Food and Agriculture Organization of the United Nations

SUPPORTING LOW EMISSIONS DEVELOPMENT IN THE ETHIOPIAN DAIRY CATTLE SECTOR

Reducing enteric methane for food security and livelihoods

NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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Executive summary

This study evaluates the potential for improving milk production while reducing enteric methane emission intensity from dairy cattle production in Ethiopia. The overall objective of this study is to support Ethiopia in identifying low-cost strategies to reduce enteric CH_4 emissions while contributing to the countries' short- to long-term social and economic development and increasing resilience to climate change.

Benefits of a climate resilient and green growth strategy for the dairy sector

Like many other economies in transition, Ethiopia aims to achieve middle-income status by 2025 while developing a green economy. In 2011, the Government of Ethiopia initiated a bold policy process to accelerate development to attain middle-income status by 2025, while adopting green growth pathways that foster development and sustainability. The Climate-Resilient Green Economy (CRGE) was initiated to protect the country from the adverse impacts of climate change by identifying environmentally sustainable economic opportunities that could accelerate the country's development. In its CRGE strategy, the country recognizes that the pursuit of a conventional development path would, among other adverse effects, result in a sharp increase in GHG emissions and unsustainable use of natural resources. To avoid such negative effects, and address the dual challenge of promoting development and reducing GHG emissions, the green growth pathway envisages limiting national greenhouse gas emission levels to 150 million tonnes CO_2 eq. instead of 400 million tonnes CO_2 eq. in 2030 under business as usual (BAU) scenario. One of the key pillars of this strategy is to improve livestock productivity to ensure food security and improvement in farmers' livelihoods while mitigating emissions. In particular, the dairy sector has been identified as a priority sector for the Government, which aims to increase Ethiopian milk production at an average annual growth rate of 15.5% during the Growth and Transformation Plan GTP II period (2015-2020).

Adopting a green growth pathway for the dairy sector could benefit Ethiopia in several ways:

- Milk production from the cattle sector remains one of the most important economic sectors in Ethiopia. The dairy sector contributes considerably to the national Gross Domestic Product (GDP). It has a share of 40% in the agricultural GDP and 12–16% in the national GDP. The latter is about twice as high as it is in neighboring countries in Eastern Africa, mainly because of the significantly higher share of agriculture in the Ethiopian GDP.
- There are about 11.4 million livestock producing households in Ethiopia (Central Statistics Agency (CSA) of Ethiopia, 2013). Depending on the production zone, cattle are the dominant species in 70% to 90% of livestock producing households, depending on the production zone, and thus dominate smallholder income generation and milk production in all production zones. In addition, smallholder farmers represent about 85% of the population and are responsible for 98% of the milk production. Considering the importance of the dairy cattle sector enterprise to rural livelihoods and its potential role in poverty reduction, implementing a low-emissions development strategy for the dairy sector through the adoption of performance-enhancing technologies is expected to significantly increase milk yields with net benefits in the short and medium term producers.
- Rapidly increasing population size with a growing rate of urbanization is driving the growth in demand for dairy products in Ethiopia. Current human population of Ethiopia is estimated at about 93 million and is increasing at a rate of 3% per annum. Currently, Ethiopia's milk consumption is only 19 liters per person per year – 10%

of Sudan's and 20% of Kenya's – but urbanization is driving up consumption: for example, per capita consumption in Addis Ababa is currently 52 liters per person. At the same time, the sector is unable to meet this expanding demand as a result of the large productivity gap; average annual milk yield per cow ranges from 270kg - 3600kg. As a consequence, a proportion of the local demand for dairy products is currently being met through imports; between 2011 and 2013, Ethiopia spent approximately US$ 11–15 million in foreign exchange on imports of milk and milk products.

- With an economy highly dependent on agriculture, Ethiopia is likely to suffer disproportionately from the impacts of climate change. Given that 80% of the population depends on agriculture for their livelihoods, increasing the resilience of agriculture is a priority for Ethiopia. Current climate variability is already imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters. Productivity-enhancing technologies are also important in increasing the resilience of production systems and households to climate change.

Emissions and emission intensities from the dairy cattle sector

Milk production from dairy in Ethiopia takes place in 4 main production systems: (i) mixed crop-livestock systems; (ii) pastoral and agro-pastoral systems; (iii) small-scale commercial systems; and (iv) medium-scale commercial systems.[1]

This study found that in 2013, the dairy cattle sector in Ethiopia emitted 116.3 million tonnes carbon dioxide equivalent (CO_2 eq.). Within this, enteric methane represents about 87% of the total GHG emissions from dairy production, equivalent to 101.2 million tonnes CO_2 eq. Emissions associated with the management of stored manure (CH_4 and N_2O) contributes an additional 14.4 million tonnes CO_2 eq., 12.3% of the total GHG emissions from the dairy cattle sector.

The two dairy systems (rural mixed crop-livestock system and the agro-pastoral/pastoral systems) are responsible for the bulk of the emissions; 56% and 43% of the total GHG emissions associated with the production of milk, respectively. The small-scale and medium-scale commercial production systems make small contributions to the total GHG emissions, 1.1% and 0.2%, respectively.

The results indicate that the emission intensity of milk in Ethiopia is on average 24.5 Kg CO_2 eq./kg FPCM.[2] Emission intensity were on average 44.6, 18.9, 8.7 and 3.8 kg CO_2 eq./ kg FPCM for mixed crop-livestock, pastoral and agro-pastoral, small-scale commercial; and medium-scale commercial systems, respectively.

There is a strong inverse correlation between the emission intensity and the average annual milk yield per cow in dairy production systems in Ethiopia. Increasing milk production from 250 to 900 kg per cow can result in a reduction in emissions intensity from 45 kg CO_2 eq./kg FPCM to 12 kg CO_2 eq./kg FPCM, i.e. 73% decrease in emission intensity compared to baseline.[3]

Options for improving productivity and enteric methane mitigation

Improving animal and herd productivity is one of the key pathways to reduce enteric CH_4 emissions per unit of product. Reducing enteric CH_4 via increasing productivity can have a monetary value; several activities that reduce methane emissions have low or negative economic cost when the value of the gains in output (in product) is considered.

Research has already identified several technologies that if comprehensively applied throughout the sector would make a rapid and important contribution to improving the technical performance and profitability of production while reducing GHG emissions. Improved practices and technologies such as strategic supplementary feeding, and improving the diet quality, adequate animal health control, and genetic improvement of animals are some of the techniques that can improve dairy productivity and reduce emission intensity.

[1] See section 3 for a detailed description of dairy production systems in Ethiopia.
[2] Fat-and-protein corrected milk
[3] Baseline defined as a measurement or description of a scenario used as a basis for comparison.

This assessment evaluated interventions for the main dairy production systems. The following criteria were used to select interventions:

- Interventions had to have potential for improving productivity while at the same time reducing enteric CH_4 emissions per unit of output.
- Interventions had to be feasible in the short or medium term. Feasibility was first determined by sectoral experts and selected interventions had to have already been implemented or in use at least at farm level in Ethiopia.

A team of national experts identified key areas to address low-productivity in dairy systems including (i) improving the quality and availability of feed resources; (ii) strategic feeding and supplementation to address the constraint of feed seasonality; (iii) improved herd management and animal health interventions; and (iv) improving the genetic potential of local breeds. Within this broad categorization, 7 single interventions and 1 'package' consisting of a combination of single interventions were assessed in this study.

Mitigation of enteric methane can play an important role in food security and climate strategies

This work shows that significant reductions in methane emission intensity can be realized through the adoption of existing and proven technologies and practices. With the application of a combined set of interventions results in a reduction potential in absolute enteric methane of about 9.6 million tonnes of CO_2 equivalent, or 10% of the baseline enteric methane emissions and a corresponding increase in milk production by 170%.

Implementing the individual interventions would reduce enteric CH_4 intensity by between 15% and 62% (kg CO_2 eq./kg FPCM), depending on the intervention and production system. These emissions reduction potentials can be considered conservative, in that the analysis did not assume any major changes in technology or change in production systems but focused on reducing the efficiency gap between producers in the same production system. All interventions returned a positive productivity outcome with increases in production ranging between 8% - 180%.

More significant reductions in emissions can be achieved through the combination of herd and health management, genetics, and nutrition and feeding management strategies. This study estimates a reduction potential of 36%-65% in emission intensity and an increase in production (expressed in FPCM) of 62% -225% compared to the baseline situation.

Prioritization of interventions for enteric methane

From the analysis, all interventions preselected and assessed not only yield mitigation benefits but also provide production and financial benefits. The interventions assessed all returned a benefit-cost ratio greater than 1 (ranging between 1.6 and 3.2). A preliminary ranking of interventions per production systems to identify those with high reduction potential, increased production and high economic return was undertaken to provide an indication of what is workable.

The rural mixed crop-livestock system, the use of improved breeds, urea feed-based interventions and disease control had moderate to high impact; moderate impact on emission reduction and returns on investment and a high impact on productivity. Only two interventions (supplementation with leguminous shrubs and trypanosomosis control) were tested in the pastoral/agro-pastoral systems; the control of trypanosomosis in the extensive systems appears to be the most effective intervention in reducing enteric methane emission intensity, while having a positive impact on production and returns to farmers.

CHAPTER 1

A climate-resilient and green growth path for the Ethiopian dairy cattle sector

The Climate-Resilient Green Economy (CRGE) Strategy vision is to build a middle-income climate resilient green economy by 2025 (USD 1,000 GDP per capita) through zero net carbon growth. CRGE looks at three different but inter-related objectives: economic growth/viability; reduction of vulnerability to climate change/increase in climate resilience, and reduction of greenhouse gas emissions. The implementation of the CRGE strategy will ensure a resilient economic development pathway while reducing emissions greenhouse gas emissions. The CRGE identified the livestock sector as being of high relevance to the success of Ethiopia's growth model.

Today, Ethiopia remains strongly committed to voluntary action to reduce greenhouse gas (GHG) emissions. Ethiopia has made an ambitious commitment to curb its greenhouse gas emissions between now and 2030. In its Intended Nationally Determined Contribution (INDC) to the UNFCCC, Ethiopia communicated its plans to cut emissions below 2010 levels from 150 megatonnes of carbon dioxide equivalent (Mt CO2e) in 2010 to 145 MtCO2 eq. in 2030.

This represents a major shift, since conventional economic growth would more than double Ethiopia's greenhouse emissions by 2030. Ethiopia's contribution represents a 64 percent emissions reduction from business-as-usual emissions by 2030. With its INDC, Ethiopia has made a clear commitment to adopt a low-carbon growth agenda, thus contributing to the international commitment to address climate change.

In the CRGE, Ethiopia identified climate actions with the greatest mitigation potential, giving priority to steps that will yield significant co-benefits and reduce climate vulnerability.

In recognition of the need for future growth of its economy; Ethiopia's climate action plan on mitigation builds on improving livestock productivity for greater food security, higher incomes for farmers and reduction in emissions, enhancing carbon sequestration, and increasing the use of renewable energy resources.

The adoption of improved technologies and practices provides opportunities for sustainable intensification consistent with food security and development goals, climate change adaptation and mitigation needs, thus enhancing development with considerations of environmental, social, and economic issues. At the same time, Ethiopia will be significantly impacted by climate change and adaptation solutions are needed to reduce its vulnerability.

This report presents the findings and recommendations from an initial assessment of the dairy cattle sector of Ethiopia. It is undertaken as part of a project funded by Climate and Clean Air Coalition (CCAC), the New Zealand Government and Food and Agriculture Organization of the United Nations in collaboration with the Ministry of Livestock and Fisheries, (Ethiopia), the Ethiopian Climate Science Center including experts and stakeholders from national institutions.

The primary focus of this initial assessment is to identify and prioritize interventions to reduce enteric methane emission intensity from ruminant systems. To that end, this report examines Ethiopia's dairy cattle sector to assess the scale of enteric methane emissions, and identify cost-effective interventions through which methane can potentially be reduced. This analysis is meant to inform where reductions can be made and to systematically explore emission reduction opportunities with the objective to translate emission savings into benefits for producers.

[4] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Ethiopia/1/INDC-Ethiopia-100615.pdf

CHAPTER 2

Objectives and approach

This study seeks to identify and evaluate low-cost options that Ethiopia can implement in the short-to-medium term geared towards improving productivity in dairy production systems, reducing enteric methane emissions and fostering economic development.

Three main methodological steps were employed in this study (Figure 2.1):

1) Definition of the baseline scenario. Including the selection and characterization of production system, estimation of GHG emissions and emission intensity, and identification of key drivers of low productivity and emission intensity.

2) Explore the mitigation potential. Identification of system specific interventions consistent with development objectives for improving productivity, addressing enteric methane emissions and assessment of the mitigation potential.

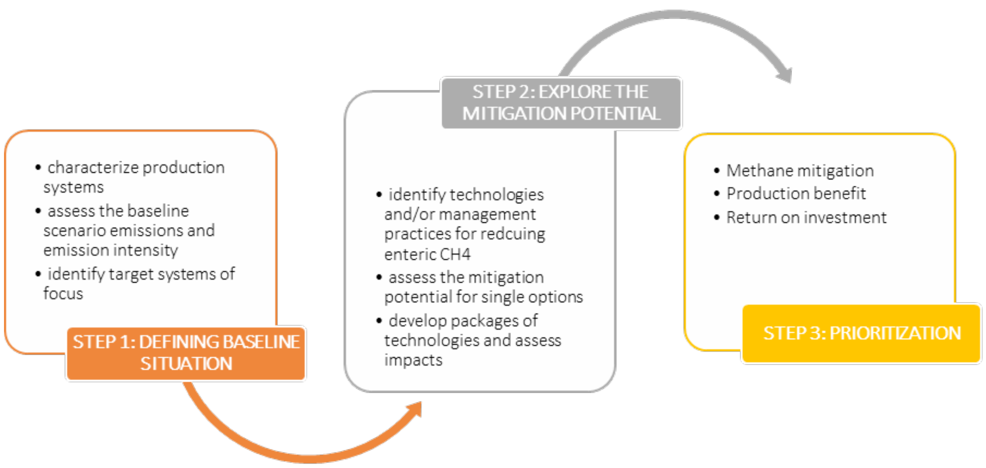
3) Prioritization of interventions. Prioritization of interventions is undertaken by drawing on modeling results and cost-benefit analysis. Three criteria - methane abatement, the impact on production and profitability for farmers - are used in the prioritization of interventions.

A key focus of this work is on interventions that *reduce emission intensity while maintaining or increasing production* such that climate change and productivity improvement can be pursued simultaneously (Box 1).

The analysis focuses on the dairy cattle sector, a strategic sector of importance to Ethiopia that was jointly identified in consultation with front-line government ministries e.g. ministry of livestock, environment, academia institutions, and public and private stakeholders.

The study undertakes biophysical modeling and scenario analysis using the Global Livestock Environmental Assessment Model (GLEAM) to provide a broad perspective of opportunities and the potential achievable goals in terms of productivity gains and emission intensity reduction in the dairy sector (Box 2).

Figure 2.1: Process framework for the identification and prioritization of interventions to address enteric methane



Box 1: Absolute emissions versus emission intensity

The primary drivers of enteric methane emissions are feed intake, and fermentation characteristics of that feed in the rumen. In general, management practices that increase the proportion of feed used to produce meat or milk rather than maintain the animal, reduce the amount of methane per unit of animal product produced (emissions intensity).

Higher individual animal productivity generates more animal product and more methane per animal but as a smaller proportion of the feed consumed is used to maintain the animal, emissions intensity is reduced. The same amount of animal product can be produced with fewer methane emissions if producers keep fewer animals. More intensive production provides flexibility to control emissions and generally improves profitability. However, increasing feed intake per animal will always lead to an increase in total farm methane production unless the total number of animals is reduced. In low and medium income countries, the concept of emission intensity remains the most attractive mitigation route because it allows for the harnessing of synergies between food security and development objectives and climate change mitigation goal. Emissions intensity reductions will reduce absolute emissions below business-as-usual.

Box 2: Modelling GHG emissions from dairy production systems in Ethiopia

In this study, the Global Livestock Environmental Assessment Model (GLEAM; Gerber *et al*. 2013) is the main analytical tool used to assess the emissions and emission intensities in the baseline scenario and to assess the emission reduction potentials of selected interventions.

GLEAM is a spatial model of livestock production systems that represents the biophysical relationships between livestock populations (FAO, 2007, 2011a), production, and feed inputs (including the relative contribution of feed types—forages, crop residues, and concentrates—to animal diets) for each livestock species, country, and production system. The production parameters and data in GLEAM have been drawn from an exhaustive review of the literature and validated through consultation with experts during several joint projects and workshops. The relationships between GHG emissions and production have also been cross validated for ruminants across a range of regions and studies, and published reports on GLEAM have also been through rigorous peer review (Opio *et al*. 2013; Gerber *et al*. 2013). GLEAM works at a definition level of 1 km2, the spatially explicit GLEAM model framework allows the incorporation of heterogeneity in emissions, emission reductions and production responses.

The model was further developed to meet the needs of this study. The dairy production systems in GLEAM were further refined to reflect the specificities of the dairy cattle production systems in Ethiopia and the database of production systems parameters was updated with more recent and system specific information and data on populations, performance parameters, feeding systems, manure management, etc. taken from national databases.

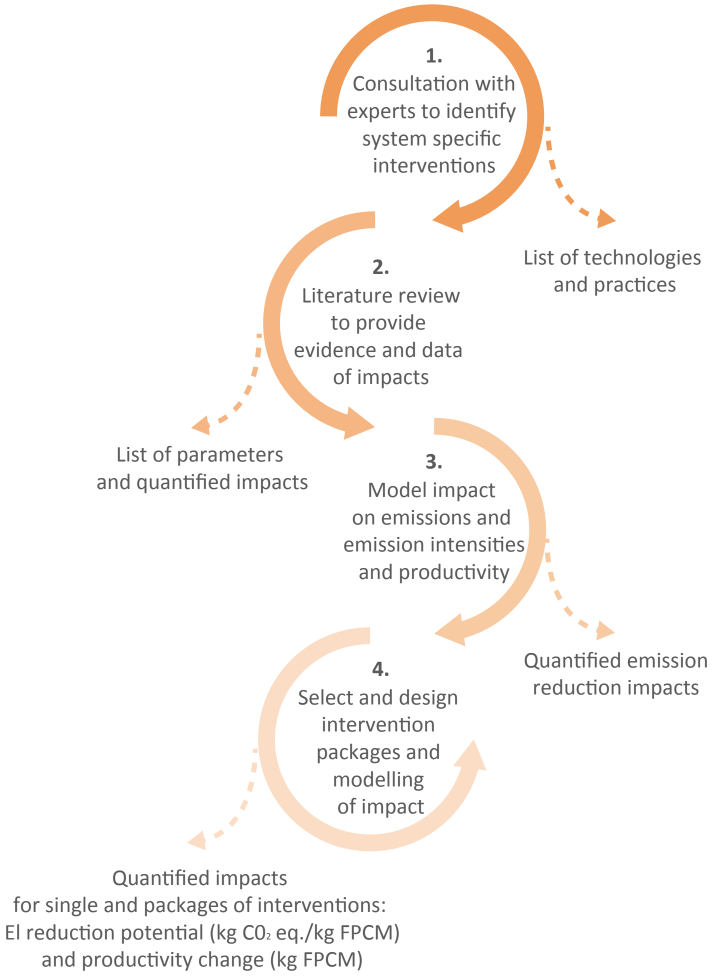
The GLEAM framework is used to characterize the baseline production and GHG emission output of the dairy production systems. Emissions and emission intensities are reported as CO_2 eq. emissions, based on 100-year global warming potential (GWP100) conversions factors; methane = 34, nitrous oxide = 298.

The abatement potentials for each practice were calculated by estimating the changes from the baseline GHG emissions, following the application of each system specific intervention. To specify each abatement practice within GLEAM, it was necessary to incorporate additional data and information on the impacts associated with the application of the interventions. These data were obtained from a range of literature sources and databases as elaborated in the supplementary information.

The calculations are performed twice, first for the baseline scenario and then for the mitigation scenario. Emission intensity reductions and changes in productivity achieved can then be compared to those under baseline scenario.

Source: http://www.fao.org/gleam/en/

Figure 2.2: Process for exploring mitigation impacts



The scenario analysis uses the outputs of the bio-physical analysis combined with information taken from published literature, existing studies and expert knowledge on potential impacts of each intervention on herd performance and production to quantify the emission intensity reduction potential.

The range of options evaluated (referred to as "interventions") were selected by national sector experts based on their potential for methane emission intensity reductions, their impact on yield and their feasibility in terms of political, social, institutional, and other preconditions. The interventions identified are presented individually and with a subset evaluated as a 'package', in order to demonstrate to stakeholders how a combination of interventions would impact reduction potential and productivity gains. It also gives the ability to assess this flexibly within the framework of political conditions, available resources, and other considerations. Figure 2.2 presents the generic steps undertaken in the identification of interventions and assessment of their impacts on enteric methane emissions and production.

For purposes of prioritization of interventions, the assessment considered three aspects: the emission reduction potential, the production impacts and the profitability for farmers assessed by quantifying the return to farmers per dollar invested. The impacts on enteric methane emissions and production were assessed using the GLEAM model described above.

The cost-benefit analysis of selected interventions to assess the profitability for farmers were quantified using typical farm input and output costs provided by local experts and are presented as a ratio of the $ returned per $ invested. The purpose of the cost benefit analysis is to guide decisions on which interventions would be profitable for farmers.

CHAPTER 3

Overview of dairy production in Ethiopia

Ethiopia has the largest national livestock population in Africa. Recent data estimates 54 million cattle, of which 32.6 million are involved in the dairy sector. The vast majority of the cattle are mainly kept by smallholders. Of the total 16.5 million Ethiopian farms with cattle, 95% are holdings with less than five head of cattle. And 5% of the farms have 10 or more head of cattle; almost one million farms are in this category.

Indigenous stock produce 97% of the milk produced by cattle and the remaining 3% comes from improved exotic crosses and pure grade exotic cattle. These smallholders keep additional cattle to provide traction power, to produce meat and manure, and to serve as an insurance in times of drought or a household emergency. With these multiple functions, cattle serve as a vehicle for improving food security and better livelihood of the rural population.

Rapidly increasing population with a growing rate of urbanization is resulting in a shift in demand for dairy products. Current human population of Ethiopia is estimated at about 93 million and is increasing at a rate of 3% per annum (Central Statistics Agency, CSA 2014). Dairy development can lead to income generating activities in the rural areas increasing farm incomes and employment opportunities.

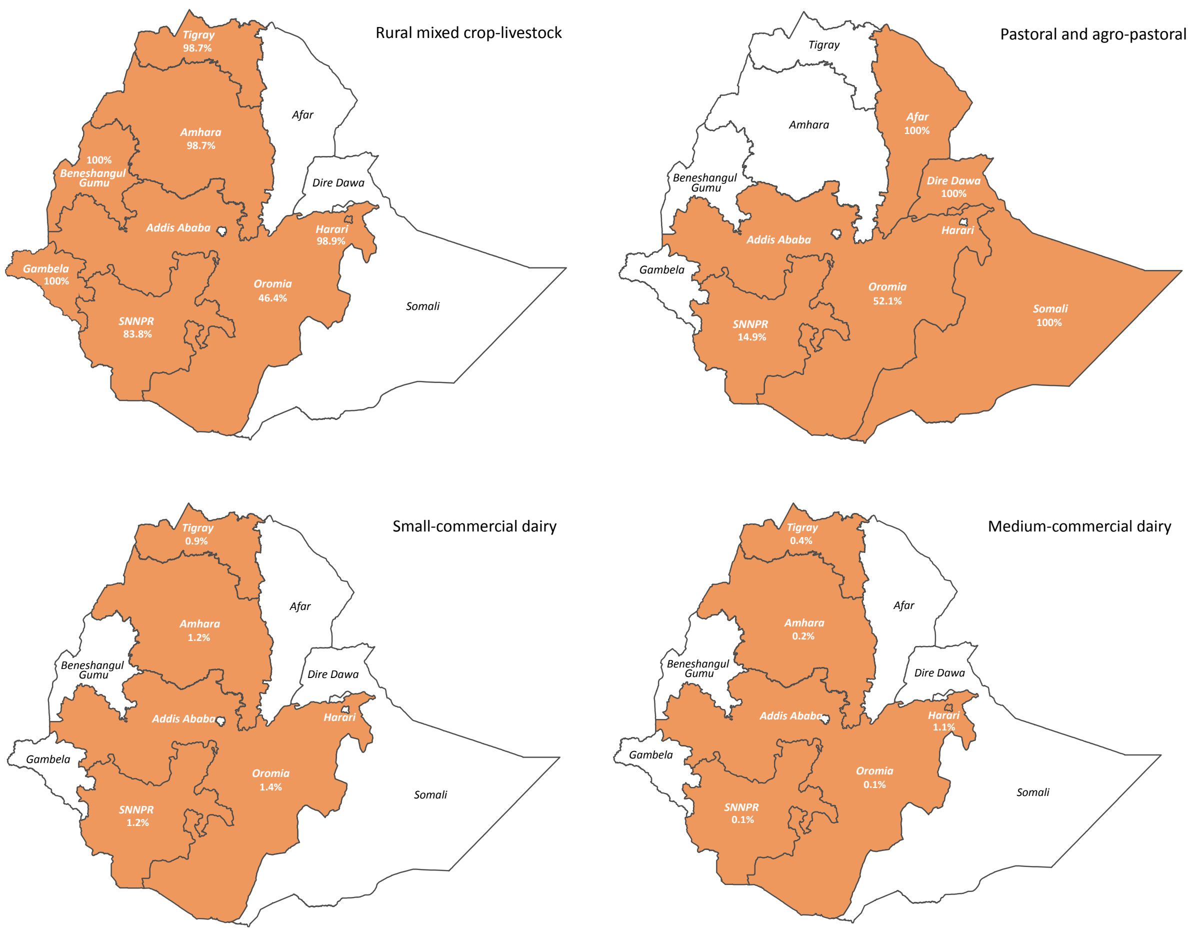
Milk production in Ethiopia takes place within four main dairy production systems: medium-scale commercial, small-scale commercial, rural mixed crop-livestock dairy system and pastoral/agro-pastoral. The latter two systems are classified as rural dairy production systems.

Map 3.1 illustrates the distribution of dairy cattle herd across the regions. The Ethiopian dairy cattle population is distributed over all regions of the country. The four regions with the greatest number of dairy cattle are shown in Map 3.1 below. Almost all of the cows in Tigray, Amhara, Oromia and Southern Nations Nationalities and People region (SNNP) are located in highlands. The highlands are also the regions with market-oriented milk production.

There is however considerable diversity within these four high level categories of production systems.

- Pastoralism is the major system of milk production in the lowlands. It is estimated that about 36% of the dairy population are found in the pastoral areas. Due to the erratic nature of rainfall that results in shortage of feed availability, milk production in the agro-pastoral/pastoral system is low and highly seasonal. The reliance of the agro-pastoral and pastoral systems on the overgrazed natural resource base makes them most vulnerable to climate change hence interventions that improve natural grassland management can increase productivity and resilience at the same time targeting these systems are most likely to increase their adaptive capacity.
- The rural mixed crop-livestock dairy system is part of the subsistence farming systems that are mainly concentrated in the highlands. It is found in the mid-and high altitude agro-ecological zones where cereals and cash crops are dominant components of the farming systems. It is estimated that 63% of the dairy cattle population are found in the mixed crop-livestock dairy system and about 72% of the total milk production in Ethiopia is produced on these smallholder farms. In this system, cattle are used for traction and milk is mainly consumed in the household or sold to neighbors. Surplus milk is converted to butter or ghee and fermented dairy products such as local types of yoghurt and soft cheese.
- The small-scale and medium-scale commercial production systems are on the other hand located mainly in close proximity to towns and cities. Production is market oriented and specifically targets consumers in urban areas and producers tend to have a better understanding of dairy management. Farmers use part or all of their land to grow fodder crops for their dairy cattle. The animals do

Map 3.1: Share of dairy cattle herd by production system and region



not provide draft but their manure is used as fertilizer. Milk is the main source of farm income and the herd is dominated by improved or crossbreed cattle.

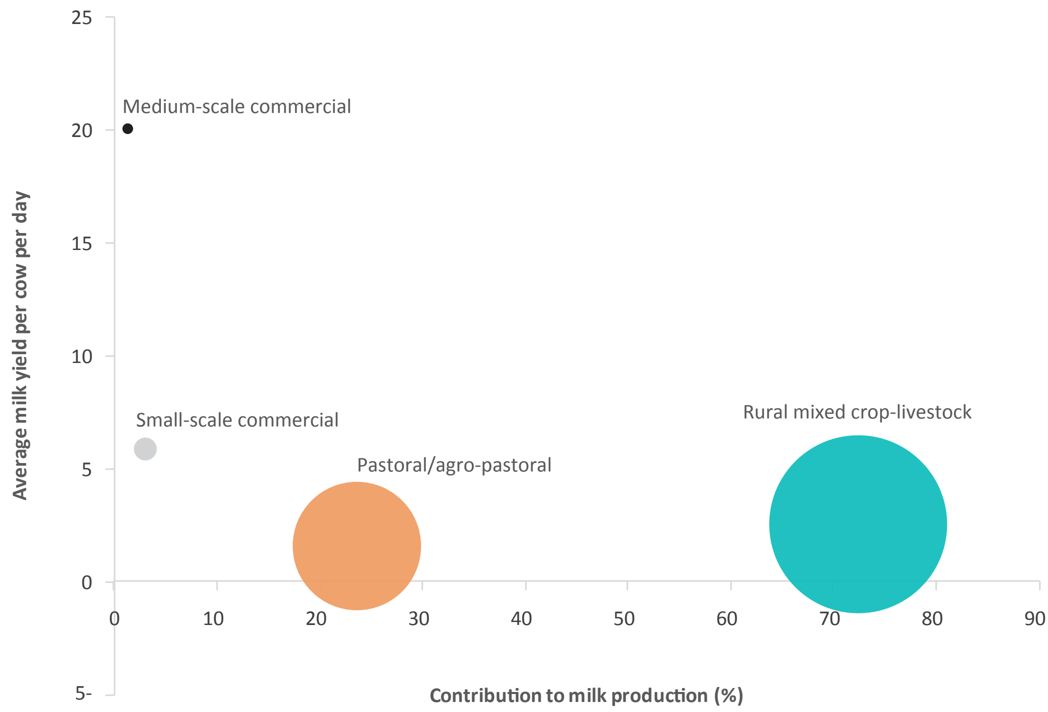
Table 3.1 provides a summarized description of the characteristics of dairy production systems in Ethiopia.

Based on the above classification and characterization, milk production systems represent a gradually increasing level of management and investment. The higher levels of management and investments are found near the main urban markets where the higher milk prices can be obtained.

Ethiopia produces approximately 3.8 million litres of milk from 12 million milking cows – an average of 1.7 litres per cow per day over an average lactation period of 180 days. In terms of production system contribution to milk production, the rural mixed crop-livestock dairy system produces the largest share of milk, contributing 72% of total milk supply from 65% of milking animals. Pastoral/agro-pastoral systems and the market-oriented systems contribute 24% and 4% of the total milk, respectively, with 34% and 1% of the milking cows, respectively (Figure 3.1).

The generally low productivity of dairy animals (Figure 3.2) and low number of high-yielding genotypes results in a shortage of supply of dairy products relative to demand and increases the dependence on imports. Milk yield performance of cows as reported by farmers varies widely across the different dairy production systems, mainly due to differences in breed and management. It ranges from 1.5 litres per cow per day in pastoral and agro-pastoral systems to 20 litres per cow per day in medium-scale commercial.

Figure 3.1: Production system milk yield and contribution to milk production



Note: Size of bubble: share of milking cows represents the share of milking cows in each system.
65% (rural mixed crop-livestock); 34% (pastoral/agro-pastoral) and 1% (market oriented).

Figure 3.2: Average milk yield per lactation (kg per cow per lactation) by production system

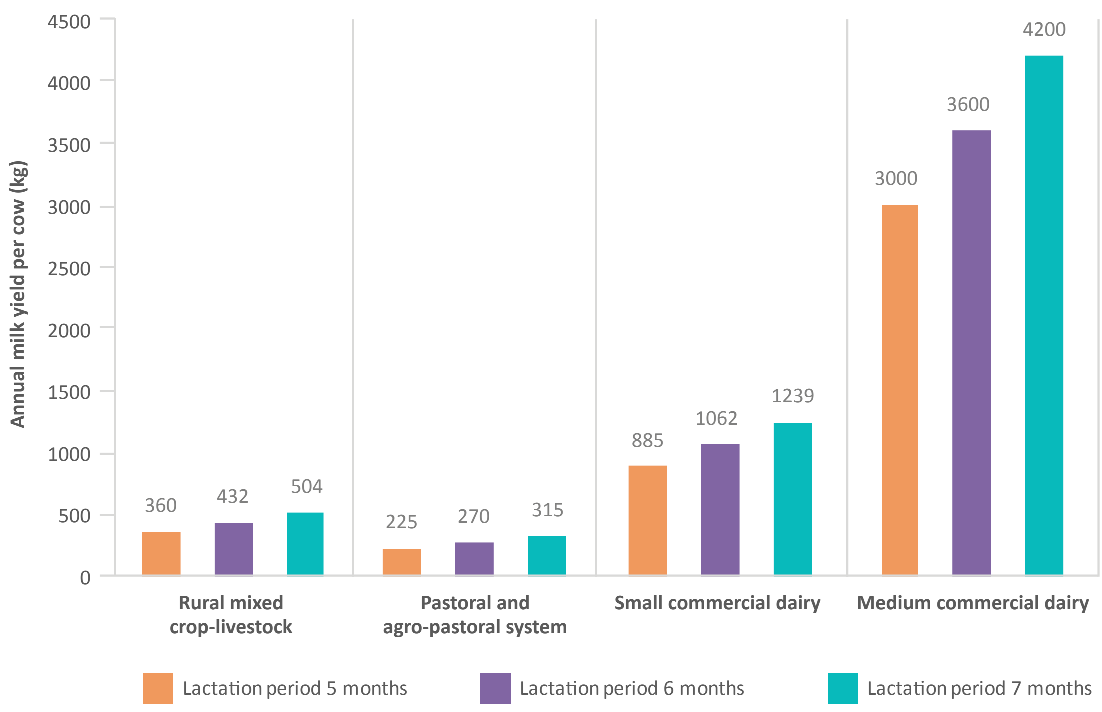


Table 3.1: Summary of dairy production systems in Ethiopia

Production system	Characteristics	Description
MIXED CROP-LIVESTOCK SYSTEMS		
Traditional crop-livestock farms in rural areas	Average size	Smallholder farms, average of 4 cows per household
	Feed-base	Extensive natural pasture based grazing system, roadside grazing, cut and carry and crop residues
	Genotype	Largely indigenous Zebu breed
	Health	Mortality rate – 4%, high morbidity due to internal and external parasites. Vaccination for some important diseases
	Reproductive strategy	Uncontrolled natural mating widespread, calving season all year
	Productivity	About 400-680 kg milk per lactation
	Level of investment	Very low investment except land opportunity cost, little or no external inputs
Crop-livestock farms with intensive cropping	Average size	Average of 5 cows per household
	Feed-base	Extensive natural pasture based grazing system, roadside grazing, cut and carry feeding systems, crop residues and supplementary feeds (home-made concentrate) fed to crossbred cattle
	Genotype	Indigenous Zebu cattle and cross-bred cattle
	Health	High mortality rate and morbidity due to internal and external parasites
	Reproductive strategy	Natural mating with communal bulls Limited artificial insemination
	Productivity	Indigenous cattle: milk yield 1.2 kg per cow/day Crossbred: 6 kg per cow/day
	Level of investment	Low level of investment
SMALL-SCALE COMMERCIAL LIVESTOCK SYSTEMS		
Intensified crop-livestock farms in rural areas	Average size	Smallholder farms average of 4 cows per household
	Feed-base	Limited grazing, improved forage for cut and carry, crop residues, home-made concentrate (wheat bran, wheat middlings, oilseed cake)
	Genotype	Indigenous Zebu cattle and cross-bred cattle
	Health	Mortality rate (5%), morbidity (due to internal parasites). Vaccination done
	Reproductive strategy	Natural mating with bulls Artificial insemination also practised. Early weaning practised
	Productivity	460-782 kg milk per cow per lactation period
Peri-urban farms	Average size	Average number of 5 cows per household
	Feed-base	Crop residues, supplementary feed or homemade concentrate of wheat, wheat middlings, oilseed cake, molasses, bran minerals and salts
	Genotype	Crossbred and grade dairy cattle
	Health	Common health problems: mastitis, infertility, bovine tuberculosis. Low mortality, vaccination undertaken.
	Reproductive strategy	Artificial insemination
	Productivity	Average daily milk yield per cow 10-12 kg per cow per day
	Level of investment	Medium level of investment (purchase of improved breed, inputs such as feed, veterinary drugs, services, labor)

(cont.)

Table 3.1: *cont.*

Production system	Characteristics	Description
MEDIUM-SCALE COMMERCIAL LIVESTOCK SYSTEMS		
Urban farms in secondary farms	Average size	Average number of 5-10 cows per household
	Feed-base	Supplementary feed or concentrate , purchased fodder (hay) and crop residues
	Genotype	Pure exotic and grade dairy cattle
	Health	Common health problems: mastitis, infertility, bovine tuberculosis. Low mortality, vaccination undertaken
	Reproductive strategy	Artificial insemination and limited natural mating
	Productivity	Average daily milk yield per cow 10-12 kg per cow per day
	Level of investment	Medium level of investment (purchase of improved breed, AI, inputs such as feed, veterinary drugs and services, labor)
Intra-urban dairy farms in Addis Ababa	Average size	Average number: 10-50 cows per farm
	Feed-base	Supplementary feed or concentrate, mineral and salt, molasses, purchased fodder (hay) and crop residues
	Genotype	Crossbred, Pure exotic and grade dairy cattle
	Health	Common health problems: mastitis, infertility, bovine tuberculosis. Low mortality and morbidity, vaccination undertaken
	Reproductive strategy	Artificial insemination and limited natural mating
	Productivity	Average daily milk yield per cow 15-20 kg per cow per day
	Level of investment	Medium level of investment (purchase of improved breed, AI, inputs such as feed, veterinary drugs and services, labor)
Specialized dairy farms	Average size	Average number: 50 cows per farm
	Feed-base	Cultivated forage and legumes, concentrate feed, hay, silage
	Genotype	Pure exotic and grade dairy cattle
	Health	Common health problems: mastitis, bovine tuberculosis
	Reproductive strategy	Artificial insemination
	Productivity	Average daily milk yield per cow 20 kg per cow per day
	Level of investment	High level of investment
PASTROAL AND AGRO-PASTORAL LIVESTOCK SYSTEMS		
	Average size	Large herds of indigenous cattle up to 200 head or more.
	Feed-base	Natural pasture for extensive rangeland grazing including crop residues for agro-pastoral systems
	Genotype	Indigenous zebu cattle
	Health	Common health problems: tick-borne diseases, trypanosomosis, bovine tuberculosis. Vaccination in some area
	Reproductive strategy	Uncontrolled mating with communal breeding bulls
	Productivity	Average daily milk yield per cow 1.5 kg per cow per day
	Level of investment	No/low level of investment (no/limited external inputs)

CHAPTER 4

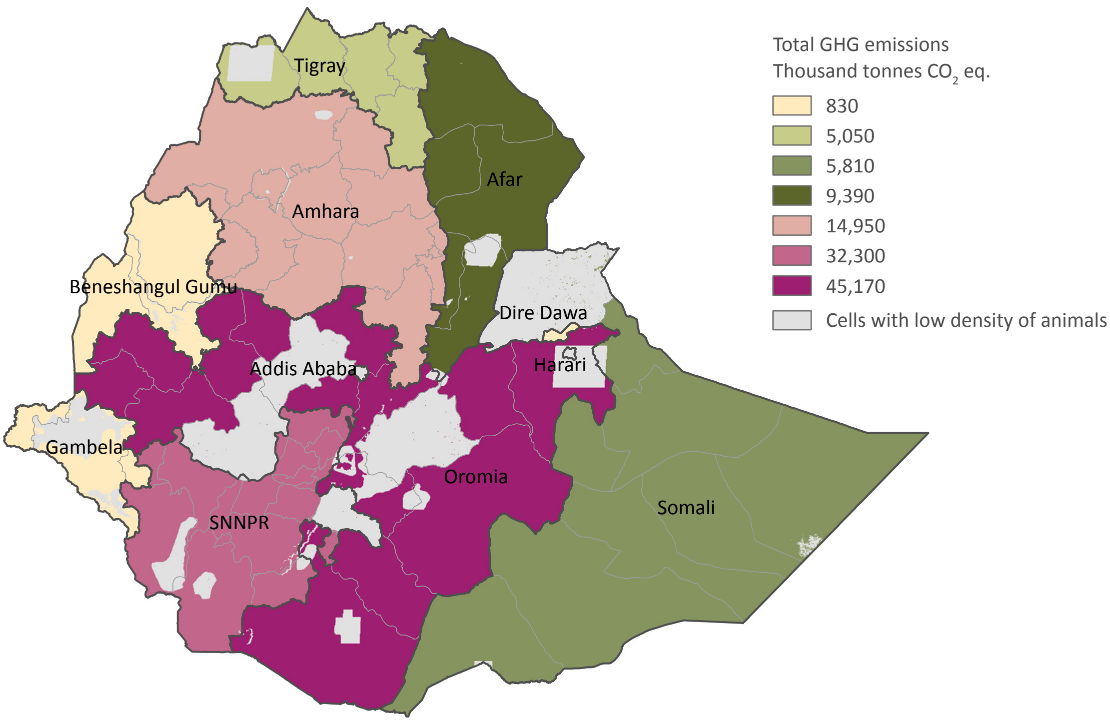
Emissions and emission intensities from the dairy cattle sector

Milk production from the cattle dairy sector in Ethiopia is responsible for about 116.3 million tonnes CO_2 eq. in 2013 (GLEAM, 2016). These emissions are distributed throughout the entire country as shown in Map 4.1. Absolute emissions are concentrated in three regions with the highest share of the national dairy herd (80%): Oromia (34%), SNNPR (31%) and Amhara (14%).

The activities and processes that contributed towards the GHG emissions from dairy cattle is shown in Figure 4.1. Figure 4.1 presents the GHG profile which is dominated by methane (97.3%), while the contribution of nitrous oxide (N_2O) and carbon dioxide (CO_2) is negligible (2.1% and 0.5% of the total, respectively).

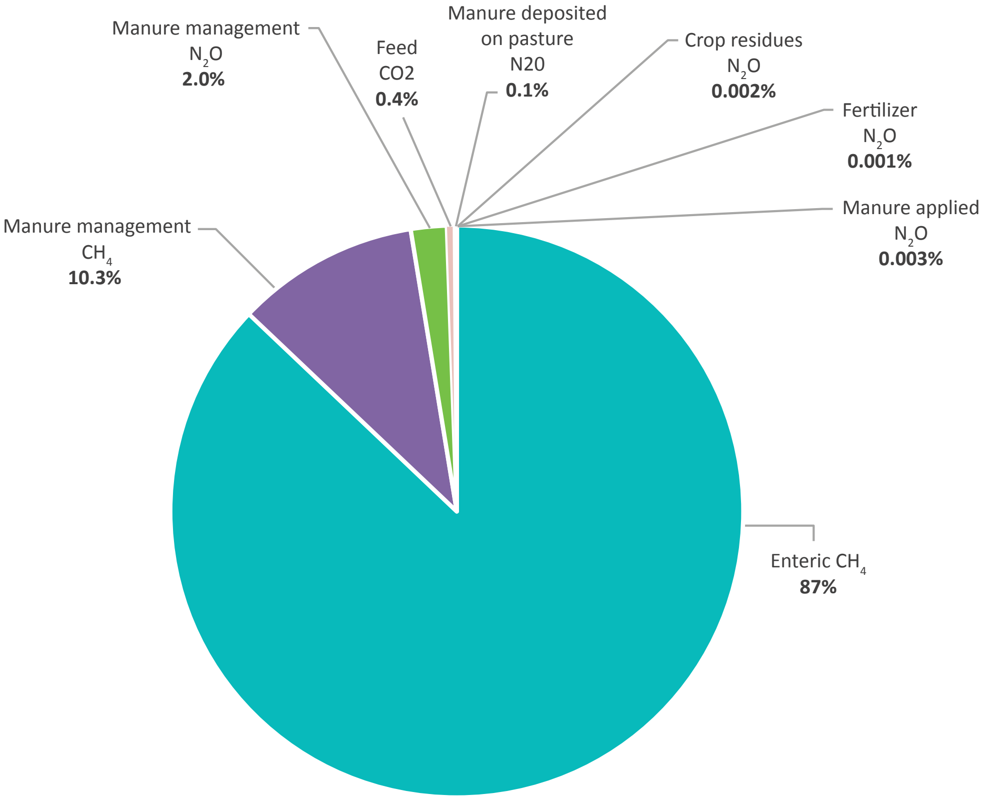
Approximately 87% of the emissions arise from methane produced by the rumination of cows and 10% from the management of stored manure. Nitrous oxide arising from dung and urine contributes about 2.1%. The contribution from the production of feed is negligible because the proportion of external inputs such as supplementary feed and fertilizer for feed production is low.

Map 4.1: Regional distribution of regional greenhouse gas emission from milk production



Source: GLEAM, 2016

Figure 4.1: Share of total emissions by emission source



Source: GLEAM, 2016

Production system contribution to the total GHG emissions and milk production

Figure 4.2 illustrates emissions in absolute terms disaggregated by dairy production system and sources of emissions. The rural mixed crop livestock system is responsible for a large share of total GHG emissions; contributing 56% of total emissions, while the pastoral and agro-pastoral system contributes 43% (Figure 4.2). The market-oriented farms, small-scale and medium-scale commercial production systems make small contribution to the total absolute emissions, 1.1%, and 0.2%, respectively.

Across all production systems methane emissions from enteric fermentation comprise the bulk of emissions ranging from 80% - 88% of the total emissions. Emissions from manure management (nitrous oxide and methane) make up the remaining share; ranging from 11% in pastoral and agro-pastoral systems to 19% in medium-scale commercial dairy.

Greenhouse gas emissions per kg of fat-and-protein corrected milk (FPCM)

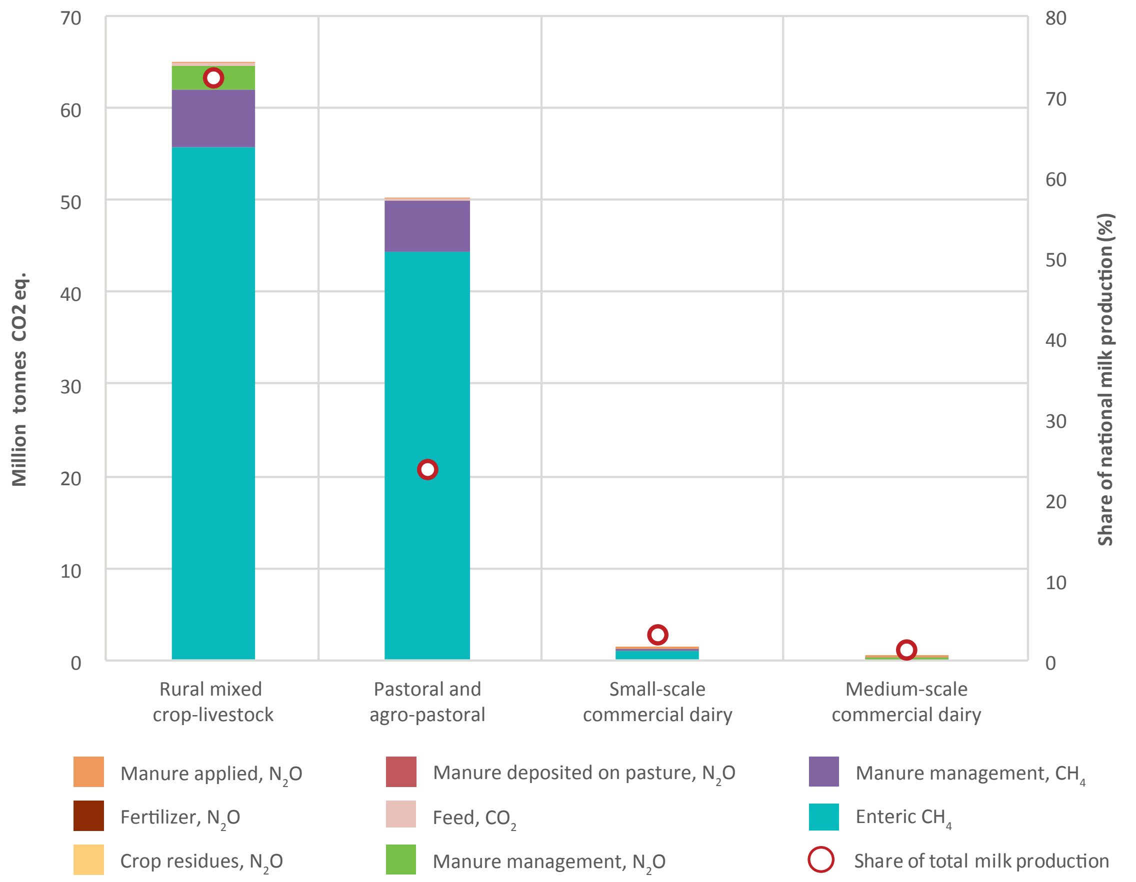
At national level, the emission intensity of milk produced in Ethiopia is on average 24.5 kg CO_2 eq./kg FPCM; the highest values for pastoral and agro-pastoral systems and the lowest in medium-scale commercial systems. Emissions were on average, 44.6, 18.9, 8.7 and 3.8 kg CO_2 eq./kg FPCM for the pastoral and agro-pastoral, rural mixed crop-livestock, small-scale and medium-scale commercial systems, respectively (Figure 4.3).

Variability in emission intensity within dairy production systems

At production system level, there is a wide variation in emission intensity which is closely related to diversity the production and management practices in the 4 dairy production systems (Figure 4.4).

At production system level, the highest variabil-

Figure 4.2: Absolute emissions by production system and emission source



Source: GLEAM, 2016

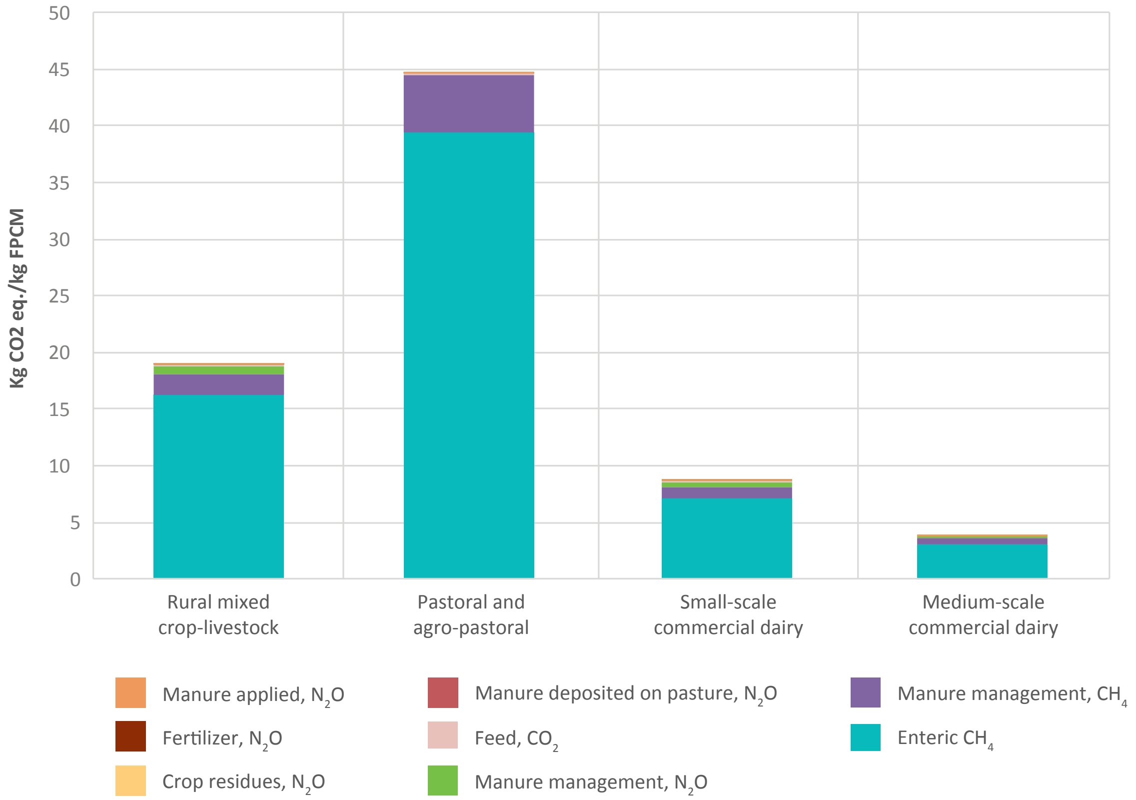
ity in emission intensity is observed for the pastoral and agro-pastoral systems with a range from 25 to 70 kg CO_2 eq./ kg FPCM (Figure 4.4). In medium commercial dairy systems, 50% of the producers are spread over a smaller range of values, indicating less variation in emission intensity. The existence of a wide variability is strong indication of the potential for reductions in GHG intensity of milk through the adoption of practices associated improvements in efficiency.

Drivers of emissions and emission intensities

A number of factors influence emissions and emission intensitiesfrom dairy production in Ethiopia:

- **Inadequate and poor quality feed.** An inadequate supply of quality feed is the major factor limiting dairy production in Ethiopia. Feeds, are either not available in sufficient quantities due to fluctuating weather conditions or even when available are of poor nutritional quality. The diet is largely made up of low quality feed products such as crop residues (between 30-35 percent of the ration in the rural mixed crop livestock system and the two market oriented systems) and native pastures of poor nutritive value (56% in the rural mixed crop-livestock and 90% in the agro-pastoral and pastoral systems). Consequently, the digestibility of average feed ration in all 4 systems is very low: 43%, 45%, in pastoral systems, and rural mixed crop-livestock system, respectively and 49% in the market-oriented systems. These constraints explain the low milk yields and short lactations, high mortality of young stock, longer parturition intervals,

Figure 4.3: Average emission intensity per kg FPCM, by system



Source: GLEAM, 2016

Figure 4.4: Variability in milk emission intensity, by production system

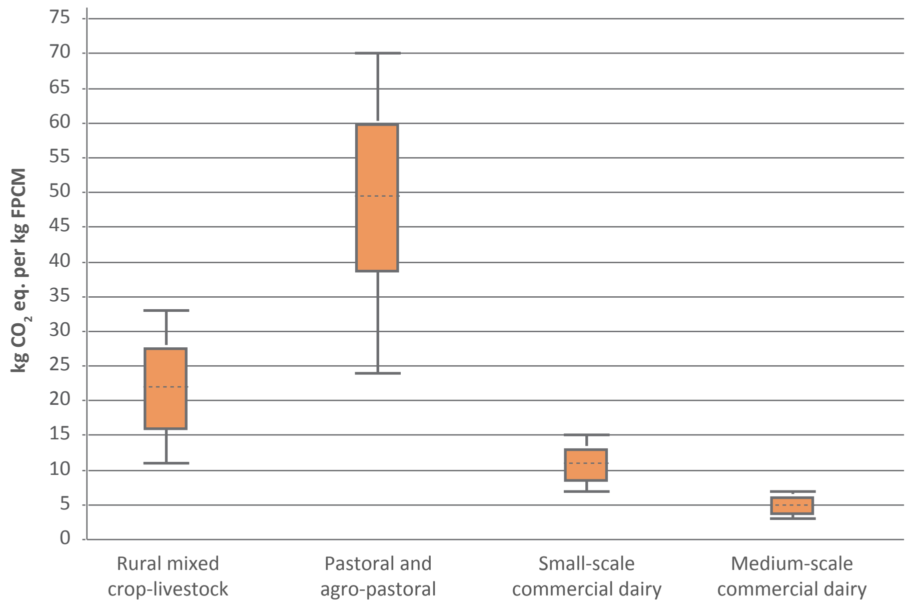
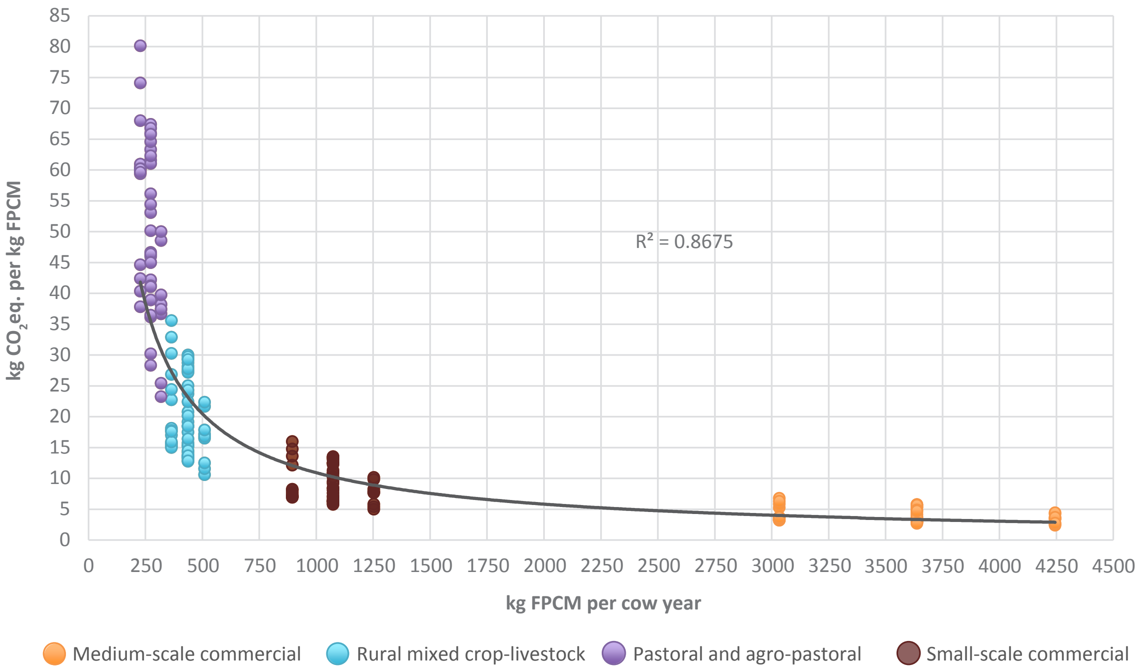


Figure 4.5: Variation in greenhouse gas (GHG) emission intensity of milk in relation to milk productivity per cow (kg FPCM, fat and protein corrected milk per cow). Each dot represents a district



low animal weights and high enteric methane emissions per unit of metabolizable energy.

- **Animal health.** The prevalence of various animal diseases, tick-borne diseases, internal and external parasites affects the performance of dairy cattle. Animal health affects emission intensity through the "unproductive emissions" related to mortality and morbidity. Calf mortality is high in all systems, and particularly in the pastoral and mixed crop-livestock systems where mortality ranges between 12%-16%. Many of the health problems result from poor animal condition as a result of inadequate nutrition, but also from the limited access to animal health services. Morbidity has an indirect effect on emission intensities through slow growth rate, reduced mature weight, poor reproductive performance and decreased milk production. This is particularly true for improved exotic dairy cattle breeds which are often inherently more susceptible to diseases compared to the indigenous cattle.
- **Reproductive efficiency.** Reproductive efficiency affects emission intensity by influencing the portion of the herd that is in production (e.g. milked cows and young stock fattened for meat). It is also a key parameters to the economic performance of dairy systems. Improvements in reproductive performance is a major efficiency goal of the dairy industry. However, achieving this goal is currently hampered by a number of factors, particularly feed availability and quality. Poor reproductive performance in the Ethiopian dairy herd is manifested in a number of parameters such as low fertility rates (50%), delayed time to reach puberty and age at first calving (2.8 and 3.6 years in rural mixed crop-livestock and pastoral systems, respectively). The proportion of lactating cows ranges from 26%-28% which implies a large proportion of the dairy herd comprises of non-productive stock (bulls, replacements and dry cows).
- **Genetic limitation and a low number of improved genotypes.** About 97% of the cattle population in Ethiopia are indigenous. While adapted to feed and water shortages, disease challenges, and harsh climates, the productivity of these breeds is generally low. Milk production is as low as 0.5 to 2 litres per cow per day over a lactation period of 160-200 days.

All these factors contribute to low milk yield, both at animal and herd levels. As a result, we observe a strong inverse correlation between the emission intensity and the average annual milk yield per animal in dairy production systems in Ethiopia (Figure 4.5). For animals with a higher annual milk yield, the overall farm GHG emissions (from all animal cohorts) are distributed over a larger amount of milk. In terms of feed energy utilization, the herd directs a higher percentage of feed energy intake to generate the products, rather than simply maintain body and reproduction functions.

The R2 value describes the proportion of the variation in values that is explained by the trend. In other words, an R2 value of 0.87 means that 87% the variation in emissions intensity is explained by milk production per cow. According to the trend line, increasing per cow milk production from 250 to 900 kg per cow would decrease emissions intensity from 45 kg CO_2 eq./kg FPCM to 12 kg CO_2 eq./kg FPCM, i.e. 73%.

CHAPTER 5

Exploring the mitigation potential in dairy cattle production

The analysis of current production shows that management practices and technologies that increase milk production per cow will reduce the GHG emissions intensity of milk production. This approach to mitigation also serves the national objective of increasing overall milk output.

The abatement technologies and practices assessed in this study were selected for their potential impact on enteric CH_4. Another important consideration taken into account during the selection of target interventions was the need to integrate mitigation with a number of key developmental goals for the dairy sector, such as its role in promoting food security, rural and overall economic development.

The mitigation options evaluated in this analysis were selected in a consultative process with national experts where those options identified as having the potential for large improvements in productivity were assessed alongside their potential to reduce on-farm greenhouse gas emission intensity while taking into account the feasibility of implementation and their potential economic benefits at the farm level. Box 3 summarizes the criteria used to identify interventions to be included in the analysis.

The interventions evaluated covered areas ranging from improved feeding practices to better herd heath and animal husbandry practices management and improved genetics. These comprised: supplementation with leguminous shrubs, supplementation with urea-molasses multi-nutrient blocks, use of urea treated crop residues, supplementation with high protein/energy concentrate, artificial insemination, disease control (trypanosomosis), and use of sexed semen. Interventions were selected to address the key drivers of low productivity and inefficiencies in production cycle. These are summarized in Table 5.1.

Table 5.1: Summary of selected interventions for Ethiopian dairy systems

Practice	Objective	Constraint addressed	Benefits
1. Supplementation with leguminous shrubs	Improve management of forage resources by better matching available resources to animal requirements/herd nutrient demand	Addresses feed scarcity and quality constraints	Improved animal and herd health Higher conception rates Improved weaning weights
2. Supplementation with urea-molasses multi-nutrient blocks (UMMB) 3. Use of urea-treated crop residues	Improve the quality of diet	Low quantity and quality of forage	Increased intake and digestibility Improved growth rates Shorter finishing periods and/or higher slaughter weights
4. Supplementation with low-cost high protein/energy concentrates	Increase adequacy of diet	Address energy and protein constraints during periods of low availability and quality	Improved cow condition Improved reproductive performance Higher conception rates
5. Disease control (trypanosomosis)	Control a disease that affects both physical and financial performance of dairy herds	High mortality and morbidity	Reduction in mortality and morbidity Increase in animal productivity Improvements in reproductive performance (fertility, age at first calving)
6. Use of superior genetics (improved breeds)	Improve production and reproductive traits	Low productivity of the indigenous cattle breeds	Increased weaning weights Improved conception rates Higher calf survival Increased final weights Increased milk yields

Box 3: Criteria for selection of interventions

Three principal criteria were used to identify interventions for analysis in the study; **the potential for improving production efficiency, feasibility of adoption by farmers and the potential to reduce enteric methane emission intensity.**

Improving production efficiency: A good strategy that farmers can implement to decrease methane emissions. Using this approach comprises the adoption of effective management of forage and other feed resources (e.g. supplementation, ration balancing), improved fertility and reproductive management of the herd, greater use of animals selected for improved production and better animal health management.

Reduction in enteric CH_4 emission intensity: Many measures that have the potential to increase productivity are associated with increased individual animal performance and this increased performance is generally associated with a higher level of absolute emissions (unless animal numbers are decreasing) but reduced emissions intensity. The figure below demonstrates some of these impacts. The use of improved breeds results in an increase in absolute emissions per animal because animals are more productive. Overall, however, a reduction in emission intensity occurs because productivity increases. Similarly, controlling disease results in a decrease in mortality and increase in number of animals in the herd hence increase in absolute emissions. From an emission intensity perspective, these interventions however translate into a decrease in emission intensity (see Figure 5.1). Some however can result in a decrease in both absolute enteric emissions and emissions intensity (see feed-based interventions in figure below).

Feasibility of implementation: The third criterion is that the interventions had to be feasible in the short or medium term. For the purposes of selecting interventions, "feasibility" was first determined by sectoral experts in terms of their technical potential, production system and territorial applicability, and market development. The study also assumed reliance on existing and proven technologies. The selected interventions were discussed with a broader group of stakeholder to assess the social and institutional feasibility of adoption and up-scaling of interventions. Ensuring that this criterion was met required investigation of information on barriers that keep farmers from adopting these interventions at large scale. Other factors taken into consideration included: location of interventions should be informed by location of drivers/barriers such as how geophysical aspects can affect applicability; and the potential to provide additional benefits, e.g. poverty reduction.

Impact of technical interventions on absolute emissions by systems

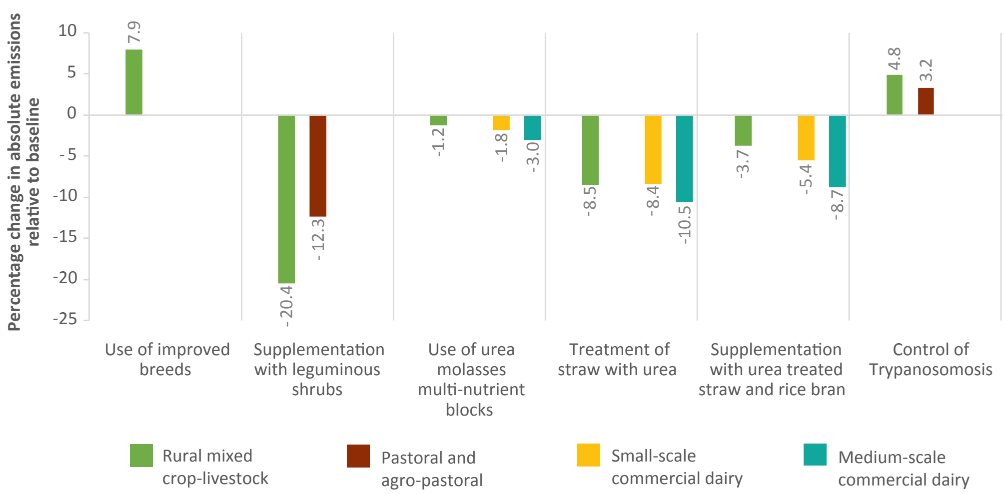
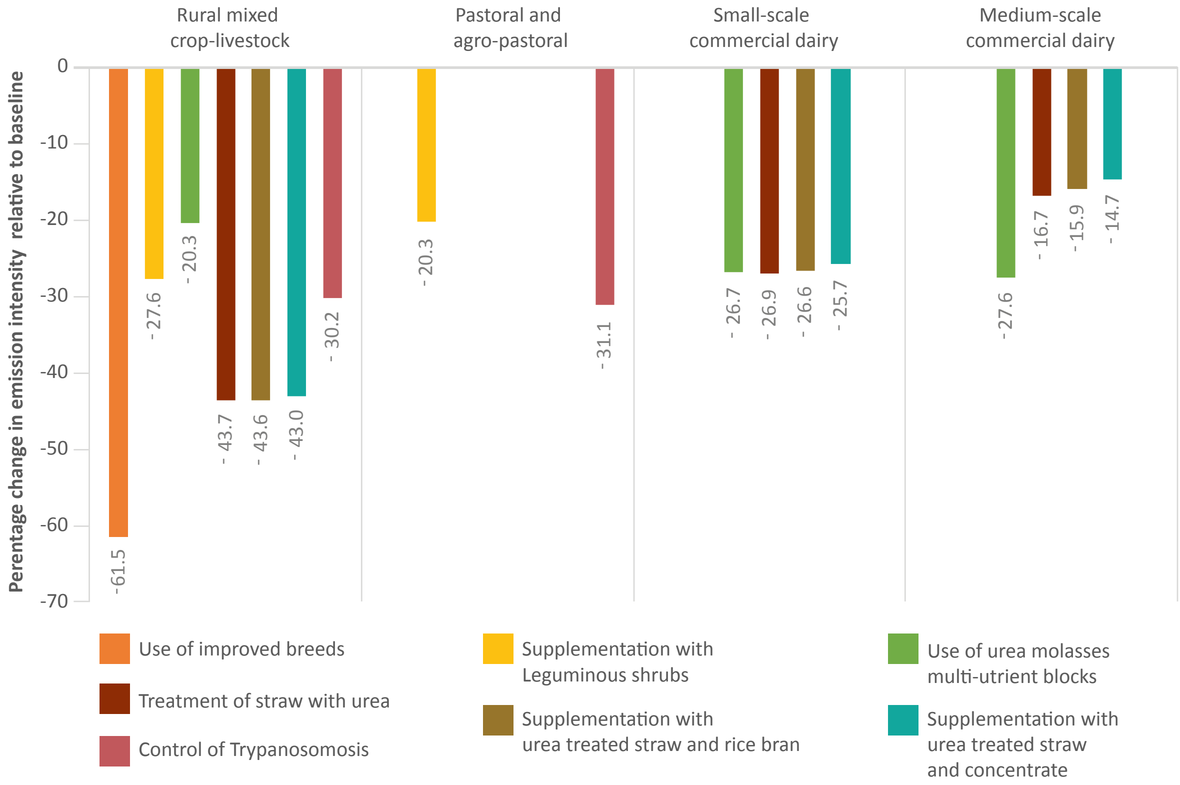


Figure 5.1: GHG emission intensity reduction potential relative to baseline emission intensity for single intervention



Source: GLEAM, 2016

The strategies were not applied uniformly, but selected for each production system, animal category, and agro-ecological zone using evidence from modelling and field studies and expert judgement of their specific operating requirements and likely impact on performance.

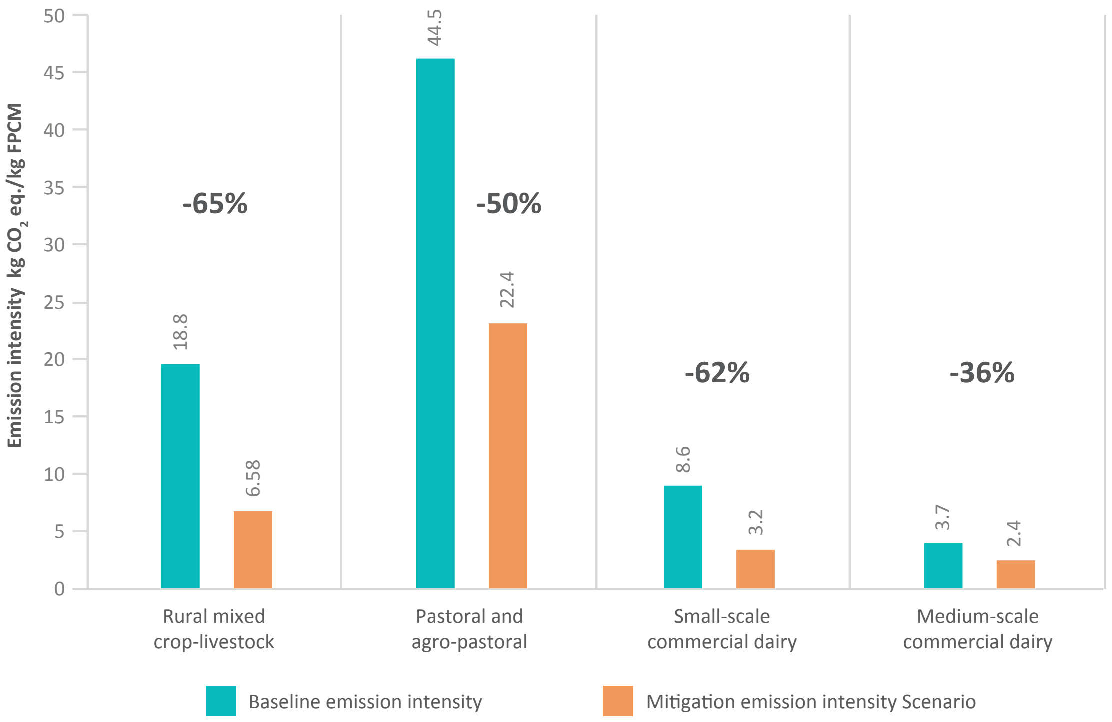
Quantitative summary of mitigation outcomes from the application of single interventions

The mitigation outcomes by system from the single interventions considered in this report are presented in Figure 5.1. Overall, the analysis shows that there is a high potential to reduce emission intensities; total emission intensity (Kg CO_2 eq./kg FPCM) can be reduced by 15% to 62%, depending on the intervention and production system (Figure 5.1). Please note that not all interventions were judged as being suitable for all systems. Where no value is given in Figure 5.1 for an intervention in a particular system it signifies that this intervention was not tested in that system.

The feed and nutrition related interventions (supplementation with leguminous shrubs, use of urea molasses multi-nutrient blocks, use of urea treated crop residues, supplementation with high protein/energy concentrate) results in a reduction in emission intensities between 16% - 50%. The treatment of crop residues with urea results in an emission intensity reduction of 17% - 44% relative to the baseline. Including rice bran in with urea treated straw to the basal diet, results in a similar emission intensity reduction potential: 16% - 50% of the baseline emissions.

Supplementation of lactating cows with UMMB results in a reduction of emission intensity between

Figure 5.2: Package of mitigation options (supplementation with leguminous shrubs, use of urea treated crop residues, control of trypanosomosis, use of improved genetics)



Source: GLEAM, 2016

20% - 27%. The reduction in emission intensity is a consequence of the improved feed digestibility, increase animal feed intake and associated increases in milk production.

The use of improved breeds with higher milk yield potential results in 62% reduction in emission intensity in the rural mixed crop livestock system (Figure 5.1). The impacts on emission intensity are achieved through reductions in number of replacement breeding animals, improvements in reproductive performance of the herd (age at first calving) and through increased milk production via a combination of higher milk yields per day and longer lactation periods).

In Ethiopia, trypanosomosis has substantial effects on cattle health and the livelihoods of rural farmers. Animal trypanosomosis reduces the offtake of animal protein and decreases milk production. The control of trypanosomosis in cattle was applied to both the rural mixed crop-livestock and the pastoral and Agro-pastoral system and resulted in a reduction of emission intensity between 30% - 36% relative to the baseline.

Quantitative summary of mitigation and productivity outcomes from the application of mitigation packages (combined technologies)

Additional significant reductions in emissions can be achieved through the combination of herd and health management, nutrition and feeding management strategies, and genetics. The reality is that farmers are likely to combine technologies and will select the combination of technologies that will maximize a number objectives. To test this concept a combination of interventions aimed at improving herd health (control of trypanosomosis), improving feed quality and availability (supplementation with leguminous shrubs and urea treated straw) and use of improved breeds was tested. This resulted in a reduction potential of 36%-62% in emission intensity relative to the baseline emission intensity (Figure 5.2). With this intervention package, milk production (expressed in FPCM terms) increases by 200%, 62%, 225% and 67% for the mixed crop-livestock systems, pastoral/agro-pastoral, the small-scale, medium-scale commercial systems respectively, compared to the baseline situation. This change in production is achieved with the assumption that the number of milking animals are kept constant.

CHAPTER 6

Prioritization of interventions to address enteric methane

Having identified and assessed the mitigation of potential, the next step was to prioritize these technologies for wider dissemination and adoption. Prioritization should not only consider enteric methane mitigation potential but also the productivity benefits, income advantages to farmers and other co-benefits that are likely to provide additional incentives for farmers to adopt mitigation interventions (Figure 6.1). A key incentive to farmers for adoption is increased revenue and/or reduced costs costs of production. To better understand the implications for farmers, a cost benefit analysis was conducted to assess the profitability of each intervention. The benefit-cost ratio is the ratio between the present value of the benefit stream and the present value of the cost stream. It provides an indication of how much the benefits of an intervention exceed its costs. Obtaining data was difficult for some of the interventions tested meaning that the economic implications of some of the interventions could not be assessed.

The prioritization process

All individual practices were ranked for their ability to reduce enteric methane. They were then assessed against two other criteria; productivity improvement and economic benefits. For ease of interpretation a 'colored light' system was developed for assessing impact where red was 'high, blue 'medium' and yellow 'low'. As the impact of an individual practice varies by system, practices were prioritized separately for each system. The values associated with the high, medium and low classification system are shown Table 6.1. It must be emphasized that this system was developed as an aid to more easily identifying those practices with the highest potential both within and between practices and systems. It does not signal "no potential" since even practices ranked 'low' against all three criteria reduced enteric methane emissions, increased output and returned a net financial benefit.

Figure 6.1: Initial prioritization process of technical interventions

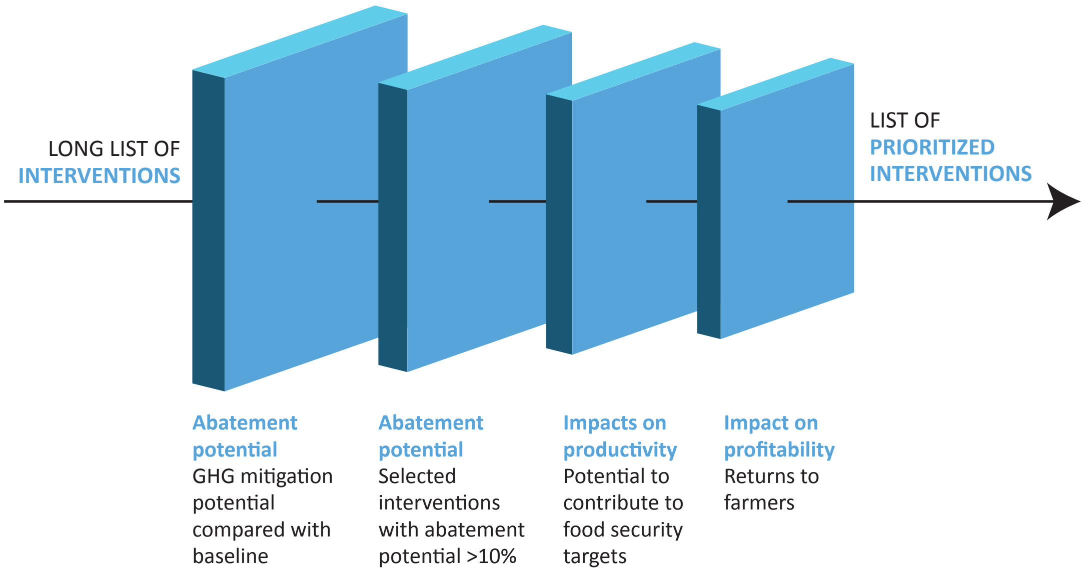


Table 6.1: Results from the prioritization of single interventions for dairy production systems

Intervention	Use of improved breeds	Leguminous shrub supplementation	Supplementation with UMMB	Urea treated straw	Urea treated straw + rice bran	Urea treated straw and High energy & protein supplementation	Trypanosomosis control
RURAL MIXED CROP LIVESTOCK							
Methane reduction	High		Low	Medium	Medium	Medium	Medium
Production increase	High		Low	High	High	High	High
Econimic benefit	Medium		Medium	Medium	Medium	Medium	Medium
PASTORAL/AGRO-PASTORAL							
Methane reduction	Medium	Low					Medium
Production increase	Low	Low					High
Econimic benefit	Medium	Medium					Medium
SMALL-SCALE COMMERCIAL							
Methane reduction			Medium	Medium	Medium	Medium	
Production increase			Medium	Medium	Medium	Medium	
Econimic benefit			Low	Low	Low	Low	
MEDIUM-SCALE COMMERCIAL							
Methane reduction			Medium	Low	Low	Low	
Production increase			Medium	Low	Low	Low	
Econimic benefit			Medium	Low	Low	Low	

Assessment criteria:

Methane mitigation:	Low: >15 <25	Medium: >25 <50	High: >50
Production increase:	Low: <25	Medium: >25 <50	High: >50
Economic benefit:	Low: <2	Medium: >2 <3	High: >3

Comparison of individual interventions

In addition to decreasing enteric methane production, all the individual interventions assessed resulted in increased milk production and returned a positive benefit-cost ratio irrespective of system. However, the magnitude of the impacts varied considerably with each system. There were large differences in the number of interventions that local experts identified as appropriate for each system. Table 6.1 summarizes the impacts of the individual interventions.

In rural mixed crop-livestock systems seven technologies were considered relevant and these spanned improved genetics, improved feeding and disease control. The use of improved breeds had the highest potential impact on all of the assessment criteria which is achieved through a combination of increased daily milk yield, increased lactation length and a reduction in age at first calving. The

Table 6.2: Prioritization results for the "package" intervention for dairy production systems

Common intervention 'package'	Methane reduction	Production increase	Economic benefit
Rural mixed crop livestock	High	High	Medium
Pastoral/agro-pastoral	High	High	Medium
Small-scale commercial	High	High	High
Medium-scale commercial	Medium	High	High

Assessment criteria:

Methane mitigation:	Low: >15 <25	Medium: >25 <50	High: >50
Production increase:	Low: <25	Medium: >25 <50	High: >50
Economic benefit:	Low: <2	Medium: >2 <3	High: >3

control of trypanosomosis and the feeding interventions involving urea treated straw with or without additional supplements gave similar benefits in terms of methane reduction, milk yield increase and financial returns. Leguminous shrub supplementation achieved similar reductions in enteric methane to the feeding and disease intervention but had a smaller impact on productivity. Supplementation with UMMB had moderate effects on milk production (<25%) although financial returns were similar to other feeding approaches. The higher price of milk received by these farmers explains the higher returns; highlighting that even for very small changes in emissions and production farmers can gain financial given the right conditions and incentives. Although the use of improved and higher yielding cattle clearly stands out as an intervention that should be prioritized, achieving that potential may not in fact be easy. Exploiting superior genetics will mean that other facets of the system will also need to change, in particular improved diet (both quantity and quality), disease control, etc. The gains from feeding interventions and disease control, although ranked lower than improvements in genetics on their potential, may well be easier to achieve in practice.

Only two interventions were considered for pastoral/agro-pastoral systems and of these the control of trypanosomosis had a greater impact on all three criteria compared to leguminous shrub supplementation.

However, despite the low impact on methane emissions and production, supplementation with leguminous shrub has a moderate impact on the financial returns because of the low cost of the intervention.

Four similar interventions were tested on small and medium-scale commercial farms. All of these interventions aimed at improving diet quantity and quality. Low-quality feeds such as crop-residues and low-quality grasses are important basal feeds in smallholder systems such as those in Ethiopia. Dairy production in Ethiopia is faced with seasonal feed constraints during which animals rely solely on crop residues. The supplementation with UMMB worked equally well in both systems (ranked medium for all for two assessment criteria (emissions and productivity) but gave contrasting impacts on financial returns.

The urea-based feeding approaches gave considerable lower financial returns to farmers in both market oriented systems and this is explained by the low price of milk. These farmers sell a larger share (or all) of their milk to cooperatives that offer lower prices compared to the informal market. On the other hand, higher financial benefits are achieved for the same intervention in the rural mixed crop-livestock system largely because most of the milk output is sold on the informal markets, where milk prices are 40% above the price paid by cooperatives.

Intervention packages

The large number of possible intervention 'packages' ruled out a comprehensive comparison and prioritization of alternative 'packages'. Expert judgment was therefore used to define what was deemed an appropriate common intervention 'package' to compare across the four dairy systems. Results of an assessment of this package, which comprised interventions aimed at improving herd health, nutritional status and genetics, are shown in Table 6.2. There is a clear benefit from introducing a package of interventions since in all systems enteric methane reduction was increased while milk production was increased in all the four systems (>50%). The financial implications of the package of interventions were moderate in smallholder systems and high in market oriented systems.

CHAPTER 7

Unlocking the potential of 'no regrets' opportunities

This study reveals that pathways for enhancing productivity and achieving emission reductions exist in all systems. The greatest opportunities for mitigation and productivity increases at scale lie in the smallholder production systems; the rural mixed crop livestock systems and pastoral and agro-pastoral systems for the following reasons:

- Rural mixed crop livestock systems and pastoral and agro-pastoral systems account for 63% and 36% of the dairy cattle herd, respectively and provide livelihood support to a large number of smallholder farmers.
- The milk output is considerably less than it should be; this is confirmed by the wide productivity gaps in these systems.
- Approximately 99% of the enteric methane emissions originate from these two systems.
- Emissions and emissions intensity are highest in these a systems and improving productivity can address the dual challenges of development and climate change.
- Interventions to improve productivity will have to be tailored to specific production system practices. These two systems operate within diverse conditions and face different constraints and therefore will require distinct set of interventions and incentives.

This study didn't consider changes in systems i.e. from smallholder to commercial oriented production, however, it is also possible to meet the increasing demand for dairy products by expanding milk production in the existing market-oriented systems however such choices will have to be made taking into account the implications for livelihoods and poverty reduction.

The results presented in the preceding sections indicate that there are significant opportunities for growth on a low carbon path for the dairy sector and that economically viable opportunities exist across all production systems. Increasing individual animal productivity as a consequence of better feeding practices, health and herd management, also results in a reduction of the herd. Reduction in animal numbers, particularly in subsistence production systems, allows for the provision of adequate feed, better health management leading to improvements at both animal and herd levels. Methane emissions will be reduced at both the total herd and per liter of milk. However, these mitigation options might be in conflict with the interests of smallholders who generally tend to keep large herds for non-productive functions such as traction, nutrient value and risk management. This analysis shows that the implementation of these interventions can have important impacts on the revenue profile of these dairy production systems (Table 7.1). If wider adoption is to be pursued, such barriers will have to be addressed through for example, incentives/measures that support the replacement of such functions and compensate farmers for loss of these functions.

The study also indicates that while there are

Table 7.1: Comparison of farm revenue profile in baseline and intervention scenarios in dairy systems in Ethiopia

Baseline Scenario	meat	milk	manure	Intervention Scenario	meat	milk	manure
Rural mixed crop-livestock Systems	65%	30%	5%	Rural mixed crop-livestock Systems	41%	56%	3%
Pastoral & Agro-pastoral Systems	75%	25%	0%	Pastoral & Agro-pastoral Systems	68%	32%	0%
Small-scale commercial dairy Systems	53%	44%	3%	Small-scale commercial dairy Systems	27%	72%	1%

many potential interventions to reduce emissions and improve productivity, the same intervention can have contrasting impacts on emissions, production and farmer revenues as Table 6.1 illustrates. This reinforces the need to tailor interventions to local conditions.

It is important to note that the costs and benefits (and profitability) of the technology are only one part of the picture: adoption also depends on policy incentives, technical support, farmers' capacity, and other factors. Putting in place an enabling environment with supportive policies and programs to overcome the market, regulatory and institutional barriers is essential for mitigation potential to be realized. A better understanding of the barriers to adoption is also required before designing interventions are farm level and contributing to the design of policies and programs that can support practice change at scale.

Drawing clear conclusions from the prioritization process around realized potential is challenging; some options could prove to be a better option at system level and may not work at farmer level where other criteria may be important. Consequently, there is a need to consider how these interventions behave on the ground. In particular a better understanding of the barriers to adoption at the farm level is required. The most commonly cited barriers include opportunity cost of labor, limited knowledge of farmers, access to markets, inputs and services, and environmental constraints. This information currently does not exists for the individual interventions assessed in this report. Developing an understanding of why individual technologies are not being adopted requires a much more intensive effort at the local and system scale than has been possible in this study. The assessment however provides a guide to where subsequent efforts should be focused.

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