mitigation in smallholder dairy production systems

In 2016, the Gold Standard, a private, voluntary carbon standard, approved a draft "Methodology for quantification of GHG emission reductions from improved management in smallholder dairy production systems using a standardized baseline". Rather than calculate baseline emissions in detail for each participating farming household, the methodology requires that a statistically representative survey covering at least 80% of dairy production systems in a region is conducted. Data from the survey is used to estimate Tier 2 emission factors for cattle on each farm and then to establish a statistical relationship between GHG emission intensity (kg CO_2e/kg fat and protein corrected milk) and annual milk yield per farm. When any individual farm enrols to participate in mitigation activities in that region, baseline emission intensity for that farm can be estimated simply by collecting data on farm yields. Emission reductions are then calculated as the difference between total emissions in the project scenario and total emissions if project scenario yields were produced at the baseline emission intensity (Figure 13). Although this approach will incur significant costs in conducting and analyzing the baseline survey, subsequent monitoring costs will be relatively low. It also means that any dairy mitigation activities in the region can use the standardized baseline for that region to facilitate quantification of GHG mitigation benefits.

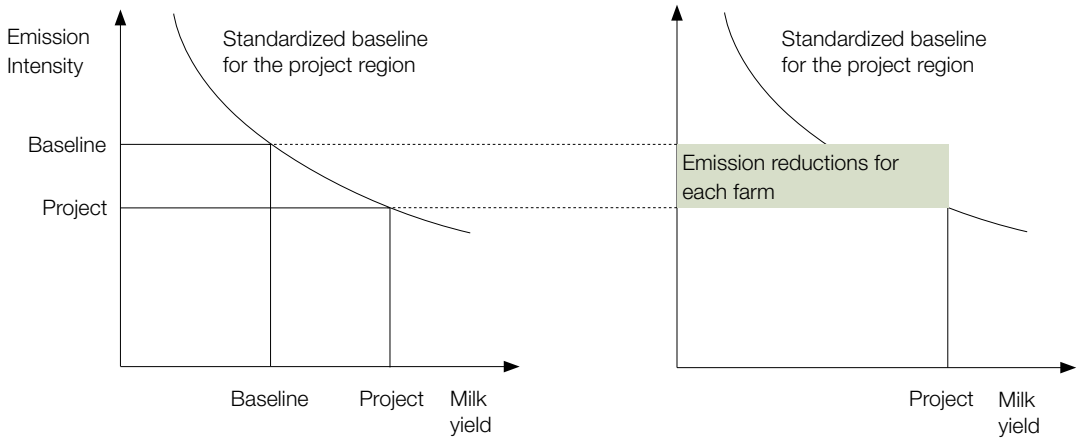


Figure 13: Calculating emission reductions using a standardized baseline for smallholder dairy farms

Source: Gold Standard and FAO (2016).

[120] See FAO (2015).
[121] https://cdm.unfccc.int/methodologies/index.html, JISC (2011).

4.3.2.3 Levels of accuracy and uncertainty

Few sources of international finance for NAMAs have issued explicit guidelines on quantification methodologies. This is most likely because many funding agencies seek to balance GHG benefits with sustainable development co-benefits, and also because appropriate MRV approaches depend on resources, capacities and policy objectives in the host country. This leaves open opportunities to use currently available and feasible methods, while investing resources to improve accuracy and reduce uncertainty over time.

Guidance under the UNFCCC does not specify levels of reliability or accuracy to be achieved in estimating emission reductions from mitigation actions. In general, the accuracy required for emission reduction estimates depends on the user and the resources available. For example, where mitigation actions create tradeable emission reduction units (e.g. in the CDM, other compliance markets, voluntary carbon markets or other future new market mechanisms), it is important that the units generated by different activities are comparable, so high accuracy is required. Carbon market standards often specify the levels of confidence and precision that activity data sample surveys must achieve. For example, the CDM requires that sample surveys achieve a confidence of 90% and a precision of ±10%.[122] Carbon market methodologies related to livestock generally require that project-specific emission factors are developed using a Tier 2 approach. Recognizing the importance of cost-effective use of resources in quantification, most carbon standards also allow the use of conservative estimates when accurate measurement of parameters contributing to the Tier 2 emission factor is not cost effective or feasible. Some carbon standards have also allowed the use of conservative default values and deductions for uncertainty to reduce the costs of measurement. 'Conservative' is generally defined as an estimate that would not over-estimate GHG emissions in the baseline or under-estimate emissions in the project scenario. Specific default values may be derived from IPCC Tier 1 default values or from other sources, where the value can be shown to be conservative.

Where mitigation actions do not generate marketed carbon credits, accuracy requirements may be lower. For example, MRV of domestically supported NAMAs that are expected to be reflected in the national GHG inventory should generally meet or exceed the accuracy level of the national inventory. For internationally supported mitigation actions, the level of accuracy required may depend on whether the funding agency has specific requirements. Few sources of international finance for NAMAs have issued explicit guidelines on quantification methodologies. This is most likely because many funding agencies seek to balance GHG benefits with sustainable development co-benefits, and also because appropriate MRV approaches depend on resources, capacities and policy objectives in the host country. This leaves open opportunities to use currently available and feasible methods, while investing resources to improve accuracy and reduce uncertainty over time.[123]

The practical implications of these general considerations for data collection in the livestock sector have yet to be fully explored. One major area of concern relates to the costs of data collection. Several approaches may be used to manage the costs of data collection, including:

- using default values from existing literature or other sources;
- farmer self-reporting, including via information and communication technologies;
- using proxy variables with lower data collection costs;
- using models to estimate data values;
- integrating data collection for MRV with existing data management systems.

The implications of these approaches for accuracy and uncertainty may need to be assessed (Text Box 39). For example, different methods for measurement or estimation of milk yields have different potential biases and levels of accuracy.[124] Questionnaire design can affect the accuracy of estimates of livestock numbers and livestock performance indicators, as well as the costs of data collection.[125] The accuracy of farmer-self-reported data depends on a number of factors, such as recall periods and farmer characteristics, and will most likely vary among different production systems.[126]

[122] CDM (2012).
[123] While there are few examples in the livestock sector, this approach has been taken in some other sectors. See, e.g. https://www.nefco.org/sites/nefco.org/files/pdf-files/8_nama_performance_metric_and_mrv_system.pdf; http://www.ndf.fi/sites/ndf.fi/files/attach/exs_report_i_4_1-4_nama_cement_sector_mrv.pdf
[124] ICAR (2016).
[125] GSARS (2016b).
[126] Zezza et al. (2016b).

Text Box 39

Assessing constraints to accurate milk yield reporting

Milk yield is a key parameter used in estimating GHG emissions and emission reductions in Kenya's proposed dairy sector NAMA (see Text Box 38). The NAMA will be implemented through public-private partnerships with dairy processors. Some dairy processors have begun to provide extension services to their suppliers in recent years, and have established farmer and cow recording systems to provide information on cow populations, reproduction and performance. Donor projects in the dairy sector also have established M&E systems to track project progress and impacts. An assessment of the suitability of processor and donor recording systems as a basis for NAMA MRV identified a number of issues potentially affecting the accuracy of milk yield reports.

Two in-depth case studies found that in both processor and donor recording systems, data on milk yields derives from farmer self-reporting. Sometimes this involves the farmer documenting yields, and sometimes it involves the farmer verbally reporting yields to visiting extension workers. The most commonly used equipment for measuring milk yield in western Kenya include hanging scales, non-graduated buckets and aluminum cans. Each of these measurement tools has potential sources of error. Further considerations arise when estimating yield over a year or a lactation cycle. For example, when using the Test Interval Method, which interpolates daily milk off-take between measurements, accuracy and potential bias may be affected by the frequency of measurement, period of measurement, suckling of calves and milk yield observations of sick animals.

The assessment recommended a two-pronged approach to improving accuracy over time. First, research should be undertaken in the Kenyan context on the error and bias associated with different methods of measurement or estimation. The results could inform improvements in data management by all of the NAMA's implementation partners, for example by highlighting unreliable methods. Second, research could be conducted on the error and bias of the methods used by each implementation partner. This would enable the implications of research findings to be assessed alongside capacity, resource and other practical constraints affecting each particular partner's information management systems.

Source: Wilkes et al. (2017)

4.3.2.4 Credibility of MRV

The credibility of MRV is not only a reflection of adherence to principles such as accuracy, but also a property of rules and institutions within which MRV is conducted.[127] For example, carbon offset standards (i.e. bodies that set rules and procedures for generating and trading carbon credits) specify rules for the validation of methodologies and proposed project design documents, and for the verification of monitoring data. Often, these roles are performed by independent third-party experts, who may also have gone through an accreditation process. Given the large degree of flexibility in the UNFCCC guidance on MRV of mitigation actions, it may be useful for developing countries to make use of carbon standards' reputation to support the credibility of emission reduction estimates, although the level of accuracy and precision required may exceed the needs of donors. Independent validation and verification, and reporting by carbon standards, can enhance the trustworthiness of mitigation claims. Many standards also have environmental and social safeguard requirements, which may also enhance trust in the sustainability benefits of the mitigation actions implemented. For first-of-a-kind project types in particular, validation of the GHG quantification and monitoring methodology by an established carbon standard can help ensure that the GHG quantification approach is in line with international best practice. Text Box 40 further elaborates on the potential relevance of carbon standards and carbon markets for NAMAs.

[127] Wilkes et al. (2011).

Text Box 40

The relevance of carbon standards and markets for MRV of NAMAs

Finance supporting or rewarding mitigation actions is a key driver of the adoption of GHG quantification and monitoring methodologies. Issuance of emission reduction credits by a robust standard provides investors with assurance of the environmental integrity of the emission reductions claimed. Validation of projects using a recognized carbon standard also enhances the conditions for investors and project developers to invest, with the prospect that credits will provide a necessary financial return. These functions of carbon standards may also be relevant in the context of national mitigation actions, where domestic or international investors require assurance that their investments will be effective in achieving mitigation outcomes. Discussions on New Market Mechanisms are still ongoing within the UNFCCC.

A number of countries have implemented livestock-related mitigation programmes at sub-national or national level in connection with international carbon markets. For example, large-scale household biogas programmes have been implemented in Nepal and China and accredited by the CDM,[128] while others have been accredited by voluntary carbon standards in countries including Vietnam, India, Indonesia and Kenya.[129] In some cases, the finance from credits sold is critical to the financial performance of the programme, but such programmes have rarely been solely implemented using carbon finance. Carbon markets can thus complement domestic and international grant finance to support implementation of mitigation actions. Specifically, carbon finance can help leverage initial investment capital, while payments for performance can provide positive incentives for good management.[130]

However, experience from the CDM suggests that high transaction costs of preparing, approving, managing and managing the risk associated with projects has been a significant constraint on access to the CDM for agricultural projects.[131] For example, the World Bank estimates that pre-registration project development costs average about $200,000, not including costs of registration and validation of projects by carbon standards. New methodologies may take a significant time and investment to develop and approve, in addition to which significant delays in approval of methodologies have affected some carbon standards, which further increases the uncertainty for project developers and investors.[132] Another significant issue affecting carbon markets is the factors affecting carbon credit pricing. Since compliance markets are created by political fiat, carbon pricing is also highly sensitive to political factors. This exposes project developers to additional risks, and low prices may make some project types financial unviable in a carbon market context.

The outcome of UNFCCC Paris Agreement discussions on new market mechanisms will be critical in determining the extent to which carbon markets and national MRV processes become linked. Until then, three types of linkage are likely to co-exist:

- Adoption of carbon market methodologies with validation and verification by carbon standards, including the CDM;
- Adoption of carbon market methodologies with validation and verification by national institutions;
- Reference to carbon market methodologies in the development of MRV of national mitigation actions.

Within domestic MRV systems, there are several options that can improve the credibility of MRV. In the context of BURs, developing countries are encouraged to describe domestic MRV arrangements, including:[133]

- institutions, systems and arrangements involved in domestic MRV;
- the approach used to measure domestically supported NAMAs, including documentation of methodologies;
- the approach used to verify domestically supported NAMAs, including the experts engaged and mechanisms used.

Transparent documentation of MRV arrangements at the national level can increase confidence in the reliability and robustness of the resulting emission reduction claims. Similarly, at the level of specific

[128] https://cdm.unfccc.int/Projects/projsearch.html
[129] E.g. https://mer.markit.com/br-reg/public/index.jsp?entity=project&sort=project_name&dir=ASC&start=0&entity_domain=Markit,GoldStandar
[130] World Bank BioCarbon Fund (2011).
[131] Larsson et al. (2011).
[132] See, e.g. https://cdm.unfccc.int/EB/049/eb49annagan2.pdf
[133] UNFCCC (2014).

mitigation actions, codifying data collection and management procedures and roles in data management processes can increase transparency; quality control systems can play key roles in ensuring the completeness, consistency and accuracy of data; and quality assurance systems can further increase confidence that data quality is being maintained.[134]

4.4 Discussion

This chapter has provided an overview of developing countries' interest in mitigation actions related to livestock and key issues affecting institutional and technical aspects of MRV system design. While many countries have noted the relevance of mitigating livestock GHG emissions, few have proposed specific policies or measures. There is a need in many countries for further analysis of mitigation options and mitigation potential to move towards the identification of policies and measures. Among those countries that have identified mitigation actions in the sector, most are still designing policies, programmes or projects. While all of these countries have begun to consider options for MRV systems, the design of these MRV systems is still in process.

There are no uniform institutional and technical requirements of MRV systems for mitigation. Rather, each country, according to its specific context, is considering suitable solutions out of a range of options. Interviews with a small number of countries suggest that these options are defined across a number of dimensions, as summarized in Figure 14, although the list of dimensions in Figure 14 is not exhaustive. Most countries are seeking to align MRV of mitigation actions with the national GHG inventory. But as described above, this is not always straightforward, and some countries may focus on developing MRV systems for specific mitigation actions without creating this linkage. Some countries have prioritized MRV of non-GHG benefits, while others are focusing efforts on development of MRV systems for GHG benefits. At the UNFCCC level, there is considerable flexibility in MRV requirements. For some certain uses (e.g. linking with carbon markets) and users (e.g. international funders or implementation agencies) there may be specific requirements of MRV. This may determine other decisions in MRV system design, such as the level of accuracy required. In the case of internationally-supported actions, the balance between developing MRV systems that are suited to and build on existing capacities and MRV following other requirements (e.g. policies of international implementation agencies) may need to be addressed. Reporting to the UNFCCC is only one potential function of MRV systems. Other potential functions include support to policy-making and meeting other stakeholders' information needs. The extent to which these (or other) dimensions are relevant in any particular country will vary. They all, however, have implications for institutional and technical decisions in MRV design.

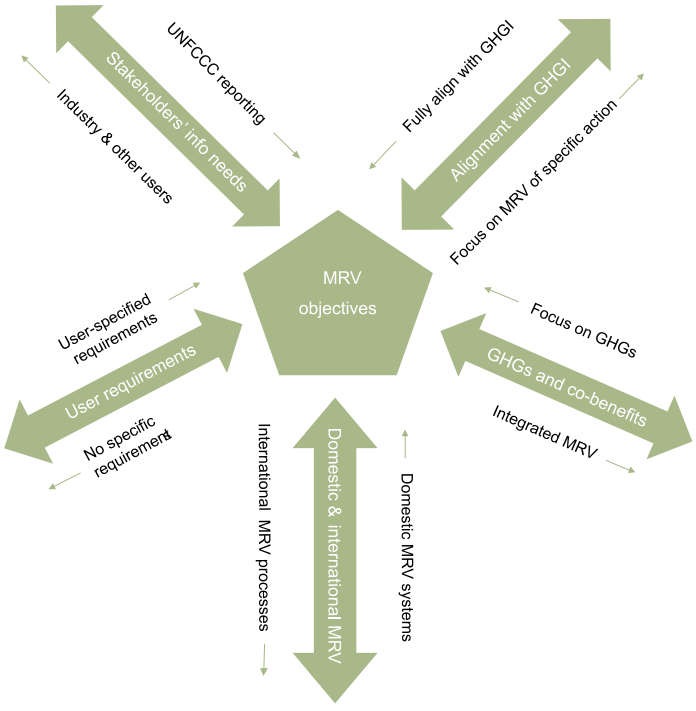


Figure 14: Five dimensions framing decisions in MRV system design for mitigation actions

Note: GHGI: national GHG inventory

[134] Wilkes et al. (2017).

5. Trajectories for livestock MRV going forward

Key messages

- For many countries describing baseline scenarios, assessing mitigation potentials, and identifying policies and measures will be the priorities for promoting livestock mitigation.
- The main trajectories for the development of livestock MRV systems in the coming years will involve:

1. GHG inventory improvements, including
   a. Improvements in livestock population data
   b. Moving from Tier 1 to Tier 2 approaches
   c. Adjusting existing Tier 2 approaches to reflect trends in the livestock sector
   d. Continuous improvement of Tier 2 approaches through regular updating
2. Development of intervention-specific MRV systems, including baselines
3. Integrating MRV of livestock emissions with existing livestock information systems
4. Integrating MRV of livestock emissions with MRV of other land-based and energy sources and sinks.

- Broadly speaking, countries are likely to seek to measure progress in their NDCs through national GHG inventories, or by developing intervention-specific MRV systems, which may or may not be linked with national GHG inventories.
- Countries where stakeholders are able to make convincing justifications for investment in improved MRV, and where institutions in different sectors are able to collaborate smoothly, will make more rapid progress.
- While the benefits for national policies of moving to a Tier 2 approach in national inventories and of linking national inventories with MRV of progress in NDCs and specific mitigation actions are widely recognized, there is less agreement on acceptable practices or minimum standards for making the required improvements. Among a small number of experts surveyed, there was a consensus that the best available data should be used, that a Tier 2 approach using national data would be more accurate than a Tier 1 approach, and that emission factors should be periodically updated. Most experts agreed that while the *IPCC Guidelines* are a key reference for MRV systems, they give insufficient guidance for quantifying the effects of mitigation actions.

5.1 Identifying mitigation policies and measures as a precondition for MRV

To inform MRV needs, more countries will need capacities for national- and sub-sector specific analysis of mitigation options to identify cost-effective policies and measures that contribute to national development objectives. Seventy-six developing countries' national communications to the UNFCCC recognize the potential for mitigation of livestock-related GHG emissions, but only 19 provide any analysis and only 13 mention related policies or plans. More countries mention the potential for mitigation of manure management emissions than for mitigation of enteric fermentation emissions, even though the latter are on average about three times larger than the former in developing countries and existing trajectories for sustainable livestock development often decrease emissions intensities.

Clarity on the linkages between MRV systems and policy objectives can also help shape strategies for improving MRV. In addition to climate policy objectives, many developing countries also have agricultural and livestock policies, strategies and plans that aim to increase livestock productivity. In many countries, stakeholders do not have strong awareness of the contribution of GHG inventory improvement and the development of MRV systems to meeting policy objectives.

For many countries describing baseline scenarios, assessing mitigation potentials, and identifying policies and measures will be the priorities for promoting livestock mitigation. Identification of policies and measures is also closely related to setting baseline and mitigation scenarios to inform NDCs as well as measurement of emission reductions. Of the countries whose INDC includes livestock-related emissions, the majority intend to measure emission reductions compared to a business-as-usual scenario. Not all of these countries have made an in-depth assessment of baseline and mitigation emission scenarios, and only about a quarter of these countries have identified specific policies and measures to reduce livestock-related emissions.

For livestock emissions, analysis of mitigation options should be carried out using a Tier 2 approach. Collation of available data for a Tier 2 approach can also inform assessment of the potential for adopting a Tier 2 approach in national GHG inventories. Mitigation analysis can therefore potentially contribute to GHG inventory improvement. Analysis of mitigation options and scenarios in other sectors has been facilitated in part by user-friendly software.[135] GLEAM, recently developed by FAO, can be used to facilitate data analysis in assessment of mitigation options in the livestock sector, and a simplified version (GLEAM-i) has been released.[136] Continued development of GLEAM-i software capabilities for analysis of mitigation scenarios over time and for incorporating economic assessment would further enhance its utility. Increasing model transparency would also be necessary if GLEAM is also to be used in the compilation of national GHG inventories or for scenario analysis in support of NDCs.

Beyond the identification of policies and measures, future trajectories for developing countries' MRV of livestock emissions and emission reductions are likely to be shaped by countries' starting points, the types of mitigation action pursued, their mechanisms for implementation, and national policies on MRV.

5.2 Trajectories for MRV improvement

Starting points for MRV: Many developing countries face challenges in obtaining data on livestock populations. Better data can support policy and investment decisions, as well as contributing to more accurate accounting for GHG emissions. For some countries, livestock population data exists, at least for key livestock types, and moving from a Tier 1 to a Tier 2 approach will be the priority for MRV improvement. National policies on livestock development and climate change mitigation in the livestock sector also vary. There is therefore no 'one-size-fits-all' approach for improving livestock MRV in developing countries.

Mitigation actions by sector: The effects of some mitigation actions (e.g. promotion of specific management practices) could be measured by tracking livestock emissions alone, but others will require a broader approach that captures changes in all significantly affected GHG sinks and sources. MRV systems will be needed that capture effects of changing practices in particular production systems rather than focusing only on changes in particular GHG inventory categories. Changes in dairy management practices affect not only dairy emissions but also production of calves destined for the beef sector. Where mitigation actions affect the production of feed or have impacts on grassland or forest vegetation, MRV of livestock emissions will need to be addressed within a landscape approach. It will be necessary to develop MRV systems that link with other existing MRV systems (e.g. for REDD+) and systems under development in other sectors.

Mechanisms for implementation: Options for MRV of these mitigation actions will be shaped in part by the type of implementation mechanism developed. Where a policy or project has significant national coverage, it may make sense to align MRV with the national GHG inventory. Where projects target specific regions or sub-sectors, project-specific MRV systems may be more appropriate.

[135] See, e.g. http://unfccc.int/resource/cd_roms/na1/mitigation/
[136] http://www.fao.org/gleam/resources/en/

National MRV policies: Some countries have made a policy decision to track progress in INDCs and NAMAs through the national GHG inventory. Of 92 countries that include livestock-related emission sources in their INDC, only five have national inventories that capture changes in livestock productivity over time; 73 are currently using a Tier 1 approach and nine are using a Tier 2 approach based on literature and other sources that are not updated over time. Thus, a major challenge will be to improve national GHG inventories so that the effects of mitigation actions can be captured. Where countries seek to measure progress in mitigation through intervention-specific MRV systems, various challenges may be faced in aligning these with national GHG inventories, as described in Chapter 4.

This suggests that the main trajectories for the development of livestock MRV systems in the coming years will involve:

1. **GHG inventory improvements, including**
   - **a. Improvements in livestock population data**
   - **b. Moving from Tier 1 to Tier 2 approaches**
   - **c. Adjusting existing Tier 2 approaches to be able to reflect trends in the livestock sector**
   - **d. Continuous improvement of regularly updated Tier 2 approaches**
2. **Development of intervention-specific MRV systems**
3. **Integrating MRV of livestock emissions with existing livestock information systems, and**
4. **Integrating MRV of livestock emissions with MRV of land-based and energy emissions.**

5.3 Improving national GHG inventories

5.3.1 Institutional arrangements

Globally, large gaps in the availability and quality of livestock statistics are common. Above all, this impedes effective decision-making for investment in and management of the livestock sector. There are therefore potential synergies between improvements in livestock MRV and stakeholders' needs for improved information in the sector. At the international level, the Global Strategy for Improvement of Agricultural Statistics, and the System of Economic-Environmental Accounting are major initiatives of direct relevance to livestock statistics. Both are translated into action plans at country level. The potential for linking these processes with MRV processes should be further explored.

Common constraints to improvement include weak linkages between inventory compilation processes and national data providers, and lack of funding for inventory improvement.

Common constraints to improvement include weak linkages between inventory compilation processes and national data providers, and lack of funding for inventory improvement (see Chapter 3). Suggestions from participants at a "Workshop on implementing MRV to meet countries' mitigation and sustainable development goals in the livestock sector" also illustrate the importance of political engagement, human resources and technical capacities (Text Box 41). Close collaboration between agencies involved in livestock inventory compilation and statistical agencies has been identified as an enabler of inventory improvement. Political and financial support for making inventory improvements are likely to be stronger where stakeholders are aware of how proposed MRV improvements contribute to policy goals in climate, livestock, environment or other sectors. Where suitable platforms do not exist, agencies responsible for livestock inventory compilation (whether researchers or officials) may need to consider other ways to engage relevant stakeholders in defining policy goals, identifying and justifying improvements and related investments. Involving the private sector in discussions on inventory improvement and strengthening research-policy linkages may be of particular relevance in some contexts.

5.3.2 Inventory methods

Priorities for improvement may focus on livestock population data or moving from a Tier 1 to a Tier 2 approach, or improving existing Tier 2 approaches. Assessing available data to address gaps in data availability and data quality (including uncertainty) are likely starting points. In some countries, it may be relevant to link on the resulting plans for inventory improvement with statistical agencies' efforts to improve livestock statistical data. Agricultural censuses and sample surveys between censuses also provide opportunities to collect relevant data. There are a variety of census, survey and other data collection tools, each of which has pros and cons in terms of their ability to deploy at scale on a regular basis and to provide reliable data cost-effectively. Where data collection is not possible, modelling, expert judgment and other data procedures are potential options to consider. Comparison of different data collection methods, such

as comparisons of 'gold standard' methods with a range of alternative methods can give guidance to stakeholders on available options to choose from.

Countries may be held back from moving from Tier 1 to Tier 2 by the perception that complete and accurate data is required on all parameters in the IPCC Tier 2 model for enteric fermentation, or by a misperception that direct measurements of methane emissions are required. Text Box 42 shows that among people compiling or using national GHG inventories, there is widespread agreement that it is acceptable to use the best available data, even though there is little agreement on acceptable practices and data sources in inventory compilation. The current practices of developing and developed countries described in Chapter 3 highlighted the flexibility in existing guidance and the diversity of actual practices. Countries prioritizing the ability to quantify the trend in livestock GHG emissions could decide to proceed by using available data and developing a strategy for improvements in accuracy over time. The IPCC Tier 2 models can also be populated with data on livestock production practices and performance, while using default values for parameters that have never or rarely been measured. Initially, few countries will have all the data needed for a regularly updated Tier 2 approach available. It is also possible that countries could share data where production systems and mitigation practices are similar, but there has been little assessment of the strengths and weaknesses of using such an approach, especially for the purpose of inventories. Increasing the transparency of data sources, methodologies and improvement plans are essential where pragmatic inventory methods have been used to enable interpretation of the results, comparability and further improvement. In particular, uncertainty analysis for livestock emissions in national GHG inventories has not been conducted by many developing countries, and further practical guidance may be needed to support its use.

There was a consensus that the best available data should be used, that a Tier 2 approach using national data would be more accurate than a Tier 1 approach, and that emission factors should be periodically updated.

Text Box 41

Stakeholder suggestions for improvement of national GHG inventories by region

Africa:

- Establish national data registry, clarify roles, develop routine data management systems, and build capacities for data flows and data management
- Move from Tier 1 to Tier 2, by compiling national data with relevant stakeholders, verifying existing data and harmonizing data sources
- Strengthen staff, infrastructure and financial capacities for MRV
- Develop GHG and MRV policies

Asia:

- Move from Tier 1 to Tier 2 or improve existing Tier 2 approaches for key livestock emission sources
- Improve data collection involving statistics agencies and researchers
- Clarify national inventory and MRV roles and strengthen capacities

Latin America:

- Improve activity data by improving data collection forms and establishing institutional arrangements
- Strengthen institutional linkages and capacity building for data provision involving extension agencies and the private sector

Source: participants at "Workshop on implementing MRV to meet countries' mitigation and sustainable development goals in the livestock sector", Rome, 20-21 February 2017.

Text Box 42

Do inventory compilers and users agree on acceptable practices in developing a Tier 2 approach?

Appendix 4 describes the results of an online survey of 18 people who either compile or use livestock inventories in developing countries, including five people who have taken part in IPCC expert meetings related to national GHG inventories.

Respondents were asked whether they agreed with statements about acceptable Tier 2 approaches (Table 14). For some questions, an option was given of "depends on context" or "may or may not be acceptable". For the full sample of respondents, there was a consensus that the best available data should be used, that a Tier 2 approach using national data would be more accurate than a Tier 1 approach, and that emission factors should be periodically updated. However, there was no consensus that using unbiased methods is more important than lowering uncertainty, or that it is necessary to estimate the uncertainty of Tier 2 approaches used in national inventories. While there was no consensus on these questions among inventory compilers, there was consensus among users of inventories in their responses (Table 14, last column).

When asked whether direct measurements are essential for different parameters (methane yield, animal live weight, feed intake, feed digestibility, animal productivity) there was strong consensus that direct measurements are always essential. But when asked if different data sources are acceptable when measurement data is lacking, there was no consensus among all respondents on some possible data sources. However, there was consensus on all possible data sources among those involved in IPCC expert meetings (Table 15). Neither users nor inventory compilers agreed on what are and are not acceptable data sources.

Table 14: Consensus on characteristics of acceptable Tier 2 approaches

Question: To what extent do you agree with the following statements?	**Consensus answer for all respondents**	**Consensus answer for inventory users**
Using data and methods that are not biased is more important than using data and methods with lower uncertainty	No consensus	Depends on context
Any Tier 2 approach using national data for at least some parameters will be more accurate than a Tier 1 approach, even if uncertainties are high	Agree	Depends on context
If the best available data are used, but bias and uncertainty are unknown, a Tier 2 approach is acceptable if data sources and assumptions have been transparently documented	Agree	Agree
A Tier 2 approach should not be used in a national inventory if the uncertainty cannot be estimated	No consensus	Agree
Emission factors should be updated periodically to reflect trends in the livestock sector	Agree	Agree

5.4 Improving MRV of mitigation actions

There are no uniform institutional and technical requirements of MRV systems for mitigation actions. Despite this lack of formal standards, however, experts involved in developing MRV systems do agree on some characteristics of MRV systems (Text Box 43). In this context, each country, according to its specific needs, is considering suitable solutions out of a range of options (see Chapter 4). Some countries have prioritized MRV of non-GHG benefits, while others are focusing efforts on development of MRV systems for GHG benefits. While the UNFCCC has considerable flexibility in its reporting requirements, for some certain uses (e.g. linking with carbon markets) and users (e.g. international funders or implementation agencies) there may be specific requirements of MRV, such as for some of the institutions described in Text Box 34. This may determine other decisions in MRV system design, such as the level of accuracy

required. In the case of internationally-supported actions, the balance between developing MRV systems that are suited to and build on existing capacities, and MRV following other requirements (e.g. policies of international implementation agencies) may need to be addressed. Reporting to the UNFCCC is only one potential function of MRV systems. Other potential functions include support to policy-making and meeting other stakeholders' information needs. The extent to which these (or other) dimensions are relevant in any particular country will vary.

MRV of livestock mitigation actions is at an early stage in most countries, and there is little mature experience to draw on. There is a need to continue piloting MRV systems at different scales – from project to national level – and different methods, including innovative approaches involving mobile and ICT technologies. Documenting pilot experiences and sharing experiences between countries would increase awareness of the range of options available, and the suitability of different methods in different contexts.

While 70% (of technical experts surveyed) agreed that the IPCC Guidelines should be taken as a reference, more than 60% agreed that the IPCC Guidelines give insufficient guidance for quantifying the effects of mitigation actions.
70% of respondents agreed that NAMAs should use project-specific activity data and emission factors.

Table 15: Consensus on acceptable data sources in a Tier 2 approach

Question: When accurate data on diets and livestock performance are unavailable, which of the following data sources are acceptable?	**Consensus answer for all respondents**	**Consensus answer for those involved in IPCC processes**
National feed ration standards	No consensus	May or may not be acceptable
Literature reports	Acceptable	Acceptable
Expert judgement	Acceptable	Acceptable
Small-scale surveys in targeted production systems	No consensus	Slightly acceptable
Question: When reliable official data is lacking on the population of different sub-categories of livestock (e.g. cattle by age or sex, dairy vs. non-dairy), which of the following data sources are acceptable?		
Literature reports	Acceptable	Acceptable
Expert judgement	Acceptable	Acceptable
Models of herd composition and dynamics	No consensus	Acceptable
Extrapolation from the last livestock census	Acceptable	Acceptable
Small-scale surveys in targeted production systems	No consensus	Slightly acceptable

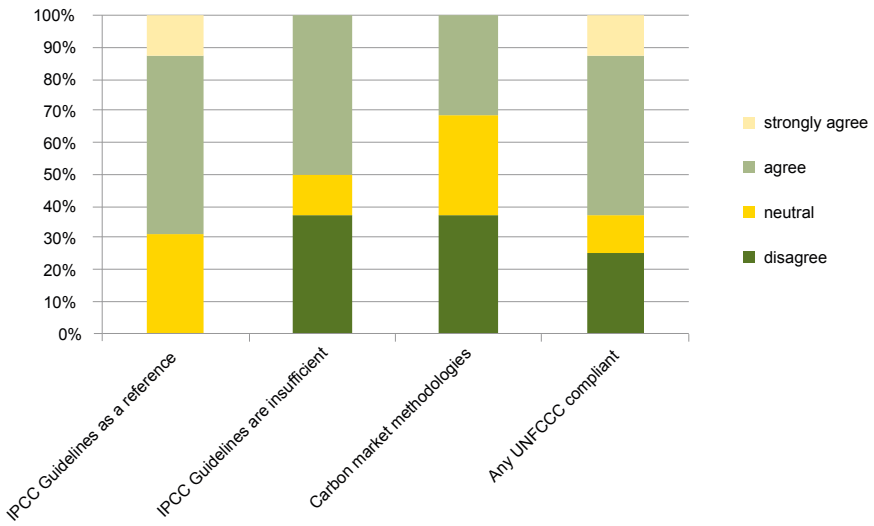


Figure 15: Which standards should be taken as the main reference for MRV of mitigation actions?

Text Box 43

Do experts on MRV of mitigation actions agree on acceptable practices for MRV?

Appendix 4 describes the results of an online survey of 16 people involved in MRV of mitigation actions in developing countries, including six who are involved in developing NAMAs and four with carbon market experience.

About 70% of respondents agree that MRV systems for mitigation actions should be linked with national GHG inventories and systems for measuring progress on NDCs. However, there was less consensus on the reference standards for MRV of mitigation actions. While 70% agreed that the *IPCC Guidelines* should be taken as a reference, more than 60% agreed that the *IPCC Guidelines* give insufficient guidance for quantifying the effects of mitigation actions. One third of respondents agreed that carbon market methodologies should be the main reference, but one third disagreed. One third also disagreed with the statement that countries should use any methodology that adheres to the UNFCCC principles for credible MRV (Figure 16).

Although there was no consensus on the reference standards, there was consensus on some of the characteristics of acceptable MRV practices. On completeness, respondents agreed that all significant GHG sinks and sources should be quantified, but there was no consensus that only the main sinks and sources should be quantified if resources for MRV are limited. Despite the consensus that MRV systems should align with national GHG inventories, almost 70% of respondents agreed that NAMAs should use project-specific activity data and emission factors. Respondents did agree, however, that NAMA baselines should be consistent with NDC baselines. The vast majority of respondents agreed that countries should strive to improve MRV over time, should quantify the uncertainty of estimates of emission reductions, and should have robust quality assurance and quality control procedures.

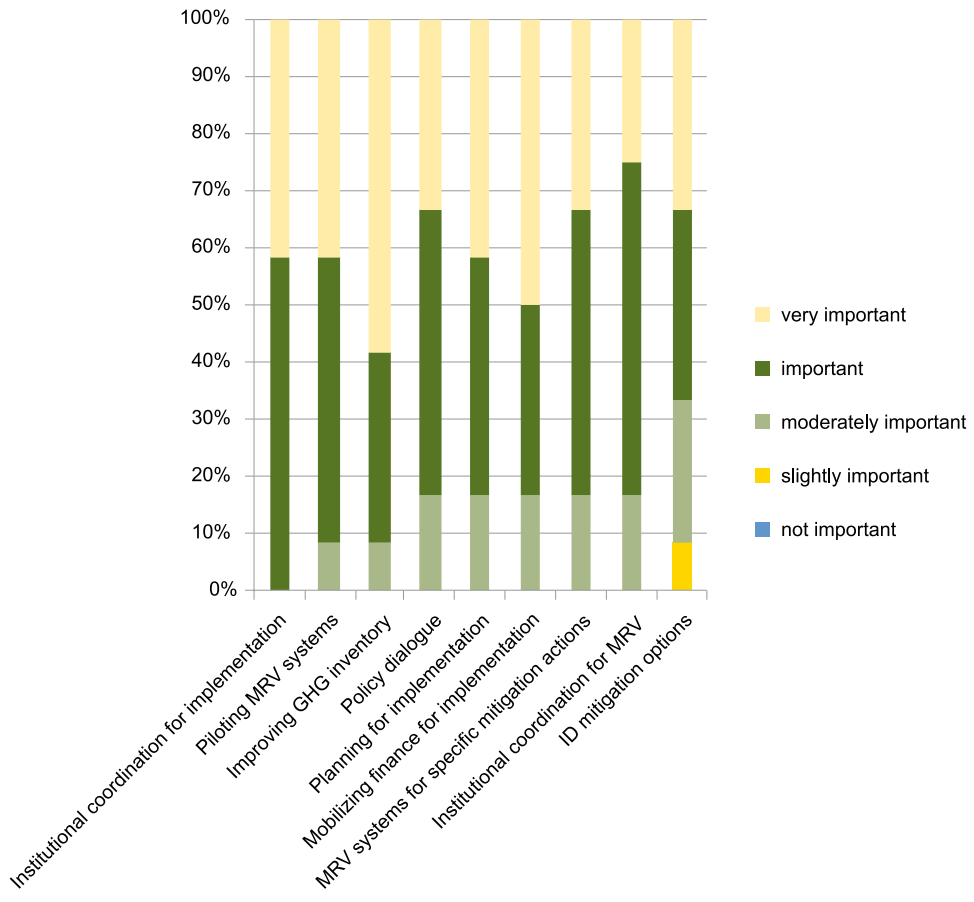


Figure 16: Importance of different aspects for improved mitigation and MRV

Note: "Implementation" refers to the implementation of mitigation actions.

5.5 Priorities for MRV improvement

Appendix 4 reports the results of an online survey of 18 people about the relative priorities in their countries for improvement of mitigation actions and MRV. Bearing in mind that the number of survey respondents was very small, some key findings can be highlighted. Responses indicate that improvements in institutional aspects, planning and MRV are all important or very important (Figure 17). This suggests a need to understand better how improvements in one component of MRV systems can support improvements in overall performance in terms of mitigation and MRV.

Research can contribute to improvements in MRV in several ways. The highest proportion of respondents indicated that assessing sustainable development benefits of livestock mitigation is either important or very important, but research on gender was assessed as of less importance. Research on data collection methods, mitigation scenarios, and improvements in activity data and emission factors were also widely recognized as important.

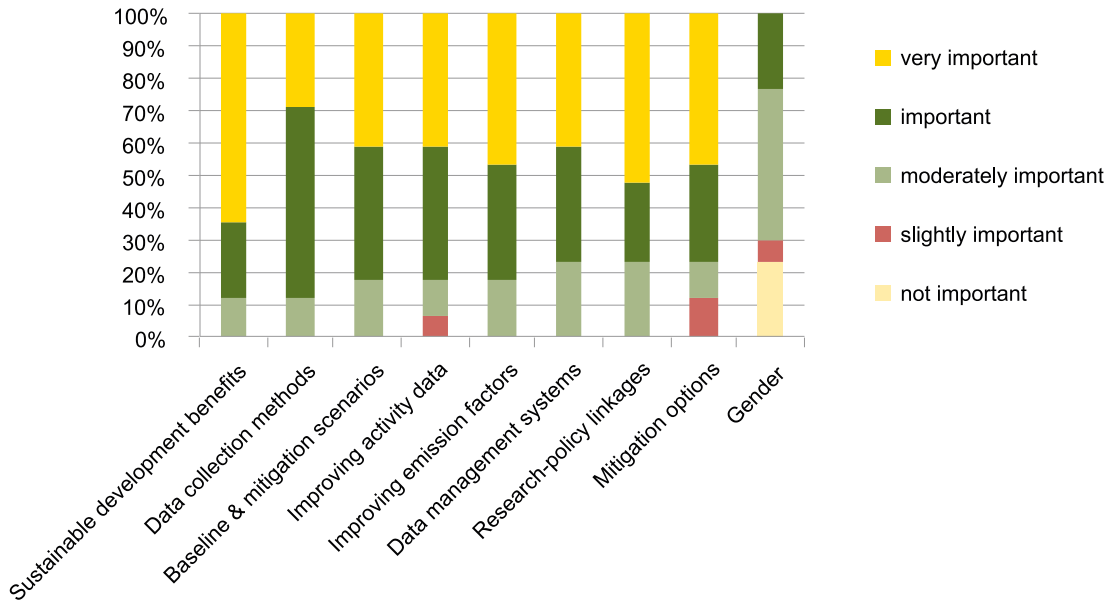


Figure 17: Importance of research topics in support of MRV improvements

6. Recommendations

Based on the preceding chapters, the following recommendations are made for developing countries and their international partners. The purpose of these recommendations is to assist countries to improve their MRV systems and to identify initial steps on the path to continuous improvement, including consideration of which data sources and MRV practices are "good enough" to support the continuous improvement process. Some of the recommendations below are relevant to many developing countries, while others are targeted to international agencies working in partnership with developing countries, and highlight activities that can support improvement of livestock MRV in developing countries in general.

6.1 Recommendations for MRV implementation

1. **Use a Tier 2 approach for priority livestock types and production systems,** to increase accuracy of livestock emissions estimates in line with policy priorities and capture a broader range of mitigation impacts.

2. **Involve key stakeholders** from the livestock sector, statistics and other sectors (including the private sector, farmers and scientists) in:
   - o clarifying policy objectives served by inventory improvement
   - o identifying priorities for inventory improvements, and
   - o developing inventory improvement plans.

Including:

- Improve inventory in line with climate, livestock and other policy objectives (e.g. mitigation plans in the livestock sector, Sustainable Development Goals).
- Assess and communicate the value of improvements in MRV to policy makers and industry stakeholders to support collaboration and investment in inventory improvement.
- Strengthen inter-minsterial cooperation on data collection, sharing, and inventory improvement.
- Facilitate stakeholder engagement, including inventory compilers, users and others) in clarifying feasible and acceptable inventory compilation practices and plans for improvement over time.
- In the light of policy and stakeholders' objectives, consider how to balance the relative priorities of making accurate estimates of emissions vs. accurate estimates of emission trends.

3. Improve inventory data

- Strengthen the synergies between improvements in statistical systems or other livestock data systems, to improve the availability of data needed in the livestock sector while meeting inventory needs.
- Assess the availability of data, gaps between available data and demand for data, and the efficient functioning of livestock data management systems.
- Use the best available data and use practical steps to fill data gaps, whether through statistics, literature, expert judgement, modelling, interpolation or other methods, and assess data quality.
- When pragmatically choosing data and methods, increase transparency of national GHG inventory documentation.
- Consider how regularly reported data on livestock production and productivity can be used to periodically update the Tier 2 estimates.

4. Improve MRV of mitigation

- Focus on MRV of mitigation options that are aligned with national livestock development policies and other guiding development strategies.
- Consider how to link MRV of sub-national mitigation actions to national MRV systems (especially inventories) in the light of donor MRV requirements, the scope of sources and sinks included, the scale of data and the need for conservative estimates of emission reductions.
- Where national MRV systems (including national GHG inventories) are still under development, develop intervention-specific MRV systems.
- Pilot MRV methods and approaches, including quality assurance and quality control procedures, recognizing that countries should strive to improve MRV over time.

- Seek to align baselines and monitoring systems for intervention-specific MRV systems with NDC baselines and targets.
- Consider how to measure non-GHG benefits of mitigation practices, including adaptation and contributions to the SDGs.

6.2 Recommendations for MRV support and analysis

1. Demonstrate value of improved MRV

- Analyse how improvements in inventories and other MRV systems can help countries and stakeholders within those countries to meet their climate and sustainable development policy goals.
- Share examples of how countries are improving national MRV systems, especially how improvements in components support overall performance.
- Enable regional sharing of experiences on MRV improvement.
- Assess whether enhanced reporting formats (either as voluntary guidance or within the Enhanced Transparency Framework) could increase the transparency of developing country inventory reporting while providing flexibility in the light of capacities and resources.
- Provide resources to build countries' capacities for inventory compilation, including institutional arrangements that facilitate collaboration and information flows, political and scientific engagement, human resources and technical capacities, and financial resources in line with the needs for increased transparency.

2. Analyze existing methods and data to inform MRV development

- Review how Tier 2 approaches adopted by developed and developing countries have improved over time and how these methods link to policy goals, MRV design and specific data needs to inform other countries of potential incremental approaches.
- Compare methods for data collection on livestock populations, herd structure, feed intake, livestock performance and other parameters to guide the choice of more reliable and cost-effective methods, including practical alternatives methods to 'gold standard' methods.
- Assess the potential for countries to use research results from similar production systems in other countries, so that not all countries need to undertake original research for all parameters in the Tier 2 approach.
- Provide guidance on uncertainty analysis, transparency and QA/QC, including how to deal with data gaps and mixed data sources, and their relevance for different policy objectives.
- Document and share case studies of the approaches, including institutional arrangements, used by different countries to compile and improve their national GHG inventories.

3. Support guidance, learning and tools for MRV of mitigation actions

- Provide guidance on principles, practical advice and best practices for MRV of livestock-related mitigation actions, acknowledging the need for countries to have flexibility to design systems best suited to their contexts and capabilities.
  - o Develop principles for credible MRV practices based on input from country experts and users of MRV information about what is considered widely acceptable.
  - o Provide guidance on good practices in baseline and mitigation scenario analysis for NDCs and specific mitigation actions.
  - o Provide guidance on uncertainty analysis in the estimation of emission reductions.
  - o Share case studies and examples of approaches (including institutional arrangements) and methods used in MRV at different levels (national, sub-national, project).
- Support piloting and testing of MRV systems at the sub-national level.
- Enable regional and inter-regional exchange on MRV of livestock-related mitigation actions.
- Improve the software capabilities and transparency of available assessment tools for estimating emissions for use in national decision-making.

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Appendix 1: Livestock GHG emissions in developing countries

Reporting to the UNFCCC by developing countries and economies in transition does not easily enable quantification of levels or trends in all livestock emission sources. In the Common Reporting Format (CRF), enteric fermentation and manure management are reported in one category, while dung and urine deposit on pastures in another emission category, where it is grouped together with other sources of N_2O from agricultural soils, and rarely reportedly separately. Here, we use data from two sources to estimate the contribution of livestock emissions to total national emissions, and to identify countries contributing large proportions of total livestock emissions and the proportion of national emissions from livestock sources.

A. DATA SOURCES

Data on total gross GHG emissions (i.e. excluding LULUCF) were obtained from the UNFCCC website (http://unfccc.int/di/DetailedByParty.do). Data was obtained on livestock emissions from 137 developing countries and economies in transition that have reported livestock emissions.[137] The data available on that website refer to different years, but are an easily accessible source of data on total national GHG emissions and key livestock emission sources. The data refer to inventories for years between 1990 and 2013, with a mean of 2000. The data from this source includes estimates of enteric fermentation emissions from 134 countries and data on manure management from 125 countries. While there is data from 116 countries on emissions from agricultural soils, separate data for dung and urine deposit on pastures is not available for the vast majority of these countries from that source.

Data on separate livestock emission sources (i.e. enteric fermentation, manure management, dung and urine deposit on pastures) are available from the FAO database (http://www.fao.org/faostat/en/). GHG emission data in FAOSTAT differs from that reported by countries to the UNFCCC. FAOSTAT uses the IPCC Tier 1 methodology (as do 86% of countries reporting to the UNFCCC), but data on livestock populations and assumptions about the distribution of livestock among different manure management systems differ. Data were obtained for livestock emission sources for the same year that the UNFCCC website reported total emissions.

B. RESULTS

Data from 137 developing countries and economies in transition that have reported livestock emissions suggest that enteric fermentation and manure management together account for about 9.2% of the total GHG emissions of these countries. However, these emissions exceed 20% of total emissions in 48 countries (i.e. 35% of countries), and exceed 5% in 95 countries (i.e. 69% of countries).

Comparing data from the two sources, FAOSTAT suggests that total emissions in the same years from all 137 countries due to enteric fermentation, manure management, dung and urine deposit on pastures was 18% higher (i.e. 2,127,422 Gg CO_2-eq) than the sum of the first two of these emission sources presented in national reporting to the UNFCCC (i.e. 1,835,181 Gg CO_2-eq). The sum of these 3 emission sources from all 137 countries is equal to about 10.9% of total national emissions reported in the same year, and exceeds 5% of emissions in 72% of countries. IPCC Good Practice Guidance recommends that particular attention is given to the accurate quantification of key source categories, i.e. those GHG sources that make up the 95% of cumulative emissions in national GHG inventories. The quality of measurement and reporting of livestock emissions is therefore relevant to a significant proportion of developing countries.

The top 10 and 20 countries with the largest livestock emissions were identified from both the UNFCCC and FAOSTAT sources. There is a high degree of overlap between the two lists (see Table A.1). Using data from either source, livestock emissions represent a high proportion of total national emissions in many of these countries. However, there is no relationship between the absolute level of livestock emissions and the proportion of total national emissions due to livestock sources. Using data from the UNFCCC website, the top 10 and top 20 countries account for 71% and 81% of total livestock emissions from these 137 countries, respectively. Using data from FAOSTAT, the top 10 and top 20 countries account for 69% and 80% of total livestock emissions from these 137 countries, respectively.

[137] Countries for which livestock emission data could not be obtained from the UNFCCC website include Angola, Brunei Darussalam, Equatorial Guinea, Iraq, the Kingdom of Bahrain, Libya, Maldives, Marshall Islands, Nigeria, Singapore, Solomon Islands, Somalia and South Sudan.

Table A.1: List of 20 countries with largest livestock greenhouse gas emission estimates in UNFCCC and FAOSTAT databases

UNFCCC data						FAOSTAT data					
TOP 10 countries	Total of EF and MM (Gg CO_2e)	% of national emissions	TOP 20 countries	Total of EF and MM (Gg CO_2e)	% of national emissions	TOP 10 countries	Total of EF, MM & PD (Gg CO_2e)	% of national emissions§	TOP 20 countries	Total of EF, MM & PD (Gg CO_2e)	% of national emissions*
Argentina	58,890	0.209	Argentina	58,890	0.209	Argentina	88,068	0.312	Argentina	88,068	0.312298
Brazil*	260,378	0.302	Bangladesh*	28,054	0.282	Brazil*	368,805	0.427	Bangladesh*	30,881	0.31054
Cameroon*	83,376	0.503	Brazil*	260,378	0.302	China	337,208	0.045	Brazil*	368,805	0.427447
China	444,563	0.059	Cameroon*	83,376	0.503	Colombia*	46,070	0.299	China	337,208	0.045167
Colombia*	34,446	0.224	China	444,563	0.059	Ethiopia*	83,008	0.568	Colombia*	46,070	0.299379
Ethiopia*	66,161	0.453	Colombia*	34,446	0.223	India	343,049	0.225	Ethiopia*	83,008	0.567924
India	216,517	0.142	Egypt*	17,353	0.089	Mexico*	66,035	0.103	India	343,049	0.225132
Mexico*	38,356	0.059	Ethiopia*	66,161	0.453	Nigeria	33,963	0.159	Indonesia	28,256	0.050973
Pakistan	47,981	0.299	India	216,517	0.142	Pakistan	62,012	0.386	Iran	25,909	0.053567
Sudan	57,412	0.846	Indonesia	14,598	0.026	Sudan	68,224	1.005	Kenya	21,640	1.008107
			Iran	17,844	0.037				Mexico*	66,035	0.102946
			Kazakhstan	16,412	0.058				Myanmar	24,940	0.649909
			Mexico*	38,356	0.059				Nigeria*	33,963	0.158552
			Pakistan	47,981	0.299				Pakistan	62,012	0.386154
			South Africa	19,394	0.051				South Africa	22,348	0.058836
			Sudan	57,412	0.846				Sudan	68,224	1.00567
			Thailand	13,332	0.056				Tanzania	19,703	0.502154
			Uruguay*	16,534	0.456				Uruguay*	22,304	0.6148
			Venezuela	17,070	0.089				Venezuela	23,918	0.124451
			Vietnam*	18,028	0.068				Vietnam*	19,277	0.072457

Appendix 2: Quality of reporting on livestock emissions in national GHG inventories

2.A METHODOLOGY FOR ASSESSMENT OF REPORTING QUALITY

In this Appendix, a scoring approach is applied to assess the quality of reporting of livestock emissions by developing countries and economies in transition. Scoring approaches have previously been used to assess capacities for GHG inventories,[138] for MRV in the context of REDD+,[139] and for change in capacities in response to international capacity building initiatives.[140] This, and other work, indicates that capacities for national level inventories can be characterized in terms of political engagement, institutional arrangements and technical capacities. Here we restrict the focus to an assessment of the quality of livestock emission reporting in national communications, national inventory reports and BURs that have been submitted to the UNFCCC. This approach assumes that the quality of submissions is a reflection of underlying capacities.[141] However, the assessment of the quality of reporting does not reflect the quality of the underlying measurement.

We identified four criteria of the quality of reporting based on the UNFCCC MRV principles of completeness, accuracy, consistency and transparency, and developed one or more indicators for each criterion. Scores were given for each country for each indicator, with a higher score indicating higher quality, and negative scores given for reporting practices that do not comply with the criteria (Table A.2). More detail on the scoring of indicators is given in Table A.3.

Table A.2: Scoring criteria for the quality of national reporting of livestock emissions

Criteria	Indicators	Scoring
Completeness	1. The main livestock emission sources were included in the latest inventory	0 – 9
Accuracy	2. IPCC tier approach used for livestock emission sources	0 – 3
	3. National data on livestock population is available	0 – 3
	4. Efforts are being made to identify and reduce uncertainty	0 – 3
Consistency	5. Consistency of time series reported	0 – 9
Transparency	6. Justification was not given for omitting one or more GHG source	-3 – 0
	7. Tier level used was not stated or a Tier 2 emission factor was used but was not referenced or explained	-3 – 0
	8. Reference to livestock population data source was not given and livestock population data was not presented	-3 – 0

Note: positive scores were given for indicators of adherence to complete, accurate and consistent reporting, while negative scores were given for non-adherence to indicators of transparency.

[138] IGES (2016).
[139] Romijn et al. (2012).
[140] Neeff et al. (2015).
[141] This assumption may not always hold, as other factors, such as political and editorial decisions may also influence the information presented in these sources.

Table A.3: Explanation of scoring criteria for quality of national reporting of livestock emissions				
Principle	**Indicator**	**Criteria and scoring**		**Min / Max score for category**
Completeness	1. The main livestock emission sources were included in the latest inventory	1a. Enteric fermentation CH_4	Y=3	Min = 0 Max = 9
		1b. Manure management CH_4	Y=2	
		1.c Manure management N_2O	Y=2	
		1.d N_2O from animal manure deposited on agricultural soils	Y=2	
Transparency		1e. Justification was not provided for any exclusion	-3	Min = -3 Max = 0
Notes: In the 1996 Guidelines, livestock emissions include methane from enteric fermentation and manure management, and N_2O emissions from manure management in anaerobic lagoons, liquid systems, solid storage and drylot, and "other systems", while daily spread and pasture range and paddock are reported under Agricultural Soils. If a source is not reported, a score of '0' is given, but if no transparent justification for this omission is given (whether based on national conditions or methodological considerations), a score of '-1' is given.				
Accuracy	2. Tier 2 methods are used for livestock emission sources	2a. For each of 3 emission sources, Tier 1 only is used for all livestock types, production systems and regions	Y=0 per emission source	Scored separately for each livestock GHG source Min = 0 Max = 3
		2b. For each of 3 emission sources, Tier 1b approach (i.e. Tier 1 default factors disaggregated by region or production system) is used for some or all livestock types	Y=0.5 per emission source	
		2b. For each of 3 emission sources, the source is a key source and Tier 2 approach is used for some or all livestock types, systems or regions, and Tier 1 approach used for others	Y=0.75 per emission source	
		2c. For each of 3 emission sources, the source is not a key source and Tier 2 approach is used for some or all livestock types	Y=0.5 per emission source	
		2d. For each of 3 emission sources, the source is a key source and the Tier 2 approach is structured to enable periodic updating or has been updated.	Y=1 per emission source	
Transparency		2e. Tier used is stated or a Tier 2 emission factor was used and was referenced or explained	-1 per source not meeting this criterion	
Notes: "Parties may use different methods (tiers) included in the Guidelines, giving priority to those methods which are believed to produce the most accurate estimates, depending on national circumstances and the availability of data. As encouraged by the IPCC Guidelines, Parties can also use national methodologies where they consider these to be better able to reflect their national situation, provided that these methodologies are consistent, transparent and well documented."				
Accuracy	3. National data on livestock population is available	3a. Population data for all types of livestock for the inventory year were not available, were estimated or extrapolated, or international sources to replace lack of national data were used	0	Min = 0 Max = 3
		3b. Population data for some types of livestock for the inventory year were available, but others were estimated or extrapolated or international sources to replace lack of national data were used	1.5	
		3c. Data on all types of livestock were available from national sources	3	
Transparency		3d. Source of livestock population data was not stated and the livestock population data was not presented	-3	
Notes: Countries without livestock population data for the inventory year face a greater challenge in addressing livestock GHG emissions, while countries using estimates or extrapolations face challenges in increasing the accuracy of livestock population estimates. No consideration is made of whether the IPCC basic categorization or enhanced categorization of livestock types is used because the presentation of enhanced categorization depends on the tiered approach used.				

Principle	Indicator	Criteria and scoring		Min / Max score for category
Accuracy	4. Efforts are being made to identify and reduce uncertainty	4a. Uncertainty analysis that included livestock emission sources was not conducted or only unsystematic comments on uncertainty in livestock emission estimates were presented	0	Min = 0 Max = 3
		4b. Qualitative methods were used for uncertainty analysis that included livestock sources	1	
		4c. Quantitative methods were used for uncertainty analysis that included livestock sources	2	
		4d. Specific measures to improve activity data or emission factors for livestock emissions were explicitly mentioned in the NC, NIR or BUR	Y=1 N=0	
Notes: Countries that made no effort to assess uncertainty in either activity data or emission factors face a greater challenge in improving inventory accuracy. Practices used to assess uncertainty vary by country, ranging from general comments to systematic qualitative or quantitative methods for uncertainty assessment in line with the IPCC guidance. Drawing inferences for future improvement of inventories shows a higher level of capacity, which is sometimes contained in an inventory improvement plan, but often made in other general statements in the NIR or NC.				
Consistency	5. Time series data	5a. Only a single year of data has been reported for livestock emissions	0	Min = 0 Max = 9
		5b. Inventories for livestock emissions for more than 1 year are presented, but methods and GHG sources considered are not consistent between years	0	
		5c. Inventories for livestock emissions for more than 1 year are presented, and consistent methods and GHG sources are presented for some multi-year time series, but not for the whole-time series of reported data	4.5	
		5d. Inventories for livestock emissions for more than 1 year are presented with a consistent time series based on consistent methods and GHG sources	9	
Note: Positive scores are given if more than one NC, NIR or BUR has been submitted and either (a) the same method and same livestock GHG emission sources were accounted for, or (b) there was a change in emission sources or methods used but data for earlier submissions were recalculated. Recalculation was indicated either if the country presented a recalculated time series, or if they stated that recalculation had been done.				
Transparency	UNFCCC defines transparency as “Assumptions & methodologies used are clearly explained to enable informed consideration”. Transparency is indicated by criteria 1e, 2e and 3d.			

While the UNFCCC requires that the principles of completeness, accuracy, consistency, completeness and transparency are adhered to, no indication is given of the relative importance of each. During the workshop "Making MRV work: Workshop on implementing MRV to meet countries' mitigation and sustainable development goals in the livestock sector",[142] participants were asked to weight the relative importance of each of these principles. The participants included 32 experts from developing (18 people) and developed (5 people) countries, and staff of international organizations (9 people), and included both those involved in inventory compilation (15 people) and the users of inventory reports (14 people). The results of the weighted scoring were analysed using cluster analysis, which identified two main groups of roughly equal size. The weighting given to the four principles used for inventory quality assessment in this report is shown in Table A.4. On average, the experts consulted give a higher weight to transparency, followed by accuracy, consistency and completeness. However, the two groups vary significantly, with Group A giving a much higher weighting to transparency than to the other principles, and Group B giving a higher weighting to accuracy. For the analysis presented in the main text of this report and in Section 2.b below, the average weighting of all respondents is used. The implications of using the average weighting from Group A or B and other alternative weighting methods is assessed in Section 2.C below.

Scoring was applied to information obtained from the NCs, NIRs and BURs available on the UNFCCC website.[143] No NCs or BURs are available on the website for five developing countries, and livestock emissions were not reported in the latest inventories of four countries (Bahrain, Maldives, Singapore and Solomon Islands).[144] Thus, the submissions of 140 countries were assessed. Assessment focused on the quality of the latest NC, NIR or BUR submitted by each country, with reference to earlier submissions only for assessment of the consistency of the time series of emissions reported and in the case where Tier 2 emission factors were unexplained in an inventory to identify whether earlier submissions had provided a reference or explanation. The full scoring was not applied to each available submission, due to time limitations, but such an exercise could be conducted in the future to evaluate change in inventory reporting quality over time.

2.B MAIN FINDINGS

Figure A.1 shows the distribution of scores among all countries. The scoring system used allowed for a minimum score of -7 and a maximum score of 27.[145] The resulting scores for the 140 countries ranged between -3 and 24, indicating considerable variation in the quality of livestock emission reporting. The mean score was 13.6, with a standard deviation of 6.1.

ANALYSIS BY CRITERIA

Figure A.2 compares the average scores across all 140 countries with the maximum possible score for each criterion. It visually illustrates that the largest capacity gap is in relation to the accuracy of livestock GHG reporting, with some gaps in consistency and transparency.

Completeness: Submissions were given scores for reporting CH_4 emissions from enteric fermentation, CH_4 and N_2O from manure management, and N_2O emissions from agricultural soils (due to animal manure application and/or dung and urine deposit on pastures). 70% of countries reported on all these GHG sources, and the average score for completeness was 6.4 out of a possible 7.0 points. While only 5 countries did not report on manure management CH_4 emissions, 24 countries did not report manure management N_2O emissions, and 23 did not report N_2O emissions from livestock sources in agricultural soils (for which 13 gave a justification). 11 countries did not report N_2O emissions from livestock sources in either the manure management or agricultural soils reporting categories (for which only 4 countries gave a justification).

[142] 20-21 February 2017, FAO, Rome.
[143] http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php, http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php
[144] Bahrain's first NC did include livestock, but NC2 did not, with the justification that the sector contributes an insignificant amount of emissions.
[145] Because only GHG inventories reporting livestock emissions were assessed, at least one livestock-related emission source would be recorded, giving a score of 2, so the minimum possible score is -7, not -9 as suggested by the description of the scoring system in Table A.2.

Table A.4: Relative importance of the UNFCCC principles for inventory compilation						
	All respondents		Group A		Group B	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Transparency	0.31	0.15	0.39	0.15	0.22	0.06
Accuracy	0.26	0.10	0.24	0.10	0.28	0.10
Completeness	0.20	0.09	0.15	0.07	0.25	0.07
Consistency	0.24	0.08	0.22	0.10	0.25	0.07

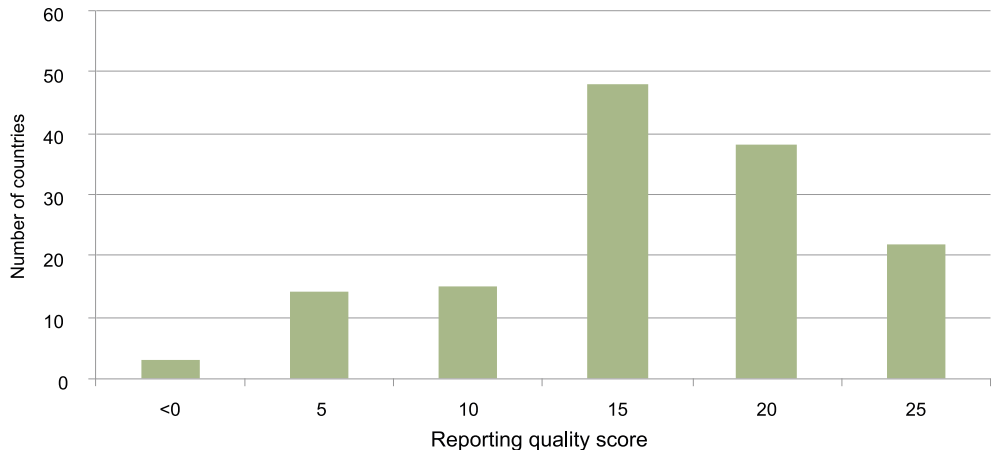

Figure A.1: Distribution of scores for the quality of national reporting of livestock emissions (n=140)

Figure A.2: Maximum possible scores and average score for each criterion for all countries assessed (n=140)

Accuracy: Accuracy scores were given for the use of national data on livestock populations, tiered approaches used in estimation of livestock emissions for key sources, and efforts to reduce uncertainty. Out of a maximum score of 9.24, the average score was 3.99, with a standard deviation of 1.35. National data were not available for all types of livestock for 11 countries, and for some types of livestock for 15 countries. For 113 countries (81%), national data were available on livestock populations. Twenty-one countries used a Tier 2 approach (for enteric fermentation and/or manure management emissions) for some or all types of livestock, typically one or more type of cattle. 118 countries used a Tier 1 approach for all emissions, including 6 countries that used a Tier 1b approach for manure management emissions. 88 countries made no assessment of uncertainty in their inventory, although 9 of these countries did propose methods to improve either activity data or emission factors in the future. Only 53 countries used qualitative or quantitative methods to assess uncertainty of livestock emission estimates. In terms of accuracy scores, the biggest gap with the maximum score was for the use of higher Tier approaches. This reflects the fact that most countries used a Tier 1 approach, but stands in contrast to the finding that livestock emission sources are key emission categories for many countries that reported key source analysis (Table 4), and that livestock emissions are likely to exceed 5% of total emissions in many developing countries (Appendix 1).

Consistency: Increasing scores were given for presentation of consistent multi-year time series. Out of a maximum score of 8.5, the average score was 5.4 (st. dev. 3.8). 21 Parties reported for only 1 year, for which a score of '0' was given. Zero scores were also given for presentation of inconsistent time series. 22 parties presented inconsistent time series for all years presented, and 15 parties were able to present a consistent time series for some of the reported years. The main reasons for inconsistency were a change of GHG emission sources between inventory reports or a change of method (e.g. changing from 1996 to 2006 emission factors) with no recalculation of the previously reported inventory.

Transparency: Transparency was assessed in relation to the justification for excluding some GHG sources, reporting of emission factors, and referencing the source of or presenting activity data. 20 countries did not justify excluding a GHG source; 30 countries did not state the Tier level of emission factor used or used a T2 emission factor but provided no reference or explanation; and 39 countries did not state the source of activity data or present livestock population data. For the average country, negative scores applied for lack of transparency as assessed by these criteria resulted in the loss of 2.23 points.

Based on the scoring system applied, for the average country, accuracy contributed most significantly to a gap between the scores given and the maximum possible score (i.e. gap between the average score and maximum possible score of 5.25), followed by consistency (gap of 3.05), transparency (gap of 2.23) and completeness (gap of 0.63). Within the category of accuracy, use of Tier 1 approaches was the most common reason for the gap, but for almost two thirds of countries, not using any method to address uncertainty also contributed to a lower score in this category. These results contrast with the likelihood for many countries that livestock are a key source category, to which higher tier methods should be applied.

ANALYSIS BY COUNTRY GROUPINGS

Geographical groupings: Figure A.3 shows the scorings for countries grouped by continent and special grouping (i.e. SIDS and LDCs).

Africa: The mean score for 50 African countries was 13.35 (compared to an average for 140 countries of 13.6). 20 African countries were given a score of 15.9 or greater, which is equal to or greater than the score of the top 40% of all countries, and 3 countries were in the top 20% of all countries. 10 countries received a score of 20.77 or less, putting them in the bottom 20% of all countries. The average score for transparency was slightly higher than the average score for all 140 countries, while the scores for all other criteria were slightly lower (0-8%) than the average for all 140 countries.

Americas: The mean score for 32 countries in the Americas was 14.42 (compared to an average for 140 countries of 13.58). 11 countries were given a score of 15.9 or greater, which is equal to or greater than the score of the top 40% of all countries, and 10 countries were given a score of 19.6 or greater, putting them in the top 20% of all countries. Only 5 countries received a score of 9 or less, putting them in the bottom 20% of all countries. The average score for accuracy was 10% higher than the average score for all 140

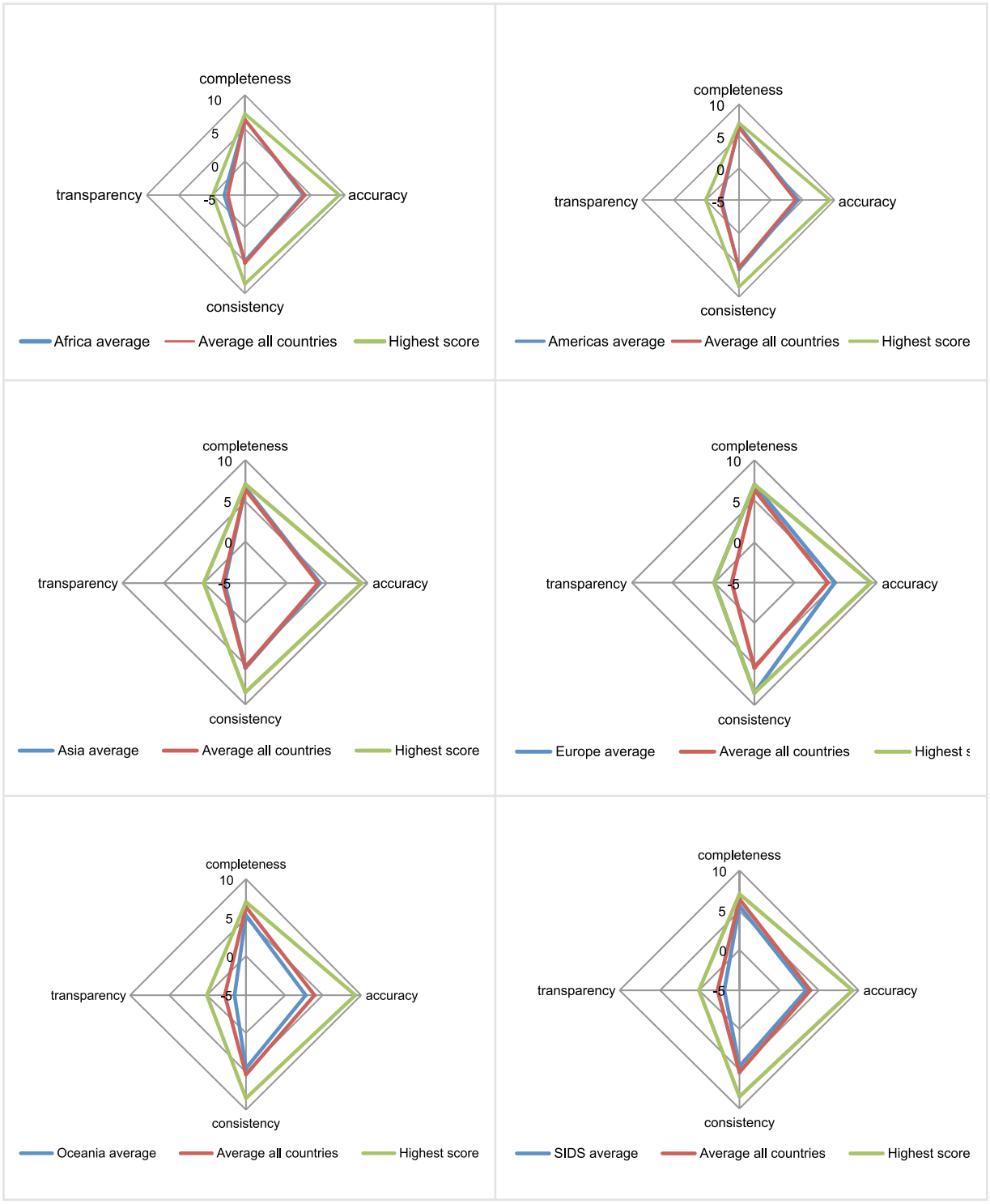

Figure A.3: Radar charts of scoring for countries grouped by continent and special grouping

countries, while scores for completeness, consistency and transparency were slightly (0-8%) higher than the average for all 140 countries.

Asia: The mean score for 40 Asian countries was 14 (compared to an average for 140 countries of 13.58). 17 countries were given a score of 15. 9 or greater, which is equal to or greater than the score of the top 40% of all countries, and 7 countries were given a score of 19.6 or greater, putting them in the top 20% of all countries. Nine countries received a score of 9 or less, putting them in the bottom 20% of all countries. On average, the scores for completeness, consistency and accuracy were slightly higher (3-4%) than the average for all 140 countries, while the transparency score was 9% lower.

Europe: The sample contained only 5 European countries. Their average score was 20.3, and 3 out of the 5 countries scored 19.6 or greater, putting them in the top 20% of countries. Scores against all criteria were significantly higher (by 10-56%) on average than the average for 140 countries. No deductions were made for transparency, all countries were able to present a consistent time series and all livestock emission sources were included.

Oceania: The average score for 12 countries in Oceania was 9.05, significantly lower than the average for 140 countries. Only 1 country was given a score greater than 15.9, and 7 out of 12 countries were scored in the bottom 20% of the sample of all 140 countries. Average scores for completeness, accuracy, consistency and transparency were significantly lower (15-58%) than the average for the whole sample. In particular, 5 of the 12 countries lacked livestock population data for some or all types of livestock, which contributed significantly to the gap between the average score for accuracy and the average of the 140 countries.

SIDS and LDCs:[146] The 140 countries assessed included 35 SIDS. The average score for SIDS was 10.58. Average scores for completeness, accuracy, consistency and transparency were all lower (by 12-40%) than the average for 140 countries. 13 out of 35 SIDS were given a score of 9 or less, putting them in the bottom 20% of all countries, but 3 countries received a score of 19.6 or more, putting them in the top 20% of all countries. For the 44 LDCs in the sample, the average score was 13.1, slightly lower than the average for 140 countries of 13.58. 17 out of 44 countries were in the bottom 40% of countries, while 16 were in the top 40% and 3 were in the top 20%. Compared to the average for 140 countries, LDCs were on average more able to present a consistent time series, but the biggest gap for the average LDC was in the scores for accuracy (10%), while completeness and transparency were slightly (3-10%) lower than the average for all 140 countries.

In summary, Asian and Oceanian countries are most overrepresented in the bottom 20% of all countries. Europe and the Americas are overrepresented in the top 20% of countries. Africa and Oceania have few countries in the top 20%.

2.C ALTERNATIVE WEIGHTINGS OF ASSESSMENT CRITERIA

The preceding analysis is based on the scoring system described and the average weighting given to the four UNFCCC principles assessed. Table A.4 showed that some experts give relatively more priority to transparency (and less to completeness), while others give relatively more priority to accuracy. Figure A.4 compares the scores for each country obtained using these alternative weightings with the average weighting by all experts. When accuracy is prioritized, the average score increases marginally and when transparency is prioritized, the average score decreases marginally. The relative weighting of specific indicators for each of the UNFCCC principles (Table A.3) has a greater impact on the score than the weighting of principles.

[146] The list of SIDS was obtained from http://unfccc.int/resource/docs/publications/cc_sids.pdf, and the list of LDCs from http://www.un.org/en/development/desa/policy/cdp/ldc/ldc_list.pdf

Table A.5: Percentage of countries in each continent in different ranges of the total distribution of 139 countries				
	Number of countries	**% in bottom 20%**	**% in top 40%**	**% in top 20%**
Africa	50	20%	40%	6%
Americas	32	16%	34%	31%
Asia	41	23%	43%	18%
Europe	5	0%	100%	80%
Oceania	12	58%	8%	0%

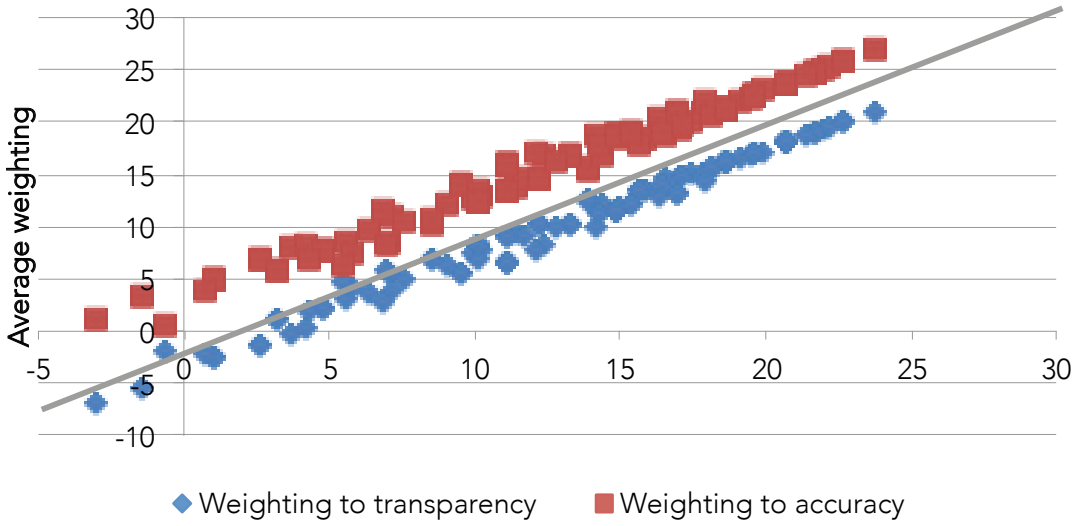

Figure A.4: Comparison of inventory scores using different weighting to principles for credible MRV

Appendix 3: Selected GHG quantification and monitoring methodologies relevant to livestock GHG emission reduction

This appendix presents summaries of and links to further information on selected GHG accounting protocols and methodologies approved by various compliance and voluntary carbon standards. Section A includes methodologies focusing on quantification of GHG emission reductions from livestock management activities in beef and dairy production systems, and Section B includes livestock-relevant methodologies with a broader focus (e.g. including land management, afforestation).

A. SELECTED METHODOLOGIES APPLICABLE TO LIVESTOCK MANAGEMENT MITIGATION ACTIVITIES

A.1 Methodologies applicable to actions reducing emissions in beef production systems

Name of standard: Alberta Carbon Offset System
Title of methodology: Quantification protocol for reducing the age at harvest of beef cattle v. 2.0
Weblink: http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/documents/ProtocolReducingAgeHarvestCattle-Jul2011.pdf
Geographical coverage: Alberta Province, Canada
Practices covered: Any change in beef cattle rearing practice that results in reduced age at harvest of animals compared to the baseline condition.
GHG sinks and sources: CH_4 from enteric fermentation CH_4 and direct and indirect N_2O from manure management N_2O from land application of manure
Monitoring requirements: The following parameters must be measured, at frequencies specified in the methodology: • Mass of cattle produced (kg beef) • Number of cattle in each class
Other information: Baseline determined as average emissions per head in the 3 years prior to implementation of the project. Calculation approach draws on IPCC 2006 Guidance

Name of standard: Alberta Carbon Offset System
Title of methodology: Quantification protocol for reducing GHG emissions from fed cattle
Weblink: http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/documents/ReducingGHGEmissionsFedCattle-Feb25-2016.pdf
Geographical coverage: Alberta Province, Canada
Practices covered: Any change in practice that results in increased feed use efficiency in beef cattle, e.g. improved animal performance tracking, changes in feed or feeding technologies or genetic improvements.
GHG sinks and sources: CH_4 from enteric fermentation CH_4 and direct and indirect N_2O from manure management N_2O from land application of manure
Monitoring requirements: The following parameters must be measured, at frequencies specified in the methodology: • Number of cattle in each class • Days on feed for cattle in each feed regime in each class • Average dry matter intake for cattle in each feed regime in each class • Average weight on entry to feedlot (kg) • Average weight at off-take (kg) • Average carcass weight (kg)
Other information: Baseline determined as average emissions per head in the 3 years prior to implementation of the project. Calculation approach draws on IPCC 2006 Guidance

Name of standard: Alberta Carbon Offset System
Title of methodology: Quantification protocol for selection for low residual feed intake in beef cattle
Weblink: http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/documents/ProtocolLowFeedIntakeCattle-Apr2012.pdff
Geographical coverage: Alberta Province, Canada
Practices covered: Selective breeding using a genetic marker for low residual feed intake
GHG sinks and sources: CH_4 from enteric fermentation CH_4 and direct and indirect N_2O from manure management N_2O from land application of manure
Monitoring requirements: The following parameters must be measured, at frequencies specified in the methodology: • Number of cattle in each class • Days on feed for cattle in each feed regime in each class • Average dry matter intake for cattle in each feed regime in each class • Number of head in each class sent to slaughter
Other information: Calculation approach draws on IPCC 2006 Guidance

Name of standard: Carbon Farming Initiative
Title of methodology: Beef cattle herd management
Weblink: https://www.legislation.gov.au/Details/F2015L01434
Geographical coverage: Australia
Practices covered: Any of the following: • increasing the ratio of weight to age of the herd reducing the average age of the herd; • reducing the proportion of unproductive animals in the herd; • changing the ratio of livestock classes within the herd to increase total annual live weight gain of the herd Cattle in feedlots are not eligible under this methodology.
GHG sinks and sources: CH_4 from enteric fermentation N_2O from dung and urine
Monitoring requirements: The following parameters must be recorded and entered into a spreadsheet-based tool mandated by the methodology: • Live weight and live weight gain for animals in each class • Annual number of animals in each class • Date of entry to and exit from herd for animals in each class • Days on each type of feed for each animal class
Other information: The methodology requires the use of a Herd Management Calculator. Emissions in the project period are compared to emissions in a three-year reference period. Calculation approach is consistent with methods used in the Australian National Inventory Report.

Name of standard: Carbon Farming Initiative
Title of methodology: Reducing GHG emissions by feeding nitrates to beef cattle
Weblink: https://www.legislation.gov.au/Details/F2015C00580
Geographical coverage: Australia
Practices covered: Feeding nitrate lick blocks
GHG sinks and sources: CH_4 from enteric fermentation
Monitoring requirements: • Number of animals in each class • Average live weight of animals in each class • Start and end date of each nitrate supplementation period • Nitrate lick block consumption • Consumption of other non-nitrate nitrogen supplements and its chemical consumption
Other information: A spreadsheet-based calculator is provided to accompany the methodology. Calculation approach is consistent with methods used in the Australian National Inventory Report.

A.2. Methodologies relevant to reducing emissions in dairy production systems

Name of standard: Clean Development Mechanism
Title of methodology: AMS-III.BK: Strategic feed supplementation in smallholder dairy sector to increase productivity
Weblink: https://cdm.unfccc.int/methodologies/DB/XI8MS5YYSGRSISWLADHND28QPJN6YA
Geographical coverage: Global
Practices covered: Strategic supplementation to improve the digestibility of feedstuff fed to large ruminants (i.e. dairy cows and/or buffalo) in the smallholder diary sector
GHG sinks and sources: CH_4 from enteric fermentation CO_2 from fossil fuel combustion in supplement manufacture and transport
Monitoring requirements: Projects must measure 14 parameters, including numbers, average weight and milk yield of supplemented animals, dry matter intake of supplement and other fodder and feed.
Other information: Project emissions are compared to emissions in a baseline survey conducted in the target region.

Name of standard: Gold Standard
Title of methodology: Methodology for quantification of GHG emission reductions from improved management in smallholder dairy production systems using a standardized baseline
Weblink: http://www.goldstandard.org/sites/default/files/documents/gs_dairy_methodology.pdf
Geographical coverage: Developing countries with a Human Development Indicator of 0.7 or less in the 5 years prior to the project
Practices covered: Any practice that decreases the GHG intensity of milk production, including improved feeding, breeds or improved animal health practices.
GHG sinks and sources: CH_4 from enteric fermentation CH_4 and direct and indirect N_2O from manure management N_2O and CO_2 from fertilizer manufacture and use N_2O and CO_2 from feed supplement manufacture and use CO_2 from land use change induced by changing demand for feed
Monitoring requirements: Project proponents need only monitor the average milk yield of cows on participating farms and the fate of animals leaving the farm.
Other information: A baseline survey is conducted in the target region and analysed to establish a statistical relationship between average milk yield per cow and GHG intensity ($kgCO_2e$/kg milk). Monitoring of project milk yields enables estimation of project emissions and emission reductions.

A.3. Methodologies relevant to manure management

There are a large number of methodologies applicable to biogas adoption, depending on the baseline energy use and type of biogas facility installed and the application of the biogas. Below are summaries of a small selection of commonly used methodologies relating to biogas and composting.

Name of standard: Clean Development Mechanism
Title of methodology: AMS.I.E: Switch from non-renewable biomass for thermal applications by the user
Weblink: https://cdm.unfccc.int/methodologies/DB/9LFOR81TCT5FLI1AJYP46CQY8O2J79
Geographical coverage: Global
Practices covered: Generation of thermal energy by introducing renewable energy technologies (e.g. biogas) for end users that displace the use of non-renewable biomass
GHG sinks and sources: CH_4 from manure management CO_2 emissions from combustion of woody biomass
Monitoring requirements: Project proponents must monitor various parameters related to woody biomass consumption, thermal energy production by biogas and the project population.
Other information: Biogas thermal energy quantification accomplished using AMS-I.I: Biogas/biomass thermal applications for households/small users.

Name of standard: Clean Development Mechanism
Title of methodology: AMS.III.D: Methane recovery in animal manure management systems
Weblink: https://cdm.unfccc.int/methodologies/DB/WGW9F4QB0YWBGY5CEMARU25N5LP6D6
Geographical coverage: Global
Practices covered: Replacement or modification of anaerobic animal manure management systems in farms with confined livestock management
GHG sinks and sources: CH_4 from manure management
Monitoring requirements: Project proponents must monitor 26 parameters related to livestock populations, weight and production of volatile solids, manure management practices, ambient conditions of the biogas facility and combustion of biogas.
Other information: Quantification approach based on IPCC 2006 Tier 2 approach for manure emissions is used.

Name of standard: Clean Development Mechanism
Title of methodology: AMS.III.F: Avoidance of methane emissions through composting
Weblink: https://cdm.unfccc.int/filestorage/V/5/B/V5BK1NFHM6ORYGI324CD78L0ZA9UJQ/EB92_repan11_AMS-III%20F.pdf?t=V1F8b2lhaXY4fDCQ0hiF1N4mK4qCRltUtVUc
Geographical coverage: Global
Practices covered: Controlled aerobic treatment by composting of biomass (including livestock waste) that would otherwise have decomposed anaerobically
GHG sinks and sources: CH_4 and N_2O from manure management CO_2 emissions from fossil fuel combustion associated with composting
Monitoring requirements: Same parameters as in AMS.III.D plus parameters related to leakage.
Other information: An associated methodological tool is used to quantify leakage emissions (https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-13-v1.pdf)

Name of standard: Climate Action Reserve
Title of methodology: Mexico livestock project protocol Version 2.0
Weblink: http://www.climateactionreserve.org/how/protocols/mexico-livestock/
Geographical coverage: Mexico
Practices covered: The installation of a biogas control system that captures and destroys methane gas from manure treatment and/or storage facilities on livestock operations
GHG sinks and sources: CH_4 from manure management CO_2 from fossil fuel combustion in farm machinery displaced by use of biogas
Monitoring requirements: A number of parameters relating to livestock populations, manure management, ambient conditions, biogas production and consumption
Other information:

B. SELECTED METHODOLOGIES APPLICABLE TO MITIGATION ACTIVITIES INCLUDING BUT NOT LIMITED TO LIVESTOCK MANAGEMENT

B.1 Methodologies relevant to development of silvopastoral systems

Name of standard: Clean Development Mechanism
Title of methodology: AR-AM0009: Afforestation or reforestation on degraded land allowing for silvopastoral activities --- Version 4.0
Weblink: https://cdm.unfccc.int/methodologies/DB/HQ3U8IFDTG5N8987T3LR9D3Z76UB8O
Geographical coverage: Global
Practices covered: Afforestation or reforestation on degraded lands where natural encroachment is not expected to cause forest cover to reach the national definition of forests and livestock manure deposited on pastures is not managed
GHG sinks and sources: CO_2 sequestered in aboveground biomass and belowground biomass (dead wood, litter and soil carbon are optional) Livestock emission sources are not included
Monitoring requirements: The project area shall be stratified, and for each stratum data on the area of each stratum and biomass carbon pools in each stratum shall be directly measured through sampling.
Other information: see also https://cdm.unfccc.int/methodologies/DB/MDKSSZCV62M6V0K49Y0L5H9YD7WLR5 for a simplified small-scale silvopastoral afforestation/reforestation methodology, and https://cdm.unfccc.int/methodologies/index.html for other CDM afforestation/reforestation methodologies

B.2 Methodologies relevant to smallholder mixed farming systems

Name of standard: Verified Carbon Standard
Title of methodology: Adoption of Sustainable Land Management
Weblink: http://database.v-c-s.org/methodologies/adoption-sustainable-agricultural-land-management-v10
Geographical coverage: Global
Practices covered: Adoption of sustainable land management practices (e.g. including manure application to arable lands) on degraded lands
GHG sinks and sources: CO_2 removals in aboveground and belowground biomass CO_2 removals in soil carbon pools N_2O emissions from fertilizer application N_2O emissions from cultivation of N-fixing species CH_4 and N_2O emissions from biomass burning CO_2 and CH_4 from fossil fuel combustion by agricultural vehicles
Monitoring requirements: A statistically representative activity baseline and monitoring survey must be conducted in the project area, collecting data relevant to monitoring change in carbon pools and emissions depending on the specific management practices expected to change during the project period.
Other information: Livestock numbers and manure management are considered as affecting arable and grassland soil carbon pools.

B.3 Methodologies relevant to grassland management

Name of standard: Verified Carbon Standard
Title of methodology: Methodology for sustainable grassland management
Weblink: http://database.v-c-s.org/sites/vcs.benfredaconsulting.com/files/VM0026%20Sustainable%20Grasslands%20Management_0.pdf
Geographical coverage: Global
Practices covered: Adoption of sustainable management practices on degraded grassland, e.g. rotational grazing, restoration of degraded grassland through planting of perennial grasses.
GHG sinks and sources: CO_2 removals by aboveground woody biomass CO_2 removals by soil carbon pools N_2O emissions from use of fertilizers N_2O and CH_4 emissions from biomass burning N_2O and CH_4 emissions from dung and urine deposited on pastures CO_2 emissions from fossil fuel combustion by agricultural machinery CH_4 emissions from enteric fermentation
Monitoring requirements: The methodology specifies a large number of parameters that may be monitored depending on the activities planned in the project and their expected impacts on carbon pools and GHG sources.
Other information: Soil carbon stock changes can either be directly measured or estimated using activity data together with default stock change factors developed through the use of a biogeochemical model (e.g. Century model)

Name of standard: American Carbon Registry
Title of methodology: Methodology for avoided conversion of grasslands and shrublands to crop production
Weblink: http://americancarbonregistry.org/carbon-accounting/standards-methodologies/methodology-for-avoided-conversion-of-grasslands-and-shrublands-to-crop-production
Geographical coverage: United States and Canada
Practices covered: Practices that prevent conversion of grassland or shrubland to annual crop production (e.g. through land conservation agreements)
GHG sinks and sources: CO_2 removals from soil carbon CO_2 removals in above- and below-ground woody biomass are optional N_2O from nitrogen fertilizer use and livestock dung deposit on pasture CH_4 from enteric fermentation CO_2 from fossil fuel combustion by farm machinery is optional
Monitoring requirements: A monitoring plan is required that includes monitoring of • Actors responsible for grassland conversion • Management practices of these actors in the baseline scenario • Land use change in the project region • Livestock numbers and grazing practices • Vegetation in the project region
Other information: The baseline is set on the basis of historical or planned grassland conversion in the project region and must be reassessed every 5 years during project implementation. Leakage due to shifting of grassland conversion activities is also assessed.

Name of standard: Carbon Farming Initiative
Title of methodology: Sequestering carbon in soils in grazing systems
Weblink: http://www.environment.gov.au/climate-change/emissions-reduction-fund/methods/sequestering-carbon-in-soils
Geographical coverage: Australia
Practices covered: Any practice that increases soil carbon, including conversion of cropland to pasture, restoration of degraded pastures and changes in grazing management.
GHG sinks and sources: CO_2 removals from soil carbon CH_4 from enteric fermentation CH_4 and N_2O from dung and urine deposit on pasture CO_2 and N_2O from synthetic fertilizer use CO_2 from lime application CO_2, CH_4 and N_2O due to tillage activities
Monitoring requirements: This methodology requires direct measurement of soil organic carbon at intervals of 1-5 years, with measurement and analysis procedures following a specified method. Other data required include livestock population in each livestock group and number of days in the project area, mass and N content of fertilizer applied, mass and carbonate content of lime applied, area under tillage and crop harvest volumes.
Other information: Detailed guidelines for soil organic carbon sampling and analysis and a spreadsheet calculator are provided at http://www.environment.gov.au/climate-change/emissions-reduction-fund/methods/sequestering-carbon-in-soils

Name of standard: American Carbon Registry
Title of methodology: Grazing land and livestock management methodology
Weblink: http://americancarbonregistry.org/carbon-accounting/standards-methodologies/grazing-land-and-livestock-management-gllm-ghg-methodology
Geographical coverage: Beef and dairy production worldwide
Practices covered: Any management practice that affects some or all of the GHG sinks and sources listed below, including e.g. change in grazing management, feed, manure management, tree planting, pasture management.
GHG sinks and sources: CH_4 emissions from enteric fermentation CH_4 and N_2O emissions from livestock manure N_2O emissions from fertilizer use, CO_2 emissions from fossil fuel emissions CO_2 removals from above- and below-ground biomass CO_2 removals from soils
Monitoring requirements: The methodology provides 4 modules (enteric, manure, fertilizer, biotic), each of which can be selected and used to estimate changes in the related GHG sinks and sources, and each of which specifies a number of parameters that must be monitored.
Other information: Calculation tools are provided for use at different project scales and for use in or outside of the USA. For small-scale projects, simplified (Tier 1) accounting tools can be used, while larger projects use another tool that is based on the COMET 2.0 tool.

Appendix 4: Results of online survey on GHG inventories and MRV improvement

A4.1 METHODOLOGY

The acceptability of different MRV practices were explored using an on-line survey. Invitations to participate were sent to more than 100 people involved in livestock mitigation as government officials, researchers or consultants. In the end, there were 20 respondents, including 18 who indicated they had some familiarity with Tier 2 approaches for livestock emissions in national GHG inventories, and 16 respondents who indicated some familiarity with MRV of mitigation actions.

The questionnaire asked participants to indicate the extent to which they agreed or disagreed with (or found acceptable or unacceptable) statements representing MRV practices. In some cases, an option of 'may or may not be acceptable' or 'depends on context' was given. The statements were developed from interviews with 25 experts conducted in the course of this study, and were selected to represent divergent opinions expressed in those interviews. The questionnaire was divided in four parts:

Part 1: Tier 2 approaches in national GHG inventories, including benefits of moving to a Tier 2 approach, characteristics of acceptable Tier 2 approaches, and acceptable data sources.

Part 2: MRV of mitigation actions, including alignment between MRV systems, reference standards and characteristics of acceptable MRV systems.

Part 3: Priorities for improving livestock mitigation and MRV, and priorities for research.

Part 4: Attributes of the respondents, including country, type of employer (government, natural agricultural research institute, international research organization, international development agency and other), roles in MRV processes (e.g. inventory compiler, inventory user, participant in IPCC expert meetings, assessing other countries' inventories in UNFCCC processes, experience of developing NAMAs or carbon market projects), professional background (livestock, agriculture, environment or other) and number of years involved in livestock and MRV.

The survey was administered in English and Spanish through an online survey website in April 2017. In total, there were 20 valid responses. Eighteen respondents indicated some familiarity with IPCC Tier 2 approaches for livestock or manure management and were asked questions in Parts 1, 3 and 4. Sixteen respondents indicated some familiarity with MRV of NAMAs are were asked questions in Parts 2, 3 and 4. The respondents included seven respondents from OECD countries, and 13 from developing countries in Asia (5), Africa (2) and Latin America (6).

Data were analysed using Cultural Consensus Analysis (CCA), implemented in Anthropac software (Borgatti 1996). Groups of people involved in a common enterprise (e.g. MRV) may or may not share beliefs about domains such as objectives, acceptable outcomes and appropriate practices in common. CCA assesses the degree of agreement or consensus among a group, and can be used to identify the culturally 'correct' answers to a set of questions when the correct answer is not known in advance. The mathematical expression of cultural consensus theory is given by Romney et al. (1986). In brief, CCA compares the similarity between respondents' responses and estimates the probability of each response being the culturally correct response. Mathematically, eigenvalues are calculated from the response matrix, and if the ratio of the first to the second eigenvalue is less than 3:1, then it can be concluded that there is no single culture, i.e. no consensus on the culturally 'correct' answers (Borgatti 1996). CCA can therefore be used to identify the statements or sets of statements that respondents share a common agreement on. Depending on the variability among responses, CCA can be applied to small samples (Weller 2007).

Further analysis also attempted to identify respondents' attributes associated with their responses. Because both dependent and independent variables collected through the survey are categorical variables, ordinary regression approaches could not be used. The quadratic assignment procedure (QAP) in Anthropac was used to regress a matrix of respondent attributes on the matrix of responses. In general, the attributes for which data was collected had no significant correlation with responses, but the few cases where they did are noted in the text below.

A4.2 RESULTS ON TIER 2 APPROACHES IN NATIONAL GHG INVENTORIES

There were 18 respondents to questions on Tier 2 approaches in national inventories, including eight people involved in inventory compilation and six people who only use inventory results without compiling them. These respondents included five people who have participated in IPCC expert meetings on GHG inventories, including two who have assessed other countries' inventories as part of UNFCCC MRV processes.

Topic 1: The benefits of moving to a Tier 2 approach in national inventories

Respondents were asked to rank the relative importance of six potential benefits of adopting a Tier 2 approach in a national GHG inventory (Figure A5.1). Five benefits were ranked as either important or very important by more than 80% of respondents. Only compliance with UNFCCC requirements was ranked of moderate or little importance by about 40% of respondents. Respondents' roles played in inventory processes had a significant influence on responses ($p<0.10$) but explained little of the variation in responses, most likely because of subjective differences in scoring when using the Likert scale.

Topic 2: Characteristics of acceptable Tier 2 approaches

Respondents were asked whether they agreed with each of five statements about the characteristics of acceptable Tier 2 approaches. There was no consensus among the full sample of respondents on their responses to these statements together. For each statement separately (Table 4A.1), there was a consensus among all respondents on three statements, but there was no consensus on the relative importance of using unbiased methods or on the necessity of estimating the uncertainty of Tier 2 approaches used in national inventories. For separate groups of respondents, there was no consensus among people who take part in inventory compilation in their responses, but there was a consensus among people whose only role is as a user of inventory results. Their consensus answers are indicated in Table 4A.1.

Topic 3: Acceptable data sources in developing a Tier 2 approach

Respondents were asked which parameter values must be based on direct measurement. The consensual response is that all parameters (i.e. methane yield, live weight, feed intake, feed digestibility and animal productivity) must always be measured (Figure A5.2).

However, when asked if data on diets and livestock performance or livestock sub-populations are lacking, there was less consensus on what estimation methods are acceptable (Table 4A.2). For all respondents and all options, there is no consensus among the group of respondents. There was consensus, however, that literature reports and expert judgement are acceptable data sources, and that livestock sub-populations can be extrapolated from the last census. There was not consensus, though, on the use of models of herd composition and dynamics, national feed ration standards or small-scale surveys. While there was no consensus among the whole group on all data sources together, there was a consensus among those involved in IPCC expert meetings on which methods were or were not acceptable (Table 4A.2). Users and inventory compilers did not agree on what are and are not acceptable data sources.

A4.3 RESULTS ON MRV OF MITIGATION ACTIONS

For the questions on MRV of mitigation actions, there were 16 respondents, including six involved in developing NAMAs, four with experience of carbon market projects, seven who take part in inventory compilation and 12 whose only role in inventories is as a user.

Topic 1: Alignment of MRV of mitigation actions with GHG inventories and NDCs

There is consensus among the group as a whole that MRV of mitigation actions should be aligned with GHGI and NDC (Figure A5.3).

Topic 2: On reference standards for MRV of mitigation actions

On reference standards for MRV of mitigation actions, there was no overall consensus among the respondents. While 70% agreed or strongly agreed that the IPCC Guidelines should be taken as a reference, more than 60% agreed that the IPCC Guidelines give insufficient guidance for quantifying the effects of mitigation actions (Figure A5.4). One third disagreed that carbon market methodologies should be the main reference and one third did not agree that any methodology compliant with the UNFCCC

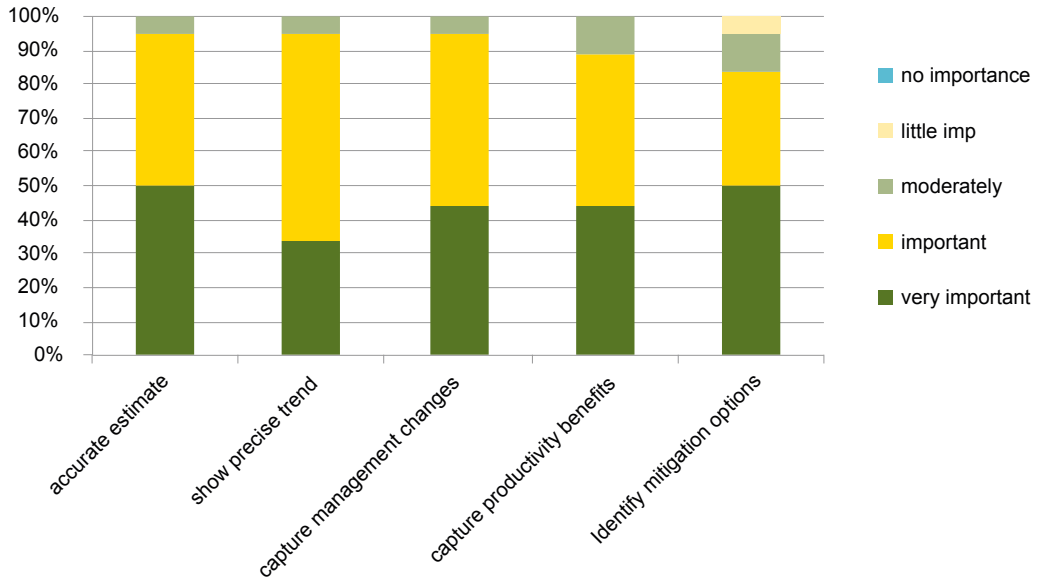

Figure A5.1 Relative importance of different benefits of moving to a Tier 2 approach in national inventories

Table 4A.1: Consensus on characteristics of acceptable Tier 2 approaches

Question: To what extent do you agree with the following statements?	**Consensus answer for all respondents**	**Consensus answer for inventory users**
Using data and methods that are not biased is more important than using data and methods with lower uncertainty	No consensus	Depends on context
Any Tier 2 approach using national data for at least some parameters will be more accurate than a Tier 1 approach, even if uncertainties are high	Agree	Depends on context
If the best available data are used, but bias and uncertainty are unknown, a Tier 2 approach is acceptable if data sources and assumptions have been transparently documented	Agree	Agree
A Tier 2 approach should not be used in a national inventory if the uncertainty cannot be estimated	No consensus	Agree
Emission factors should be updated periodically to reflect trends in the livestock sector	Agree	Agree

principles (i.e. transparency, accuracy, comparability, consistency and completeness) is acceptable. Whether respondents worked for an international research organization, took part in assessment of other countries' GHG inventories or had experience of carbon markets had some influence on their responses.

Topic 3: On characteristics of acceptable MRV approaches

Although there was no consensus on the reference standards, there was consensus on some of the characteristics of acceptable MRV approaches (Table 4A.3). On completeness, the consensus is that all significant sinks and sources should be quantified. But there was no consensus on whether it is acceptable to measure only enteric fermentation when a NAMA mainly affects enteric fermentation, or on whether sinks and sources can be omitted if resources for MRV are limited. Responses varied depending in part on the respondent's professional background. On compatibility of MRV of mitigation actions with other MRV systems, there was no consensus that NAMAs should use the same emission factors as the GHG inventory, and almost 70% agreed that NAMAs should use project-specific activity data and emission factors. There was consensus that baselines for NAMAs should be consistent with baselines for NDCs. On accuracy and uncertainty, there was no consensus on whether there should be fixed standards for accuracy of emission reduction estimates, with respondents' positions depending on part on whether they take part in inventory compilation and are employed by a national agricultural research institute. The vast majority agreed that countries should strive to improve over time, should quantify uncertainty, and that robust QAQC procedures would increase the credibility of MRV.

Topic 4: Priorities for improvement and research

Respondents were asked to indicate the relative priority of improvements in different aspects of mitigation planning and MRV in their own country. The majority of these components were rates as important or very important by most respondents (Figure A5.5). This clearly shows that institutional coordination for implementation of mitigation actions are the highest priority for MRV improvement, and that piloting MRV and improving the national inventory are also widely perceived as very important.

Research can contribute to improvements in MRV in several ways. The highest proportion of respondents indicated that assessing sustainable development benefits of livestock mitigation is either important or very important, but research on gender was assessed as of less importance than all other research topics. Research on data collection methods, baseline mitigation scenarios, and improvements in activity data and emission factors were also widely recognized as important (Figure A5.6).

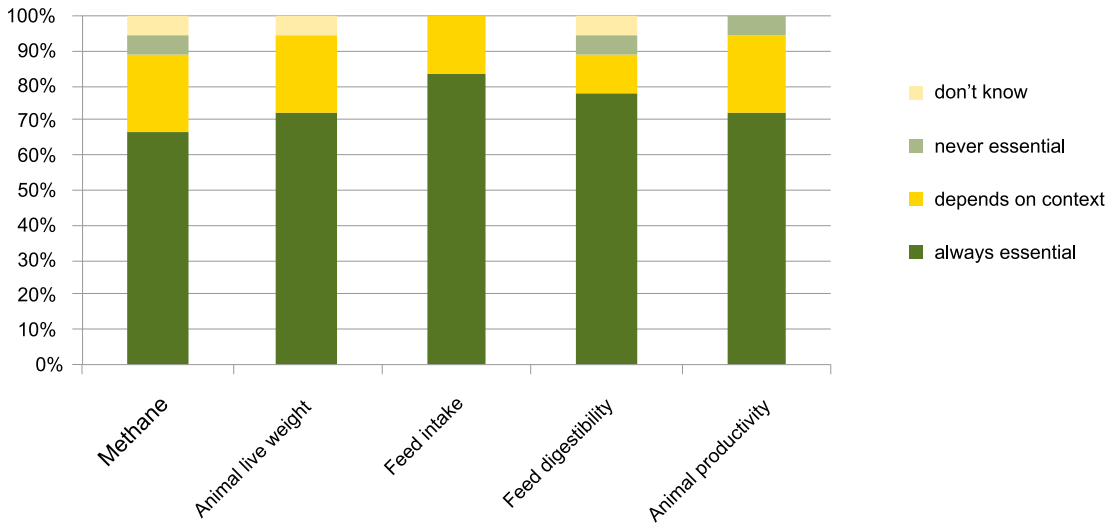

Figure A5.2 Responses as to whether data for parameters in the Tier 2 model must come from direct measurements

Table 4A.2: Consensus on characteristics of acceptable Tier 2 approaches		
	Consensus answer for all respondents	**Consensus answer for those involved in IPCC processes**
Q3: When accurate data on diets and livestock performance are unavailable, which of the following data sources are acceptable?		
National feed ration standards:	no consensus	may or may not be acceptable
Literature reports	acceptable	acceptable
Expert judgement:	acceptable	acceptable
Small-scale surveys in targeted production systems:	no consensus	slightly acceptable
Q4: When reliable official data is lacking on the population of different sub-categories of livestock (e.g. cattle by age or sex, dairy vs. non-dairy), which of the following data sources are acceptable?		
Literature reports	acceptable	acceptable
Expert judgement:	acceptable	acceptable
Models of herd composition and dynamics	no consensus	acceptable
Extrapolation from the last livestock census	acceptable	acceptable
Small-scale surveys in targeted production systems:	no consensus	slightly acceptable

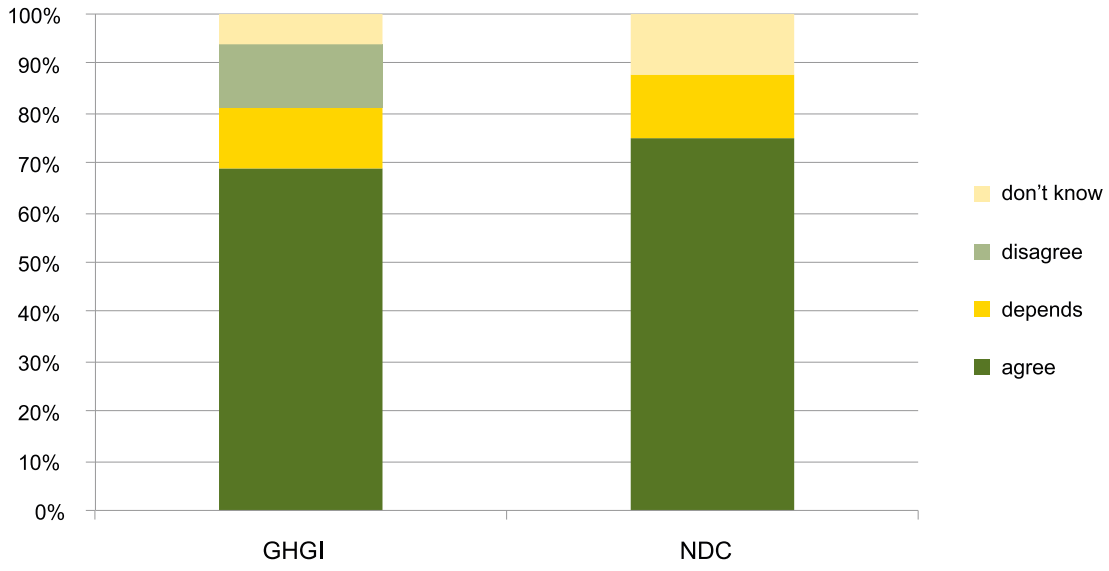

Figure A5.3
Responses as to whether MRV of mitigation actions should be aligned with national GHG inventories and NDCs

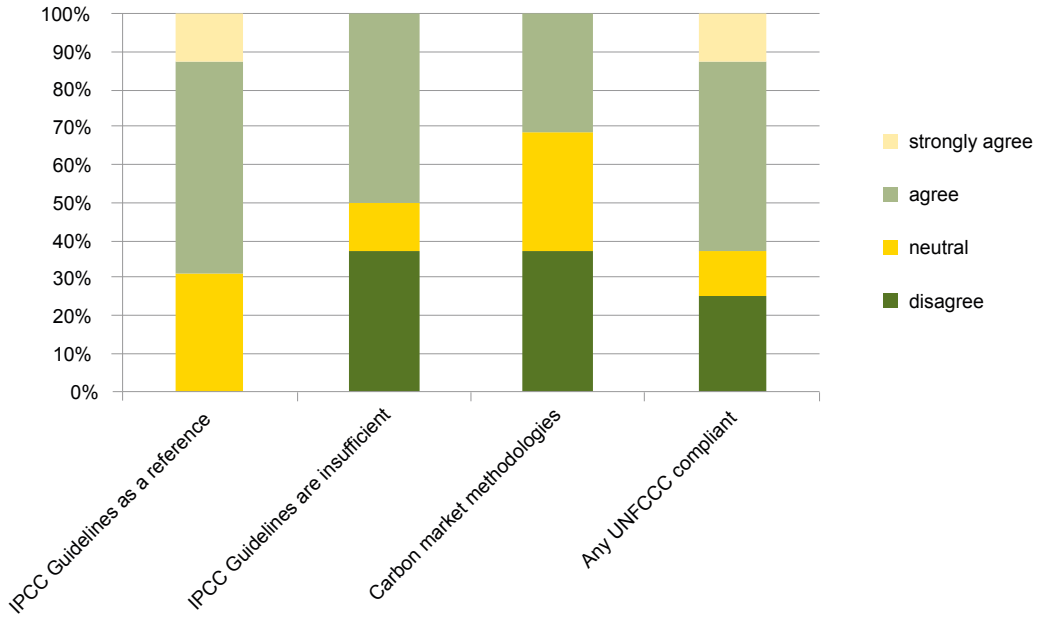

Figure A5.4
Responses on which reference standards MRV of mitigation actions should adhere to

Table 4A.3: Consensus on characteristics of acceptable MRV approaches

Question: To what extent do you agree with the following statements?	**Consensus answer among all respondents**
On completeness:	
All GHG sources and sinks that are significantly affected by a mitigation action should be quantified	Agree
If a NAMA mainly affects enteric fermentation, it is only necessary to estimate change in enteric fermentation emissions	No consensus
If resources for MRV are limited, it is acceptable to only measure change in the most important emission sources affected	No consensus
On compatibility with other MRV systems:	
MRV of NAMAs should use the same emission factors as the national inventory	No consensus
MRV of NAMAs should use project-specific activity data and emission factors that are more accurate than those used in the national GHG inventory	Agree
Baseline GHG emission scenarios for a NAMA should be consistent with baseline emission projections in that country's NDC	Agree
On accuracy and uncertainty:	
There should be no fixed standards for the accuracy of emission reduction estimates	No consensus
Credible emission reduction claims require clear procedures for data quality control, quality assurance and verification	Agree
Countries should strive to improve accuracy and reduce uncertainty over time	Agree
The uncertainty of GHG emissions must be quantified, otherwise it cannot be demonstrated that emission reductions are significantly different from zero	Agree
In addition to the UNFCCC principles for MRV (i.e. transparency, consistency, comparability, completeness and accuracy), conservativeness is an important principle when estimating emission reductions	Agree

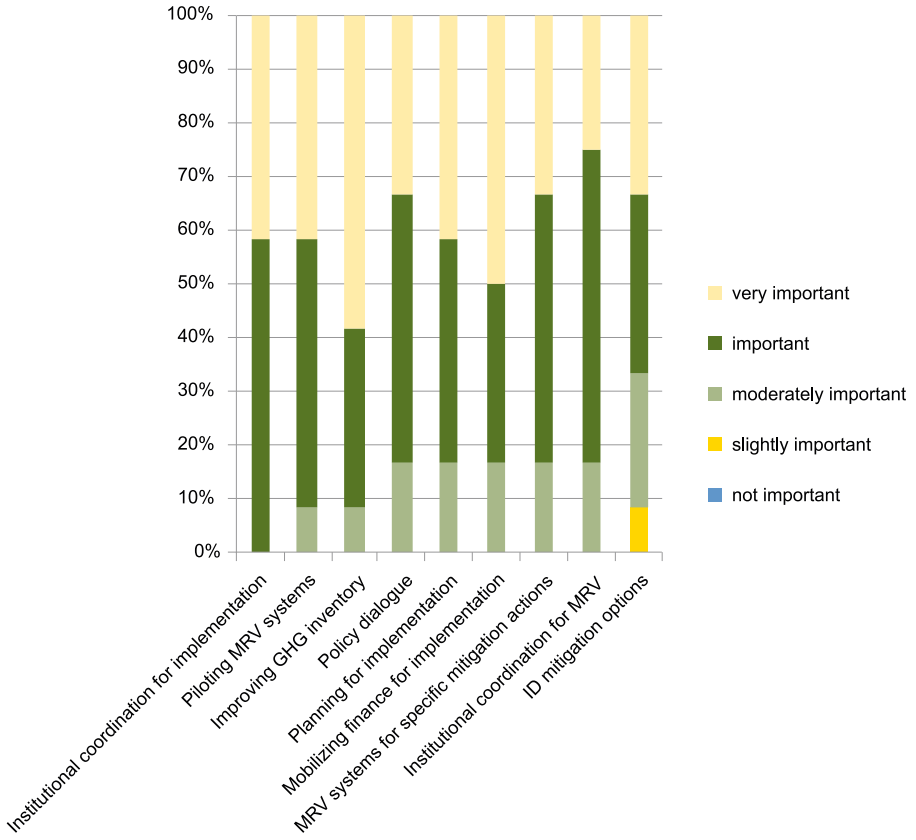

Figure A5.5
Importance of different aspects of MRV improvement

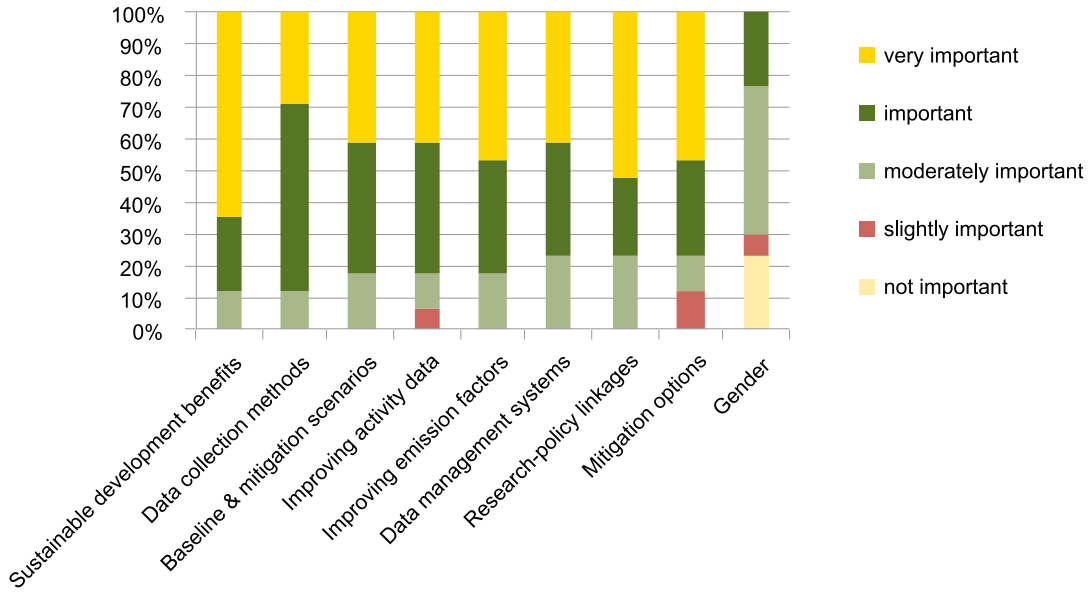

Figure A5.6
Importance of research topics in support of MRV improvements

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Appendix 5: Developing country interest in livestock-related mitigation actions

This appendix summarizes the results of a review of 150 developing countries' INDCs, 140 developing countries' latest national communications and available information on NAMAs.[147] It lists countries that include livestock and livestock-related emissions in their INDC, that have proposed livestock NAMAs and that have noted the relevance of mitigation of livestock emissions in their national communications.

Table A5.7: Countries including livestock in NDCs, proposing livestock NAMAs or noting relevance of livestock mitigation in their last national communication.

	Specific mention of livestock-related mitigation in INDC	Livestock included in agriculture or economy-wide scope, but no specific mention for livestock	Livestock-related NAMA has been proposed	Livestock mitigation mentioned in national communication	biogas or manure management mentioned in national communication	mitigation policies mentioned in national communication
TOTAL NUMBER of COUNTRIES	47	45	17	43	55	11
TOTAL NUMBER OF NAMAS			20			
Afghanistan	1			1	1	
Albania				1	1	
Algeria		1				
Angola	1					
Antigua and Barbuda						
Argentina		1		1	1	1
Armenia					1	
Azerbaijan	1				1	
Bahamas						
Bangladesh	1				1	
Barbados						
Belize						
Benin	1			1	1	1
Bhutan	1			1	1	
Bolivia	1					
Bosnia and Herzegovina	1			1	1	
Botswana	1				1	
Brazil	1		1	1	1	1
Brunei Darussalam						
Burkina Faso		1				
Burundi	1			1	1	
Cabo Verde						

[147] Based on searches of http://www4.unfccc.int/sites/nama/SitePages/Home.aspx, http://www.nama-database.org/index.php/Main_Page, http://www.namapipeline.org/

	Specific mention of livestock-related mitigation in INDC	Livestock included in agriculture or economy-wide scope, but no specific mention for livestock	Livestock-related NAMA has been proposed	Livestock mitigation mentioned in national communication	biogas or manure management mentioned in national communication	mitigation policies mentioned in national communication
Cambodia					1	
Cameroon	1			1		
Central African Republic		1		1	1	
Chad	1			1	1	
Chile	1		1			
China	1			1	1	1
Colombia	1		1	1	1	
Comoros		1				
Congo	1					
Cook Islands						
Costa Rica	1		1	1	1	
Côte d'Ivoire	1					
Cuba		1		1	1	
Democratic People's Republic of Korea	1				1	
Democratic Republic of the Congo		1				
Djibouti	1					
Dominica		1				
Dominican Republic		1	1			
Ecuador						
Egypt	1			1		
El Salvador						
Equatorial Guinea		1				
Eritrea						
Ethiopia	1			1	1	
Federated States of Micronesia					1	
Fiji					1	
Gabon						
Gambia		1	1			
Georgia		1			1	
Ghana	1					
Grenada						
Guatemala		1			1	1
Guinea	1				1	
Guinea-Bissau				1		
Guyana				1		
Haiti	1					
Honduras		1	1			

	Specific mention of livestock-related mitigation in INDC	Livestock included in agriculture or economy-wide scope, but no specific mention for livestock	Livestock-related NAMA has been proposed	Livestock mitigation mentioned in national communication	biogas or manure management mentioned in national communication	mitigation policies mentioned in national communication
India				1	1	
Indonesia		1				
Iran (Islamic Republic of)		1			1	
Iraq		1				
Israel		1			1	
Jamaica						
Jordan		1				
Kazakhstan		1				
Kenya		1	1			
Kingdom of Bahrain						
Kiribati					1	
Kuwait						
Kyrgyzstan		1			1	
Lao People's Democratic Republic				1	1	
Lebanon		1		1	1	
Lesotho						
Liberia				1		
Libya		1				
Madagascar	1			1		
Malawi	1				1	
Malaysia		1			1	
Maldives						
Mali	1					
Marshall Islands						
Mauritania		1		1		
Mauritius		1			1	
Mexico	1					1
Mongolia	1		1	1		
Montenegro	1				1	
Morocco	1				1	
Mozambique						
Myanmar				1	1	
Namibia	1			1		
Nauru						
Nepal	1			1	1	
Nicaragua		1	1			
Niger	1					
Nigeria	1			1		

	Specific mention of livestock-related mitigation in INDC	Livestock included in agriculture or economy-wide scope, but no specific mention for livestock	Livestock-related NAMA has been proposed	Livestock mitigation mentioned in national communication	biogas or manure management mentioned in national communication	mitigation policies mentioned in national communication
Niue						
Oman						
Pakistan			1			
Palau						
Panama				1		
Papua New Guinea						
Paraguay		1				
Peru*		1	2	1		1
Philippines						
Qatar						
Republic of Korea		1	2	1	1	1
Republic of Moldova		1		1	1	1
Rwanda					1	
Saint Kitts and Nevis		1				
Saint Lucia					1	
Saint Vincent and Grenadines		1				
Samoa						
Sao Tome and Principe		1			1	
Saudi Arabia						
Senegal	1					
Seychelles						
Sierra Leone		1		1	1	
Singapore		1				
Solomon Islands						
Somalia	1					
South Africa		1				
South Sudan						
Sri Lanka						
Sudan						
Suriname						
Swaziland						
Syrian Arab Republic		1			1	
Tajikistan		1				
Thailand		1				1
The Former Yugoslav Republic of Macedonia				1	1	
Timor-Leste		1				
Togo	1			1	1	

	Specific mention of livestock-related mitigation in INDC	Livestock included in agriculture or economy-wide scope, but no specific mention for livestock	Livestock-related NAMA has been proposed	Livestock mitigation mentioned in national communication	biogas or manure management mentioned in national communication	mitigation policies mentioned in national communication
Tonga	1			1	1	
Trinidad and Tobago						
Tunisia	1			1	1	1
Turkmenistan						
Tuvalu		1				
Uganda	1		1	1		
United Arab Emirates						
United Republic of Tanzania				1		
Uruguay*	1		2	1	1	
Uzbekistan		1				
Vanuatu	1					
Venezuela (Bolivarian Republic of)						
Vietnam	1		1	1	1	
Yemen		1				
Zambia	1				1	
Zimbabwe			1		1	

Ninety two developing countries have included livestock mitigation in their Nationally Determined Contributions, yet measurement of livestock emissions remains weak. To track the effects of mitigation actions – especially actions related to productivity improvements – improved measurement will be needed based on IPCC Tier 2 approaches. This report describes current practices, challenges and opportunities in the measurement, reporting and verification (MRV) of livestock greenhouse gas emissions and emission reductions by developing countries in the context of the United Nations Framework Convention on Climate Change (UNFCCC). It highlights options for improving MRV to meet evolving policy needs.

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