Food and Agriculture Organization of the United Nations

OPTIONS FOR LOW-EMISSION DEVELOPMENT IN THE UGANDA DAIRY 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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Contents

Acknowledgements iv

Executive summary v

Chapter 1
GREEN GROWTH OPTIONS FOR THE DAIRY SECTOR **1**

Chapter 2
OBJECTIVES AND APPROACH **2**

Chapter 3
OVERVIEW OF DAIRY PRODUCTION **6**

Chapter 4
EMISSIONS AND EMISSION INTENSITIES **10**

Chapter 5
EXPLORING THE MITIGATION POTENTIAL IN DAIRY CATTLE PRODUCTION **16**

Chapter 6
PRIORITIZATION OF INTERVENTIONS TO ADDRESS ENTERIC METHANE **21**

Chapter 7
UN-LOCKING THE POTENTIAL OF ‘NO REGRETS’ OPPORTUNITIES **25**

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Executive summary

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

Uganda has taken steps to chart a path towards achieving food security and other developmental goals. The government has developed a number of high level policy initiatives, including the Uganda Vision 2040[1] and the Uganda National Climate Change Policy[2] which are the overarching policy documents setting out the national development objectives. The Uganda Vision 2040 is the national long-term development plan that aims to transform the country into an upper middle-income country, promote a green economy and clean environment and provide a high quality of life to all its citizens by 2040. The National Climate Change Policy seeks to ensure a harmonized and coordinated approach towards climate-resilient and low-carbon development path in line with the national development plans, the Uganda Vision 2040, and sectoral policies.

The agricultural sector has been identified as one of the key sectors to contribute to the national economic growth. The sector is envisaged to ensure food security, provision of raw materials for agro-industries, creation of employment opportunities, generation of income and foreign exchange earnings. The sector is however one of the most vulnerable to the impacts of climate change and extreme weather events. Due to this challenge, the government recognizes the need to develop interventions that make the agricultural sector, in particular the dairy sector, more resilient to climate change and extreme weather events while minimizing its contribution to greenhouse gas emissions (GHG).

Benefits of taking a climate-resilient and low-carbon growth pathway for the dairy sector

With this in mind, the Uganda's Nationally Determined Contributions (NDC) has put forth mitigation actions to tackle its growing emissions and to play a role in global efforts to limit temperature rise to 2 degrees. Moreover, Uganda recently became the first country in Africa to sign the Partnership Plan for NDCs. The Partnership Plan will help Uganda to enhance and facilitate the implementation of its NDC by connecting the country to available partners and program resources. These efforts will play a key role in realizing the transition to a low-carbon, climate-resilient economy.

Adopting a low-carbon growth pathway for the dairy sector could benefit Uganda in several ways:

- The dairy industry is the most important livestock sub-sector, contributing about half of the total livestock Gross Domestic Product (GDP), which contributes nearly 20 percent of the total agricultural GDP. The sub-sector currently contributes to the livelihoods of 1.2 million dairy farming households through generation of income, employment and food.
- The dairy sector in Uganda has witnessed remarkable growth in the last decades, growing at about 8 percent per year thanks to policies and sector reforms, good financial institutions and expansion of the role of the private sector[3].
- Milk production in Uganda is predominantly managed by traditional small-holder farmers,

[1] Uganda Vision 2040. http://npa.ug/wp-content/themes/npatheme/documents/vision2040.pdf
[2] Uganda National Climate Change Policy, 2015. https://www.mwe.go.ug/sites/default/files/library/National%20Climate%20Change%20Policy%20April%202015%20final.pdf
[3] Balikowa, 2011. Uganda Dairy Sector Review Final Report. http://www.fao.org/3/a-aq292e.pdf

which are characterized by small herd sizes, low animal productivity, small land holdings, and greater dependence on family labour and the informal market. Traditional small-holder farming represent 98 percent of the national dairy herd, and produce 86 percent of the milk in the country. Amongst these dairy farmers are some of the poorest and most marginalized such as women. It is estimated that 23 percent of the dairy households in Uganda are headed by female farmers[4]. Considering the importance of the dairy sector 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 and use of incentives is expected to significantly increase milk yields with net benefits in the short-to-medium term.

- Milk is one of the most nutritionally complete foods; it is rich in high quality protein providing all ten essential amino acids and is an excellent source of calcium and vitamin B2, vitamin A, and a fair source of vitamin D. Current consumption of milk and dairy products in Uganda is 37 kg per person[5]; 163 litres below the recommended amount from the World Health Organization (WHO). Although 70 percent of the population consume milk at least once a week, only 36 percent can afford milk in a daily basis[3]. Milk consumption varies by region and it is highly influenced by income level and milk and dairy products availability.
- Uganda's population is expected to increase from the current 42.8 million to 63.8 million in 2030, with its urban population almost doubling during this period. With this future population scenario, per capita milk consumption is projected to grow rapidly.
- Dairy farming plays an important role in food security in Uganda. On-farm milk production contributes to 37 percent of the total household milk consumption[6]. Therefore, strategies seeking to increase milk productivity might directly benefit overall household food security.
- The current productivity of dairy animals in general is low, which results in a shortage of supply of dairy products. For example, on average, milk yields range from 1.0 litres per cow per day in pastoral systems to 25 litres per cow per day in large-scale commercial systems. Milk yields are low and largely variable mainly because of poor and limited feed resources, diseases and poor management. Seasonality in rainfall also plays an important role in milk production - the yield per cow and by extension the total amount of milk produced in Uganda fluctuates greatly during the year.
- Dairying represents one of the fastest returns for dairy farmers in the developing world. It provides milk for home consumption, regular cash flow from milk sales to farmers, especially to women, enhances household nutrition and food security and creates off-farm employment. In Uganda, dairy animals are one of the most valuable assets for rural households playing many functions such as traction, nutrient value and risk management.
- Given the dependence of the country on agriculture and natural resources, Uganda is also highly vulnerable to climate change ranking as the 14th most vulnerable country in the world[7]. Uganda agriculture has faced the effects of extreme weather events and impacts of a changing climate, including: flooding, droughts, widespread crop failures, livestock deaths and intensification of climate sensitive diseases.

Emissions and emission intensities from the dairy production

The national dairy population is estimated to be 13.8 million dairy cattle producing 1.8 billion litres of milk. Agro-pastoral dairy production systems produce the largest share of the milk produced in the country, contributing to 53 percent of total cattle milk supply. Medium-scale extensive, pastoral and medium-scale intensive systems contribute to 20, 9 and 9 percent of the total milk production, respectively; while small-

[4] Mtimet, N. and Pica-Ciamarra, U. 2016. Dairy farmers' access to market in Uganda: Observing the unobservable. 5th International Conference of the African Association of Agricultural Economists, Addis Ababa, Ethiopia.

[5] FAOSTAT, 2013.

[6] Behnke, R. and Nakirya, M. 2012. The contribution of livestock to the Ugandan economy. IGAD LPI Working Paper 02-12. Addis Ababa, Ethiopia: IGAD Livestock Policy Initiative. https://cgspace.cgiar.org/bitstream/handle/10568/24970/IGAD_LPI_WP_02-12.pdf?sequence=1&isAllowed=y

[7] ND-GAIN. Notre Dame Global Action Initiative. 2016. https://gain.nd.edu/our-work/country-index/rankings/

scale intensive, large-scale commercial and small-scale extensive contribute to 9 percent when combined.

The dairy cattle sector in Uganda is responsible for the emission of about 19.1 million tonnes CO_2 eq. The GHG emissions profile is dominated by methane (98.6 percent); nitrous oxide (N_2O) and carbon dioxide (CO_2) contribute 1.3 and 0.1 percent of the total emissions, respectively.

At national level, the emission intensity of milk produced in Uganda is on average 10.4 kg CO_2 eq./kg of Fat and Protein Corrected Milk (FPCM). Average emissions range from 5.9 to 20.8 kg CO_2 eq./kg FPCM for traditional systems, while in commercial systems they range from 1.6 to 4.7 kg CO_2 eq./kg FPCM.

Options for improving productivity and reducing enteric methane emissions per unit of output

Improving animal and herd productivity is one of the key pathways to reduce enteric methane emissions per unit of product (Box 1). Reducing enteric methane emissions via increasing productivity is economically viable in most situations; several activities that reduce methane emissions have low or negative economic cost when considering the increase in production.

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

In the assessment of technical options for the main dairy cattle production systems, the following criteria were used:

- Interventions had to have potential for improving productivity while at the same time reducing enteric methane emissions per unit of milk produced.
- 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 Uganda.

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 feed seasonality constraints; and (iii) improved herd management, water harvesting technologies and animal health interventions. Within this broad categorization, 7 single interventions and 1 'package' consisting of a combination of single interventions were assessed in this study.

Significant gains can be achieved: emission intensity can be reduced from 1.5 to 27 percent

This work shows that significant reductions in methane emission intensity (kg CH_4/kg FPCM) can be realized through the adoption of existing and proven technologies and practices. Overall, the analysis shows that there is a high potential to reduce emission intensities; methane emission intensity can be reduced by 1.5 to 27 percent depending on the intervention and production system assessed.

Many of the biological effects leading to emissions are interrelated and interdependent and, accordingly, the changes in enteric methane emissions per unit of milk are not additive. The range of reduction in methane emission intensity is modest because the interventions considered were restricted to what might reasonably be implemented or expected to occur in dairy production. In particular, the implementation of many of the interventions is limited to lactating cows for practical or economic reasons which limits the scope of the reductions in methane emissions.

Interventions to mitigate enteric methane emissions result in 3 to 40 percent increase in milk production

Interventions targeting to improve dairy breeds and animal health status returned the highest impacts on mitigation and milk production. The genetic improvement of the dairy herd by crossing local breeds with improved breeds resulted in 22 percent reduction in methane emission intensity and 32 percent increase in milk production. Vaccination against East Coast Fever reduced enteric methane emissions

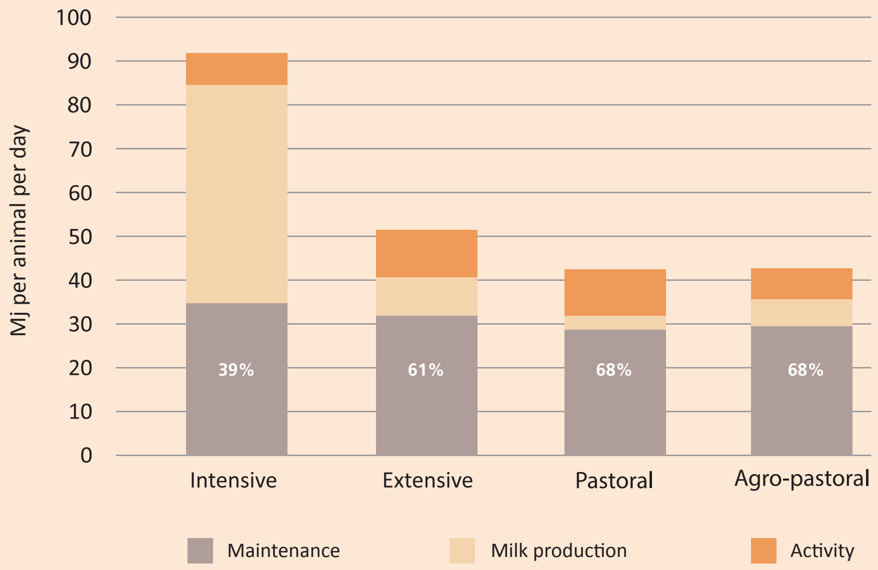
Box 1: Productive efficiency and dilution of the maintenance requirements

The nutrient requirements of cows come from two components – maintenance and production. Maintenance requirements are the nutrients needed for cows to live every day. They are used to maintain metabolic functions such as walking around, breathing, digesting food and regulating body heat. All animals have a necessary maintenance requirement that must be met and results in no production, yet are still associated with methane losses. Once all maintenance requirements are met then leftover nutrients can be used for milk production and other functions such as reproduction and growth.

The biological processes underlying improved productive efficiency is known as the 'dilution of maintenance' effect (Bauman *et al*., 1985; VandeHaar and St-Pierre, 2006). A lactating dairy cow requires daily nutrients for maintenance and for milk synthesis. The maintenance requirement does not change with production level and therefore can be thought of as a fixed cost needed to maintain vital functions.

As shown in the figure below, the average maintenance energy requirement for milking cows in intensive, extensive, pastoral and agro-pastoral is about 36.0, 31.2, 29.3 and 29.3 MJ per day, respectively. Assuming milk composition remains constant, the nutrient requirement per unit of milk production also does not change, but the total energy cost for lactation increases as a function of milk production. It can therefore be thought of as a 'variable cost' of dairy production. A dairy cow in the intensive system requires more nutrients per day than a low producing dairy cow; the cow with a daily milk output of 15.6 kg per day is using 39 percent of consumed energy for maintenance whereas a cow in the extensive system that produces 3.0 kg per day is using 61 percent of energy intake for the maintenance (Figure below). Increased production thus dilutes out the fixed cost (maintenance) over more units of milk production, reducing the total energy requirement per kg of milk output. A cow producing an average of 15.6 kg milk/day in the intensive systems requires 5.9 MJ/kg milk, whereas a cow yielding 3.0 kg/day in extensive dairy systems needs 17.0 MJ/kg milk.

Energy requirement for milking cows in dairy systems in Uganda



Source: GLEAM, 2018

Bauman, D.E., S.N. McCutcheon, W.D. Steinhour, P.J. Eppard and S.J. Sechen. 1985. Sources of variation and prospects for improvement of productive efficiency in the dairy cow: A review. J. Anim. Sci. 60:583-592; **VandeHaar, M.J. and N. St- Pierre.** 2006. Major advances in nutrition: Relevance to the sustainability of the dairy industry. J. Dairy Sci. 89:1280-1291

by 4.4 to 26.5 percent and results in milk production increases between 8 to 40 percent.

Applying combinations of interventions aimed at improving feed availability and quality, providing constant supply of clean fresh water, improving genetic status and controlling herd health can potentially result in a potential reduction of 4.5 to 52.1 percent in enteric methane emission intensity relative to the baseline scenario. With these combinations of technologies and practices, an increase in milk production of 8 to 120 percent can be achieved compared to the reference scenario. The joint impacts realized from applying a combination of technologies are better understood as multiplicative rather than additive, i.e. they are mutually enhancing and dependent.

Prioritization of interventions for enteric methane

A preliminary ranking of interventions within each production systems, to identify those with high mitigation potential, increased production and high economic return was undertaken to provide an indication of the interventions with highest feasibility and attractiveness. Interventions for which methane reduction potential were less than 10 percent were excluded from the prioritization process. Based on this initial screening, only 1 intervention (out of the 3 selected interventions tested) in commercial systems met the prioritization criteria. In traditional systems, with the exception of fodder conservation in medium-scale extensive systems, all other interventions were included in the prioritization analysis. Use of improved breeds had a low impact on methane emission intensity reduction and profitability, and moderate impact on productivity, which was achieved through a combination of increased daily milk yield, increased fertility and a reduction in age at first calving.

Mitigation options for traditional systems

East Africa is home to a significant number of pastoralists whose livelihood is based on livestock production in marginal lands. Pastoralism and agro-pastoral systems are important in supporting the local economy, the conservation of the environment, and help to maintain traditional knowledge and cultural and social relations. However, the potential of adopting mitigation practices in traditional systems is fairly limited due to lack of technical and financial capacity.

Although the economic analysis might not directly support the application of mitigation practices in traditional systems, the study does not exclude the importance of mitigation action focusing specifically on traditional systems since their existence and persistence is already threated by the effects of climatic variability and climate change. All the mitigation options analyzed in this study presented significant gains in productivity, which in practice can generate improvements in food and nutrition security, as well as boost farmers' incomes. Moreover, some of the mitigation options can maintain and/or improve herd parameters, feed resources and water supply during and after climate shocks, supporting these systems to move from relief to resilience. Given the public benefits of tackling and adapting to climate change, governments should consider policies and incentives to help livestock farmers, in particular pastoralists, to overcome the barriers to technology adoption. Practices such as forage conservation, improved water harvesting techniques and disease control are some of the mitigation options that can be implemented by national governments to support traditional systems to mitigate and adapt to climate change.

CHAPTER 1

Green growth options for the dairy sector

With 80 percent of its population dependent on rain-fed agriculture for their livelihoods, the impact of climate change and related disasters on land and natural resources has the potential to severely affect many people, and the economic growth of Uganda. In 2008, a drought caused losses of about 3 percent of the value of all food and cash crops that year. Two years later, the country lost 16 percent of the total annual value of these crops as a result of extreme weather[8].

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. At the same time, Uganda will be significantly impacted by climate change and adaptation solutions are needed to reduce its vulnerability. It is estimated that by 2025, the cost of inaction will be 20 times greater than the costs of adaptation[9].

Uganda envisions to become an upper middle-income country and provide a high quality of life to all its citizens by 2040 while promoting a green economy and clean environment according to the national long-term development blue print "Uganda Vision 2040". In line with the aspirations of Uganda's Vision 2040, the Second National Development Plan (NDPII) 2015/16 - 2019/20[10] recognizes that most of the key economic sectors (in particular agriculture, forestry and energy) will be affected by climate change, and as a result, climate change will negatively affect the national economy. The NDPII aims to strengthen the country's competitiveness for sustainable wealth creation, employment and inclusive growth by prioritizing investments in key areas with the greatest multiplier effect, such as the dairy sector.

Uganda is strongly committed to sustainable development principles and climate change action. The country has made an ambitious commitment to curb its GHG emissions by 2030. In its Nationally Determined Contributions (NDC) to the UNFCCC, Uganda communicated its plans to cut emissions by 22 percent by 2030 relative to the business as usual (BAU) scenario (of about 77.3 MtCO_2 eq. in 2030). Focusing particularly in the livestock sector, the country proposes to reduce emissions from the sector through livestock breeding research and manure management practices, if additional resources and transfer of technology are available through international cooperation.

This report presents the findings and recommendations from an initial assessment of the dairy cattle sector of Uganda. It is undertaken in collaboration with the Ministry of Agriculture, Animal Industry and Fisheries - MAAIF, and funded by Climate and Clean Air Coalition (CCAC), the New Zealand Government and the Food and Agriculture Organization of the United Nations (FAO).

The primary focus of this initial assessment is to identify and prioritize interventions to reduce enteric methane emission intensity from dairy production systems that are consistent with other development goals. To that end, this report examines the scale of enteric methane emissions from the dairy sector, and identifies 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.

[8] Economic Assessment of the Impacts of Climate Change in Uganda. National Level Assessment: Agricultural Sector report. 2015. https://cdkn.org/wp-content/uploads/2015/12/Uganda_Agricultural_Sector.pdf

[9] Economic assessment of the impacts of climate change in Uganda: Key results. 2015. https://cdkn.org/wp-content/uploads/2015/11/UGANDA_Economic-assessment-of-climate-change_WEB.pdf

[10] Second National Development Plan (NDPII) 2015/16 – 2019/20. 2015 http://npa.ug/wp-content/uploads/NDPII-Final.pdf

CHAPTER 2

Objectives and approach

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

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

1) **Establishment of a baseline scenario;** Including the selection and characterization of production system, estimation of GHG emissions and emission intensity, and identification of key determinants of low productivity and emission intensity.

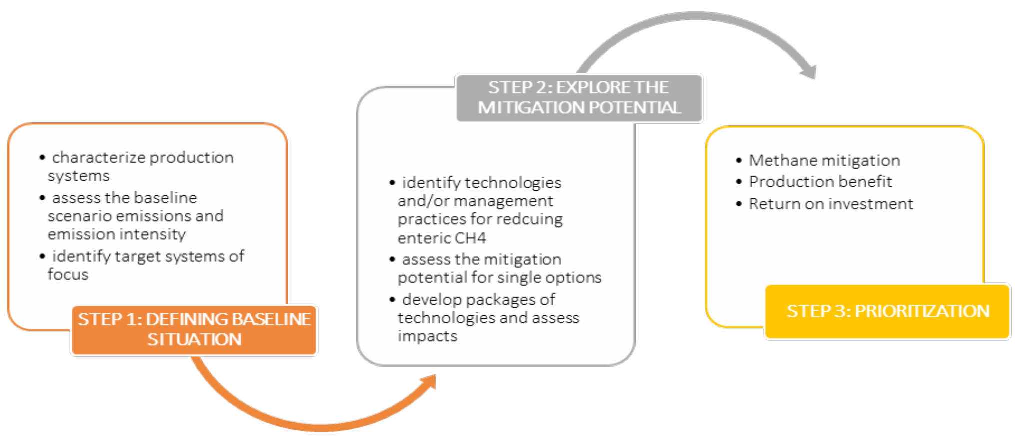
2) **Assessment of the mitigation potential.** Identification of system specific interventions consistent with development objectives for improving productivity, addressing enteric methane emissions and quantification of the mitigation potential.

3) **Prioritization of interventions.** Prioritization of interventions is undertaken by drawing on modeling results (of emission intensity reductions and productivity impacts), and a cost-benefit analysis. It assesses productivity impacts, the potential profitability for farmers in adopting implementing the selected interventions and identifies the implementation barriers.

A key focus of this work is on interventions that reduce emission intensity while maintaining or increasing milk production such that climate change and productivity improvement can be pursued simultaneously (Box 2).

The analysis focuses on the dairy cattle sector, a strategic sector in Uganda that was selected in consultation with front-line government ministries, e.g. ministry of livestock, environment, academia institutions, and public and private stakeholders. The huge and diverse livestock population, varied and favorable agro-ecology for dairying, increasing demand for dairy products in urban and peri-urban areas, as well as the long-standing culture of dairy products consumption, are criteria that have supported this choice.

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



Box 2: Absolute emissions versus emission intensity

The primary determinants 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 energy in the feed that is directed to produce milk or gain weight rather than to 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 the business-as-usual.

Small-holder dairy development presents a promising option to boost rural incomes, improve food and nutrition security, and create employment along the dairy value chain; thus contributing to the National rural development policy and strategy.

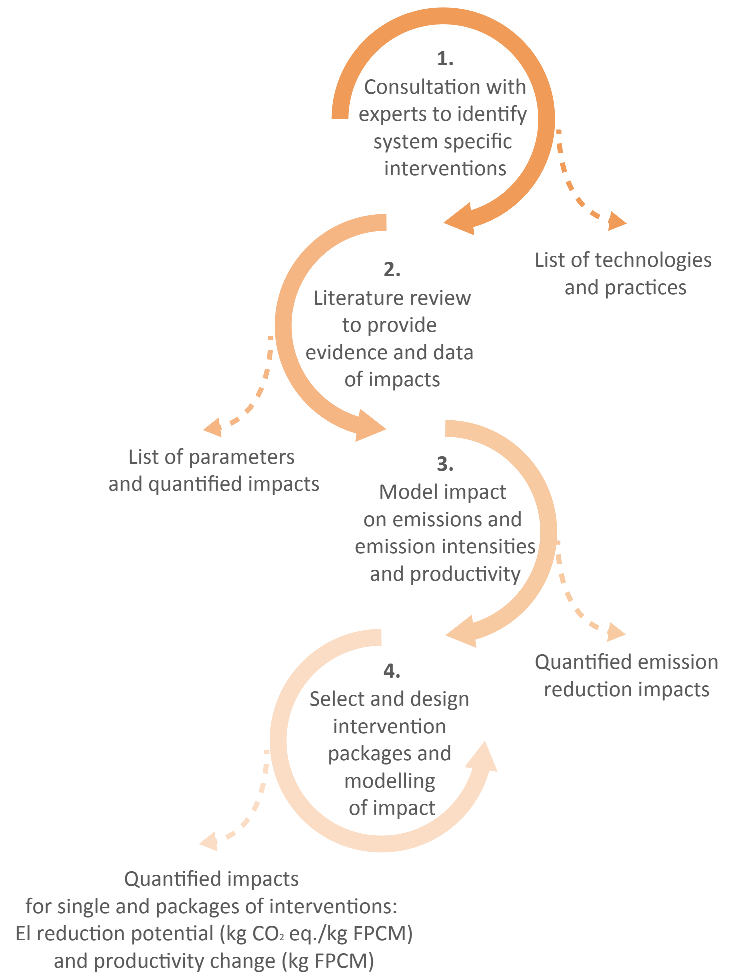
The study undertakes biophysical modeling and scenario analysis using the Global Livestock Environmental Assessment Model[11] (GLEAM) to provide a broad perspective of opportunities and attainable goals in terms of productivity gains and emission intensity reduction in the dairy sector (Box 3). The scenario analysis uses the outputs of the biophysical 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 milk production 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 impacts 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 in the Box 3. 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.

[11] FAO – The Global Livestock Environmental Assessment Model – GLEAM. http://www.fao.org/gleam/en/

Figure 2.2: Process for exploring mitigation impacts



Box 3: Modelling GHG emissions from dairy production systems in Uganda

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 spatially explicit model of livestock production systems that represents the biophysical relationships between livestock populations (FAO, 2007, 2011), 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 resolution level of 1 km^2, 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 Uganda and the database of production systems parameters was updated with more recent and system specific information and data on cattle 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 dairy production systems. Emissions and emission intensities are reported as CO_2 equivalent emissions, based on 100-year global warming potential (GWP100) conversions factors as reported by the IPCC in its 5th Assessment Report (AR5).

The abatement potential for each practice was calculated by estimating the changes from the baseline GHG emissions, following the application of system specific interventions. 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.

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

Sources:

FAO – The Global Livestock Environmental Assessment Model – *GLEAM*. http://www.fao.org/gleam/en/.

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G. 2013. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities.

Opio, C., Gerber, P.J., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. and Steinfeld, H. 2013. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment.

CHAPTER 3

Overview of dairy production

The dairy industry in Uganda is estimated to contribute more than 50 percent of the total output from the livestock sub-sector, which in turn contributes nearly 20 percent of the total agricultural GDP[12]. The dairy industry employs many people who are engaged in various economic activities along the dairy value chain, particularly in milk production, collection, bulking and transportation, processing, distribution and marketing as well as provision of inputs and support services.

The industry has witnessed tremendous growth over the last decade, growing at an average rate of 5-7 percent per annum as a result of the favorable macroeconomic environment, policy and institutional reforms, as well as numerous targeted interventions to promote development of the industry by government and the private sector. Milk production has grown at an average rate of 6.3 percent per annum from 659.5 million litres in 1999 to an estimated 1.4 billion litres in 2010, in consequence of the herd expansion, which has grown at an average of 6.3 percent per annum from 5.8 million in 1999 to 12.1 million in 2010[13].

The sector currently contributes to the livelihoods of 1.2 million dairy farming households. According to the 2008 National Livestock Census, the majority (94 percent) of the cattle-owning households keep indigenous cattle, while 6 percent of the cattle rearing households keep improved dairy breeds (exotics and their crosses with indigenous breeds). Majority (49 percent) of the improved dairy breeds are found in the Western region, followed by Central with 30 percent and Eastern with 20 percent. Indigenous cattle are almost equally distributed amongst all the regions. However, the Northern region has slightly fewer indigenous cattle than other regions[14].

Dairy production systems in Uganda may be classified into two broad categories, namely (i) "traditional" milk production systems, and (ii) "commercial" milk production systems[14].

The **traditional production system** generally refers to the small-scale, farm/household production system closely associated with the informal marketing system. This production system is to a large extent based on small herds of cattle managed mostly by family labor, and few purchased inputs. The majority of dairy producers fall under the traditional production system, characterized by low-input low-output, greater dependence on family labor and keeping cattle primarily for various objectives, including household nutrition, manure for crop production and energy (biogas), store of wealth (saving), ready source of income (sale of animals for beef), social status (based on number of cattle), and daily income from sale of surplus milk. Women and youth play a key role as source of labor for feeding, watering, cleaning, milking and milk marketing in this system. On the contrary, women and the youth are to a large extent marginalized in terms of decision making and utilization of the cash income and other benefits from the dairy enterprise. This study defines four types of traditional milk production systems namely: *small-holder extensive, medium-holder extensive, pastoral (semi-nomadic pastoralists) and agro-pastoral.*

- *Small-holder extensive:* The average household in this system owns a small piece of land, averaging 2 ha but may have access to more land either from rent or communal access. The majority of

[12] Ekou, J. 2014. Dairy production, marketing in Uganda: Current status, constraints and way forward.
[13] FAOSTAT. 2018
[14] Balikowa, 2011. Uganda Dairy Sector Review Final Report. http://www.fao.org/3/a-aq292e.pdf

farms in this category keep about 1-3 indigenous cows, which produce a few liters of milk mainly for home consumption and a little surplus for sale. The household relies on the informal market and may not have the incentive to deliver milk to distant rural milk collection facilities owing to the low milk volume produced and marketed per day. No commercial feed is used, but common salt and rock salt are frequently provided as mineral supplement. The major economic activity is crop production and farmers have fewer opportunities for off-farm income.

- *Medium-holder extensive:* In this system, the farmer is engaged in off-farm income generating activities, including formal employment. Family members spend less time on the dairy enterprise. Hired workers take the animals to pastures and carry out other dairy-related duties. Animals graze on both owned and rented land and sometimes communal grazing land. It is common to combine two or more small herds of different households to be grazed by one hired worker or family labor. Usually the morning milk is sold while the evening milk is consumed by the household. Milk is sold to a cooperative collection center but may also be sold to rural collectors (agent of raw milk traders). This type of household does not have access to as much land as the pastoralist and agro-pastoralist which limits the herd size to an average of 13 indigenous milking cows. This system is common in areas where there is enough land for both grazing and crop production.
- *Agro-pastoral:* The farmer's main economic activity is cash crop production (bananas, coffee, pineapples, and other crops with a ready market). Dairying is undertaken because it allows better utilization of the available low-priced land and labor, and produces manure to fertilize the crops. Farmers keep a mix of indigenous and low grade crossbreeds which are managed by extensive grazing on unfenced land. This system relies on crop residues to feed the animals during the dry season. This farming system represents the starting point of transformation from traditional to commercial. The farmer earns significant income from crop enterprises and with time finds it easy to fence the land and to increase the number of improved dairy cattle in the herd. The herd has an average of about 35 indigenous and improved cows.
- *Pastoral:* This is a semi-nomadic farming system. Owing to the decreasing communal grazing land area, pure nomadic systems are disappearing very fast. Some pastoralists rent private land which allows them to stay in one place for most parts of the year, only relocating to the greener marshes, river banks and lake shores during severe drought. Extensive grazing on unimproved natural pastures is the common practice. This farming system is common in the relatively drier or semi-arid areas such as the traditional cattle corridor which extends from Ntungamo and Isingiro districts in south-western Uganda through Central region to Karamoja region in north-eastern Uganda. Apart from natural pastures, animals may be supplemented with rock salt. Access to water and pastures of good quality is a major constraint during the dry season. The household may hire a herdsman but it is more common to use family labour. Most of the milk produced is for home consumption and processing of traditional products with a longer shelf life such as ghee. Only a small surplus is sold to the informal market.

The commercial production systems are generally characterized by greater reliance on hired labor and on a greater range of purchased inputs and services. This study defines three categories of commercial milk production systems namely small-holder intensive, medium-holder intensive and large-scale (commercial) producers.

- *Small-holder intensive:* This farm type represents the typical zero grazing unit rearing 1 to 3 improved dairy cows and a total herd of around 2 to 6 animals. The household owns some land which is mainly used for fodder production (mainly Napier or Pennisetum purpureum) for dairy and some cash-crop production. Milk yield per cow reaches 2,500 kg milk per lactation, which is obtained with relatively high use of concentrates. Manure is collected and used as fertilizer on crops. The household income from off-farm sources is significant.
- *Medium-holder intensive:* The average herd size is 15 improved cows but the number may range between 10 and 20 grazing on fenced paddocks. Both lactation yield and use of concentrates

Table 3.1: Dairy cattle distribution by region and production system

Region	Total (million head)	Commercial dairy systems			Traditional dairy systems				Share by regions
		Small-scale intensive	Medium-scale intensive	Large-scale commercial	Small-scale extensive	Medium-scale extensive	Pastoral	Agro-pastoral	
Central	2,9	23,411	45,307	18,268	129,266	575,368	585,323	1,575,047	21%
Eastern	3,0	16,133	22,519	4,179	56,354	380,384	161,512	2,398,931	22%
Karamoja	2,7	-	-	-	11,229	56,814	2,362,731	340,761	20%
Northern	2,0	4,251	6,961	1,227	42,669	185,856	142,313	1,627,776	15%
Western	3,1	18,015	55,465	5,558	204,705	791,032	536,727	1,490,836	22%
Totals and share of total	**13,8**	**61,810 (0.4%)**	**130,252 (0.9%)**	**29,232 (0.2%)**	**444,223 (3.2%)**	**1,989,453 (14.3%)**	**3,788,606 (27.3%)**	**7,433,351 (53.6%)**	

per animal are lower than in the small-holder intensive. Although this system has extra costs in fencing and farm maintenance, it has lower feed and labor cost compared to the small-holder intensive.

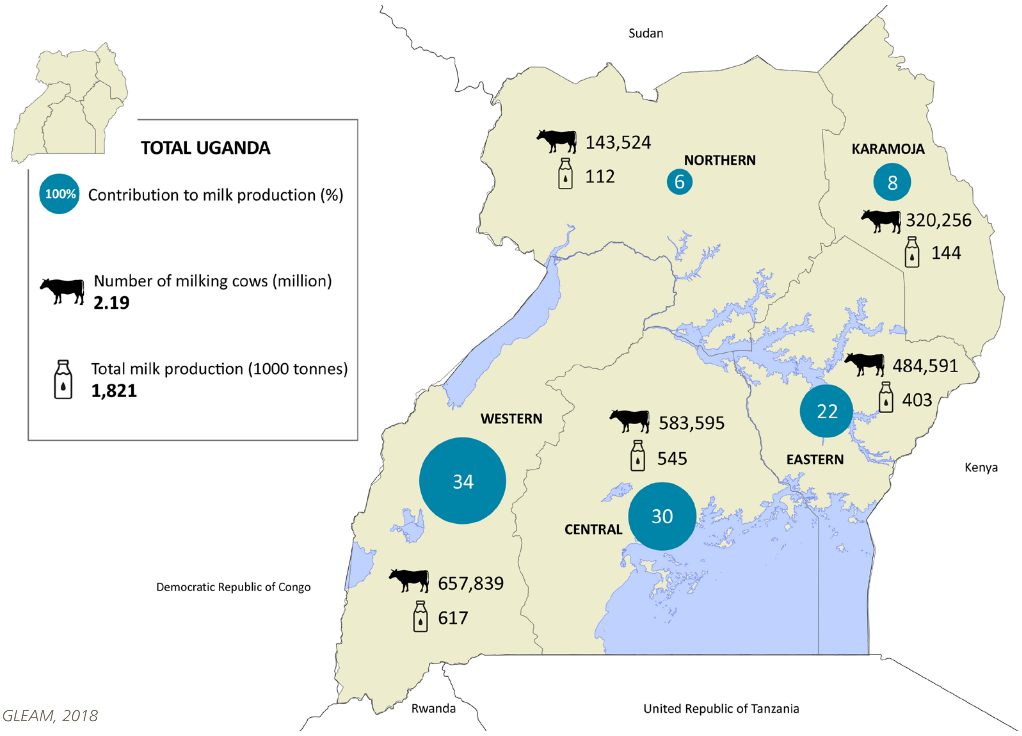
- *Large-scale (commercial) producers:* This farm type has high investment in farm infrastructure such as transport vehicle, tractors, buildings, fencing, pasture improvement and highly productive animals. It also uses expensive purchased inputs such as feed, veterinary drugs and chemicals, incurs high costs on professional veterinary and breeding services and relies almost entirely on hired labor. This farm is able to capture relatively higher milk prices than other farm types. It is seen as both a lucrative economic activity and attractive option for investing off-farm income. Although they exist, large-scale commercial producers are still very few in number owing to the large investment capital requirement. The herd size averages 30 improved cows including pure exotics and crossbred cows.

Uganda is divided into five milk-sheds (dairy regions) based on agro-ecological factors, as well as the milk production and market situation (Figure 3.1). Each geographical region is equivalent to a milk-shed except the western region which combines two milk-sheds namely south-western and mid-western. The five dairy regions (namely Western, Central, Eastern, Karamoja and Northern) exhibit significant differences in terms of milk production potential, cattle numbers, market dynamics and dairy infrastructure among others. Most of the commercial systems (75 percent) are located in the central and western regions, while traditional systems are equally distributed across the five regions (Table 3.1).

Figure 3.1 shows the distribution of milked cows by region. The total number of milking cows is estimated at 2.2 million cows producing 1.8 billion tonnes of milk. Most part of the milking cows are distributed across the western and central regions representing 57 percent of the total milking cows and accounting for 64 percent of the national milk production. The high concentration of dairy animals in both western and central regions can be explained by the pasture and forage supply, as well as water availability for the animals. The northern and Karamoja regions, when combined, hold 21 percent of the milking cows and contribute to 14 percent of the national milk production. Lack of water for livestock is very common and it is a serious production constraint in these regions, which is generally semiarid with poorly developed water sources.

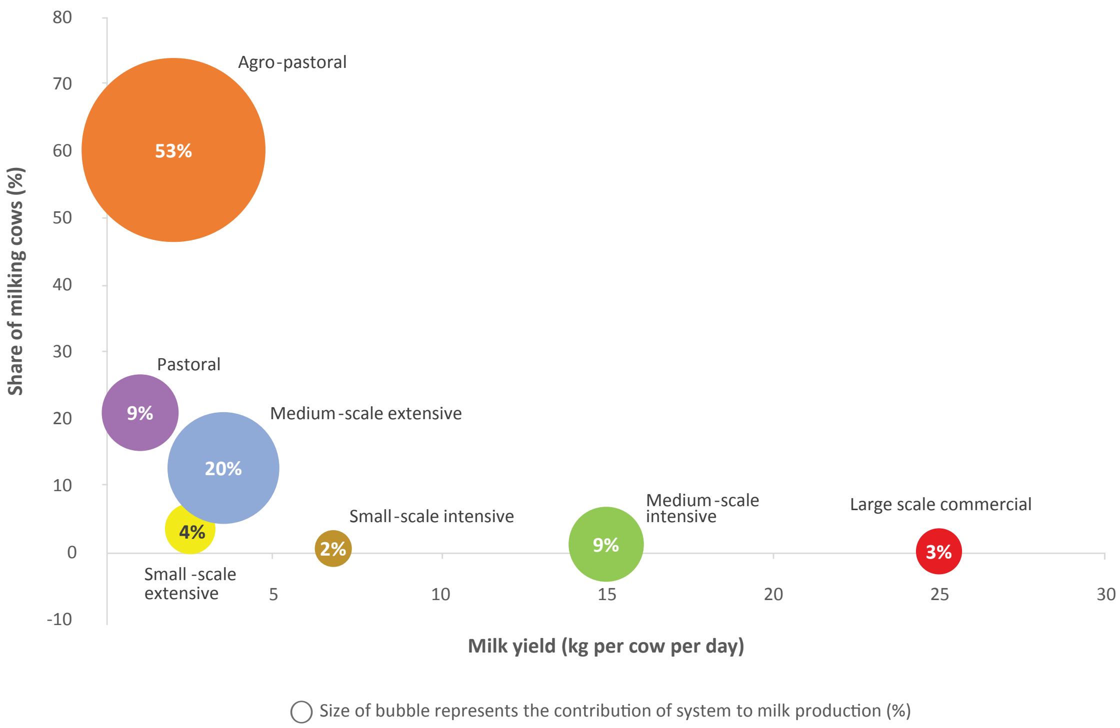
When looking at the contribution of each production system to the national milk production, agro-pastoral dairy system produces the largest share of milk, producing 53 percent of total milk supply with 60 percent of milking animals in the country producing an average of 2 litres per animal per day. On the other hand, the commercial systems produce almost 15 percent of the national milk with 2 percent of the milking herd due to the higher milk yields observed for these systems (Figure 3.2).

Figure 3.1: Milking cows, milk production and contribution to milk production per region



Source: GLEAM, 2018

Figure 3.2: Milk yield and contribution to milk production by production system



Source: GLEAM, 2018

CHAPTER 4

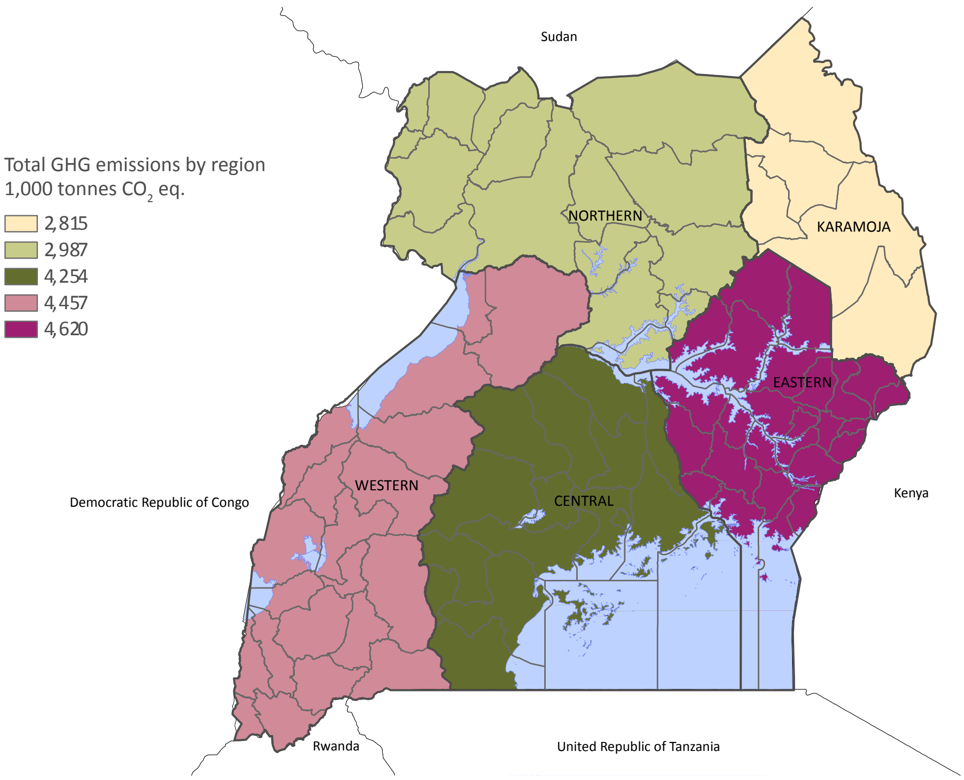
Emissions and emission intensities

Milk production from the dairy cattle sector in Uganda emits about 19.1 million tonnes CO_2 eq. More than two-thirds of the total emissions are concentrated in three regions with the highest share of the national dairy herd: Eastern (24 percent), Western (23 percent), and Central Province (22 percent) (Map 4.1).

The activities and processes that contribute towards the GHG emissions from dairy cattle sector are shown in Figure 4.1. The GHG profile of milk is dominated by methane (98.6 percent), while nitrous oxide (N_2O) and carbon dioxide (CO_2) contribute to 1.3 and 0.1 percent of the total emissions, respectively.

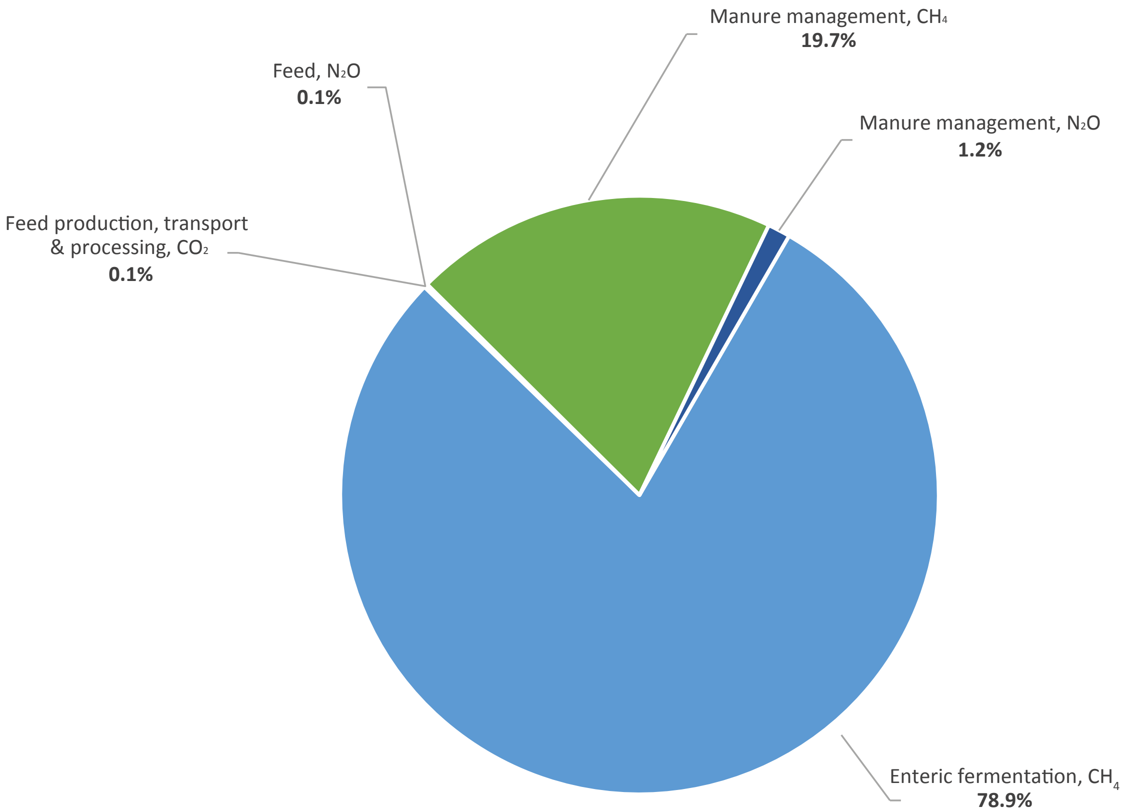
Approximately 79 percent of the emissions arise from methane produced by the rumination of cows and 19.7 percent from the management of stored manure. Emissions arising from other sources make a negligible contribution to overall emissions.

Map 4.1: Regional distribution of total GHG emissions from cattle milk production



Source: GLEAM, 2018

Figure 4.1: Share of total emissions by emission source



Note: N_2O emissions from manure applied to feed, manure deposited on pasture, fertilizer application and decomposition of crop residues were aggregated into Feed, N_2O.

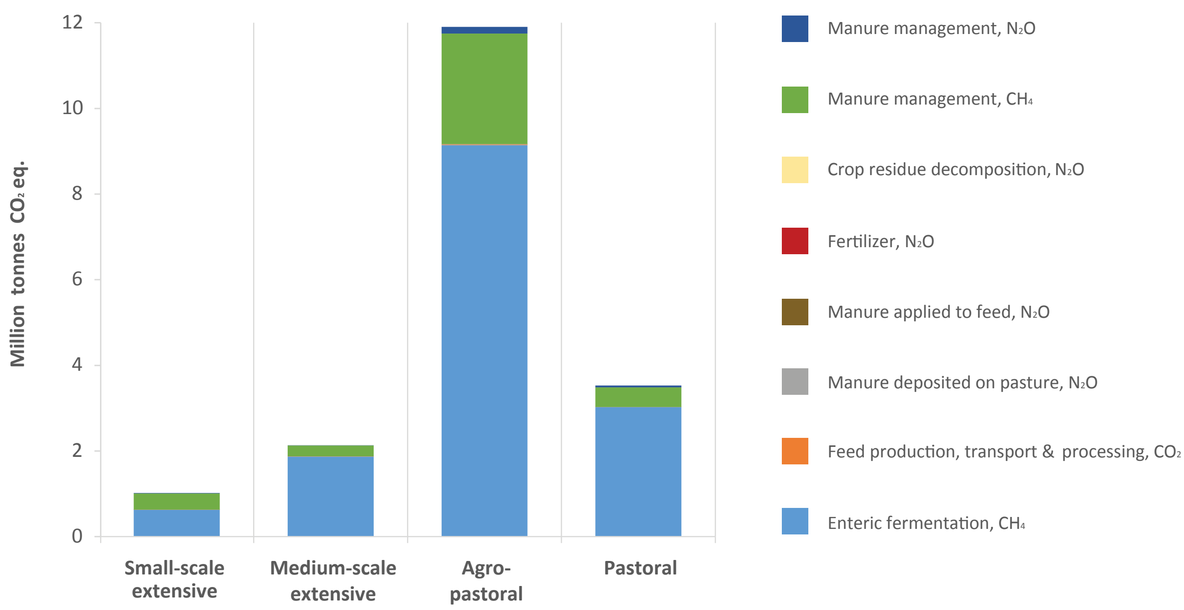
Source: GLEAM, 2018

Production system contribution to the total GHG emissions

Within the dairy cattle sector, the traditional dairy production systems which produces 86 percent of the national milk, is responsible for 97.2 percent (18.6 million tonnes CO_2 eq.) of the total GHG emissions (Figure 4.2a). The commercial production systems contribute to 14 percent of the milk and 2.8 percent of the emissions (Figure 4.2b).

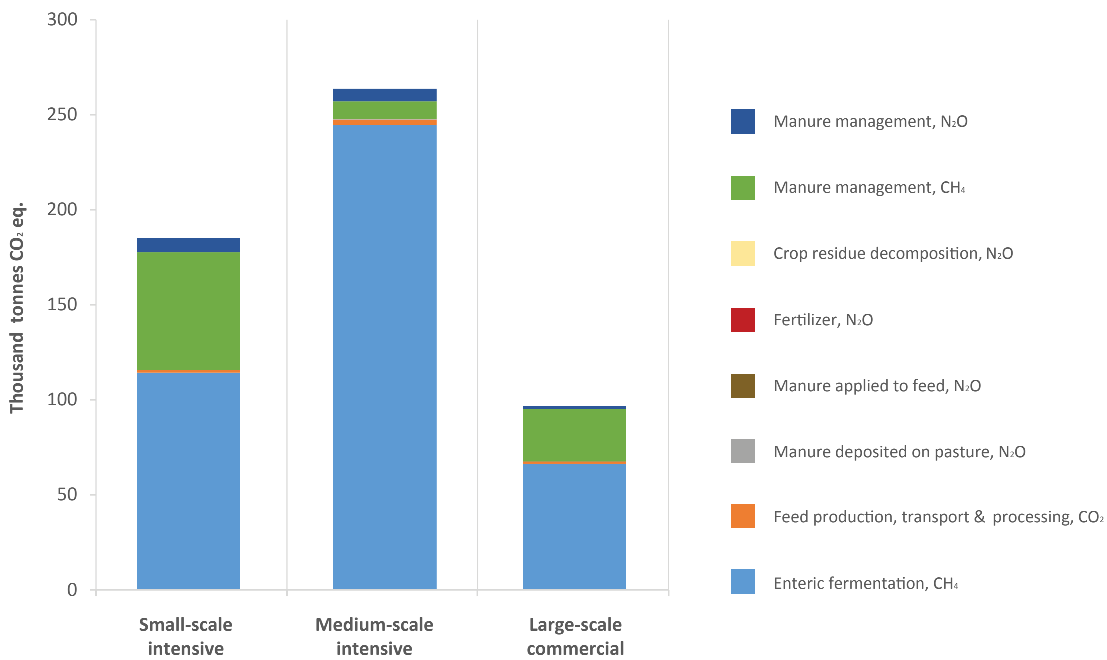
Across all production systems methane from enteric fermentation comprises the bulk of emissions ranging from 62 to 93 percent of the total emissions. Traditional systems have similar emission profiles; enteric methane and methane from manure management dominate both profiles. In small-scale extensive and agro-pastoral systems, in particular, methane emissions from manure management are particularly higher mainly because part of the manure is managed in liquid form or burned. Likewise, commercial systems present similar emission profiles with enteric methane, and methane and nitrous oxide from stored manure contributing to most of the emissions.

Figure 4.2a: Absolute emissions by traditional production systems and source of emissions.



Source: GLEAM, 2018

Figure 4.2b: Absolute emissions by commercial production systems and source of emissions



Source: GLEAM, 2018

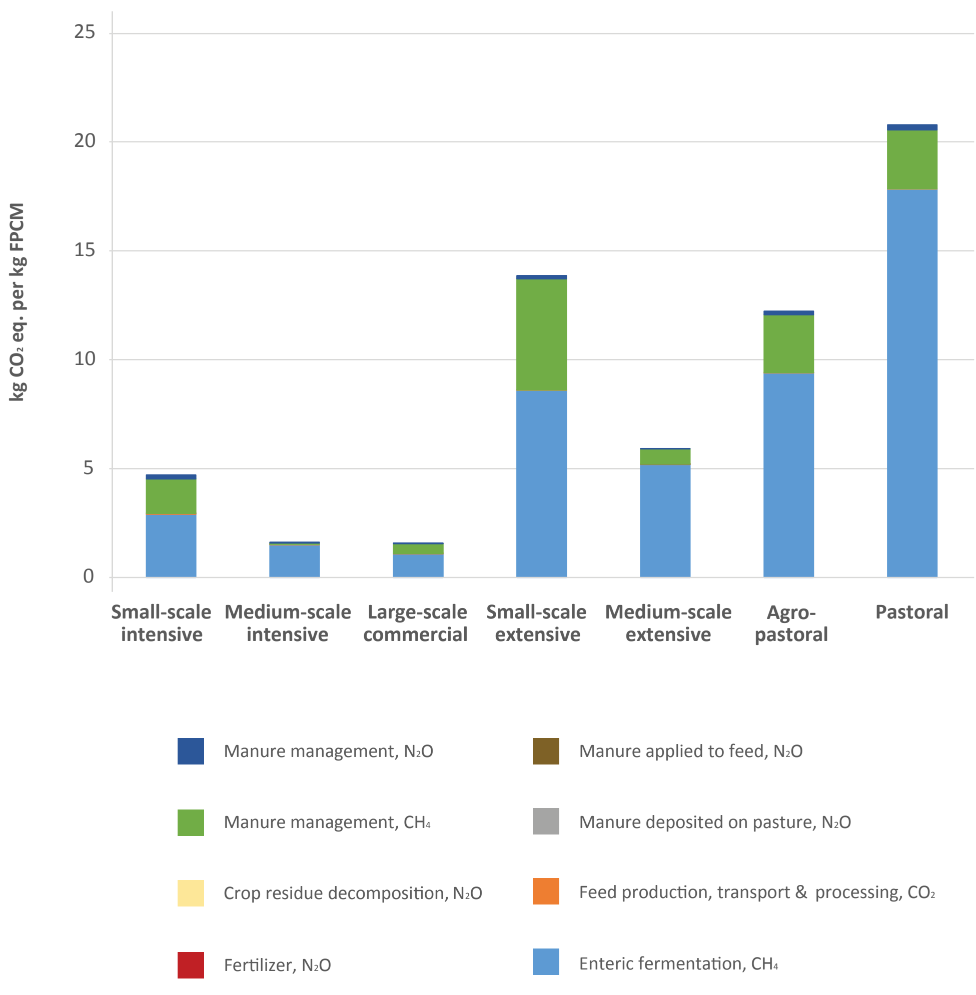
Greenhouse gas emissions per kg of fat and protein corrected milk (FPCM)

At national level, the emission intensity of milk produced in Uganda is on average 10.4 kg CO_2 eq./kg FPCM; the highest values were estimated for the traditional systems and the lowest in commercial systems. Average emissions ranged from 5.9 to 20.8 kg CO_2 eq./kg FPCM for traditional systems, while in commercial systems they ranged from 1.6 to 4.7 kg CO_2 eq./kg FPCM (Figure 4.3).

Variability in emission intensity within dairy production systems

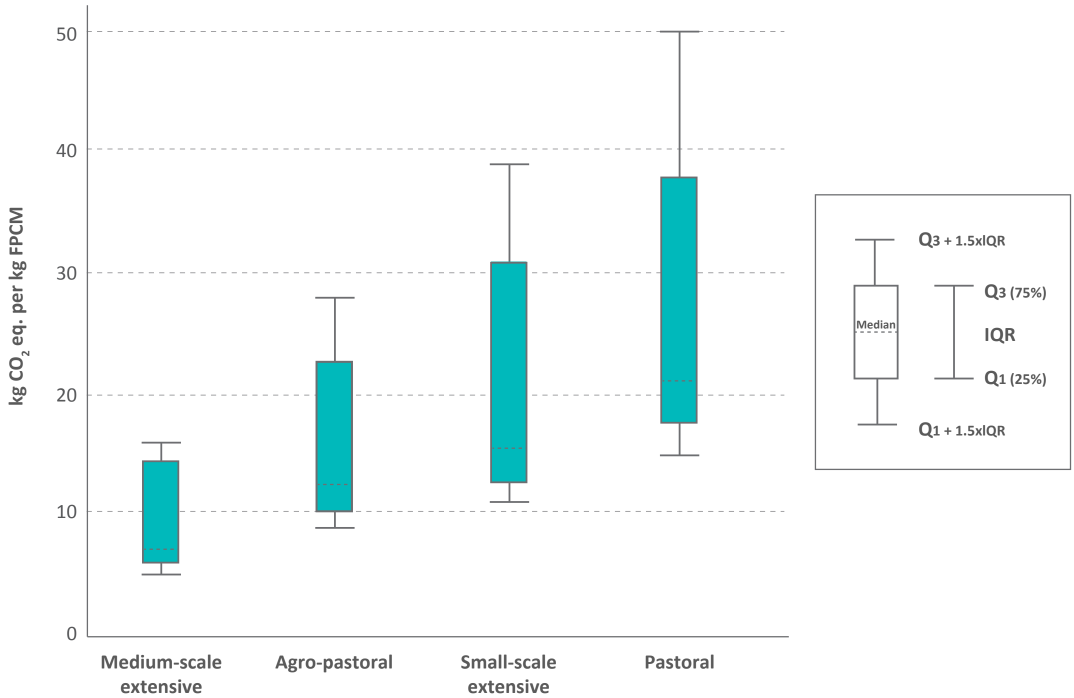
At production system level, there is a wide variation in emission intensity, which is closely related to the level of productivity, and feeding and management practices adopted by each system (Figure 4.4). The highest variability in emission intensity is observed for pastoral systems with a range from 14 to 50 kg CO_2 eq./kg FPCM. In medium-scale extensive systems, 50 percent of the producers are spread over a smaller range of values (from 6 to 14), 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.

Figure 4.3: Emission intensity per kg FPCM, by production system



Source: GLEAM, 2018

Figure 4.4: Variability in milk emission intensity among traditional production systems



Source: GLEAM, 2018

Determinants of emissions and emission intensities

A number of factors influence emissions and emission intensities from dairy production in Uganda:

- **Inadequate and poor feeding.** An inadequate supply of quality feed is the major factor limiting dairy production in Uganda. Feed resources, are either not available in sufficient quantities due to fluctuating weather conditions or even when available are of poor nutritional quality. Generally, the productivity of dairy farms is relatively low. Across all systems, fodder availability is inadequate and prices are too high for small-holder dairy farmers to access it, which constrains their milk output and their ability to expand production. This problem is compounded by seasonal changes in pasture conditions, with poor productivity during the dry season. High milk fluctuations arise because most farmers depend on rain for feed production and rarely make provisions for preserving fodder for the dry-season. In addition to seasonality of feed supply, diets are largely made up of low quality feed products, such as crop residues and native pastures of poor nutritive value. Consequently, the digestibility of feed rations in all systems is low: ranging from 59 to 66 percent across production systems. These constraints explain the low milk yields and short lactations, high mortality of the young stock, longer parturition intervals, low animal weights and high enteric methane emissions per unit of metabolizable energy.
- **Animal health.** The prevalence of various animal health diseases affect the performance of dairy cattle. Animal health affects emission intensity through the "unproductive emissions" related to mortality and morbidity. Animal mortality rates are high (ranging between 3 to 14 percent) regardless of the system. Major animal diseases include East Coast Fever (ECF), mastitis, foot and mouth, and lumpy skin disease. 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 often have higher nutritional demands, poor adaptability, low production efficiency under small-holder conditions, and often inherently are more susceptible to diseases compared to the indigenous cattle. This also partly explains the lower calving rates (52 percent) in commercial systems.

- **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 parameter 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 Ugandan dairy herd is manifested in a number of parameters such as low fertility rates (58 to 60 percent in traditional systems vs. 65 to 70 in commercial systems), delayed time to reach puberty and age at first calving (3.4 and 2.5 years in traditional and commercial systems, respectively).
- **Poor genetics:** The bulk of Uganda's dairy herd has a relatively low genetic base due to years of inbreeding and use of bulls of low quality. The dairy sector is dominated by local cattle breeds such as the Ankole longhorn (50 percent), zebu (30 percent) and the Nganda (16 percent). The milk yield of the local breeds are estimated to be about 500-1,500 kg per lactation year. While enhancing the genetic potential of the animal is critically important, it is equally important not to promote high genetic potential animals into climates and management environments where high-producing animals can never achieve their potential and will, in fact, perform worse than native breeds or crossbreeds due to management, disease, and/or climatic challenges.

CHAPTER 5

Exploring the mitigation potential in dairy cattle production

The analysis of current production of milk in Uganda shows that improved management practices and technologies that increase milk production per cow can reduce the GHG emissions intensity of milk production. This approach to mitigation is compatible with the national objective of increasing overall milk output for improved nutrition and food security. The abatement technologies and practices assessed in this study were selected for their potential impact on enteric methane. This is not a purely technical process but incorporates other factors such as existing political priorities. As such, other consideration taken into account during the selection of interventions was the need to integrate mitigation with a number of key developmental goals for the dairy sector, such as their role in promoting food security, and rural and overall economic development.

The mitigation options evaluated in this analysis were selected in a consultative process with national experts. These 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 4 summarizes the criteria used to identify interventions that were included in the analysis.

Enhancing animal productivity has several dimensions including animal genetics, improved feeding, reproduction, health and overall management of the herd. The interventions evaluated ranged from improved feeding practices to better herd health and management. These comprised: high yielding drought tolerant forages, intercropping grasses with legumes, urea treatment of crop residues, fodder conservation, water harvesting technologies, improved animal health and improved animal genetics. Interventions were selected to address the key determinants of low productivity and inefficiencies in dairy production cycle such as seasonality of feed resources, low quality of feed, poor reproductive status of breeding herd, and animal health.

Table 5.1 provides a summary of the pre-selected interventions. The interventions 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 judgment of their specific operating requirements and likely impact on performance.

Quantitative summary of mitigation outcomes from the application of single interventions

Overall, the analysis shows that there is potential to reduce emission intensities; methane emission intensity can be reduced by 1.5 percent to 27 percent and the magnitude of impact varies by production system (Figure 5.1). All interventions returned a positive productivity outcome with increases in milk production ranging between 2 to 40 percent.

Feeding is the major productivity constraint to achieving the targeted milk production due to the heavy reliance on rainfed forage and pasture production. During the dry season, feed availability reduces and animals are forced to survive on scarce, low quality mature grass and crop residues. Improved feed availability and quality is thus a key strategy to realize the greater animal productivity levels.

In most small-scale dairy farms, animals graze on unimproved, natural grass. Natural grass which commonly forms the bulk of roughage for dairy cows, are generally low in crude protein, especially so during the dry season. Although crop residues may be added to grass-based diets, they are not sufficient and balanced to support milk production. In addition, commercial protein sources that could supplement these roughages are too costly for many small-holder dairy farmers to afford on a regular basis and in adequate quantities.

Box 4: Criteria for selection of interventions

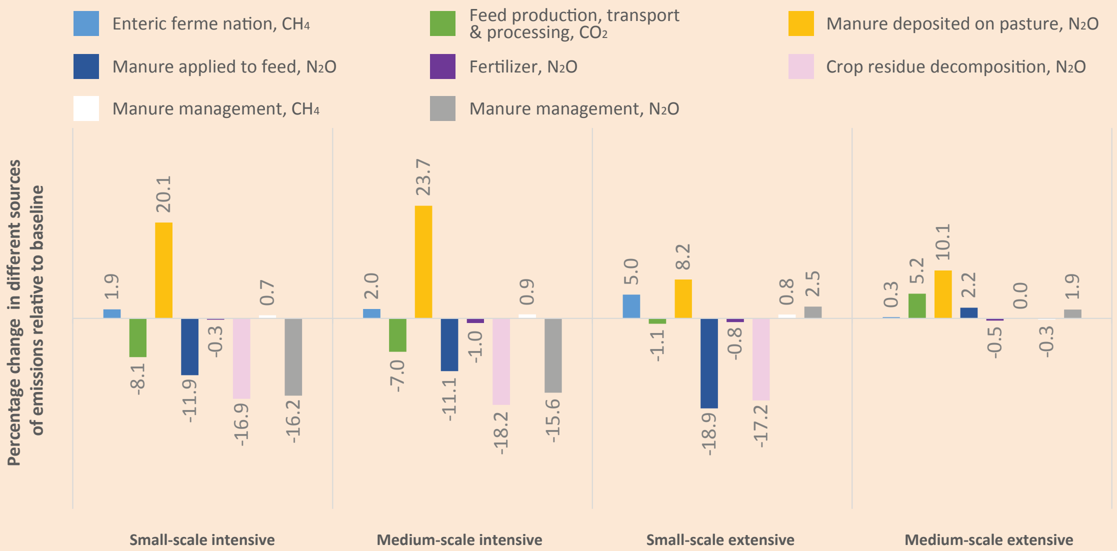
Three principal criteria were used to identify interventions for analysis in the study; **the potential for improving production efficiency, technical feasibility of adoption by farmers and the potential to reduce enteric methane emission intensity.**

Improving production efficiency is a strategy that farmers can implement to decrease methane emissions. Enhancing animal productivity has several dimensions including animal genetics, feeding, reproduction, health and overall management of the herd.

Reduction in enteric methane emission intensity. Many measures that have the potential 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 impacts of intercropping legumes grasses with grasses were evaluated for dairy cattle in semi-intensive systems. Legume-grass intercropping increased protein intake of the animals. In consequence, the excess N in the diet increased N excretion, leading to increased nitrous oxide emissions from manure deposited on pasture. Likewise, enteric methane emissions slightly increased because feeding animals with a grass-legume mix increased dry matter intake as a consequence of the improved digestibility and palatability of the diet. In terms of absolute emissions, intercropping legumes with grasses slightly increased absolute emissions from 0.2 to 3.4 percent. However, from an emission intensity perspective, this intervention translated into a decrease in emission intensity resulted from increased milk production (see Figure 5.1). Some practice changes however might result in a decrease in both absolute enteric emissions and emission intensities.

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 subsequently 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 also required investigation of information on barriers to adoption. Other aspects taken into consideration with regard to feasibility included: applicability of interventions should be informed by location-specific determinants, e.g. soil type, and potential to enhance other benefits, raising income of target population (poverty reduction), biodiversity conservation, and ecosystem services provision

Impacts of legume grass intercropping on total emissions



Source: GLEAM, 2018

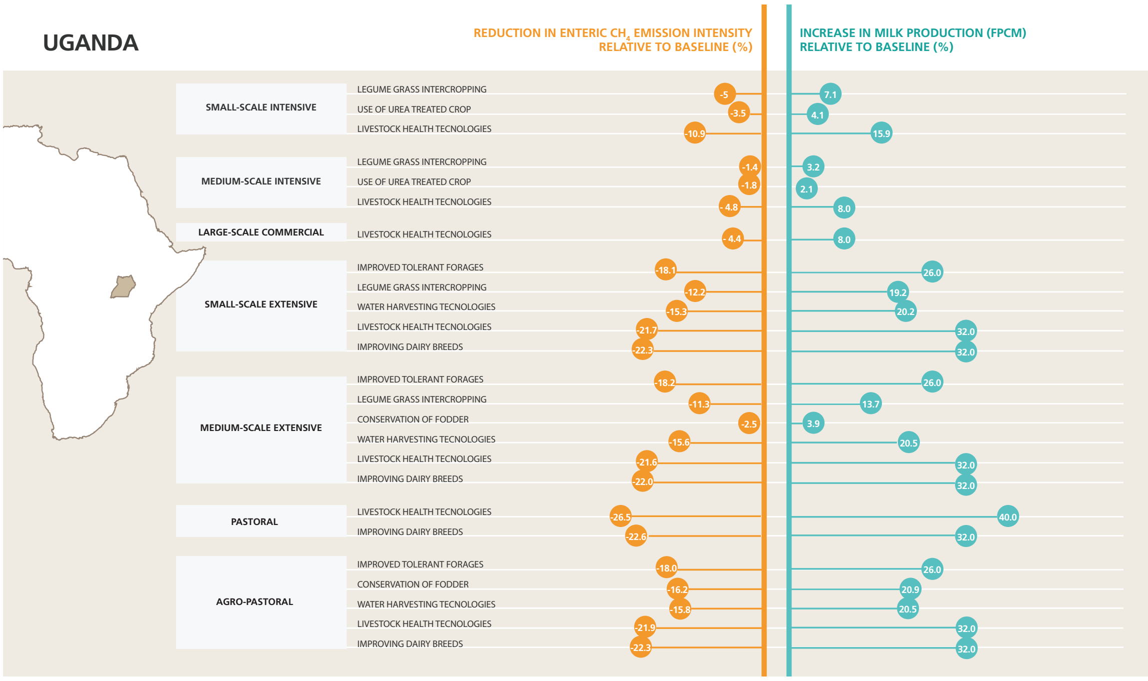
Table 5.1: Summary of selected interventions for dairy cattle systems in Uganda

Intervention	Objective and constraint addressed	Mode of action
Use of improved high yielding drought tolerant forages	Minimizes quantitative and qualitative deficiency of basal diet to address feed seasonality and quality constraints	Improvements in digestibility lead to increased Dry Matter Intake, energy availability, milk yields and decreased CH_4 emissions per unit of product
Legume-grass intercropping	Minimizes quantitative and qualitative deficiency of basal diet to address feed seasonality and quality constraints	Lower CH_4 emissions observed with legumes is attributed to lower fiber content and faster rate of passage of feed through the rumen
Supplementation: Urea-treated crop residues	Improves the utilization of low quality roughages to address feed seasonality and quality constraints	Improving the nutritive value by increasing digestibility, palatability and crude protein content. The urea is converted to ammonia, which breaks down the fibrous material, making it accessible to the microbes in the rumen
Water harvesting technologies	Improves the utilization of low quality roughages	Satisfies the requirement of the rumen microorganisms by creating a better environment for the fermentation of fibrous material and increasing production of microbial protein. Reduces methane released by increasing the rate of utilization of the dry matter intake
Feed conservation (use of silage)	Improves the quality of basal diets and addresses feed availability during periods of scarcity	Promotes high dry matter intake and accelerates the rate of passage through the rumen
Animal health technologies	Improves health status of animals, increase productivity, reduce economic and losses for farmers. Addresses high morbidity, low milk production and milk wastage in dairy systems	Enhances animal productivity and reduces GHG emission intensity
Use of improved breeds	Improves production and reproductive traits of the indigenous cattle breeds	Genetic improvement can improve animal performance by increasing weaning weights and daily weight gain, improving conception rates and increasing milk yields

Forage legumes are a known and cheap source of protein for dairy cattle. They help bridge the gap between supply and demand of protein especially during the dry season. Production and utilization of forage legumes is one of the low-cost methods for improving both the quantity and quality of livestock feeds on small-holder farms. The legumes can also concurrently enhance soil fertility for companion fodder grasses and subsequent crops, thereby reducing the cost of livestock feed and crop production for resource-poor farmers. Forage legumes are an ideal solution to supplement dairy animals with high quality feed especially during the dry season. Feeding lactating animals and heifers with a legume-grass mix can reduce enteric methane emission intensities between 1.4 and 12.2 percent depending on the production system.

Few farmers currently use alternative feeding strategies such as the use of conserved feeds or use of non-conventional feed resource materials to smoothen seasonal fluctuations in milk production. Two interventions were assessed to address the problem of feed seasonality: use of urea-treated crop residues and feed conservation (silage making) by preserving forage during periods of abundance (rainy season) for use during periods of feed scarcity. Although crop residues can be used to bridge the feed gap during the dry season, they do not supply adequate nutrients without supplementation. Because of their low digestibility they remain in the rumen for a long time, limiting intake. Another major limitation is they do not contain sufficient crude protein to support adequate microbial activity in the rumen. This often leads to feeding of a nutritionally imbalanced ration which contains proteins, energy, minerals and vitamins either in excess or shortage relative to the nutrient requirements of the animals. Imbalanced feeding adversely impacts productivity, animal health and increases the environmental impact. Treating crop residues with urea solution improves its nutritive value by increasing the digestibility, palatability and crude protein content. The intervention was applied in the small-scale and medium-scale intensive systems where use of crop-residues is common. Feeding urea-treated crop residues in commercial systems

Figure 5.1: Impact of single interventions on enteric methane emission intensity and milk production relative to baseline



Source: GLEAM, 2018

results in a reduction in methane emissions between 2 and 3.5 percent. A conservative approach was adopted to reflect the current low adoption rates due knowledge and technical barriers, e.g. fear of ammonia poisoning and lack of technical skills in mixing and treatment of residues.

The use of feed conservation techniques was evaluated as an intervention to even out seasonality of feed quantity and quality and consequent fluctuations in milk production. Feeding conserved fodder results in 2.5 percent reduction in medium-scale extensive systems and 16 percent in pastoral systems.

Tick borne diseases constitute the largest component of all animal diseases that impact negatively on the dairy industry, with East Coast Fever as one of the most serious causes of economic loss in Uganda. East Coast fever is enzootic throughout Uganda except in the drier open plains of the Karamoja region. In fact, 62.6 percent of dairy farmers in Uganda have reported East Coast Fever as the most common livestock disease[15]. East Coast Fever poses a significant threat to the livestock sector through the economic impact of the disease from cattle morbidity and mortality and production losses for all production systems. Decreasing mortality and morbidity rates has a significant effect on methane reduction because animals that die or are culled before their first lactation represent a significant loss of energy and resources without any usable food being produced. Vaccination against East Coast Fever results in a reduction in methane emission intensity from 4.4 to 26.5 percent across all dairy production systems. These impacts are achieved through decreased mortality rates, and increased live-weight gain and milk yield.

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

Significant reductions in emissions can be achieved through a combination of herd and health manage-

[15] Livestock disease challenges and gaps in delivery of animal health services. 2011. EADD report. https://core.ac.uk/download/pdf/132634231.pdf

ment, 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 of objectives and address multiple constraints to productivity. The joint impacts realized from applying a combination of technologies are better understood as multiplicative rather than additive, i.e. they are mutually enhancing and dependent.

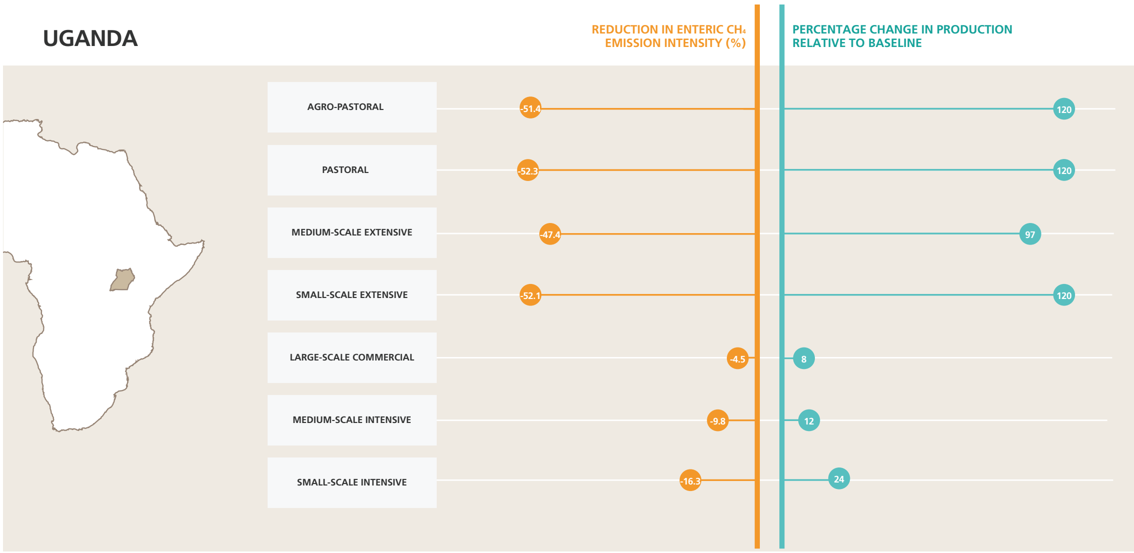
Applying combinations of interventions aimed at improving feed availability and quality, water availability, genetic potential and herd health can potentially result in a reduction of 5 to 52 percent in methane emission intensity relative to baseline emission intensity (Figure 5.2). With these combinations of technologies, an increase in milk production of 8 to 120 percent can be achieved compared to the baseline.

The application of the mitigation package was carefully carried out based on a conservative approach that considered the particularities and constraints of each production system. For instance, given that potential of adopting mitigation practices by traditional systems is fairly limited due to environmental and socio-economic barriers, the intervention legume-grass intercropping was not applied in pastoral and agro-pastoral systems.

On the other hand, it is expected that commercial systems are better prepared to cope with seasonality effects, thus the application of water harvesting technologies was only applied to agro-pastoral, small-scale extensive and medium-scale extensive systems for a period of 120 days, assuming that the technology would be applied during the dry period. Likewise, considering that commercial systems already use superior genetics, improving dairy breeds through the crossing of local breeds with high productivity breeds and use of community bull services were only applied in traditional systems.

The application of system-specific interventions within the package also explains the differences in productivity and mitigation potential between traditional and commercial systems. Moreover, the impacts of the mitigation package are higher in the traditional systems because a large proportion of the animals (91 percent of the total herd) are found in these systems.

Figure 5.2: Impact of a package of mitigation options on enteric methane emission intensity and milk production.



Source: GLEAM, 2018

CHAPTER 6

Prioritization of interventions to address enteric methane

Having identified and assessed the mitigation of potential, these technologies can be prioritized 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. A key incentive to farmers for adoption is increased revenue and/or reduced costs. 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. Results from the cost-benefit analysis are presented in Box 5.

The prioritization process

All individual practices were ranked for their ability to reduce enteric methane. Given that there is always uncertainty around any estimation of reduction potential we discarded any practice that would reduce emissions by <10 percent. This reduces the risk of promoting practices that have marginal or no enteric methane reduction benefit. The remaining practices were then assessed against their enteric methane reduction potential and two other criteria; productivity improvement and economic benefits (Figure 6.1).

For ease of interpretation a 'coloured 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

Box 5: Assessing the costs and benefits of mitigation interventions

The benefit-cost ratio (BCR), i.e. the ratio of the present value of the benefits to the present value of the costs. Costs were calculated as production costs (baseline scenario) plus costs involving the implementation of the mitigation strategy, while benefits were calculated as total revenue from milk and meat output within a year. The analysis considered the characteristic of the dairy value chain and production systems, such as: milk sales and milk prices in the formal and informal markets, household consumption, animals and meat sales, manure management, etc. The benefit-cost ratio indicates the overall value for money of the interventions. Generally, if the ratio is greater than 1, benefits of the interventions outweigh the mitigation costs.

The magnitude of the impacts varied considerably among interventions. This variability can be explained by how the interventions were modelled in the economic analysis (intervention cost, duration of intervention period, rate of adoption, animal response, etc.). In this study, given the wide range of results across production systems and interventions, the economic returns were classified according to the percentage change over the baseline scenario (low: returns below 5%; medium: 5 to 15%; high: greater than 15%; negative: less than 0). The BCR for different mitigation options ranged from -11 to 20 percent in traditional systems and from 1 to 28 percent in improved systems.

The benefit-cost ratio analysis reveals that in traditional systems, the application of mitigation options present low economic returns. These results can be explained by the low productivity of traditional systems, household milk consumption, and restricted access to formal markets, which limits the outputs (milk and meat) available for commercialization. In commercial systems, all interventions assessed presented a higher return over investment, that is, adopting mitigation practices would increase farm profitability.

each system. The values associated with the high, medium and low classification system are shown at the bottom of Table 6.1. It must be emphasized that this system was developed as an aid to facilitate the identification of those practices with the highest potential both within and between practices and systems. The outcomes of the prioritization process are shown in Table 6.1.

Comparison of individual interventions

Interventions for which methane reduction potential were less than 10 percent were excluded from the prioritization process. Based on this initial screening, only 1 intervention (out of the 3 selected interventions tested) in commercial systems met the prioritization criteria. In traditional systems, with the exception of fodder conservation in medium-scale extensive systems, all other interventions were included in the prioritization analysis. With the exception of livestock health technologies in agro-pastoral systems, the remaining interventions assessed, in addition to decreasing enteric methane emission intensity, resulted in increased milk production and returned a positive benefit-cost ratio.

There were large differences in the number of interventions that local experts identified as appropriate for each system. The magnitude of the impacts varied considerably across and within production systems. Table 6.1 summarizes the impacts of the individual interventions within the main production systems.

The use of improved tolerant forages ranked low on both enteric methane reduction and possible economic returns, but presented moderate response on milk production in traditional dairy systems. Legume grass intercropping ranked low for all three criteria (productivity, enteric methane mitigation and economic return) in small-scale and medium-scale extensive systems. One of the reasons for the low returns in productivity and methane reduction is the low adoption rate that was considered in this intervention scenario.

Fodder conservation in agro-pastoral systems can bring similar benefits in terms of methane reduction, milk yield increase and financial returns. Water harvesting technologies in both small-scale and medium-scale extensive and agro-pastoral also presented low production and methane reduction potential, but it gave considerably higher financial returns to farmers, ranging from medium (agro-pastoral) to high (small-scale and medium-scale extensive).

Figure 6.1: Initial prioritization process of technical interventions

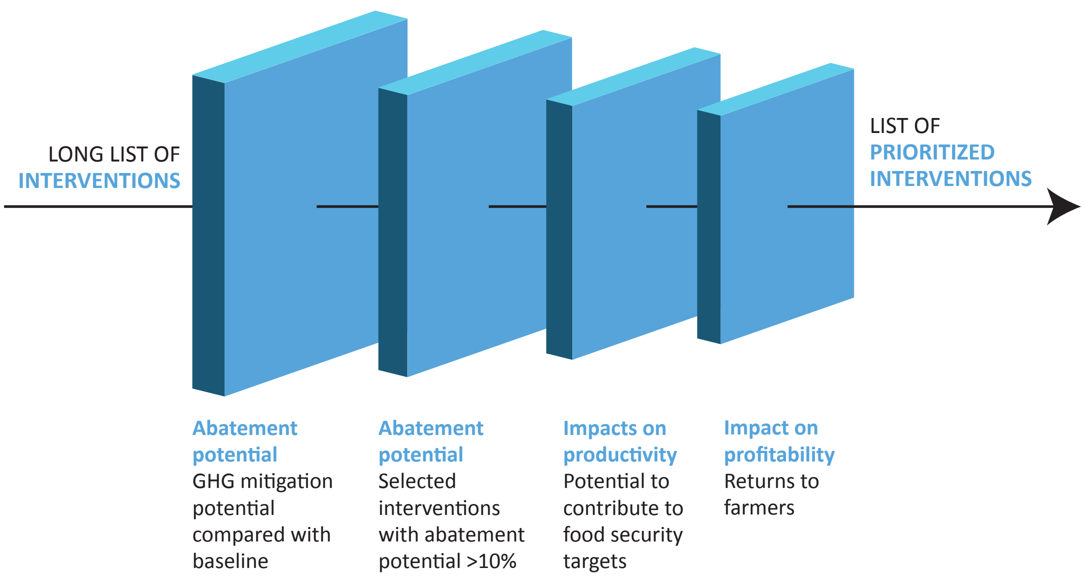


Table 6.1: Results from the prioritization of single interventions for dairy cattle production systems

Intervention	Improved tolerant forages	Legume grass intercropping	Use of urea treated crop	Conservation of fodder	Water harvesting tecnologies	Livestock health tecnologies	Improving dairy breeds
SMALL-SCALE INTENSIVE							
Methane reduction		**	**			● Low	
Production increase						● Low	
Economic benefit		**	**			● Low	
MEDIUM-SCALE INTENSIVE							
Methane reduction		**	**			**	
Production increase							
Economic benefit		**	**			**	
LARGE-SCALE COMMERCIAL							
Methane reduction						**	
Production increase							
Economic benefit						**	
SMALL-SCALE EXTENSIVE							
Methane reduction	● Low	● Low			● Low	● Low	● Low
Production increase	● Medium	● Low			● Low	● Medium	● Medium
Economic benefit	● Low	● Low			● High	● Low	● Low
MEDIUM-SCALE EXTENSIVE							
Methane reduction	● Low	● Low		**	● Low	● Low	● Low
Production increase	● Medium	● Low			● Low	● Medium	● Medium
Economic benefit	● Low	● Low		**	● High	● Low	● Low
PASTORAL							
Methane reduction						● Medium	● Low
Production increase						● Medium	● Medium
Economic benefit						● Low	● Low
AGRO-PASTORAL							
Methane reduction	● Low			● Low	● Low	● Low	● Low
Production increase	● Medium			● Low	● Low	● Medium	● Medium
Economic benefit	● Low			● Low	● Medium	● Negative	● Low

Note: ** Impact on methane emissions less than 10%

Assessment criteria:

Methane mitigation: ● Low: >10 <25 ● Medium: >25 <50 ● High: >50

Production increase: ● Low: >10 <25 ● Medium: >25 <50 ● High: >50

Economic benefit: ● Low: <5 ● Medium: >5 <15 ● High: >15 ● Negative: <0

Vaccination against East Coast Fever (livestock health technologies) ranked from low to moderate on the productivity and enteric methane mitigation criteria. In terms of economic returns, the intervention had a low impact on financial returns in small-scale and medium-scale extensive and pastoral systems, and presented negative returns in pastoral systems. Although part of the costs with East Coast Fever is subsided by the government, the vaccination costs are still high for agro-pastoral farmers.

The use of improved breeds had low impact on reducing methane emission intensity and profitability and moderate potential impact on productivity, which was achieved through a combination of increased daily milk yield, increased fertility and a reduction in age at first calving. Although the use of improved and higher yielding cattle clearly stands out as an intervention that should be prioritized, achieving that potential might be challenging. Exploiting superior genetics will mean that other facets of the system will also need to change, in particular improved diet (both in terms of quantity and quality) and disease control.

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 three dairy systems. Results of an assessment of this package, which comprised interventions aimed at improving herd health and genetics, as well as improving feed availability and quality, and water access are shown in Table 6.2 (more details on the interventions selected for the package can be found at Chapter 5).

Based on the methane mitigation criteria, the medium-scale intensive and large-scale commercial systems were excluded from the prioritization process. Despite the high economic returns of the package in small-scale intensive systems, the interventions ranked low on both methane reduction and productivity for this system. Among traditional systems, the package of intervention had low impacts on profitability, except in agro-pastoral systems, which the package presented negative economic returns. Enteric methane mitigation potential and productivity ranked high in all productions systems, except for medium-scale extensive systems which ranked moderate. A discussion on the limitations of the benefit-cost analysis in measuring the socio-economic value of cattle in traditional systems is further discussed in Box 6.

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

Common intervention 'package'	Methane reduction	Production increase	Economic benefit
Small-scale intensive	● Low	● Low	● High
Medium-scale intensive	**		**
Large-scale commercial	**		**
Small-scale extensive	● High	● High	● Low
Medium-scale extensive	● Medium	● High	● Low
Pastoral	● High	● High	● Low
Agro-pastoral	● High	● High	● Negative

Assessment criteria:

Methane mitigation:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Production increase:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Economic benefit:	● Low: <5	● Medium: >5 <15	● High: >15	● Negative: <0

Box 6: Are pastoralism and mitigation mutually exclusive?

East Africa is home to a significant number of pastoralists whose livelihood is based on livestock production in arid and semi-arid rangelands. Pastoral and agro-pastoral systems are important in supporting the local economy, the maintenance of the cultural heritage, and is often the most compatible type of agricultural enterprise with wildlife conservation. However, the potential of adopting mitigation practices by pastoralist farmers is fairly limited due to environmental and socio-economic barriers. These barriers include, the environment in which these systems exist (generally in remote and marginal areas with extremely harsh environmental conditions and limited natural resources), combined with lack of technical resources and financial capacity.

In this study, the application of mitigation options in traditional systems was carefully carried out based on a conservative approach that considered the particularities and limitations of these systems. Accordingly, the benefit-to-cost ratio analysis reflects the preliminary considerations taken into account in the mitigation assessment. The benefit-to-cost analysis was developed based on the farm inputs and outputs, and did not account for non-monetary transactions and livestock co-benefits. Although this type of economic analysis is a tool in supporting decisions on technology adoption, it cannot fully capture the socio-economic value of livestock for the livelihoods of pastoralists and agro-pastoralists and underestimate the potential economic benefits derived from the application of mitigation practices in traditional systems.

Although the economic analysis might not directly support the application of mitigation practices in traditional systems, the study does not exclude the importance of mitigation action focusing specifically on traditional systems since their existence and persistence is already threated by the effects of climatic variability and climate change. All the mitigation options analyzed in this study presented significant gains in productivity, which in practice can generate improvements in food and nutrition security, as well as boost farmers' incomes. Moreover, some of the mitigation options can maintain and/or improve herd parameters, feed resources and water supply during and after climate shocks, supporting these systems to move from relief to resilience. Given the public benefits of tackling and adapting to climate change, governments should consider policies and incentives to help livestock farmers, in particular pastoralists, to overcome the barriers to technology adoption. Practices such as forage conservation, improved water harvesting techniques and disease control are some of the mitigation options that can be implemented by national governments to support traditional systems to mitigate and adapt to climate change.

CHAPTER 7

Un-locking the potential of 'no regrets' opportunities

This study reveals that that there are significant opportunities for growth on a low carbon path for the dairy sector and that economically viable opportunities exist (in varying degree and circumstances) in all the seven systems; however, the greatest opportunities for immediate mitigation and productivity increases at scale lie in traditional dairy systems. Nevertheless, achieving these reductions will require ambitious action. Translating the actions outlined in this document into food security and developmental goals will require bolder efforts to support the transfer and uptake of technology, reduce costs of technologies, scale-up private sector finance, and support access to climate finance.

This study did not consider changes in systems, i.e.: from small-holder 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.

Increasing individual animal productivity as a consequence of better feeding practices, increased water availability and improved health and herd management, could also result in a reduction of the herd. Reduction in animal numbers, particularly in traditional production systems, would allow the provision of adequate feed and better health management, which would lead to improvements at both animal and herd levels and consequent reduction of methane emissions, both in terms of total emissions and emission intensities. However, these mitigation options might be in conflict with the interests of pastoralists and small-holder farmers who generally tend to keep animals for other functions, such as wealth, traction, nutrient value and risk management. Particularly in traditional systems, appreciation of these roles is necessary if any policy geared towards change in the structure of the systems is to succeed.

Improved integration of small-holder households into the market will possibly reduce non-market roles of dairy cattle. However, this will entail deliberate efforts geared towards the development of product markets and incentives/measures to support the replacement of such functions and compensate farmers for loss of these functions. With well-functioning markets, the role of cattle as insurance against risk and that of financing unexpected expenditures will decline. This is because functioning markets would provide signals for investment decisions as well and opportunities for long term planning.

The study also indicates that while there are many interventions to reduce emissions and improve productivity, the same intervention can also have contrasting impacts on emissions, production and farmer revenues as Table 6.1 illustrates. This reinforces the need to tailor interventions to local realities. 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.

Moreover, it is important to note that the costs and benefits (and profitability) of the application of technologies are only one part of the picture: adoption also depends on policy incentives, technical support, access to inputs and services, farmers' capacity to implement, and other factors. 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 exist for the individual interventions assessed in this report.

A better understanding of the barriers to technology adoption at the farm level would contribute to the design of policies and programs that can support practice change at scale. For instance, a study revealed that social capital networks can contribute to technology uptake by livestock farmers in Uganda. In other words, social capital networks help farmers to connect to extension work organizations (government and non-governmental organizations), share information among other peers and influence farmers' decisions. As a result, farmers who participate in social capital networks are more likely to adopt technologies and acquire information in livestock management and development. Moreover, the study also observed that farmer's possession of a mobile phone influenced development of his or her livestock enterprise and enhanced farmer to farmer and farmer to extension worker relationships[16]. Understanding the drivers of technology adoption is essential and should be considered when designing supportive policies and programs that seek to increase adoption of mitigation technologies and promote livestock development.

[16] Ntume B., Nalule, A.S. and Baluka, S.A. 2015. The role of social capital in technology adoption and livestock development.

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