RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

Piloting innovations for improved data collection and management to support livestock monitoring, reporting, and verification (MRV) of greenhouse gas emissions in Ethiopia

October 2021

Shimels Eshete
Million Tadesse
Derek Baker
Andreas Wilkes
Dawit Solomon

Piloting innovations for improved data collection and management to support livestock monitoring, reporting, and verification (MRV) of greenhouse gas emissions in Ethiopia

Technical Report

CGIAR Research Program on Climate Change

Shimels Eshete
Million Tadesse
Derek Baker
Andreas Wilkes
Dawit Solomon

Citation:

Wassie SE, Million T., Baker D., Wilkes A, Solomon D. 2021. *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).

Authors

Shimels Eshete Wassie (UNIQUE forestry and land use GmbH, Germany)

Million Tadesse (Holeta Agricultural Research Centre, Ethiopian Institute for Agricultural Research, Ethiopia)

Derek Baker (University of New England's Centre for Agribusiness, Australia)

Andreas Wilkes (UNIQUE forestry and land use, Germany)

Dawit Solomon (CCAFS)

Acknowledgements:

"This work was supported by a grant from the Australian Centre for International Agricultural Research (ACIAR) Grant ACI029 and was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. The authors would like to sincerely thank Ali Abdulhakim and Mustefa Abu who have been instrumental during data collection. For details, please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinions of these organizations."

Contact:

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), East Africa. P.O. Box 5689. Addis Ababa, Ethiopia | Phone: +251-11 617 2000 | Fax: +251-11 617 2001 | Email: ccafsea@cgiar.org | Website: http://ccafs.cgiar.org/regions/east-africa

Contents

Tables

Figures

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BAU	Business-As-Usual
BUR	Biennial Update Report
CCAFS	Climate Change Agriculture and Food Security program of the CGIAR
CRGE	Climate-Resilient Green Economy
CSA	Central Statistical Agency
DE	Digestible energy
EFCCC	Environment, Forestry and Climate Change Commission
ECCD	Environment and Climate Change Directorate
GHG	greenhouse gas
GTP	Growth Transformation plan
LMP	livestock master plan
ME	Metabolizable energy
MMS	manure management system
MRV	measurement, reporting and verification
Mt	million metric tonnes
NC	National communication
NDC	Nationally Determined Contribution
SRA	Small Research Activity
UNE	University of New England's Centre for Agribusiness, Australia
UNFCCC	United Nations Framework Convention on Climate Change

Summary

To complement an ongoing CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) project 'Enhancing capacities for MRV of sustainable livestock action in East Africa (Kenya and Ethiopia),' which is implemented by UNIQUE forestry and land use and CCAFS, the Australian Centre for International Agricultural Research (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 gas (GHG) emissions in Ethiopia. This report summarizes the rationale for and overall design of the pilot activities, pilot results, stakeholders' evaluations of the tools tested, and recommendations for adoption of positively evaluated tools.

Section 1 explains the rationale for piloting tools to collect livestock activity data in the Ethiopian context. Ethiopia has identified livestock as a key sub-sector for GHG mitigation. An advanced livestock GHG inventory has been compiled using the Tier 2 method. However, some gaps remain in terms of data availability and data quality. The pilot activities were designed to fill those gaps, and thus enable Ethiopia to better quantify livestock GHG emissions and emission reductions in line with its national commitments on climate change.

Section 2 describes the design of the pilot activities. The Tier 2 GHG inventory uses annual sample surveys from Central Statistics Agency (CSA) for data on many variables. Some tools were tested to see if they would lead to improvements in CSA data collection methods for the purpose of the GHG inventory. Some data gaps in the GHG inventory require specialist knowledge and tools and they were tested for data collection by staff of the Ministry of Agriculture or other stakeholders with technical backgrounds. In addition to data collection, data management and communication are key to ensuring that the data is available to those who can make use of it. A further pilot involved the Ethiopian Institute for Agricultural Research (EIAR) in analysis and communication of data.

Section 3 summarizes the results of the pilot activities on diet composition, manure management, milk yield including stakeholders' evaluation of different data collection tools and data management activities. In addition to the accuracy of different data collection tools, stakeholders evaluated the tools tested in relation to other criteria such as cost-effectiveness and ease of adoption within existing data management systems.

Section 4 highlights key recommendations for the adoption of the tools and data management activities evaluated by stakeholders. Some tools can be readily adopted by existing actors in existing data management systems. Other tools were positively evaluated but further discussion is needed to clarify the roles and responsibilities for their use. The tools tested can also be used by other stakeholders, such as the Oromia Forested Landscape Programme. This section ends with some reflections on the piloting process from the project team, which may provide some guidance for future piloting of MRV innovations elsewhere in East Africa.

1 Origin of the livestock activity data pilot activities in Ethiopia

1.1Ethiopia'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.[2] 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. 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 10-Year Development Plan. 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).

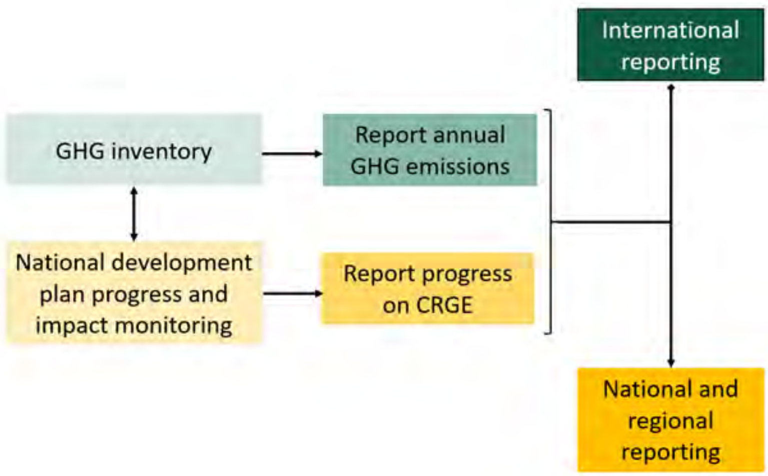


Figure 1: Schematic overview of Ethiopia's MRV needs

Source: This study.

[1] https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf#page=18
[2] https://www.undp.org/content/dam/ethiopia/docs/Ethiopia%20CRGE.pdf

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 carbon 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 study based on CRGE Strategy.

Mitigation actions: Ethiopia's strategy for climate change action is the CRGE Strategy.[3] The CRGE Strategy was issued in 2011 and has not been updated since. The CRGE Strategy aims to have the country achieve middle-income status by 2025 in a climate-resilient green economy. The CRGE Strategy forms the basis for Ethiopia's NDC.[4] The CRGE Strategy identifies priority sectors and priority interventions in those sectors. Interventions were screened for both mitigation and adaption benefits with the intention that mitigation actions implemented would also strengthen Ethiopia's climate resilience.

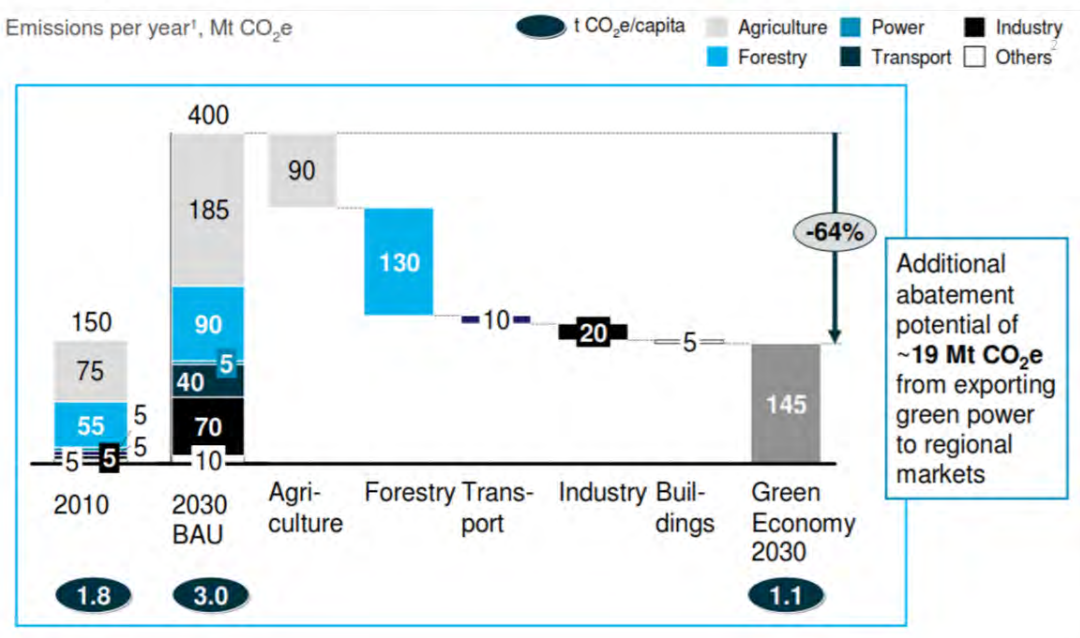
The livestock sector has been identified as one of the priority sectors in the CRGE.[5] Within the livestock sector, four main intervention areas were identified in the CRGE (see Table 1 and Box 1). The CRGE Strategy has been mainstreamed into the national development plan, the Growth and Transformation Plan (2016-2020, [GTP II]) and will most likely be integrated with the upcoming 10-year Perspective Development Plan. Building a climate-resilient green economy is one pillar of the GTP II. The monitoring matrix for GTP II includes the indicators to monitor progress in implementing and achieving the CRGE targets.[6] The CRGE indicators related to the intervention areas above 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.

[3] https://www.undp.org/content/dam/ethiopia/docs/Ethiopia%20CRGE.pdf
[4] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ethiopia%20First/INDC-Ethiopia-100615.pdf
[5] The priority sectors are agriculture, forestry, energy and transport.
[6] https://www.cmpethiopia.org/media/gtp_ii_policy_matrix_english_final_august_2016_2

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 assumes 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 business-as-usual (BAU) projections in 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: Ethiopia's First NDC

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;[7]

• 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;[8]

• 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: CRGE Strategy

---

[7] Note that although sheep and goat fattening also occurs, they were not included in the CRGE scenario analysis.
[8] Note that although sheep and goats are also sometimes referred to as low-mitting species, they were not included in the CRGE scenario analysis.

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.

Updated NDC commitments:

The 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 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 CO2e) of the livestock sector compared to the first NDC (124 Mt CO2e). The level of ambition communicated through this updated NDC indicate that the 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, the livestock master plan (LMP), the 10YDP, and the CRGE strategy, have identified optimal policy interventions in the sector. According to the new or 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

1.2 MRV systems in Ethiopia’s livestock sector

1.2.1 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).[9] The inventory estimates GHG emissions from cattle, sheep and goats from 1994 to 2018.

1.2.2 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 the 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 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, mixed crop-livestock and pastoral / agro-pastoral systems). This method can use the same data sources as the Tier 2 GHG inventory for livestock; ii) calculate the total amount of livestock products produced. For milk, this was calculated from the Tier 2 inventory (excluding milk suckled by calves) and for meat, this was calculated using data from CSA on numbers of cattle sold and slaughtered. Furthermore, large-scale regional and national projects (LFSDP[10] and OFLP[11]) 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.

1.3 Data needs and data gaps for livestock MRV

1.3.1 GHG inventory data needs

Based on the Tier 2 inventory, 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, an inventory can be 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 can be where national data quality is

[9] https://cgspace.cgiar.org/bitstream/handle/10568/110982/Ethiopia%20Tier%202%20Inventory%20Final%20Version.pdf
[10] Livestock and Fishery Sector Development Project
[11] Oromia Forested Landscape Project

limited. Future improvements in data availability would then provide new, improved data and the GHG inventory can be revised accordingly, as stipulated in the IPCC (2006) Guidelines.[12]

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

1.3.2 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 CRGE 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 CRGE 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

[12] See IPCC (2006) Vol 1 Chapter 5 on recalculations due to methodological revisions or refinements.

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 such as diet composition, manure management, milk yield in the mixed crop-livestock, urban and peri-urban and large commercial dairy and feedlot system are also data requirements for the CRGE-MRV system. These highlight the need to develop innovations for improved data collection and management to improve both GHG inventory and CRGE-MRV system. Accordingly, UNE-CCAFS-UNIQUE consortium has developed five innovations for piloting filling the data gaps and improving data quality in the mixed crop-livestock, urban and peri-urban, commercial dairy and feedlot sectors.

2 Design of pilot activities to improve livestock MRV

2.1 Rationale and goals

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

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

These motivation maps data gaps (outlined in the previous section) to stakeholders' needs are shown in Figure 2.

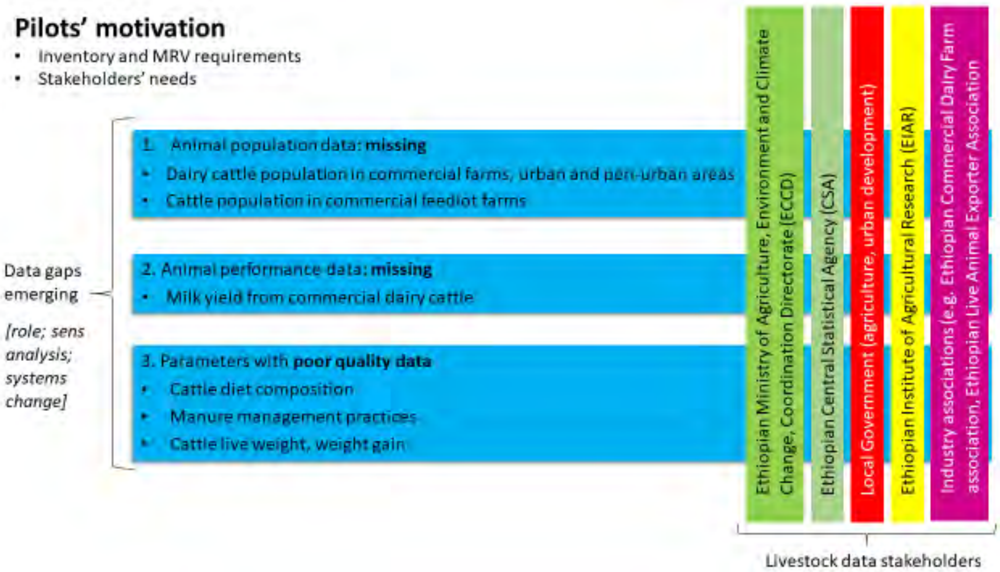


Figure 2. Motivation for pilots

The goals of the pilot program were 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.

2.2The data collection environment

2.2.1 Stakeholders

The key stakeholders in the data collection environment are the:

- 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. the Ethiopian Commercial Dairy Farm Association, the Ethiopian Live Animal Exporter Association)

The roles and interests of these stakeholders are elaborated in Section 2.3 below.

2.2.2 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 associated 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 trialed 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 incorporated these data and tested methods for their collection.

2.2.3 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 (AI). 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.

2.2.4 Human resource issues

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

2.3Opportunities identified with stakeholders

2.3.1 Central Statistics Agency

The CSA expressed interest in several of the data gaps identified. The agency 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 trialing new data collection and analysis methods. The CSA has staff located at kebele level and a supervision infrastructure in place. It has well-established sampling frames and procedures in mixed rural areas and has extensive experience in training enumerators.

2.3.2 Environment and Climate Change, Coordination Directorate

The ECCD has an existing hierarchy and data aggregation system used to handle administrative data, including direct links to local government. It is overall responsible for GHG inventory and livestock MRV, and so has substantial interest in improved production and productivity data.

2.3.3 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.

2.3.4 Ethiopian Institute of Agricultural Research

The EIAR is an experienced research partner whose staff possess analytical skills for use on the pilot data. Its role includes disseminating research outputs to the private and public sectors.

2.3.5 Industry associations

Industry associations are in constant touch with members that would form a part of the sampling base for large farms, which are not well addressed in the CSA's sampling procedures. The associations have 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.

2.4Pilot designs

2.4.1 Priorities identified for pilots

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

- Feed digestibility: feed type, percent 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).

2.4.2 Description of pilots

The pilots were tested from 7 December 2020 – 7 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 (Figure 3).

Figure 3. Farmers interview by enumerators (Shimels E. Wassie).

Table 6. Number of kebeles 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 and peri-urban system, and large commercial dairy and feedlot farms.

Farmers were 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 and 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 digestible energy (DE) (%) of feed for animal subcategory 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 six different categories of forage, fodder and feed. The categories of feed are:

1. green fodder obtained by grazing,
2. crop residue: harvested by-products (straw and chaff of cereals and pulses, etc.),
3. improved feed (e.g. oat or alfalfa),
4. hay includes any type of grass, clover etc. cut and dried as fodder,
5. industrial by-products are oil cakes (e.g. noug cake, sunflower cake, etc.), bran, and brewery residue, and
6. others (non-conventional feedstuffs).

However, data collection tools currently used by the 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 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 (see Appendixes):

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 type: 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 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 values of each feedstuff was estimated using metabolizable energy content of feedstuffs (Wilkes et al., 2020)[13]. In general, after data on diet composition was calculated, expert judgment was used to allocate specific feedstuffs to the six main feed components. The list of feedstuffs with their respective chemical composition and nutritive values including digestible energy (DE) and metabolizable energy (ME) was taken from the national feed database (Ethiopian Institute of Agricultural Research, 2007) which contains more than 200 samples from six agro-ecological regions of the country. Feed energy digestibility (DE, %) as a percentage of gross energy values of each feedstuff was estimated using the following equations from CSIRO (2007): DE (%) = Digestible energy (DE, MJ)/18.4, and DE (MJ) = Metabolizable energy (ME MJ)/0.81.

[13] Wilkes, A., Wassie, S.E., Tadesse, M., Assefa, B., Abu, M., Ketema, A. Solomon, D., 2020. Inventory of greenhouse gas emissions from cattle, sheep, and goats in Ethiopia (1994-2018) calculated using the IPCC Tier 2 approach. Environment and Climate Change Directorate of the Ministry of Agriculture, Addis Ababa. Ethiopia. https://hdl.handle.net/10568/110982.

Pilot 2

The national GHG inventory also identified a lack of data on manure management, milk yield and live weight 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 live weight from commercial dairy farms and urban and peri-urban dairy farms. Furthermore, no official data sources collect data on manure management. Therefore, Pilot 2's aim was to test a data collection tool for manure management, milk yield, and live weight activity data. These data gaps (e.g. milk yield, live weight, manure management) are aligned with Ministry of Agriculture's interests and existing responsibilities, and the pilot activities were managed by that ministry.

Manure management system: A tool was tested to estimate the fraction 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) Fraction (%) 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).

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 (i.e. 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 GTPII, 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 supports and trials engagement of data collection and analysis with users.

The pilot activities, novelty and functions in capacity building and dissemination are presented in Figure 4.

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 Red Meat Feedlots: animal numbers Urban Dairy; Feedlot; mixed crop-livestock: Manure management systems Urban Dairy; Feedlot; mixed crop-livestock: Feed digestibility (DE) Feed types allocated to herd structure	Urban Dairy: milk production and liveweight Urban Red Meat Feedlots: liveweight Mixed crop and livestock: liveweight	Synthesis of animal numbers Synthesis of herd structure Recommendations for use of pilot results in CSA systems Recommendations for use of pilot data in collaboration on MRV	Synthesis of liveweight measures Synthesis of milk production measures Synthesis of manure production and treatment Synthesis of allocation of feed to animal types	Use of performance information Recommendations for use of pilot results in Min Agr systems Recommendations for use of pilot results in MRV Communication of results to industry Associations and other interested groups 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

Figure 4. Detail of pilots (Shimels E. Wassie).

2.4.3 Stakeholders' engagement with pilots

Detail of engagement of stakeholders in pilots is presented in Figure 5.

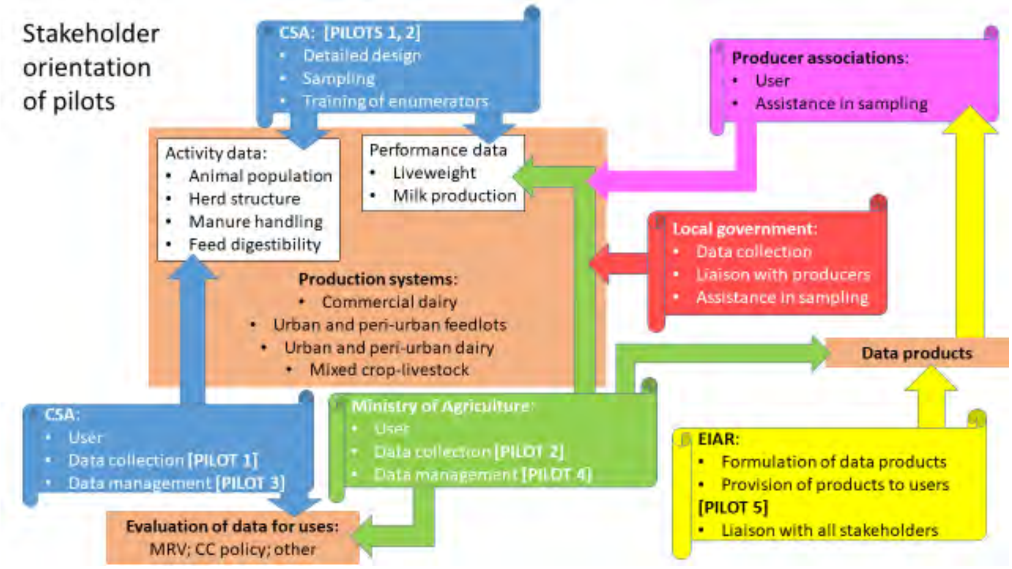


Figure 5. Stakeholders' roles in pilots (Shimels E. Wassie)

3 Pilot activity results

3.1 Descriptive results of each survey tool piloted

3.1.1 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 and pure exotic males (3 years old and above) 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 systems where crop farming is an essential part of agricultural production (Table 7).

Figure 6. Animal's barn (Shimels E. Wassie).

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

Sub-category	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 years old and above)	63.88	74.38	72.58
Adult crossbred and pure exotic males (3 years old and above)	16.69	0.93	3.71
Crossbred and pure exotic calves (<6 months old) male and female	4.64	4.28	5.27
Crossbred and pure exotic calves (6 m - < 1 year old) male and female	4.64	4.28	5.27
Crossbred and pure exotic growing males (1 - < 3 years old)	3.91	5.11	3.49
Crossbred & pure exotic growing females (1 -< 3 years old)	6.25	11.02	9.68

3.1.2 Diet composition

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.

Figure 7. Animal feed (Shimels E. Wassie).

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 diet composition and feed digestibility 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 crossbred cattle using Tool 1

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

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

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

When these diet components are 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 crossbred 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)
Crossbred	56.98^{A} (1.63)	57.15^{A} (0.44)
Tool 1: Z-statistic =5.96, P= 0.0001 (significance, two-tailed) Tool 2: Z- statistic =4.644, P= 0.0006 (significance, two-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?

However, 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. two-tailed) Crossbred cattle: Z statistic = 1.25, P = 0.2316 (sig. two-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 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 or 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 (sig.two-tailed) Indigenous cattle: Z statistic < 1.96, P > 0.05 (sig.two-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 the highest difference is 5.27% for 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

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 urban and peri-urban dairy farm system. Tool 3 essentially estimates the annual average diet composition for specific animal subcategories 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 crossbred cattle using Tool 3 and Tool 5.

	Grazing	Crop residue	Improved feed	Hay	Agro-industrial by-products	Concentrate	Other
Z statistics	-1.02	4.130	1.16	-0.81	-2.35	-0.91	-1.67
P (two-tailed 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 test 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 6 (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 have no effect on DE estimates. However, collecting diet composition data by season using Tool 5 and Tool 6 has 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^{A}	62.89^{A}
Z statistic	3.12	0.07	2.10	-0.12
P-value (2 tail sign)	0.0001	0.4681	0.09	0.46

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

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 ($P < 0.05$)

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.**

Figure 8. Commercial feedlot (Shimels E. Wassie).

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 two tail)		

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

3.1.3 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	Dry lot
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 in the mixed crop-livestock system 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 and urine on pasture	22.7%	2.0%	5.9%	0.0%
2	Daily spread	14.2%	5.5%	2.6%	23.3%
3	Dry lot	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 burned for fuel	17.3%	22.0%	23.9%	5.4%
10	Collect fresh, dried and burned 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?

MMS data for solid storage, liquid storage and composted were taken separately as dependant variables while housing type and flooring types (Table 24) were taken as class variables in a logistic regression model in SAS to see if there were any significant associations among these variables (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 tends to use solid storage (P = 0.0002, Table 23).

Figure 9. Manure management (Shimels E. Wassie).

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 either dry lot, solid storage, composting or 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).

Dry lot storage system/ left where animal kept

Urban and peri urban dairy farm: about 3.3% of manure was left where cattle kept (dry lot). It was found that 4 households reporting this management left it for an average of 7.25 days after which one household spread on pasture and the other 3 households disposed of outside the farm. Therefore, the MCF from this source was adjusted for residence time as (7.25/365) * 2= 0.040.

Mixed crop livestock farm: about 1.38% of manure was left where cattle are kept (dry lot) by 6 households who left it for an average of 3.30 days, after which 5 households spread on pasture or crop land and 1 household stored it in a pit. No adjustment was made for the latter one, because only one household adopted it. Therefore, the MCF from this source was adjusted for residence time as ((3.30* 2)) + (365-3.30) *0))/365= 0.018.

Large commercial feedlot farms: about 18.92% of manure was left where cattle were kept (dry lot). It was found that 7 farms reporting using this management system for an average of 90 days after which one farm spread manure on pasture or crop land and 6 farms disposed of it outside the farm and 1 farm composted it. No adjustment was made for the latter one, because only one household adopted it. Therefore, the MCF from this source was adjusted for residence time as (90/365) *2=0.49.

Solid storage system

Urban and peri-urban production system: about 29.36% of manure in urban and peri-urban system was stored using pile storage system by 42 households for an average of 102.9 days, after which 5 households spread on pasture or crop land, 7 households burned it for fuel, 7 households sold it and the other 17 households disposed of it outside the farm, and 2 households then composted it. Therefore, the MCF from this source was adjusted for residence time as ((103*5) + ((365-103) *0))/365=1.41.

Mixed crop-livestock system: about 17.47% of manure in mixed crop-livestock system was stored using solid or pile storage system by 63 households for an average of 141.9 days, after which 24 households spread it on pasture or crop land, 15 households stored it in piles for several months, 13 households composted it, 5 households burnt it for fuel, 2 households sold it, 3 households disposed of it outside the farm and 1 household stored it in a pit. Therefore, the MCF from this source adjusted for residence time as ((141.9 * 5%) + ((365-141.9) *2.5%)) /365= 3.47.

Large commercial dairy cattle farm: about 38.90% of manure was managed using solid storage system by 19 farms for an average of 116.7 days, after which 2 farms composted it, 2 farms stored it in a pile for several months, 5 farms sold it and 9 disposed of it outside the farm. Therefore, the MCF from this source was adjusted for residence time as ((116.7 *5%) + ((365-116.7) * 2.5%))/365= 1.599.

Large commercial feedlot farm: about 25.76% of manure was managed in solid or pile storage system by 15 farms for an average of 188.1 days, after which 11 farms spread it on pasture or crop land and 4 sold it. Therefore, the MCF from this source was adjusted for residence time as ((188.1* 5%) + ((365-188.1) *0))/365= 2.577.

Figure 10. Manure management (Shimels E. Wassie).

Composting

Urban peri-urban dairy farms: about 4.74% of manure was managed as compost by 9 farms for a period of 159.9 days after which 5 farms spread it on pasture or crop land, 1 farm burnt it for fuel and 1 farm disposed of it outside the farm. Therefore, the MCF from this source was adjusted for residence time as ((159.9* 2.5) +((365-159.9) *0))/365=1.095.

Mixed crop-livestock farms: about 4.21% of manure was stored as compost by 22 households for a period of 150 days after which 19 farms spread it on pasture or crop land, 2 farms composted it, and 1 household stored it in piles for several months. No adjustment was made for the latter because of only one farm adopted this method. Therefore, the MCF from this source was adjusted for residence time as ((150* 2.5%)) + ((365-150) *0))/365= 1.03.

Large commercial dairy farms: about 4.08% of manure stored as compost by 3 farms for an average of 200.1 days, after which 2 farms spread it on pasture and 1 farm sold it. Therefore, the MCF from this source was adjusted for residence time as ((200.1 * 2.5%)) +((365-200.1) * 0))/365=1.37.

Commercial feedlot farms: about 2.26% of manure was stored as compost by 3 farms for a period of 90 days. Therefore, the MCF from this source adjusted for residence time as ((90* 2.5%)) +((365-90) *0))/365= 0.6164.

Liquid storage system

Urban and peri-urban farms: about 18.09% of manure was stored in a liquid storage system (pit plus slurry storge system) by 8 farms for an average of 221.4 days, after which 1 farm stored it in piles for several months before use, 4 farms stored it in a liquid or pit storage system for a long time, 2 farms disposed of it outside the farm and 1 farm composted it. No adjustment was made for the latter one, but adjustment was made by changing MCF-liquid storage from the IPCC default value of 80% (for 12 months storage) to 73% (6 months storage).

Mixed crop-livestock system: about 13.74% of manure was stored in a liquid storage system for an average of 7 months by one household. The MCF for liquid storage in the mixed crop-livestock system was changed from the IPCC default value for 12 months (i.e. 80%) to the 6-month value of 73%.

Large commercial dairy farms: about 19.31% of manure was stored in a liquid storage system by 3 farms for an average of 159.9 days, after which 1 farm spread it on pasture and 2 farms stored it in a pit storage system. The MCF for this source in commercial dairy was changed from IPCC default value for 12 months (i.e. 80%) to the 4 months value (i.e. 64%).

Large commercial feedlot system: about 19.44% of manure was stored in a liquid storage system by one farm for an average of 30 days after which it was spread on pasture. The MCF for this source was changed from the 12 months IPCC default value (i.e. 80%) to the one-month value (i.e. 36%).

Table 26 summarizes the effects of resident time at different manure management system on emission factors. The results indicate that as a result of the four 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 dry lot	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%

3.1.4 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 Wilkes et al. (2020), see Annex 3.

Figure 11. Milk yield measurement (Shimels E. Wassie).

Energy requirements of calf's estimates is based on metabolizable energy for maintenance and growth as follows. Metabolizable energy (Mcal) = $(0.1*(LW^{0.75})) + (((0.84*(LW^{0.355})) * (LWG^{1.2})))$ where LW is average live weight of a calf between birth and weaning, and LWG is live weight gain of calf before weaning (kg day^{-1}). The LW (70.70 kg) and LWG (0.362), calving rate (71.9%), lactation length (325 days) values were obtained from the national GHG inventory. Then the estimated calf milk consumption (3.56 Mcal), was converted into 5.31 kg day^{-1} based on assumed metabolizable energy (5.37 Mcal kg^{-1} DM^{-1}) and dry matter (12.5%) content of milk (NRC 2001). The estimated milk consumption (5.31 kg day^{-1}) was converted into annual average daily milk yield (i.e. average over 365 days) by assuming the calves are weaned at 90 days, so the kg milk consumption required by calves is multiplied by (90/365), resulting in estimated calf milk consumption of 1.31 kg/day. With a calving rate of 0.719, 1.31kg/day was then multiplied by 0.7191, i.e. = 1.20 kg/day. Cow milk yield was then calculated as the sum of milk offtake and estimated calf milk consumption, for measured milk yield it was= 9.56 kg/day and for reported milk yield =8.34 kg/day.

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 yield (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.

3.2Stakeholder evaluations of pilot tests and comparisons

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 innovations to support the effective operation of an improved livestock MRV system in Ethiopia. Furthermore, the results of pilot tests were evaluated against set criteria. The criteria list primarily consists of features important in suitability for filling data gaps, alignment, and potential for improving the existing CSA data collection tool.

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 tests results confirmed that there were no significant difference 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 system.

Mixed crop-livestock

Mixed crop-livestock	DE (%)			
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 and 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	DE (%)			
	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 and DE data	5	3	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
Sub-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	**44**	**42**	**41**	**40**

Commercial dairy/feed lot

Commercial dairy/feed lot	DE (%)	
	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 and 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

Urbana and peri-urban farms	Milk yield	
	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**

4 Recommendations and reflections

4.1Conclusions and recommendations

Based on the results presented in Tables 8 – 27, the following recommendations are suggested:

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 Too1, 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 Too2, 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 does not 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.

4.2Reflections

GHG inventory for the livestock sector has been produced using IPCC Tier 2 approach. The GHG inventory is a major tool in monitoring progress in achieving Ethiopia' CRGE strategy targets. Data gaps (i.e. missing data and poor quality-data) and data needs has been identified based on analysis of the national GHG inventory. The data gaps are presented in Table 3 and Table 4. It was highlighted the need to develop innovative Tools for improved data collection and management to improve GHG inventory and CRGE-MRV system. Accordingly, five innovative Tools have been designed for piloting for filling the data gaps and improving data quality in the mixed crop-livestock, urban and peri-urban dairy, commercial dairy, and feedlot sector. It was agreed that the innovations should be part of the existing methods which has been implemented nationally. The following are some reflections on the questionnaires used during the pilot survey:

Stakeholder participation: A continued participation of multiple stakeholders on their needs and activities surrounding livestock data is a necessary step to take to assure inclusion of urban and peri-urban dairy cattle populations, and livestock in mixed 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 daytime. 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.

5 References

Community Managed Project Ethiopia. 2016. *GTP II Policy Matrix (English) Final.* (Available at: https://www.cmpethiopia.org/media/gtp_ii_policy_matrix_english_final_august_2016_2

Decision 18/CMA.1. 2018. *Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement*. (Available at: https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf#page=18)

The Federal Democratic Republic of Ethiopia. No date. Intended Nationally Determined Contribution (INDC) of the Federal Democratic Republic of Ethiopia. (Available at: https://www.undp.org/content/dam/ethiopia/docs/Ethiopia%20CRGE.pdf)

The Federal Democratic Republic of Ethiopia. 2016. Ethiopia second Growth and Transformation Plan (GTP II, 2016 – 2020). National Planning Commission, Addis Ababa.

Intergovernmental Panel on Climate Change (IPCC). 2006. *Guidelines for National Green-house Gas Inventories*. IGES, Kanagawa, Japan.

IPCC. 2019. *Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IGES, Kanagawa, Japan.

Wilkes, A., Wassie, S.E., Tadesse, M., Assefa, B., Abu, M., Ketema, A. Solomon, D. 2020. *Inventory of greenhouse gas emissions from cattle, sheep, and goats in Ethiopia (1994-2018) calculated using the IPCC Tier 2 approach*. Environment and Climate Change Directorate of the Ministry of Agriculture, Addis Ababa. Ethiopia. https://hdl.handle.net/10568/110982

Appendixes

GHG EMISION INVENTORY
PILOT SURVEY-2020

Questionnaire for Mixed System Household Pilot Survey

Area Identification

Region		Zone		Wereda		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 crossbred/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 Leg-ume)						
	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 Leg-ume)						
	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 To-tal feed)	No	Code
	Green fod-der/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														
			Lac-tat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age														
	Concentrate supp														
	Agro-indus-trial by prod														
	Others														
	Total;		100%		100%		100%		100%		100%		100%		100%

2	Feed type provided to crossbreed cattle by age														
			Lac-tat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age														
	Concentrate supp														
	Agro-indus-trial 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														
			Lac-tat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age	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														
			Lac-tat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age														
	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														
			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%
2	Feed types provided to different animal sub-categories in the wet season														

			Lac- tat- ing cows		Dry cows		Grow- ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow- ing/ young males		Calves < 1yea
			% of total diet		% of total diet		% of to- tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz- ing														
	Grass hay														
	Crop residue														
	Improved for- age														
	Concentrate supp														
	Agro-indus- trial 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														
			Lactat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
	Feed type		% of to-tal diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age														

	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

			Lac-tat-ing cows		Dry cows		Grow-ing and young cattle Heifers		Draug ht oxen		Bree ding bulls		Grow-ing/ young males		Calves < 1yea
	Feed type		% of total diet		% of total diet		% of to-tal diet		% of total diet		% of total diet		% of total diet		% of total diet
2	Dry season														
	Natural graz-ing														
	Grass hay														
	Crop residue														
	Improved for-age														
	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 supple-ment										
				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 leftovers
		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 does not 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)