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Contents

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2 Executive summary

To complement an ongoing CCAFS project 'Enhancing capacities for MRV of sustainable livestock action in East Africa (Kenya and Ethiopia)', implemented by UNIQUE forestry and land use and CCAFS, ACIAR supported CCAFS to implement a Small Research Activity (SRA) entitled 'Building capacities for an integrated livestock MRV system in Ethiopia'. The objective of the SRA was to support Ethiopian stakeholders to improve the methods and procedures used to produce and manage the livestock activity data required for measurement, reporting and verification (MRV) of greenhouse gases (GHG) in Ethiopia.

Ethiopia has made clear commitments to limit national GHG emissions, and priority sectors for GHG mitigation include the livestock sector. National GHG inventories are expected to be a main tool used in measuring and reporting progress towards national GHG emission targets. With support from CCAFS, an inventory of GHG emissions from cattle, sheep and goats was previously developed using the best available data. Compilation of that inventory showed that there were some data gaps due to missing data or poor quality data. As an input to stakeholders' efforts to improve the available data, this SRA focused on testing and evaluating different data collection and data management tools to fill the data gaps.

The project was implemented in four main phases: (1) Understanding stakeholders' needs and priorities for data improvement and assessing stakeholder interests and capacities in addressing those needs. (2) Working with stakeholders involved in data collection and management activities to identify options for testing improvements, and planning the pilot activities. (3) Conducting pilot data collection, analysis and dissemination activities and engaging stakeholders in evaluating the pilot results. (4) Consulting with a broader range of stakeholders on how the positively evaluated tools could be adopted and scaled up.

Five pilots were implemented involving:

1. Collection of data on animal populations, herd structure, diet composition and manure management systems data in commercial, urban/peri-urban and mixed crop-livestock systems (Central Statistics Agency [CSA])
2. Collection of data on animal performance (milk yield, live weight) in commercial, urban/peri-urban and mixed crop livestock systems (Ministry of Agriculture with local government staff)
3. Analysis of activity data (CSA)
4. Analysis of production data (Ministry of Agriculture)
5. Communication of pilot results and stakeholder evaluation.

In pilot activities 1 and 2, different tools were used to collect the same data, and the results were compared in pilots 3 and 4. Pilot 5 applied a range of user-relevant assessment criteria to assess each pilot's results. Based on stakeholders' assessments, recommendations were made for which data collection tool to use in a range of data collection activities. As a result, CSA has stated its intention to revise the diet composition data collection tool used in its annual livestock sample survey, and to incorporate the positively evaluated tools in a planned survey of commercial and urban/peri-urban farms. The pilot's results were also used in a project to support the World Bank finance Livestock and Fisheries Sector Development project to monitor a results framework indicator on livestock GHG emission intensity, and have been written into a terms of reference for a large-scale survey in the frame of the Oromia Forested Landscape Programme.

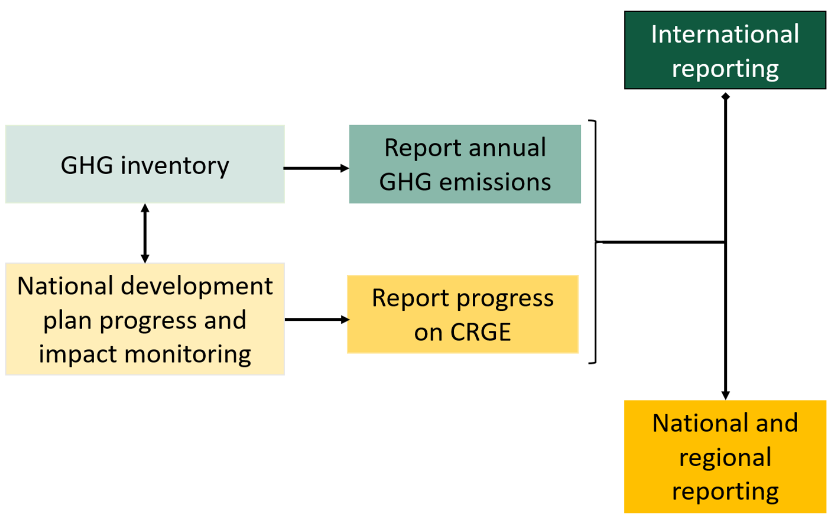
There is strong demand for improved livestock activity data in many African countries. Livestock data can support improved GHG inventories and MRV of climate policies and measures, and also meet livestock sector stakeholders' other needs for accessible, good quality data. While there is a clear need to support collection of more data, there are also needs to better understand the effectiveness and suitability of different data collection methods targeted for use by different stakeholders and for different purposes.

3 Background

3.1 Ethiopia's climate commitments in the livestock sector

Ethiopia is a party to the UN Framework Convention on Climate Change (UNFCCC) and ratified the Paris Agreement in 2017. Parties to the UNFCCC, including Ethiopia, have agreed general requirements for measurement, reporting and verification (MRV) of GHG emissions. Under the Paris Agreement, parties have agreed a new reporting system applicable to both developed and developing countries, to be implemented from 2024.[1] The core of this MRV system is a Biennial Transparency Report, which is to be submitted every two years by each country, including Ethiopia. This report should include a national GHG inventory, and a report of progress made in implementing and achieving the nationally determined contribution (NDC). Ethiopia's initial NDC (2015), was based on the country's Climate Resilient Green Economy (CRGE) Strategy (FDRE 2011). The CRGE was mainstreamed into the national development plan, the Growth and Transformation Plan (GTP-II, 2016-2020). Ethiopia communicated an updated NDC to the UNFCCC in December 2020 (FDRE 2020). This updated NDC is in line with the measures set out in the CRGE but enhances the level of ambition and further elaborated measures for GHG mitigation in the livestock sector. The updated NDC is also in line with the country's new Ten-Year Development Plan (FDRE 2021). In summary, Ethiopia needs to be able to regularly compile and submit a national GHG inventory and to regularly report on the effects of mitigation actions, and these needs reflect both its national and international commitments (Figure 1).

Figure 1: Schematic overview of Ethiopia's MRV needs



Source: This study.

Mitigation actions: Ethiopia's strategy for climate change action is the CRGE strategy (FDRE 2011). The CRGE Strategy aims to achieve middle-income status by 2025 in a climate-resilient green economy. The CRGE Strategy forms the basis for Ethiopia's NDCs (FDRE 2015, 2020). The CRGE Strategy identifies priority sectors and priority interventions in those sectors. Interventions were screened for both

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[1] https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf#page=18

mitigation and adaption benefits with the intention that mitigation actions implemented would also strengthen Ethiopia's climate resilience.

Table 1.Livestock sector intervention areas in Ethiopia's Climate Resilient Green Economy (CRGE).

Intervention areas	General description	Likely effects on livestock
Improve cattle value chain efficiency	Increase productivity per head through improved breeding, feeding, health, marketing etc.	▪ Change in breed ▪ Increased live weight ▪ Increased milk yield ▪ Change in feed
Increase share of poultry and other low emitting animals	Increase meat supply from poultry and other low emitting animals	▪ More chickens, sheep and goats ▪ Change in breed ▪ Increased productivity
Promote mechanization	Introduce tractors through small scale mechanization programs	▪ Fewer oxen ▪ Fewer work hours per ox
Improve rangeland management	Increase productivity of pasture and improve rangeland management	▪ Improved feed availability and quality

Source: Compiled for this project based on CRGE Strategy.

The livestock sector has been identified as one of the priority sectors in the CRGE.[2] Within the livestock sector, four main intervention areas were identified in the CRGE (see Table 1 and Box 1). The CRGE Strategy was mainstreamed into the national development plan, the Growth and Transformation Plan (2016-2020, [GTP II]) and formed a key basis for the new Ten-year Perspective Development Plan. The monitoring matrix for GTP II included indicators to monitor progress in implementing and achieving the CRGE targets.[3] The CRGE indicators related to the intervention areas shown in Table 1 are:

- Emissions of CO_2e per litre of milk produced
- Estimated annual reduction in CO_2e emissions due to improved productivity of livestock
- Estimated reduction of CO_2e due to shift to rearing of low carbon emitting animal species
- Estimated reduction in CO_2 emissions due to improved grazing (total, communal and private) land management.

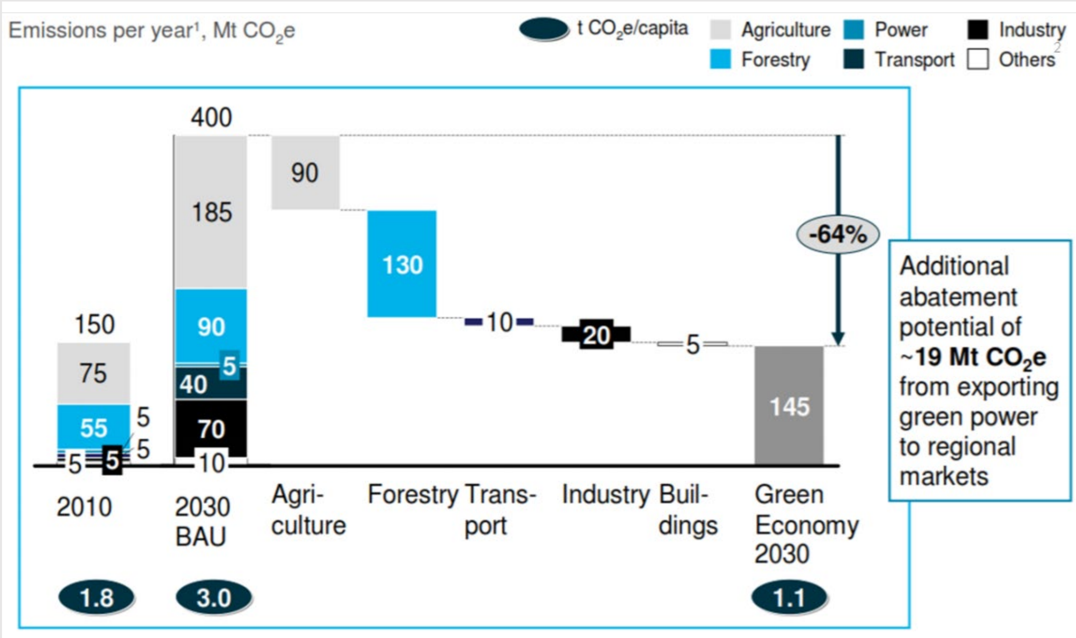
Box 1: Ethiopia's CRGE and the livestock sector

BAU projections: Analysis supporting the CRGE strategy suggests that Ethiopia's total GHG emissions would increase from 150 Mt CO_2e in 2010 to 400 Mt CO_2e in 2030, an increase of 167%. Agriculture emissions would increase from 75 Mt CO_2e in 2010 to 185 Mt CO_2e in 2030, which is based on the assumption that the total cattle population doubles over this period. Of the 2010 agricultural emissions, 65 Mt CO_2e (i.e. 87%) are from livestock and BAU projections in

[2] *The priority sectors are: agriculture, forestry, energy and transport.*

[3] *https://www.cmpethiopia.org/media/gtp_ii_policy_matrix_english_final_august_2016_2*

2030 for livestock are 124 Mt CO_2e. Of the livestock emissions, 84% are from cattle. Ethiopia's first NDC is based on the same BAU projections.



Source: FDRE (2015)

Mitigation options and potential: The CRGE Strategy identifies a mitigation potential of 90 Mt CO_2e to 2030, of which 48 Mt CO_2e is due to livestock sector interventions. The livestock sector interventions analysed were:

• Value chain efficiency (40.1 Mt CO_2e): increasing productivity per head of cattle and off-take rate, led by better health and marketing, assuming 19.5 million pastoralist and farmer households are reached through dairy development and feedlot expansion;[4]

• Increased supply and consumption of lower-emitting animal species (17.7 Mt CO_2e), assuming that poultry account for 30% of animal source protein supply in 2030;[5]

• Substituting draft oxen with mechanized ploughing and tillage (11.2 Mt CO_2e), assuming 13.2 million households reached;

• Rangeland carbon sequestration (3 Mt CO_2e), assuming 5 million ha improved.

Source: FDRE (2011)

Specific methodologies describing how progress towards these indicators are to be measured (e.g., GHG sinks and sources included, livestock types included, data sources and calculation methods) have not yet been elaborated.

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[4] *Note that although sheep and goat fattening also occurs, they were not included in the CRGE scenario analysis.*

[5] *Note that although sheep and goats are also sometimes referred to as lower emitting species, they were not included in the CRGE scenario analysis.*

Updated NDC commitments:

The updated NDC (FDRE 2020) is in line with the measures set out in the CRGE but enhances the level of ambition and further elaborated measures for GHG mitigation in the livestock sector. The new estimate of current and projected heads of livestock in the country as well as other key parameters (e.g., revised emission factors) significantly elevate BAU emissions (194.8 Mt CO_2e) of the livestock sector compared to the first NDC (124 Mt CO_2e). The level of ambition communicated through this updated NDC indicates that emission reductions in the livestock sector are to be achieved through packages of policy interventions combining mitigation, efficiency gains and output growth in the sector. In this regard, sector-specific strategies as well as national development plans have levied huge weight to the sector in a bid to reduce emission in the country. Thus, Livestock Master Plan (LMP), the 10YDP, and the CRGE strategy, have identified optimal policy interventions in the sector. According to the updated NDC, livestock policy interventions (Table 2) will reduce the emission level from 194.8 to 180 Mt CO2e (7.6%) and from 194.8 to 193 Mt CO2e (0.92%) by 2030 in the conditional pathway and in the unconditional pathway, respectively. Table 2 illustrates the envisioned policies of the sector in the coming years emanating from these policy documents.

Table 2. Policy interventions in the livestock sector.

Policy intervention	Indicator (unit)	Lead institution
Dairy, red meat and poultry intervention packages - Enhancing efficiency and productivity in livestock subsectors	Number of improved cows (Owned by women/men) GHG intensity of agricultural GDP	Ministry of Agriculture
Agricultural mechanization - Replacing cattle/oxen with tractors for farmers and smallholders	Number of heads of livestock reduced (Received by women/men) Number of tractors distributed	Ministry of Agriculture
Increase in the share of poultry -Replacing non-dairy cattle stock with chickens (supply side) and inducing a demand shift from beef to chicken	Number of non-dairy cattle replaced (Owned by women/ men)	Ministry of Agriculture
Oilseed feeding -Improved feeding to reduce emissions from enteric fermentation	Improved feeding deployed (Tons)	Ministry of Agriculture

Source: adapted from FDRE (2020)

3.2 MRV systems in Ethiopia’s livestock sector

3.2.1 National GHG inventory

In December 2020, Ethiopia’s Ministry of Agriculture adopted an inventory of livestock GHG emissions compiled using the Tier 2 method of the Intergovernmental Panel on Climate Change (IPCC) (Wilkes et al. 2020). The inventory estimates GHG emissions from cattle, sheep and goats from 1994 to 2018.

3.2.2 MRV of mitigation actions

To date, the MRV system for the livestock sector (i.e., Updated NDC and 10YDP) has not been operational due to lack of a clear methodology and available data for GHG accounting. However, such a system could be created on the basis of the Tier 2 inventory with additional data sources. Our research report (unpublished) demonstrated that a GHG emission intensity accounting method could be implemented to track the NDC mitigation actions using data available in the Tier 2 GHG inventory together with supplementary data from annual Central Statistics Agency (CSA) livestock sample surveys. Emission intensity is a measure of GHG emissions per unit of livestock product output. For dairy cattle, a measure of emission intensity is kgCO_2e/kg milk while a measure of emission intensity is kgCO_2e/kg meat for beef cattle. Because livestock have multiple outputs and to enable calculation across different livestock products and species (e.g. combining milk, meat and eggs together), another measure of emission intensity is kgCO_2e/kg protein. GHG emission intensity is increasingly used worldwide to estimate emission reductions in the livestock sector. It can be applied into two steps: i) calculate total GHG emissions from the target livestock species in all production systems in Ethiopia (i.e., commercial and smallholder dairy, and mixed crop-livestock and pastoral / agro-pastoral systems) using the same data sources as the Tier 2 GHG inventory for livestock; ii) calculate the total amount of livestock products produced. For milk, this can be calculated from the Tier 2 inventory (excluding milk suckled by calves) and for meat, it can be calculated using data from CSA on numbers of cattle, sheep, goats and poultry sold and slaughtered. Furthermore, large scale regional and national projects (LFSDP[6] and OFLP[7]) proposed to use an GHG emission intensity accounting approach. Aligning national NDC-CRGE-MRV accounting methodologies with those used at regional and project level would increase the simplicity and efficiency of NDC-CRGE MRV as well as provide the methodological basis for a unified MRV system across regional and federal levels in the livestock sector.

[6] *World Bank financed Livestock and Fisheries Sector Development Project, https://projects.worldbank.org/en/projects-operations/project-detail/P159382*

[7] *BioCarbon Fund supported Oromia Forested Landscape Programme, https://www.biocarbonfund-isfl.org/programs/oromia-forested-landscape-program*

3.3 Data needs and data gaps for livestock MRV

3.3.1 GHG inventory data needs

Based on the Tier 2 livestock GHG inventory (Wilkes et al. 2020), the data gaps (i.e., missing data) listed in Table 3 were identified, and the parameters listed in Table 4 were identified as being based on very limited or poor-quality data. In the short-term, the inventory was completed using proxy data (e.g., live animal and meat export data as a proxy for commercial feedlot cattle populations), or the best available national data or international default values where national data quality was limited. Future improvements in data availability would then provide new, improved data and the GHG inventory can be revised accordingly, as stipulated in the 2006 IPCC Guidelines (IPCC 2006, Vol. 1 Ch, 5).

Table 3. Parameters with missing data in the draft GHG inventory for Ethiopia.

Population data: ▪ Cattle, sheep and goats in pastoral zones of Afar and Somali regions ▪ Dairy cattle population in commercial, urban and peri-urban systems ▪ Commercial feedlot cattle population data
Animal performance data ▪ Commercial dairy cattle milk yield annual time series

Table 4. Parameters with poor quality data in the draft GHG inventory

Animal performance data: ▪ Available data on diet composition is not specific to livestock species or cattle sub-category ▪ Cattle live weight, weight gain, mature weight are estimated based on available small-scale studies ▪ Data on manure management practices is very limited

3.3.2 Data needs for MRV of mitigation actions

Based on the analysis of national MRV needs, it follows that Ethiopia has policy needs to monitor progress in implementing the CRGE strategy in the livestock sector and to account for the resulting emission reductions. The data sources and methodologies used for MRV of emission reduction policies and measures should as far as possible be consistent and comparable with those used in the national GHG inventory, and the GHG inventory should to the greatest extent possible be capable of reflecting the changes targeted by policy interventions.

Table 5. Key parameters for estimation of CRGE livestock core indicators

Dairy value chain efficiency: ▪ Population of indigenous, hybrid and exotic cattle

▪ Productivity (meat and milk) per animal, indigenous, hybrid and exotic ▪ Emission factors for indigenous, hybrid and exotic animals
Feedlot value chain efficiency: ▪ Population of fattened and non-fattened cattle (dairy and pastoral) ▪ Productivity (meat and milk) per animal, fattened and non-fattened (dairy and pastoral) ▪ Emission factors for fattened and non-fattened animals (dairy and pastoral)
Increased share of poultry meat in meat supply: ▪ Population numbers for poultry and high-emitting species ▪ Average live weight and dressing percentage for poultry and high-emitting species ▪ Manure management emission factors for poultry

Methodologies for calculating the existing livestock related CRGE core indicators have not yet been elaborated. However, analysis of the methodologies used to construct the original CRGE scenarios suggests likely data needs as shown in Table 5. Furthermore, the Tier 2 GHG inventory data needs (e.g., diet composition, manure management, milk yield in the mixed crop-livestock system, urban and peri-urban and commercial dairy and feedlot systems) are also data requirements for the CRGE-MRV system. There are therefore needs for improved data in these areas to serve both GHG inventory and CRGE-MRV needs. This SRA focused on supporting national partners to pilot methods for collecting data to fill gaps and improve data quality in the mixed crop-livestock system, urban and peri-urban and commercial dairy, and feedlot systems.

3.3.3 Prior basis

Data needs for quantification of livestock GHG emissions using the IPCC Tier 2 method and general options for obtaining available data are generally well known (FAO 2020), and CCAFS and its partners have previously made available numerous case studies of how these data needs have been met in different countries.[8] More generally, the availability and quality of livestock statistics in developing countries is often limited (Pica-Ciamarra et al. 2014), and some previous studies have tested alternative methods for cost-effective collection of data on some livestock production parameters (FAO 2017). From these different streams of prior work, it is clear that making improvements in the availability and quality of data depend on stakeholders' interests and needs for data as well as the capacities and constraints of actors in data management systems. The Tier 2 livestock GHG inventory in Ethiopia was compiled largely on the basis of annual livestock sample survey reports produced by the Central Statistics Agency of Ethiopia (CSA). CSA has for many years been using standard data collection templates, and reporting data in standard reporting formats. These templates are in line with FAO guidance on the collection of agricultural statistics (FAO 2015). However, GHG inventory improvements give rise to new demands for the type and quality of data made available. There is therefore a need to test the most effective ways to meet users' data needs within the capacities and constraints faced by data collection agencies. This project is one of the few existing examples of testing and validating alternative livestock data collection and management for GHG inventory purposes in developing countries. The experiences of this project are therefore useful to inform other

[8] *www.agmrv.org*

countries facing data availability and data quality gaps for livestock GHG inventory and MRV purposes.

4 Objectives

The aim of the broader initiative that multiple stakeholders, including the CCAFS project, are contributing to is to ***increase the capacities of Ethiopian MRV entities to implement MRV of low-emission livestock development***.

The specific objective of this ACIAR SRA was to ***support improvements in availability and quality of administrative data on livestock production and performance.***

For the ACIAR project, adoption of MRV innovations would be indicated by their endorsement by the national agencies responsible for livestock MRV. Subsequent capacity building and implementation costs for nationwide adoption is to be supported by the Government of Ethiopia and where relevant other international partners, and was not part of this SRA.

5 Methodology

The project's methodology involved four main phases. First was to understand stakeholders' needs and priorities for data improvement and to assess stakeholder interests and capacities in addressing those needs. Second was to work with stakeholders involved in data collection and management activities to identify options for testing improvements, and planning the piloting activities, including the roles and responsibilities of each stakeholder in the piloting process. Third was to conduct pilot data collection, analysis and dissemination activities and to engage stakeholders in evaluating the pilot results. Fourth was to consult with a broader range of stakeholders on how the positively evaluated tools could be adopted and scaled up, considering different stakeholders' different use cases. Specific activities in each phase are elaborated in Section 6 below and the results of each phase are described in Section 7.

The implementation of this ACIAR project was embedded within the ongoing collaboration between the CCAFS consortium and the Ministry of Agriculture on improvement of the livestock GHG inventory and MRV systems, which also engaged with national agencies responsible for the national GHG inventory and MRV and with regional government agencies. The project was also aligned with related initiatives, including donor-supported projects (LFSDP and OFLP) and related technical support to the LFSDP and OFLP by US Forestry Service International Programmes and USDA. These initiatives and their respective stakeholders provide the user context for the project to explore options for improving data for livestock MRV and shape the short-term options available for adoption and upscaling of the project's results.

In terms of implementation, inputs from CCAFS and UNIQUE were supported from the ongoing CCAFS project, and the ACIAR supported UNIQUE to employ a 50% FTE staff also involved in the CCAFS project to ensure alignment between the two. UNIQUE coordinated the technical work in Ethiopia and CCAFS supported stakeholder engagement. ACIAR's support also engaged Prof. Derek Baker (UNE, Australia), who oversaw the stakeholder assessment and design of the pilot activities, and supported analysis and engagement of stakeholders in evaluating the pilots. The main national partners who implemented the pilots were CSA (responsible for pilots involving herd structure, diet composition and manure management data) and Ministry of Agriculture (responsible for pilots involving measurement of animal productivity) and Dr. Million of EIAR (responsible for Pilot 5 on communication of pilot results).

6 Achievements against activities and outputs/milestones

Objective 1: To define priority data improvement needs

no.	activity	outputs/ milestones	completion date	comments
1.1	*Map data collection and management procedures for MRV priority indicators*	Output: Report on priorities for livestock activity data improvement. Milestone: Priorities needs for improvement of livestock activity data identified	31/3/2020	Report on priority data improvement needs: https://cgspace.cgiar.org/handle/10568/108801
1.2	*Develop data collection and management capacity assessment tools*			
1.3	*Assess data collection and management procedures*			
1.4	*Prioritize data improvement needs*			

PC = partner country, A = Australia

Objective 2: To develop innovations for improved data collection and management

no.	activity	outputs/ milestones	completion date	comments
2.1	*Propose data collection & management innovations for piloting*	Milestone: Data collection and management method pilot activities planned	30/6/2020	Pilot activity plans and data collection tools were agreed with national stakeholders, which formed the basis for ToRs for stakeholders to implement the agreed pilot activities
2.2	*Select innovations for piloting*			
2.3	*Plan innovation pilots*			

PC = partner country, A = Australia

Objective 3: To pilot and evaluate innovations for improved data collection and management

no.	activity	outputs/ milestones	completion date	comments
3.1	*Implement data collection & management pilot activities*	Output: Report on pilot innovations implemented and	27/4/2021	Stakeholder evaluation workshop report: https://cgspace.cgiar.org/handle/10568/114853

3.2	*Evaluate innovation pilot results*	stakeholders' evaluations Milestone: Pilot data collection and management method innovations evaluated		

Objective 4: To support upscaled adoption of validated innovations

no.	Activity	outputs/ milestones	completion date	comments
4.1	*Stakeholder consultation on mainstreaming and/or replication of validated innovations*	Outputs: Manuals and tools for implementing new data collection and data management methods. Final report on options for improved livestock activity data collection and management to support MRV in Ethiopia. Milestone: Next users have discussed requirements for mainstreaming and/or replication of user-validated innovations	10/2021	Manual and tools: see Appendix 1 of https://cgspace.cgiar.org/handle/10568/116252
4.2	*Draft and disseminate manuals and tools to support adoption*		10/2021	Options for improved data collection and management: https://cgspace.cgiar.org/handle/10568/116252

7 Key results and discussion

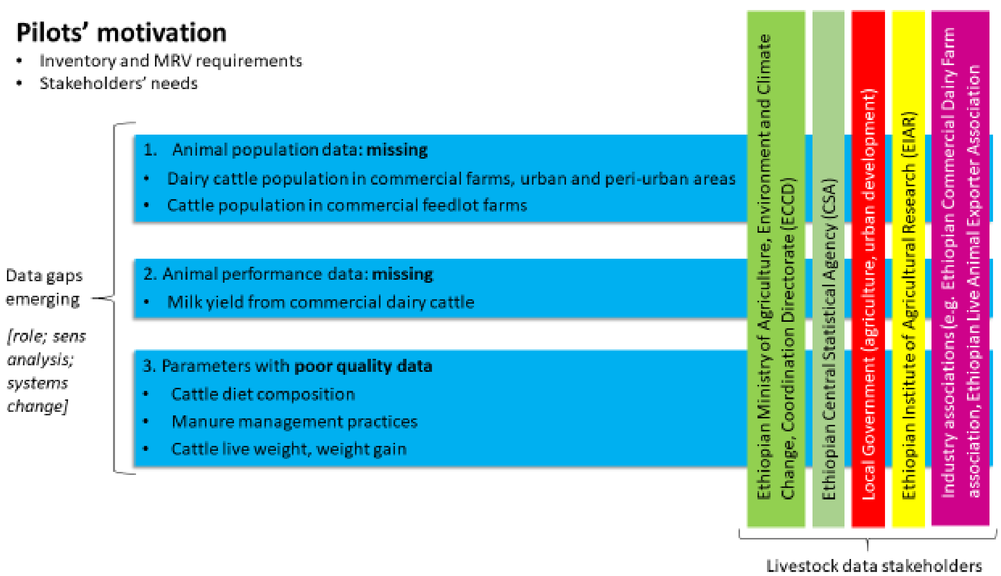
7.1 The data collection environment

The rationale for the design of a set of pilot activities was based on

- The need for action to improve data for GHG inventory and an enhanced CRGE-MRV system (see Section 3), and
- Engagement with stakeholders on their needs and activities surrounding livestock data, and particularly its quantity and quality.

This motivation maps data gaps to stakeholders' needs as shown in Figure 2.

Figure 2. Motivation for pilots



Thus the project aimed to:

1. trial ways of filling data gaps
2. trial ways of improving data quality
3. orient selected data collection, analysis and dissemination activities toward MRV
4. foster multi-stakeholder approaches to improved collection, analysis and dissemination of livestock data.

7.1.1 Stakeholders

The key stakeholders in the data collection environment are:

- Ethiopian Ministry of Agriculture, Environment and Climate Change, Coordination Directorate (ECCD)
- Ethiopian Central Statistical Agency (CSA)

- Local Government (several branches associated with agriculture, and urban development)
- Ethiopian Agricultural Research Institute (EIAR)
- Industry associations (e.g. Ethiopian Commercial Dairy Farm association, Ethiopian Live Animal Exporter Association)

The roles and interests of these stakeholders are elaborated in Section 7.2 below.

7.1.2 Technical issues

Across administrative and CSA-collected data, a number of technical improvements are desirable. These were identified during stakeholder consultations. They include the need for improved consistency in treatment of livestock age/sex categories; breed descriptors; and representation of herd structures and seasonal events. Pilots set out trials of new collection methods, generally in line with CSA procedures.

Lack of a sampling frame for urban feedlots and dairy farms was addressed by integrating the interests of local government, industry associations and CSA's existing trial work in urban areas. This established an interim sampling frame and provided guidelines for future actions.

Production data, and animal numbers data are self-reported by farmers. The pilot trialled the delivery of objective measures for several variables, and tested recall against amended recall or other measures, for selected variables.

Aside from CSA's activities, no other data collection is carried out using tablets and electronic transfer. Pilots did not address this in the current project, but conclusions drawn are readily applicable to this collection mode.

Further shortcomings identified included measurement of aspects of animal manure management, with relevance to GHG emissions and potential for reduction. Pilots tested methods for collecting manure management data.

7.1.3 Institutional issues

Local government's data collection is handed upwards in a series of aggregation steps. This introduces delays and possible distortions.

Urban farms come to the attention of local government only when they register, which is a requirement for delivery of services such as vaccination or artificial insemination. Data is then steadily collected on this cohort of farms as services are delivered.

Industry Associations communicate little with government agencies, despite expressing substantial support for governments' strategic and developmental initiatives. These groups wish to accumulate data of high quality, with which to inform their membership and formulate groups' and industries' strategies.

7.1.4 HR issues

Local governments' staff visit farms for data collection regularly (quarterly) but are essentially service providers (e.g., providing artificial insemination services). Their data collection is neither systematic nor aligned with CSA's. The pilots engaged local governments with CSA to address these problems and inform future decisions on alignment of data and improvements to its quality. Skills are lacking at local level and the pilots feature a training program. CSA enumerator staff live in the localities, and CSA supervisors and statisticians live in neighbouring areas. The same is true for local government data collectors and this proximity was utilized by the pilots.

7.2 Opportunities identified with stakeholders

7.2.1 CSA

CSA expressed interest in several of the data gaps identified. CSA is addressing some of these already, and is collecting data on them (e.g., urban dairy farms) but not releasing results due to dissatisfaction with data quality. It has experience of trialling new methods and analysis. CSA has staff located at kebele level and a supervision infrastructure in place. CSA has well-established sampling frames and procedures in mixed rural areas and has extensive experience in training enumerators.

7.2.2 Environment and Climate Change Directorate

The Environment and Climate Change Directorate of the Ministry of Agriculture (ECCD) has an existing hierarchy and data aggregation system used to handle administrative data, including direct links to local government. It has overall responsibility for GHG inventory and MRV in the livestock sector, and so has substantial interest in improved production and productivity data.

7.2.3 Local government

Local government collects and manages administrative data. It maintains relations with farmers and their supporting services and is most aware amongst stakeholders of local production patterns and industry practices and trends.

7.2.4 Ethiopian Institute of Agricultural Research

EIAR is an experienced research partner and possesses analytic skills for use on the pilot data. Their role includes disseminating research output to the private and public sectors.

7.2.5 Industry Associations

Industry associations are in constant touch with a membership that would form a part of the sampling base for large farms, which are not well addressed in CSA's sampling procedures. The associations expressed interest in new data and its analytical products, particularly performance indicators like profitability. They are also motivated to pursue social and commercial advance by way of participating in GHG reduction.

7.3 Pilot designs

7.3.1 Priorities identified for pilots

The priorities identified (Table 3 and 4) for pilots were:

- Feed digestibility: feed type, % of each feed for commercial dairy and feedlot farms, urban and peri-urban dairy farms, mixed crop-livestock system (Pilot 1)
- Manure management system: fraction of manure managed in each manure management system: for commercial dairy and feedlot farms, urban and peri-urban dairy farms, and mixed crop-livestock farms (Pilot 2)

- Milk yield: for commercial dairy farm, urban and peri-urban dairy farms (Pilot 2)
- Population and herd structure: for commercial dairy and feedlot farms, urban and peri-urban dairy farms (Pilot 1)

7.3.2 Description of pilots

The pilots were tested from 07 December 2020 – 07 January 2021 in four regions namely, Oromia, Amhara, Dire Dawa, and Southern Nations, Nationalities and People's Region in Ethiopia. The pilots targeted mixed crop-livestock farms, urban and peri-urban dairy farms, commercial dairy, and feedlot farms. A total of 314 households were interviewed from across the regions (Table 6). A team composed of 4 enumerators and 1 supervisor for each of pilot 1 (CSA staff) and pilot 2 (MoA staff) undertook the survey.

Table 6. Number of Kebele and farms selected for this study.

Production system	No. of Kebeles	No. of farms/kebeles	Total No. household
Mixed crop-livestock farms	16	10	160
Urban and Peri-urban farms	8	10	80
Commercial dairy farms	8	4	32
Commercial feedlots farms	8	4	32
Total			**314**

Pilot 1

Herd composition

The national GHG inventory indicates that CSA annual survey does not report the herd structure of indigenous cattle and crossbred dairy cattle in the mixed crop livestock system separately. Moreover, the GHG inventory reported that cattle population and herd structure is missing in the CSA annual survey for urban and peri-urban, commercial dairy and feed lot cattle production systems. Therefore, the first objective of pilot 1 was to develop and test cattle population and herd composition data collection tools for crossbred cattle in the mixed crop livestock system, urban & peri-urban system, and large commercial dairy and feedlot farms.

With the tool developed, farmers are asked for the number of cattle of each animal type owned currently. This is the same as the existing CSA survey tool, but this question was asked separately for indigenous and crossbred dairy cattle in mixed crop livestock, urban & peri-urban and commercial production systems. The purpose of this innovation is to obtain data on the herd structure disaggregated by breed type.

Diet composition (feed energy digestibility)

The national GHG inventory indicates that that feed digestibility (digestible energy, %) for animal sub-categories in different production systems has a significant influence on both enteric fermentation and manure management methane emissions. The CSA annual livestock survey collects data on diet composition by asking farmers to directly estimate the percentage of intake from 6 different categories of forage, fodder and feed. The categories of feed are:

- *green fodder obtained by grazing*
- *crop residue: harvested by-products (straw and chaff of cereals and pulses, etc.);*

- *improved feed: e.g. oat or alfalfa*
- *hay includes any type of grass, clover etc. cut and dried as fodder; and*
- *Industrial by-products are oil cakes (e.g., noug cake, sunflower cake, etc.), bran, and brewery residue.*
- *Others (non-conventional feedstuffs).*

However, data collection tools currently used by CSA to collect cattle diet data are inadequate for accurate representation of diets because the current CSA tool i) does not report feed utilization separately for indigenous and dairy cattle; ii) does not capture seasonal differences in diet; iii) does not record specific feed types within each feed category; and iv) does not report feed utilization separately for different animal sub-categories (i.e., lactating cow, oxen, calves etc.). Therefore, the second objective of pilot 1 was to compare the existing diet composition data collection tool to alternative data collection tools. Since data related to diet is the usual remit of CSA, CSA managed this pilot.

Seven tools were tested:

Tool 1: Annual diet composition: Farmers are asked to estimate the percent of each main feed category in the diet for the herd. This is the same as the CSA survey tool, but one adjustment to the CSA method was that this question was asked separately for indigenous and dairy cattle.

Tool 2: Diet by season: Farmers are first asked to define the months that are in the dry and wet seasons. Then they are asked to estimate the percent of each main feed category for the dry and wet seasons separately for the herd.

Tool 3: Annual diet composition by animal sub-category: Farmers are asked to estimate the percent of each main feed category in the diet and to estimate the percent of diet contributed by each feed category for animal sub-categories of different sex and age.

Tool 4: Diet by animal sub-category: Farmers are asked to specify the percent of each specific feed type fed and to estimate for animal sub-categories of different sex and age the percent of diet contributed by each feed type.

Tool 5: Diet composition by season for main feed category and animal sub-category: Farmers are first asked to define the months in the dry season and in the wet season and then asked to estimate the percent of each feed category in the diet fed for animal sub-categories of different sex and age.

Tool 6: Diet composition by season for specific feed type and animal sub-category: Farmers are first asked to define the months in the dry season and in the wet season and farmers are asked to specify the percent of each specific feed type fed and then asked to estimate the percent of diet contributed by each feed category for animal sub-categories of different sex and age.

Tool 7: Diet composition by season for specific feed types: Farmers are first asked to define the months in the dry season and in the wet season, and are asked to estimate the percent of diet contributed by each feed category for the herd.

Tool 1, Tool 2, Tool 3, and Tool 4 were tested for mixed crop-livestock farms, while Tool 3, Tool 4, Tool 5, and Tool 6 were tested for urban and peri-urban dairy farms. Tool 2 and Tool 7 were tested for both commercial dairy and feedlot farms.

The DE (%) value of each feed component as a percentage of gross energy, which is required to estimate GHG emission factors, was taken from the Tier 2 livestock GHG inventory.

Pilot 2

The national GHG inventory also identified a lack of data on manure management, milk yield and liveweight as important sources of uncertainty. Currently there is no established data management system (whether surveys, or administrative data) that can provide a representative annual time series of data on milk yield or liveweight from commercial dairy farms and urban and peri-urban dairy farms. Furthermore, no official data sources collect data on manure management from any production system. Therefore, Pilot 2 aimed to test data collection tools for manure management, milk yield, and liveweight activity data. These data gaps (i.e., milk yield, liveweight, manure management) are aligned with Ministry of Agriculture's interests and existing responsibilities, and the pilot activities were managed by the Ministry of Agriculture.

Manure management system: A tool was tested to estimate the percentage of manure managed in the different manure management systems in mixed crop-livestock farms, urban and peri-urban dairy farms, commercial dairy, and feedlot farms. The tool collected data on:

1) Percent (%) of manure managed in different manure management systems.
2) Residence time in different manure management systems and usage after the main storage system
3) Other manure management practices (e.g., covering manure heaps, cleaning with water, turning or mixing liquid storage, aeration of compost), and
4) Correlations of manure management system with other farm characteristics (house type and flooring type), to test whether manure management systems could be predicted using housing and flooring characteristics as proxies.

Milk yield: Tools were tested to estimate milk yield through interview (farmer recall) and direct measurement for urban and peri-urban and large commercial dairy cattle production systems.

1) Farmer recall: Farmers were asked to estimate average daily milk yield from lactating cows in the current or last lactation
2) Measured milk yield: Enumerators monitored (measured) and recorded milk production from lactating cows twice per day (morning and evening) for two consecutive days at early, mid and late lactation from individual cows to verify the farmer recall data.

Data analysis pilots (Pilots 3 and 4)

Several methods were used for data analysis. First, statistical tests were carried out to compare means and distributions of data (e.g., share of each feed type in diet composition or feed digestibility) estimated from the same households using different data collection tools. For variables with large samples and normally distributed data, a paired samples t-test was used. For samples that were not normally distributed, a median sign test was used. There was no 'gold standard' direct measurement tool, so the CSA tool (Tool 1) was taken as the reference tool, and results from other tools compared with it.

In data analysis, pilots 3 and 4 entailed integration of the data collected into existing systems. In the case of CSA (pilot 3) this entails data processing to align the data with existing procedures and products, and allocation of the results to various existing and proposed products. It also entails reporting on the potential for use of the new data in supporting national GHG inventory, CRGE-MRV and national development plans, and in other support to climate change policy in Ethiopia.

The Ministry of Agriculture, and particularly ECCD, provided synthesis of productivity data and an evaluation of the data and the pilot activities along with recommendations for adoption or change (pilot 4).

Data dissemination pilot (pilot 5)

The fifth pilot engaged EIAR in analysis of the pilot data for use by stakeholders, including the packaging of data for MRV uses and provision of basic analysis for livestock producers and the supply chain. This pilot supported and trialled engagement of data collection and analysis with users.

The pilot activities, novelty and functions in capacity building and dissemination are presented in Figure 3.

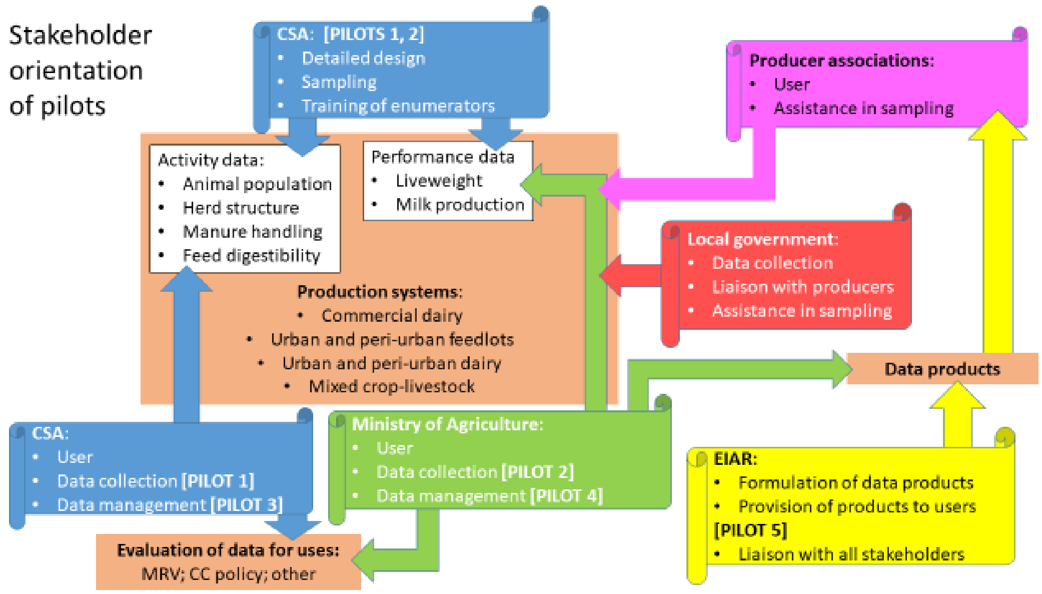
Figure 3. Detail of pilots

Detail of pilots

Item	Pilot 1: Measurement of activity data	Pilot 2: Measurement of performance variables	Pilot 3: Analysis of Activity data	Pilot 4: Analysis of production data	Pilot 5. Communication of pilot results
Pilot activities	CSA kebele or local level staff	Local government staff	CSA Addis Ababa	Min Agr MRV group Addis Ababa	EIAR
	Data gaps addressed		**Results' synthesis and interpretation**		**Dissemination to users**
	Urban Dairy: animal numbers and herd structure	Urban Dairy: milk production and liveweight	Synthesis of animal numbers	Synthesis of liveweight measures	Use of performance information
	Urban Red Meat Feedlots: animal numbers	Urban Red Meat Feedlots: liveweight	Synthesis of herd structure	Synthesis of milk production measures	Recommendations for use of pilot results in Min Agr systems
	Urban Dairy; Feedlot; mixed crop-livestock: Manure management systems	Mixed crop and livestock: liveweight	Recommendations for use of pilot results in CSA systems	Synthesis of manure production and treatment	Recommendations for use of pilot results in MRV
	Urban Dairy; Feedlot; mixed crop-livestock: Feed digestibility (DE)		Recommendations for use of pilot data in collaboration on MRV	Synthesis of allocation of feed to animal types	Communication of results to Industry Associations and other interested groups
	Feed types allocated to herd structure				Presentation of results to project's Validation Workshop
New background data	Herd structural factors	Herd structural factors	Herd structural factors	Herd structural factors	Herd structural factors
Data collection method tests	Feed type Feed seasons Feed allocation	Milk production: farmer recall vs measurement Animal Liveweight: farmer recall vs measurement		Manure measurement Manure mngt. practice Feed allocation	
Pilot management	CSA	CSA	CSA	Min Agr	EIAR
Support to Data collection	CSA and Min Agr	CSA and Min Agr	CSA and Min Agr	CSA and Min Agr	CSA and Min Agr
Capacity building	CSA and Min Agr	CSA and Min Agr	CSA and Min Agr	CSA and Min Agr	Min Agr
Research and dissemination to users	EIAR	EIAR	EIAR	EIAR	EIAR

Stakeholders' engagement in the pilots is shown in Figure 4.

Figure 4. Stakeholders' roles in pilots



7.4 Pilot activity results

7.4.1 Descriptive results of each survey tool piloted

Herd composition

Cows accounted for 74.4, 72.6 and 63.9% of cattle in large commercial dairy farms, urban and peri-urban dairy farms, and mixed crop-livestock farms, respectively. Herd structure was broadly similar across the different production systems except that the proportion of adult crossbred & pure exotic males (3 & above years) in the mixed crop-livestock farms was higher than in both urban and peri-urban and commercial dairy farms because adult male animals are kept for draft power purpose in the mixed system where crop farming is an essential part of the system (Table 7).

Table 7. Proportion of crossbred/pure exotic dairy cattle subcategory from total herd in each production system (%).

Subcategory	Crossbred dairy cattle in mixed crop-livestock farms	Urban peri-urban system	Large commercial dairy intensive system
Adult crossbred & pure exotic dairy cows (3 -10 & above years)	63.88	74.38	72.58
Adult crossbred & pure exotic males (3 & above years)	16.69	0.93	3.71
Crossbred & pure exotic calves (<6 months) male & female	4.64	4.28	5.27

Crossbred & pure exotic calves (6 m - < 1 yr) male & female	4.64	4.28	5.27
Crossbred & pure exotic growing males (1 - < 3 years)	3.91	5.11	3.49
Crossbred & pure exotic growing females (1 -< 3 years)	6.25	11.02	9.68

Diet composition

(a) Mixed crop-livestock system

Tool 1 estimates the annual average diet composition for the total herd while Tool 2 estimates seasonal weighted (wet/dry season) average diet composition for the total herd. Table 8 and Table 9 show the descriptive results using Tool 1 and Tool 2. All interviewees estimated the dry season as 8 months and the wet season as 4 months. From this, a weighted average annual diet composition was estimated (Tool 2) and compared with the results of Tool 1.

Table 8. Descriptive results of cattle feed composition using Tool 1.

Proportion of each feed category provided to cattle during last one year (%)				
Feed Category	**Indigenous cattle**		**Crossbred cattle**	
	Mean	**SD**	**Mean**	**SD**
Grazing	33.97	17.51	23.86	15.05
Crop Residue	38.71	17.73	30.57	19.73
Improved Feed	1.82	5.93	2.29	7.11
Hay	4.48	9.1	17.77	14.44
Agro-industrial by product	8.85	9.72	14.26	11.5
Others	12.17	11.89	11.26	10.33

SD: Standard deviation

Table 9. Descriptive results of cattle diet composition for indigenous and crossbred cattle using Tool 2.

Feed category	**Dry season feed type utilized (%)**		**Wet season feed type utilized (%)**		**Annual weighted Average (%)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Indigenous cattle						
Grazing	22.02	20.75	49.21	21.61	31.08	21.18
Crop Residue	47.45	21.45	29.21	20.19	41.37	20.82
Improved Feed	1.92	6.58	1.09	4.93	1.64	5.76
Hay	5.46	12.55	2.65	8.36	4.52	10.46

Agro-industrial by product	9.85	11.98	7.55	10.16	9.08	11.07
Others	13.3	14.52	10.3	11.18	12.30	12.85
Crossbred cattle						
Grazing	9.29	13.67	30.29	20.36	16.29	17.02
Crop residue	32.29	21.64	28	17.46	30.86	19.55
Improved feed	4	15.89	2	5.58	3.33	10.74
Hay	22.34	18.61	11.94	11.52	18.87	15.07
Agro-industrial by product	19.8	16.12	17.77	15.05	19.12	15.59
Others	12.29	16	10	9.24	11.53	12.62

SD: Standard deviation

Is there a significant difference in diet composition and digestibility between cattle breeds? Because the data is not normally distributed, a sign test was used to compare between cattle breed types, instead of a paired t-test which assumes a normal distribution.

When Tool 1 is used, sign tests indicate significant differences ($p < 0.05$) in proportions of grazed, crop residue, hay, and agro-industrial by-products but not in the proportion of improved feed and other feeds in the diet of indigenous and crossbred cattle (Table 10). When Tool 2 is used (diet composition per season), sign tests revealed significant differences in proportion of crop residue, hay and agro-industrial by products in the diet of crossbred and indigenous cattle breeds (Table 11).

Table 10. Sign test results comparing diet composition for indigenous and cross-bred cattle using Tool 1.

	Grazing	Crop residue	Improved feed	Hay	Agro-ind. by-products	Other
Z statistic	3.4770	2.2151	-0.3164	-5.0514	-2.5781	0.3405
P (sign 2 tail)	0.0003	0.0217	0.3821	0.0001	0.0038	0.3669

Table 11. Sign test results comparing diet composition for indigenous and cross-bred cattle using Tool 2.

	Grazing	Crop residue	Improved feed	Hay	Agro-ind. by-products	Other
Z statistic	1.304	1.772	-0.221	-4.252	-4.523	-0.439
P (2-tailed sig.)	0.0951	0.0359	0.4129	0.0001	0.0001	0.3372

When these diet components were converted to an estimate of DE for the whole diet using the GHG inventory DE default values, sign tests showed a significant difference in feed DE% for indigenous and cross-bred cattle when using Tool 1 and Tool 2 (Table 12). **Therefore, the pilot innovation suggests collecting data on feeding system separately for indigenous and crossbred cattle will increase the accuracy of the DE estimates, and thus improve GHG inventory accuracy.**

Table 12. Sign test results comparing mean feed digestibility (%) estimates for crossbred and indigenous cattle breed using Tool 1 and Tool 2 (Mean, standard deviation).

	Tool 1	**Tool 2**
Indigenous	54.84^{B} (1.06)	54.72^{B} (1.06)
Cross-bred	56.98^{A} (1.63)	57.15^{A} (0.44)
Tool 1: Z-statistic =5.96, P= 0.0001 (significance. 2 tailed) Tool 2: Z- statistic =4.644, P= 0.0006 (significance. 2 tailed)		

Different superscript letters in the same column indicate significant differences between cattle breeds (P < 0.05)

Is there a significant difference between diet digestibility estimates made using annual and seasonal data collection tools? When these diet components are converted to an estimate of DE for the whole diet using the GHG inventory DE default values, the resulting estimates of feed digestibility did not show significant different differences between Tool 1 (annual data collection) and Tool 2 (season data collection) for both indigenous and crossbred cattle (Table 13). **Therefore, the pilot result suggests that collecting diet data for indigenous and crossbred cattle by season will not make a difference in DE estimates.**

Table 13. Sign test Comparison of feed digestibility (%) estimates for indigenous cattle using data from Tool 1 and Tool 2.

	Indigenous cattle breed	**Crossbred cattle breed**
Tool 1	54.84^{A} (1.28)	56.98^{A} (1.63)
Tool 2	54.72^{A} (1.09)	57.15^{A} (0.24)
Indigenous cattle: Z statistic = 1.152, P=0.1251 (sig. 2 tailed) Crossbred cattle: Z statistic = 1.25, P = 0.2316 (sig. 2 tailed)		

Different superscript letters in the same column indicate significant differences between Tools (P < 0.05)

Is there a significant difference between diet composition estimates made for different cattle sub-categories? Tool 3 estimates the annual average diet composition for specific animal sub-categories whereas Tool 4 estimates the annual average diet composition using specific feed types for specific animal sub-categories. Diet composition data is converted to feed digestibility (%) estimates using two different methods (Tool 3 and Tool 4). There were significant differences between DE estimated using Tool 3 for crossbred cattle sub-categories i.e., lactating cows, dry cows, growing males, bulls, calves but not for heifers (Table 14). This result highlights that collecting more detailed data on diet composition for each animal sub-category (especially for lactating cows which represented more than 60% of the cattle herd) can help to increase the accuracy of DE estimates, and thus GHG estimates. However, there were no significant differences between DE estimated using Tool 3 and Tool 4 for indigenous cattle animal sub-categories (P > 0.05, Table 13).

Table 14. Comparing feed digestibility (%) estimates of between cattle sub-categories of indigenous and crossbred cattle using Tool 3 and Tool 4.

	DE% of crossbred dairy cattle		**DE% of Indigenous cattle breed**	
	Tool 3	**Tool 4**	**Tool 3**	**Tool 4**
Lactating cow	58.90^{A}	58.89^{A}	55.35^{A}	56.12^{A}
Dry cow	58.54^{A}	61.09^{A}	54.39^{A}	55.71^{A}
Heifer	56.81^{B}	56.46^{A}	54.26^{A}	55.05^{A}

Ox	-	56.98^{A}	54.44^{A}	55.52^{A}
Growing male	55.64^{AB}	58.94^{A}	54.21^{A}	55.58^{A}
Bull	57.1^{AB}	57.15^{A}	54.31^{A}	55.50^{A}
Calf	58.95^{A}	58.45^{A}	54.95^{A}	56.19^{A}

Different superscript letters in the same column indicate significant differences between Tools ($P < 0.05$)

Are there significant differences in feed digestibility when different data collection methods and default values are used? For indigenous and crossbred cattle, we compared the results of using Tool 1, Tool 2 and Tool 3 and Tool 4. The single DE (%) value for Tool 3 and Tool 4 was calculated as the weighted sum of DE values of each animal sub-category. The resulting estimates of DE% were not significantly different among tools for either crossbred and indigenous cattle (Table 15). **This result suggests that there may not be significant improvements by collecting seasonal and/or detailed data on each feed type and animal sub-category**.

Table 15. Comparison of feed digestibility (%) estimates of crossbred and indigenous cattle using Tool 1, Tool 2, Tool 3 and Tool 4

	Tool 1	Tool 2	Weighted Tool 3	Weighted Tool 4
Crossbred cattle	56.98^{A}	57.15^{A}	58.04^{A}	58.18^{A}
Indigenous cattle	54.84^{A}	54.72^{A}	54.58^{A}	55.58^{A}
Crossbred cattle: Z statistic < 1.96, $P > 0.05$ (2 tailed) Indigenous cattle: Z statistic < 1.96, $P > 0.05$ (2 tailed)				

Different superscript letters in the same row indicate significant differences between Tools ($P < 0.05$)

How much do differences in feed digestibility estimates influence inventory emission estimates? The national GHG the inventory suggests that feed digestibility is one of the most sensitive factors in estimating enteric fermentation emissions. Table 16 shows the influence of DE estimates of lactating cows on enteric methane emission factors. Taking all other factors in the national GHG inventory for crossbred and indigenous cows unchanged, enteric methane emission was calculated using feed digestibility value estimated using the different tools (Table 13 and Table 14). For indigenous lactating cows, there is some difference between using the different tools, with the highest difference equating to a 2.17% difference compared to feed digestibility estimated using the Tool 1 (Table 16). For crossbred cattle the highest difference is 5.27% with Tool 3. This variation is relatively minor compared to the large increase in time, resources and cost required to collect data using Tool 4 and Tool 3 compared with Tool 1.

Table 16. Response of lactating cow emission factors to change in digestibility values.

Tool	Crossbreed			Indigenous breed		
	DE%	**EF (CH_4 head^{-1} year^{-1})**	**% Change compared to Tool 1**	**DE%**	**EF (CH_4 head^{-1} year^{-1})**	**% Change compared to Tool 1**
Tool 1	56.98	80.43		54.84	51.57	
Tool 2	57.15	78.38	2.55	54.72	51.76	-0.37
Weighted Tool 3	58.90	76.48	4.91	55.35	51.98	-0.80
Weighted Tool 4	58.89	76.19	5.27	56.12	50.45	2.17

(b) Urban and peri-urban dairy farms

The national GHG inventory indicated a lack of data on diet composition in the peri-urban dairy farm systems. The pilot tested four different tools in the peri-urban dairy farm system. Tool 3 essentially estimates the annual average diet composition for specific animal sub-categories whereas tool 4 estimates the annual average diet composition using specific feed types for specific animal sub-categories. Tool 5 estimates the weighted seasonal (wet/dry season) average diet composition for each animal sub-category, while Tool 6 estimates the weighted seasonal (wet/dry season) average diet composition using specific feed types for animal sub-category in urban and per-urban dairy farms. In addition to the CSA-defined six feed categories, one additional feed category (concentrate) was identified in the urban and peri-urban dairy farm system.

Table 17. Sign test results for diet composition for cross-bred cattle using Tool 3 and Tool 5.

	Grazing	Crop residue	Improved feed	Hay	Agro-industrial by products	Concentrate	Other
Z statistic	-1.02	4.130	1.16	-0.81	-2.35	-0.91	-1.67
P (2 tail sign)	0.159	0.001	0.125	0.212	0.021	0.173	0.055

Table 17 summarizes sign test results comparing diet composition for crossbred cattle in urban and peri-urban dairy farms using Tool 3 and Tool 5. Sign tests result indicate significant differences ($p < 0.05$) in the proportions of crop residue and agro-industrial by-products but not in the proportion of grazing, improved feed, hay and concentrate in the diet of crossbred dairy cattle when estimated using Tool 3 and Tool 5.

Table 18. Comparison of feed digestibility estimate of crossbred dairy cattle in urban and peri-urban system using Tool 3, Tool 4, Tool 5, and Tool 6.

Tools	Mean, DE%	SD
Weighted Tool 3	56.57^{A}	0.968
Weighted Tool 4	57.19^{A}	1.107
Weighted Tool 5	50.60^{B}	0.398
Weighted Tool 6	53.00^{B}	1.106

Different superscript letters in the same column indicate significant differences between Tools ($P < 0.05$)

When the diet components in Tool 3, Tool 4, Tool 5, and Tool 6 are converted to an estimate of DE% for the whole diet using the national GHG inventory default DE values, sign tests showed significance difference in DE (%) between Tool 3 and Tool 5 and between Tool 3 and Tool 6 (Table 17). Similarly, sign tests showed significant difference in DE (%) between Tool 4 and

Tool 5 and between Tool 4 and Tool 6 (Table 18). However, there was no significant difference between Tool 3 and Tool 4 or between Tool 5 and Tool 5 (Table 17). This result suggests that collecting data on annual diet composition for each animal sub-category either using main feed categories and/or specific feed type has no effect on DE estimates. However, collecting diet composition data by season using Tool 5 and Tool 6 resulted in lower DE (%) estimates than when data is collected on an annual basis (Tool 3 and Tool 4). Furthermore, the lower DE (%) estimates based on Tool 5 and Tool 6 are not in line with what is being reported in the literature for dairy cattle in Ethiopia.

There was some variation in diet composition for different animal sub-categories and resulting estimates of feed digestibility (%) were significantly different for some sub-categories when using default feed digestibility (%) values. For instance, there was differences in mean estimated feed digestibility (%) for lactating cows and other sub-category when using Tool 3 but not when using Tool 4, Tool 5 or Tool 6 (Table 19). This suggests that there might be a significant added value to changing the CSA tool to collect diet composition data specific to lactating cows which make up about 70 % of the herd in this pilot study (Table 7). However, data on diet composition for other subcategories that have only minor effects on overall inventory uncertainty could be collected at the herd level.

Table 19. Comparison of DE estimate between lactating cows and other crossbred cattle in urban and peri- using Tool 3, Tool 4, Tool 5 and Tool 6.

	Tool 3	Tool 4	Tool 5	Tool 6
Lactating cow	57.93^{A}	58.09^{A}	59.68^{A}	62.70^{A}
Other cattle	56.71^{B}	57.99^{A}	58.79^{B}	62.89^{A}
Z statistic	3.12	0.07	4.00	-0.12
P-value (2 tail sign)	0.0001	0.4681	0.0001	0.46

Different superscript letters in the same column indicate significant differences between Tools ($P < 0.05$)

(c) Large commercial dairy farms

Tool 2 estimates seasonal weighted average diet composition using main feed category for the total herd while Tool 7 estimates seasonal weighted average diet composition using specific feed types for the total cattle herd in commercial dairy farms. When the diet components in Tool 2 and Tool 7 converted to an estimate of DE% for the whole diet using the national GHG inventory default DE values, sign tests indicated no significant difference in feed digestibility between the Tool 2 and Tool 7 (Table 20). **Therefore, the DE (%) for commercial dairy cattle herd can be estimated by applying the standard CSA tool rather than collecting data on specific feed types; however, it is necessary to better quantify typical diets and diet components within main feed categories.**

Table 20. Comparison of feed energy digestibility estimate for commercial dairy cattle using Tool 2 and Tool 7.

	Mean	SD
Tool 2	64.79^{A}	0.28
Tool 7	62.12^{A}	1.30
Z statistics= 1.4, P=0.0808 (2 tail sign)		

Different superscript letters in the same column indicate significant differences between Tools ($P < 0.05$)

(d) Large commercial feedlots

When the diet components in Tool 2 and Tool-7 are also converted to an estimate of DE% for the whole diet using the national GHG inventory default DE values, sign tests indicate no significant difference in DE between Tool 2 and Tool 7 (Table 21). **Therefore, collecting data on feed category using Tool 2 will be sufficient for the inventory.**

Table 21. Comparison of feed energy digestibility estimate for commercial feed lot using Tool 2 and Tool 7.

	Mean	SD
Tool 2	65.54^{A}	0.59
Tool 7	62.79^{A}	3.25
Z-statistic=1.498, P= 0.0681 (sign 2 tail)		

Different superscript letters in the same column indicate significant differences between Tools ($P < 0.05$)

7.4.2 Manure management practices

The manure management tool collected data on percent of manure managed in different manure management systems (MMS) and also asked supplementary questions to enable better characterization of the specific manure management practices and manure residence time in different manure management systems. Table 22 shows the correspondence of how manure management system questions were asked and IPCC manure management system categories.

Table 22. Correspondence of questionnaire phrasing to IPCC manure management categories.

Questionnaire phrasing	IPCC categories
Left where deposited on pasture	Deposit of dung and urine on pasture
Spread on pasture or crops	Daily spread
Left in area where cows kept	Drylot
Stored in pit	Pit storage
Stored in piles	Solid storage
Composted	Composting
Liquid or slurry	Liquid storage
Biodigester	Anaerobic digestion
Collected dried and sold or burnt	Burned for fuel (or other for sold)

Table 23 summarizes the manure management system in the different livestock production system data. The result indicates that deposit of dung and urine on pasture, solid storage and burned for fuel are the most common MMS, accounting for about 58% of manure management. Stored in a pit, stored in piles, and collected fresh manure and dried in the urban/peri-urban and large commercial dairy farms are the most common MMS, accounting for about 67%, and 79 % of manure management, respectively. Daily spread, stored in a pit, and collected fresh manure and dried are the most common MMS in large commercial feedlot farms, accounting for about 90% of manure management.

Table 23. Percentage of seasonally weighted manure managed in different manure management systems.

		Mixed system	Urban/Peri-urban dairy system	Large commercial dairy system	Large commercial feedlot farms
1	Deposit of dung & urine on pasture	22.7%	2.0%	5.9%	0.0%
2	Daily spread	14.2%	5.5%	2.6%	23.3%
3	Drylot	1.4%	3.3%	0.6%	18.9%
4	Pit storage	13.5%	15.5%	16.5%	16.7%
5	Solid storage	17.5%	29.4%	38.9%	25.8%
6	Composting	4.2%	4.7%	4.1%	2.3%
7	Liquid storage	0.2%	2.6%	2.8%	2.7%
8	Anaerobic digestion	0.0%	3.3%	1.8%	0.3%
9	Collected fresh manure dried and sold or burnt for fuel	17.3%	22.0%	23.9%	5.4%
10	Collect dried and burn for fuel	9.0%	11.6%	2.8%	4.6%
	Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Are manure management practices associated with housing and flooring types? The association of MMS type with housing and flooring types (Table 24) were tested using Chi-square tests (see Table 25). The purpose of this analysis was to see if these variables can be used as simple proxies for manure management systems for inclusion in CSA surveys.

Table 24. Housing and flooring type.

Housing type	Flooring type
No enclosure, no roof	Dirt
Encloser but no roof	Wooden
Encloser with roof and without walls	Stone layer
Closed, with roof and walls	Concrete

In this pilot, 66.9%, 79.7%, 68.8%, 62.2% of households had cattle housing with enclosed with roof and wall in mixed crop-livestock farms, urban and peri-urban dairy farms, large commercial dairy and commercial feedlots farms, and a very small percent housed cattle enclosed with roof but without walls, enclosed but no roof and no enclosure and no roof. Therefore, it was not possible to test for any relationship between housing and MMS. Similarly, 65.5% of households in the mixed crop-livestock farm's floor was reported to be dirt which has a tendency to use solid storage (P = 0.0002, Table 23).

Table 25 summarizes the association between housing/flooring type and three MMS (solid storage, liquid and composting) and the result indicates that solid storage system was associated with encloser with roof and walls housing type in the mixed crop-livestock production system whereas composting was associated with flooring types (stone layer and concrete) in the crop-livestock production system. However, no association was found between liquid MMS and housing/flooring system in the four production systems. **Therefore, it was not possible to establish strong associations between manure housing or flooring and manure management systems used.**

Table 25. Association between MMS and housing/flooring types (from binary analysis, yes=1, No=0).

Production system	MMS		CHISq	Pr. > CHiSq
Urban/Peri-urban dairy farms	Solid storage	Housing type	1.02	0.79
		Flooring types	4.47	0.21
Mixed crop-livestock farms		**Housing type**	**19.43**	**0.0002**
		Flooring types	2.56	0.46
Commercial dairy farms		Housing type	3.76	0.05
		Flooring types	0.0014	0.99
Commercial feedlot farms		Housing type	1.66	0.64
		Flooring types	5.12	0.08
Urban/Peri-urban dairy farms	Composting	Housing type	0.35	0.95
		Flooring types	0.0667	0.99
Mixed crop-livestock farms		Housing type	0.0895	0.99
		Flooring types	**10.175**	**0.02**
Commercial dairy farms		Housing type	1.50	0.22
		Flooring types	0.0011	0.99
Commercial feedlot farms		Housing type	0.0116	0.99
		Flooring types	0.0283	0.99
Urban/Peri-urban dairy farms	Liquid system	Housing type	0.0246	0.99
		Flooring types	0.0165	0.99
Mixed crop-livestock farms		Housing type	0.0084	0.99
		Flooring types	0.0090	0.99
Commercial dairy farms		Housing type	0.0037	0.95
		Flooring types	0.0009	0.99
Commercial feedlot farms		Housing type	0.0000	1.00
		Flooring types	0.0127	0.99

Do supplementary questions on management practices and residence time improve manure management estimates? Supplementary questions were only asked if the farmer reported using a dry lot, solid storage, composting or a liquid storage system. Then, we programmed the national GHG inventory software with the MMS activity data from Table 21 and the default values for other parameters in the inventory for both crossbred and indigenous cow in the mixed crop-livestock, urban and peri-urban dairy, large commercial dairy, and commercial feedlot farms. The estimated manure management methane emission factors were 14.85, 20.01, 34.28, and 10.67 kg CH_4 head^{-1} year^{-1} in the mixed crop-livestock, urban and peri-urban dairy, large commercial dairy farms, and commercial feedlot farms, respectively. Next, we adjusted the residence time in each manure management system using data from the survey. The following description shows how resident time was adjusted to calculate methane conversion factor (MCF). For details of how the adjustments were made, see Wassie et al. (2021b)

Table 26 summarizes the effects of residence time in different manure management system on emission factors. The results indicate that as a result of the three MMS adjustments, the emission factor decreased by 35%, 33%, 70% and 75% in the mixed crop-livestock system, urban/peri-urban dairy, large commercial dairy farms, and large commercial feedlot farms, respectively. This decrease was mainly due to accounting for the duration of dry lot, solid storage, composting, and liquid manure management. **Therefore, supplementary questions to identify the duration of residence in the selected manure management practices can improve the ability of activity data to represent actual manure management practices and can improve emission factor estimates from manure management systems.** Furthermore, this pilot study was too small to investigate the effect of specific practices such as covering or not covering manure piles, aeration or not aeration of compost, formation of crust or not crust formed on top of liquid on GHG emission. Therefore, further study with larger sample size is required to investigate the effect of specific practices on GHG emission estimates.

Table 26. Emission factor (kg CH_4 head^{-1} year^{-1}) for methane emission from manure management.

Production system	MMS						
	Original	Adjust drylot	Adjust solid storage MCF	Liquid storage (6 month)	adjusted composting	all 4 adjustments	% decrease
Mixed crop-livestock system	14.85	14.84	14.32	10.30	3.93	9.66	35.0%
Urban/Peri-urban dairy system	20.01	19.97	18.98	14.72	5.78	13.49	32.6%
Large commercial dairy system	34.28	18.56	17.18	11.74	5.33	10.27	70.1%
Large commercial feedlot system	10.67	10.47	10.34	3.81	2.92	2.65	75.2%

7.4.3 Milk yield

A survey collecting farmer recall data on milk yield was administered to selected households in urban and peri-urban dairy farms, and then compared with the results of a physical measurement of milk off-take using graduated buckets over two consecutive days in the same households. The idea is to see whether respondents provided accurate answers when asked to estimate average off-take at different stages over the lactating period. The resulting milk off-take data from farmer recall and measurement was converted to annual milk yield using weighted average milk yield, which was calculated using the number of households reporting at different lactation stages (early, mid, and late). Calf suckling before and after milking is a common practice in the urban and peri-urban dairy farm system, so annual milk off-take reported and measured from the pilot survey was corrected for milk suckled by calves using energy requirements of the calf (NRC 2001). The detailed methods and assumptions are described in the national livestock GHG inventory.

Table 27. Comparison (t-test) of mean daily milk yield reported with weighted average mean milk yield measured.

Group	Mean	SD
Milk yield reported by recall method	8.34	2.11
Milk yield measured weighted average	9.21	3.32
t-statistic= 0.938, P .t=0.38		

The resulting final daily milk yields (farmer recall vs. measured) in urban and peri-urban system were compared using a two sample t test for mean difference. The farmer recalled daily milk data was 13% lower than the daily milk yield value of the monitoring, but the difference is not significant ($P > 0.05$; Table 27). **Therefore, data collection on milk yield using the recall method is sufficient for the GHG emission inventory.**

As there was no alternative and/or existing method for measuring milk yield in the large commercial dairy farms, it was not possible to make a comparison. However, it was possible to obtain a level of information that would not otherwise be available (farm records). This method could feasibly be implemented on a wider scale.

7.5 Stakeholder evaluations of pilot tests

Stakeholders' evaluations of the piloted tools are described in this section. The recommendations made on this basis are described in Section 9 below.

A workshop was organized to discuss the results of the pilot tests with relevant stakeholders and to discuss the way forward on upscaled adoption of validated tools to support the effective operation of an improved livestock MRV system in Ethiopia. The results of pilot tests were evaluated against criteria discussed with the stakeholders. The criteria list primarily consisted of features important in suitability for filling data gaps, alignment, and potential for improving the existing CSA data collection tool to ensure integration with existing data systems.

The following criteria were used for evaluation of pilot results:

- Data collection, management and dissemination procedures' suitability for filling data gaps and enhancing MRV in Ethiopia.
- Extent to which pilots' procedures have the potential to improve existing information management systems, address the breed difference, analysis, and communication.

- Data quality, across criteria as identified by the project.
- Likelihood of scaling up piloted procedures to regional and national levels.
- Need for additional finance and human resource for implementation.
- Cost of new procedures vs existing news, including cost synergies.

Evaluation was given for subtotal score (excellent= 5, very good=4, satisfactory/Good=3, poor= =2 and unsatisfactory//very poor=1).

Based on the evaluation score (Table 28), Tool 1 (CSA tool) where farmers are asked to estimate the main feed category utilized by the crossbred and indigenous breed separately in the last one year is the best option to fill existing data gaps in the mixed crop-livestock system, while Tool 3 where farmers are asked to estimate the percent of each main feed category utilized by each animal sub-category especially for lactating cows and other groups is the best option in the urban and peri-urban dairy production system. Furthermore, Tool 2 is the best option to fill data gaps in large commercial dairy and commercial feedlot production systems. Moreover, sign test results confirmed that there were no significant differences in feed digestibility estimates between Tool 2 and Tool 7. Regarding cost and synergy with existing data collection systems, Tool 2 requires lower cost than Tool 7. **In general, before applying these tools to estimate diet composition and DE (%) for the different production systems, it is necessary to better quantify typical diets and diet components within each feed category.** This can be done through a one-off representative sample survey, and does not need to be integrated into annual sample surveys.

Comparison of milk yield between the two tools (farmer recall and measurement) indicated that there was no significant difference in average daily milk yield. The recall by survey required less resources in terms of human resource requirement, material and transport requirement and financial requirement. Moreover, in terms of synergy with existing data collection systems, the farmer recall method had better synergy with existing CSA data collection system, which is questionnaire-based (Table 29). **Therefore, the recall data collection method is the best option for milk yield data in urban and peri-urban system.**

Table 28. Stakeholder evaluation and scoring of tools to estimate feed digestibility in different production systems.

Mixed Crop-livestock system

Data evaluation criteria	Tool 1	Tool 2	Tool 3	Tool 4
Data suitability for filling data gaps				
• Data by breeds	5	5	5	5
• Herd composition used	0	0	5	5
• Level feed characterization/Feed basket & DE% values used	2	2	5	5
• seasonality of feed types	0	5	0	0
Sub=total	7	12	15	15
Data collection, management and dissemination procedures' suitability for filling data gaps and enhancing MRV in Ethiopia				
• Data collection procedure	5	5	3	3
• Data management	5	5	3	3

• Data analysis	5	5	3	3
Sub-total	15	15	9	9
Extent to which pilots' procedures have the potential to improve existing information management systems, analysis and communication				
• Data collection protocol or structure (approach, tools, questioners)	5	4	2	2
• Sampling design procedure	5	5	3	3
• Data analysis procedure	5	5	3	3
Sub-total	15	14	8	8
Data quality, across criteria as identified by the project				
• Completeness of data (Data collection protocol)	5	5	5	5
• Representation	2	3	4	4
Sub-total	7	8	9	9
Likelihood of scaling up piloted procedures to regional and national levels				
• Human resource requirements	5	3	1	1
• Material, transport etc requirement	5	3	1	1
• Financial requirement	5	3	1	1
Sub-total	15	9	3	3
Cost of new procedures vs existing news, including cost synergies				
• Cost	5	4	1	1
• Synergy with existing system	4	4	0	0
Sub-total	9	8	1	1
Total for mixed system	**68**	**58**	**45**	**45**

Urban and peri-urban

	Tool 3	Tool 4	Tool 5	Tool 6
Data suitability for filling data gaps				
• Data by Breeds	5	5	5	5
• Herd composition used	5	5	5	5
• Level feed characterization/Feed basket & DE data	3	5	3	5
• seasonality of feed types	0	0	5	5
Total	13	15	18	20
Data collection, management and dissemination procedures' suitability for filling data gaps and enhancing MRV in Ethiopia				
• Data collection procedure	3	3	2	1
• Data management	3	3	2	1
• Data analysis	3	3	2	1
Sub-total	9	9	6	3
Extent to which pilots' procedures have the potential to improve existing information management systems, analysis and communication				

• Data collection structure (approach, tools, questioners)	2	2	1	1
• Sampling procedure	3	3	1	1
• Data analysis procedure	3	3	1	1
Total	8	8	3	3
Data quality, across criteria as identified by the project				
• Completeness of data (Data collection protocol	4	4	5	5
• Representation	4	4	5	5
Sub-total	8	8	10	10
Likelihood of scaling up piloted procedures to regional and national levels				
• Human resource requirements	1	1	1	1
• Material, transport etc requirement	1	1	1	1
• Financial requirement	1	1	1	1
Sub-total	3	3	3	3
Cost of new procedures vs existing news, including cost synergies				
• Cost	1	1	1	1
• Synergy with existing system	0	0	0	0
Sub-total	1	1	1	1
Total	**42**	**44**	**41**	**40**

Commercial dairy/feed lot

	Tool 2	Tool 7
Data suitability for filling data gaps		
• Addressing available breeds	5	5
• Addressing sub-categories	0	0
• Level feed characterization/Feed basket & DE% values used	1	5
• seasonality of feed types	5	5
Sub-total	11	15
Data collection, management and dissemination procedures' suitability for filling data gaps and enhancing MRV in Ethiopia		
• Data collection procedure	5	2
• Data management	5	2
• Data analysis	5	2
Sub-total	15	6
Extent to which pilots' procedures have the potential to improve existing information management systems, analysis and communication		
• Data collection structure (approach, tools, questioners)	4	2
• Sampling procedure	5	1
• Data analysis procedure	5	1
Sub-total	14	4
Data quality, across criteria as identified by the project		

• Completeness of data (Data collection protocol)	5	2
• Representation	3	2
Sub-total	8	4
Likelihood of scaling up piloted procedures to regional and national levels		
• Human resource requirements including technical aspect	3	1
• Material, transport etc requirement	3	1
• Financial requirement	3	1
Sub-total	9	3
Cost of new procedures vs existing news, including cost synergies		
• Cost	4	2
• Synergy with existing system	4	0
Sub-total	8	2
Total	**75**	**34**

Table 29. Stakeholder evaluation result for milk yield estimate in urban and peri-urban dairy

	Reported	Measured
Data suitability for filling data gaps		
• Addressing breed	5	5
• Seasonal or stage of lactation variation	5	5
Sub-total	10	10
Data collection, management and dissemination procedures' suitability for filling data gaps and enhancing MRV in Ethiopia		
• Data collection procedure, protocols	5	4
• Data management procedure	5	5
• Data analysis	5	5
Sub-total	15	14
Extent to which pilots' procedures have the potential to improve existing information management systems, taking into account collection, analysis and communication		
• Data collection structure (approach, tools, questioners)	5	5
• Sampling design	5	5
• Data analysis procedure	5	5
Sub-total	15	15
Data quality, across criteria as identified by the project		
• Completeness of data (Data collection protocol)	5	5
• Representation of data	5	5
Sub-total	10	10
Likelihood of scaling up piloted procedures to regional and national levels		
• Human resource requirements	4	2
• Material, transport etc requirement	4	1
• Financial requirement	4	1
Sub-total	12	4
Cost of new procedures vs existing news, including cost synergies		
• Cost	3	1

• Synergy with existing system	3	0
Sub-total	6	1
Value for money of the pilot exercise	**68**	**54**

8 Impacts

8.1 Scientific impacts – now and in 5 years

Although some related studies have been conducted on livestock performance data in general, this project is one of a few examples of initiatives to test and validate alternative methods for collecting data required for livestock GHG inventories and MRV of mitigation actions. A scientific publication summarizing the approach and main findings of the project is under preparation, which will draw attention of the scientific community to the relevance and importance of improving methods for activity data collection.

The main findings of the project have already been shared with the State Department of Livestock in Kenya, which is currently considering methods to improve the availability and quality of livestock activity data in Kenya. It is likely that with support from international partners, similar studies to test and validate data collection tools will be undertaken in Kenya. A New Zealand government initiative to support livestock GHG inventory improvements in Africa and Southeast Asia is also planning to work with national stakeholders in several countries to validate data collection tools to characterise cattle diets and fill other data gaps in those countries' GHG inventories, and will be able to make use of the scientific results of this project as well as the project's methodological approach which links the scientific questions on specific data collection methods to the stakeholder user context.

8.2 Capacity impacts – now and in 5 years

Through the pilot activities, stakeholders now have an evidence-base to inform their decisions about what methods and tools to use to collect data required for livestock GHG inventories and MRV of mitigation actions.

The project has had immediate impacts on data collection activities of the World Bank Livestock and Fisheries Sector Development Project (LFSDP) and the Oromia Forested Landscape Programme (OFLP). The data collection protocols validated in this project for cattle diet composition and manure management were used in a project[9] to support the LFSDP to develop a monitoring and evaluation system for the project's results framework indicator on GHG emission intensity. This will enable the LFSDP to report annually on the change in GHG intensity of livestock production due to project interventions. Evidence of emission reductions and ability to measure and report emission reductions from the LFSDP is also in high demand from stakeholders outside the project, such as stakeholders in the OFLP. Use of the data collection tools validated in this project[10] has also been written into terms of reference for collection of livestock activity data for the OFLP. The OFLP developed a livestock GHG inventory for Oromia Region to quantify baseline livestock emissions in the region so that livestock can be included in a future emission reduction purchase agreement to reward emission reductions from the livestock sector. In 2022, data and data quality gaps in the Oromia Region GHG inventory will be filled by an OFLP-commissioned survey that will use the data collection tools validated in this project.

[9] *Supported by the US Forestry Service International Programs on behalf of the interagency technical cooperation SilvaCarbon program of the U.S. Government.*

[10] *Together with results of related projects supported by US Forestry Service International Programs*

CSA has for many years been collecting livestock activity data through annual sample surveys conducted in rural areas. It has recently trialled similar surveys on commercial farms, but the data has never been formally released due to several issues. Following the stakeholder evaluation workshop, in consultations with CSA, they agreed to revise the tool used to collect diet composition data, and to incorporate the validated tools in future surveys planned in commercial and urban/peri-urban farms. One constraint to immediate adoption of the tools is the lack of a reliable sample frame in these production systems. USDA has agreed to support activities to develop a sample frame for commercial and urban/peri-urban farms.

Thus, within the coming 5 years, it is highly likely that the innovations of this project will be in use by the Central Statistics Agency and other stakeholders in Ethiopia.

8.3 Community impacts – now and in 5 years

This SRA was not designed to have direct impacts on communities. However, in the case of the OFLP, collecting data to improve the Oromia Region livestock GHG inventory is a precondition for livestock to be included in a future emission reduction purchase agreement (ERPA). By providing validated data collection tools, this project is likely to contribute to inclusion of livestock in a future ERPA. The ERPA will provide reward payments for emission reduction achieved, which would be shared with community members through mechanisms agreed between the Government of Ethiopia and the BioCarbon Fund. It is not possible at this stage to provide any reliable estimate of the specific economic, social or environmental impacts that this may have.

8.4 Communication and dissemination activities

The project's main findings were shared with Ethiopian stakeholders prior to and during the stakeholder evaluation workshop. Participants in that workshop included representatives from several Ministry of Agriculture directorates with responsibility for different aspects of the livestock sector (e.g. dairy, red meat, forage, animal health), the Environment, Climate Change and Forestry Commission (EFCCC, with overall responsibility for GHG inventory and MRV at national level), regional government staff with MRV responsibilities, researchers from EIAR and the Ethiopian Meat and Dairy Industry Development Institute, as well as Ethiopian and international staff involved in the World Bank LFSDP and the OFLP and their colleagues in US Forest Service International Programmes and USDA.

Subsequent to the workshop, meetings were held with staff of the Ministry of Agriculture and the Central Statistics Agency (CSA) to discuss specific procedures required to have the validated tools officially adopted in related data collection activities. CSA has agreed to use the validated tools in a planned survey of commercial and urban/peri-urban farms, and USDA has agreed to work with them to develop a master sampling frame for these production systems.

The project's findings were also communicated with staff of the World Bank responsible for support to the OFLP and discussions were held together with World Bank. With endorsement of the project's results by the Ministry of Agriculture and CSA, the World Bank has agreed to include their use in the terms of reference for a large-scale survey to be commissioned in Oromia Region.

Technical reports describing the project's methodology and main results have been shared with stakeholders working on related issues in Kenya. UNIQUE is also supporting livestock GHG inventory improvements in Uganda, Zambia and Zimbabwe, and when those countries have produced initial Tier 2 livestock GHG inventories and are considering prioritization of data gaps and data quality improvements, UNIQUE will share this project's reports to ensure that stakeholders are aware of the value that method validation studies can have. The technical reports have also been shared with New Zealand Agricultural Greenhouse Gas Research Centre, which is leading a New Zealand-funded initiative on livestock GHG inventory improvement in Africa and Southeast Asia.

A scientific publication summarizing the approach and main findings of the project is under preparation, which will draw attention of the scientific community to the relevance and importance of improving methods for activity data collection.

9 Conclusions and recommendations

Based on the results presented in Tables 8 – 27, the following recommendations were suggested by stakeholders:

1. **Diet composition**
   - Diet composition for indigenous and crossbred cattle in the mixed crop-livestock system: Although there was no difference in diet composition and estimated DE (%) between Tool 1, Tool 2, Tool 3 and Tool 4, there are significant differences in diet utilized and estimated DE (%) between indigenous and crossbred cattle using those tools. Moreover, stakeholder evaluation (scoring) indicated that Tool 1 is excellent in terms of suitability in data collection, management and dissemination procedures for filling data gaps and enhancing MRV in Ethiopia, as well as in terms of addressing the existing data gaps in diet composition for crossbred dairy cattle compared to Tool 2, Tool 3 and Tool 4. Therefore, it is recommended that CSA questionnaire should collect diet composition data using Tool 1 for indigenous and crossbred cattle separately. This will improve GHG quantification for cattle given that the population of crossbred cattle is steadily increasing in Ethiopia.
   - Diet composition for crossbred cattle in the urban and peri-urban system: There were significant differences in diet composition and DE (%) of the diet estimated using annual data (Tool 3 and Tool 4) and seasonal data (Tool 5 and Tool 6). It was also highlighted that the seasonal DE (%) values were underestimated when using Tool 5 and Tool 6 compared to Tool 3 and Tool 4. Based on this study, it may not be worthwhile for CSA to adapt its existing questionnaire to separately capture dry and wet season diet composition. Moreover, according to stakeholder scoring, Tool 3 is excellent in terms of addressing existing data gaps in diet composition for crossbred dairy cattle, and cost-effectiveness compared to other tools. Although CSA doesn't currently conduct annual surveys on dairy cattle populations or diet composition in the urban and peri-urban areas and large commercial dairy and feedlot farms due to lack of a sampling frame in the large and small cities where these dairy farms are located, Tool 3 can be integrated with existing data collection systems when CSA starts to do surveys on these production systems.
   - Diet composition for crossbred cattle in the large commercial dairy and feedlot system: Although there were no significant differences in diet composition and estimated DE (%) between Tool 2 and Tool 7 in the large commercial dairy and feedlot farms, Tool 2 is excellent in terms of filling data gaps in these production systems. However, a dedicated survey to characterise the specific feed types within each feed category should be done to improve the default DE value applied to each main feed category in the inventory.
2. **Manure management**
   - The survey tool piloted is a feasible method to collect manure management data that can be used to estimate emissions.
   - Supplementary questions on the residence time in different manure management systems and additional manure management practices are useful for improving emission estimates.
   - The question on association between housing/flooring system and manure management systems suggests no strong associations between manure housing or flooring and manure management systems used. Therefore, housing/flooring type cannot be used as a proxy indicator for manure management system. Currently no official data on manure management system is being collected and manure management systems are not likely

to change rapidly. Therefore, activity data can be collected through a one-off representative sample survey using the tool piloted.

3. **Milk yield**
   - There was no significant difference in farmer recall and measured milk yield data. The milk yield data obtained through farmer recall (survey) requires less resources in terms of human resource, finance, material. Furthermore, the recall method had better synergy with existing CSA data collection system. Therefore, the recall data collection method is the best option for milk yield data in urban and peri-urban system.

In addition to these stakeholder recommendations, the researchers had the following reflections:

Stakeholder participation: Continued participation of multiple stakeholders on their needs and activities surrounding livestock data is necessary to ensure inclusion of the validated tools in data collection systems applied to different production systems.

Diet composition: The changes suggested in the alternative Tools (questionnaire) are considerably more detailed, as it now seeks information on seasonal feed usage types, quantities, and consumption by different sub-categories of cattle which are lacking in the existing CSA Tool (questionnaire). Therefore, the tools require closer attention to detail and a greater understanding of livestock production systems by enumerators and questioning needs to be systematically approached. Furthermore, although farmers benefited from additional tools like 10 grains to allocate to different feed types and white board containing the name of feed categories so that farmers easily answer the percentage of each, each category of the questionnaire was subject to limitations due to the fact of being based on farmer recall and the researchers observed farmers were struggling to recall diet offered during wet and dry season as well as farmers found it difficult to categorize each feedstuff into main feed category.

Manure management system: The researchers observed that during the survey time some farmers found it difficult to estimate the percentage of manure deposited in pasture during day-time. One option could be to ask about hours spent grazing and assume proportion of hours spent grazing is equal to the proportion of manure deposited on pasture. Furthermore, there were some missing values for supplementary questions on some manure management practices this is most likely due to that fact that farmers were asked to answer multiple questions on the similar topic.

Milk yield: Reliance upon farmer recall is more problematic, as a considerably greater degree of detail is required from the farmers (lactation stage, parity, etc). This method requires closer attention to detail and a greater understanding of production and productivity factors, as well as some skill and experience of the interviewer. On the other hand, an evaluation of the value for resources to implement milk measurement would include consideration of farmer self-recording using calibrated containers rather than enumerator-recording, due to the costs of travel and manpower associated with the latter.

There is strong demand for improved livestock activity data in many African countries. This data can support improved GHG inventories and MRV of climate policies and measures, as well as meeting livestock sector stakeholders' other needs for accessible, good quality data. While there is a clear need to support collection of more data, there are also needs to better understand the effectiveness of different data collection methods targeted for use by different stakeholders and for different purposes.

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10.2 List of publications produced by project

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Wassie SE, Tadesse M, Baker D, Wilkes A, Solomon D. 2021c. Piloting innovations for improved data collection and management to support livestock monitoring, reporting, and verification of greenhouse gas emissions in Ethiopia. Addis Ababa, Ethiopia: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://cgspace.cgiar.org/handle/10568/116277

11 Appendixes

11.1 Appendix 1: Data collection tools

Questionnaire for Mixed System Household Pilot Survey

Area Identification

Region		Zone		Woreda		Kebele		Household ID
Name	Code	Name	Code	Name	Code	Name	Code	

Interview Status

A1. Household Head Name		
A2. Respondent Name		
A3. Mobile Number		
A4. Interviewer Name and Code (Name/Code)		
A5. Date of Interview (DD/MM/YYYY)		
A6. Time Interview Started (HH:MM)		
A7. Time Interview Ended (HH:MM)		

Herd composition

1. How many local and cross-bred/exotic are cattle kept and owned by the household? (Include calves, heifers or steers, and mature animals, male and female). 1=PB/XB 2= Local

Code	Animal type	Head Count		Total
		1=PB/XB	2= Local	
21	Bulls (>3 years).			
22	Castrated adult males (oxen>3 years).			
23	growing males (< 3 years).			
24	Cows (calved at least once not lactating)			
25	Cow (lactating).			
26	Female calves (between 6 months & <1 year).			
27	Male calves (between 6 months & <1 year)			
28	Heifers (female ≥ 3 year, have not calved)			
	Heifers (female ≥ 3 year, pregnant)			
29	Pre weaning females (<6 months)			
210	Pre weaning males (<6 months)			

Tool 1: Feeding practice in the last 12 months (mixed crop-livestock farms)

1. What types of feed provided to your cattle during last one year?

	Type of livestock feed	No	Utilized Yes=1, No=2	No	Percent from the total feed utilized	No	sources of feed (Code)
1	Feed type provided to dual indigenous cattle						
	Green fodder/grazing						
	Crop residue						
	Improved feed (grass and Legume)						
	Hay						
	Agro-industrial by products						
	Others						
			Total		100%		
2	Feed type provided to crossbred dairy cattle						
	Green fodder/grazing						
	Crop residue						
	Improved feed (grass and Legume)						
	Hay						
	Agro-industrial by products						
	Others						
			Total		100%		

Coding:
1=own holding
2=purchased
3=communal holding
4= 1&2
5=1&3
6=2&3
7=1,2 & 3
8=others

Tool 2 Feeding practice during the wet and dry season for the last 12 months (mixed crop-livestock farms)

2. In your area, which months are considered 'dry season' and which months are considered 'wet season'? (Enumerator: put a tick in the appropriate box for each season)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2a	Dry season												
2b	Wet season												

3. Feed types provided to cattle during dry and wet season

		Dry Season				Wet season					Source
	Feed type	No	Utilized Yes=1, No=2	No	Percent from Total feed	No	Utilized Yes=1, No=2	No	Percent from Total feed)	No	Source of feed (Code)
1	Indigenous cattle feed types in dry and wet season										
	Green fodder/grazing										
	Crop residue										
	Improved feed										
	Hay										
	Agro-industrial by products										
	Others specify										
				Total	**100%**			**Total**	**100%**		

2		Crossbred dairy cattle feed type during dry and wet seasons									
		Dry season				Wet season				Source of feed	
		No	Utilized Yes=1, No=2	No	Percent from Total feed)	No	Utilized Yes=1, No=2	No	Percent from Total feed)	No	Code
	Green fodder/grazing										
	Crop residue										
	Improved feed										
	Hay										
	Agro-industrial by products										
	Others										
				Total	**100%**			**Total**	**100%**		

Code
1=own holding
2=purchased
3=communal holding
4= 1&2
5=1&3
6=2&3
7=1,2 & 3
8=others

Tool 3. Feed types provided to different animal sub-categories (mixed crop-livestock and urban and peri-urban dairy farms)

1	**Feed type provided to Indigenous cattle by age**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Others														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

2	**Feed type provided to crossbreed cattle by age**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Other														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

Tool 4. Feed types provided to different animal sub-categories (mixed crop-livestock and urban and peri-urban dairy farms)

1	**Feed type provided to Indigenous cattle by age**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage	111D		112D		113D		114D		115D		116D		117D	
	Concentrate supp														
	Agro-industrial by prod														

	Others														
	Mineral supplement														
	Salt														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

2	**Feed type provided to crossbreed cattle by age**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Other														

	Mineral supplement														
	Salt														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

Please use the following codes to fill feed sources in the above table

Grass hay	**Crop residue**	**Improved forage**	**Concentrate**	**Agro-industrial by-products**	**Others**
Rhodes grass hay	Teff straw	Grass-Legume mixture	Commercial concentrate	noug seed cakes	Enset leaves
Setaria spp	Wheat straw	Napier grass	home-made concentrate	Wheat bran,	Banana leave
Pennisetum spp	Barley straw	Alfalfa		Wheat middling,	Sweet potato leaves/ tuber
Brachiaria spp	Pulse straw	Brachiaria		Linseed cake	crop stand thinning (Maize and sorghum)
Oat hay	Maize stover	Clover		Bean hulls	By products from local Beverage
Oat-Vetch	Sorghum stover	Oat and vetch		Molasses	Household left-over
	other straw			Brewer's waste	Others
				Sunflower cake	
				Cottonseed meal	

Tool 5 Cattle feed practices (feed category) in the wet/dry season by cattle type (in urban and peri-urban dairy farms).

1. **In your area, which months are considered 'dry season' and which months are considered 'wet season'?** (Enumerator: put a tick in the appropriate box for each season)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2a	Dry season												
2b	Wet season												

Feed types provided to different animal sub-categories in the dry season

1	**Feed type provided to crossbreed cattle by age in the dry season**														
			Lact ating cows		Dry cows		Growin g and young cattle Heifers		Drau ght oxen		Bree ding bulls		Growi ng/ young males		Calves < 1yea
			% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Other														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

2	**Feed types provided to different animal sub-categories in the wet season**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Other														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

Tool 6. Feed types provided to different animal sub-categories in the wet and dry season (urban and peri-urban dairy farms).

1	**Wet season**														
			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														

	Others														
	Mineral supplement														
	Salt														
	Total;		100%		100 %		100%		100 %		100 %		100%		100%

If commercial or homemade concentrate, what are the ingredients? What proportion?

			Lactating cows		Dry cows		Growing and young cattle Heifers		Draught oxen		Breeding bulls		Growing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet		% of total diet
2	**Dry season**														
	Natural grazing														
	Grass hay														
	Crop residue														
	Improved forage														
	Concentrate supp														
	Agro-industrial by prod														
	Other														

	Mineral supplement														
	Salt														
	Total;		100 %		100 %		100%		100 %		100 %		100%		100%

Please use the following codes to fill feed sources in the above table

Grass hay	**Crop residue**	**Improved forage**	**Concentrate**	**Agro-industrial by-products**	**Others**
Rhodes grass hay	Teff straw	Grass-Legume mixture	Commercial concentrate	noug seed cakes	Enset leaves
Setaria spp	Wheat straw	Napier grass	home-made concentrate	Wheat bran,	Banana leave
Pennisetum spp	Barley straw	Alfalfa		Wheat middling,	Sweet potato leaves/ tuber
Brachiaria spp	Pulse straw	Brachiaria		Linseed cake	crop stand thinning (Maize and sorghum)
Oat hay	Maize stover	Clover		Bean hulls	By products from local Beverage
Oat-Vetch	Sorghum stover	Oat and vetch		Molasses	Household left-over
	other straw			Brewer's waste	Others
				Sunflower cake	
				Cottonseed meal	

Tool 7. Feed types provided to the herd in the wet and dry season (large commercial dairy and feedlot farms)

		Dry Season				Wet season					Source
	Feed type	No	Utilized Yes=1, No=2	No	Percent from Total feed	No	Utilized Yes=1, No=2	No	Percent from Total feed)	No	Source of feed (Code)
	Green fodder/grazing										
	Grass hay										
	Crop residue										
	Improved feed										
	Concentrate supp										
	Agro-industrial by products										
	Others										

	Mineral supplement										
				Total	**100%**			**Total**	**100%**		

Code
1=own holding
2=purchased
3=communal holding
4= 1&2
5=1&3
6=2&3
7=1,2 & 3
8=others

Please use the following codes to fill feed sources in the above table

Code	**Grass hay**		**Crop residue**		**Improved forage**		**Concentrate**		**Agro-industrial by-products**	Code	**Others**
21	Rhodes grass hay	31	Teff straw	41	Grass-Legume mixture	51	Commercial concentrate	61	noug seed cakes	71	Enset leaves
22	Setaria spp	32	Wheat straw	42	Napier grass	52	home-made concentrate	62	Wheat bran,	72	Banana leave
23	Pennisetum spp	33	Barley straw	43	Alfalfa			63	Wheat middling,	73	Sweet potato leaves/ tuber
24	Brachiaria spp	34	Pulse straw	44	Brachiaria			64	Linseed cake	74	crop stand thinning (Maize and sorghum)
25	Oat hay	35	Maize stover	45	Clover			65	Bean hulls	75	By products from local Beverage
26	Oat-Vetch	36	Sorghum stover	46	Oat and vetch			66	Molasses	76	Household left-over
		37	other straw					67	Brewer's waste		Others
								68	Sunflower cake		
								69	Cottonseed meal		
									Others		

Milk yield

Recall estimate of milk yield data for lactating cow.

Tag Nr.	Currently lactating cows or recently dry off cows	In current or last lactation, * total milk yield per day (morning plus evening) in liters		Number of days in milk/ lactation length	If this is not the first calving, number of months dry between last lactation and calving date	If this is not the first calving, calving interval before last calving (in months) (Calving interval)
		Maximum yield (e.g., peak yield after calving)	Minimum yield since calving			

Milk yield measurement: two consecutive days for each farm

Tag Nr.	Early/mid/late	Morning milk (liter)	Evening milk (litre)

Manure management system

1. Housing system

1 a. Housing type used for cattle

1) No enclosure, no roof
2) Encloser but no roof
3) Encloser with roof and without walls
4) closed, with roof and walls

1 b. House flooring types

1) Dirt
2) Wooden
3) Stone layer
4) Concrete

1 c. Are cattle housed only at night (=1) or are they housed all the time (=2)

1 d. is the cattle housing cleaned using water that makes slurry? (Yes=1, no=2)

1 e. is the cattle exercise yard cleaned using water that makes slurry? (Yes=1, no=2)

2. Can you tell me what % of cattle manure is used in different ways in the dry and wet seasons? (999 if respondent refuses or doesn't know)

MMs		Dry season (enter % for each use)		Wet season (enter % for each use)
Left where deposited on pasture				
Collected and spread on pasture or crops the same day				
Left in the area where cows are kept				
Stored in a pit				
Collected and stored in piles for several months before use (after collecting no tun or mix manure)				
Composted (piles with turn and mixing)				
Stored as a liquid or slurry				
Biodigester				
Collected fresh manure dried and sold or burnt for fuel				
Collect dried one and burn for fuel				
		Total should be 100%		**Total should be 100%**

3. If the manure left in the area where cows are kept,

3 a. How many days is it left before cleaning? -----------------------days

3 b. how is it stored or used after cleaning? Code C -----------------------------------

4. If stored in piles,

4 a. how many days is it left before storing in a pile? --------------------------------days

4 b. is the pile covered or uncovered? (Covered =1, uncovered =2) --------------------

4 c. How many months is it stored in the pile? ----------------------------------months

4 d. How is it stored or used after it has been in the pile? Code C ---------------------------

5. If composted,

5 a. Do you turn over or aerate the compost? (Yes=1, no=2) ----------------

5 b. How many months is the manure composted for? ------------------------months

5 c. How is it stored or used after it has composted? Code C ---

6. If stored as a liquid or slurry,

6 a. how many months is it stored as a liquid? --------------------------------months

6 b. does a crust form on the top of the liquid? Yes=1, no=2-------------------

6 c. How is it stored or used after that? Code C --------------------------

Code C	
1	spread on pasture or crops
2	stored in piles for several months before use
3	Stored in a pit
4	Composted
4	Biodigester
5	burnt for fuel
6	Sold
7	Other (disposed of outside the farm)