Food and Agriculture Organization of the United Nations

OPTIONS FOR LOW-EMISSION DEVELOPMENT IN THE KENYA 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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Executive summary

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

Kenya has taken steps to chart a path towards achieving food security and other developmental goals. The Government of Kenya has developed a number of high level policy initiatives, including Vision 2030 which is the overarching policy document setting out development objectives. The Kenya Vision 2030 is the national long-term development policy that aims to transform Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment.

The agriculture sector has been identified as one of the key sectors to contribute to the projected annual 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 the most vulnerable to the impacts of climate change and extreme weather events. Due to these challenges, the government recognizes the need to develop interventions that make agriculture more resilient to climate change and extreme weather events while minimizing its contribution to greenhouse gas emissions.

In 2010, the Government developed the National Climate Change Response Strategy to propose a cross-governmental strategy to respond to climate change challenges. Kenya has recognized the importance of green growth for achieving its Vision 2030 goals and also as an element of the implementation of the Kenya Constitution 2010 that, under the 'Bill of Rights', guarantees every citizen a clean and healthy environment. In 2013 Kenya launched the National Climate Change Action Plan which provides a vision for low carbon and climate resilient development pathway.

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

With this in mind, Kenya in its Intended Nationally Determined Contributions (INDC) has put forth adaptation and mitigation actions to tackle its growing emissions and to play a role in global efforts to limit temperature rise to 2 degrees. These mitigation actions 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 Kenya in several ways:

- The dairy industry is Kenya's single largest agricultural sub-sector in Kenya. It contributes 14 percent to agricultural Gross Domestic Product (GDP) and 3.5 percent of total GDP. The sector currently contributes to the livelihoods of many smallholders through generation of income, employment and food to 2 million people across the dairy value chain. Milk production in Kenya is predominantly managed by small scale farmers, who own one to three dairy animals, and produce about 70 percent of the milk in the country. Smallholders engaged in milk production represent about 35 percent of rural households and 26 percent of total households in Kenya. Amongst these dairy farmers are some of the poorest and most marginalized such as women. 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.

- 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 Kenya, dairy animals are one of the most valuable assets for rural households playing many functions such as traction, nutrient value and risk management.
- The Kenyan Dairy Master Plan has set a target to increase per capita consumption of milk to 220 kg per person by 2030. Current consumption of milk and milk products in Kenya is 115 kg per person; 89 liters below the recommended amount from the World Health Organization (WHO). Kenya milk consumption levels are among the highest in the developing world. Kenya's population is expected to increase from the current 48 million to 65 million in 2030, of which more than one-third will be urban residents. With this future population scenario, per capita milk consumption is projected to grow rapidly.
- 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 almost 2 litres per cow per day in extensive to 12 litres per cow per day in intensive systems. Seasonal fluctuation of production – the yield per cow and by extension the total amount of milk produced fluctuates greatly during the year. Milk yields are low and largely variable mainly because of poor and limited feed resources, disease and poor management. Milk yields remain low even in semi-intensive and intensive systems that keep high yielding exotic breed and cross-breeds. These animals cannot reach their full genetic potential if factors in their environment are limiting. Currently, a wide range in average milk yields exists, which reflects the variation in genetic potential and the variation in environment, which is altered by management practices.
- About 75 percent of the population depends directly on land and natural resources 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 the country. On average, every seven years Kenya experiences a flood that costs about 5.5 percent of GDP (USD 0.5 billion), and every five years experiences a drought that costs about 8 percent of GDP (USD 0.8 billion). Extreme flood and drought events are estimated to reduce long-term growth in Kenya by about 2.4 percent of GDP per annum[1].

Emissions and emission intensities from the dairy production

The national dairy population is estimated to be 4.3 million dairy cattle producing 3.4 billion litres of milk. The semi-intensive dairy cattle production system produces the largest share of milk production, contributing 44 percent of total milk supply from cattle. While the extensive and intensive systems contribute 22 percent and 24 percent, respectively. The dairy cattle sector in Kenya is responsible for about 12.3 million tonnes CO_2 eq. The GHG profile is dominated by methane (95.6 percent); nitrous oxide (N_2O) and carbon dioxide (CO_2) contribute 3.4 percent and 1 percent of the total emissions, respectively.

At national level, the emission intensity of milk produced in Kenya is on average 3.8 kg CO_2 eq./kg FPCM; the highest values were estimated for extensive grazing systems and the lowest in semi-intensive systems. Emissions were on average, 7.1, 2.1, and 4.1 kg CO_2 eq./kg FPCM for extensive, intensive, and semi-intensive systems, respectively.

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

Improving animal and herd productivity is one of the key pathways to reduce enteric CH_4 emissions per unit of product. Methane is produced in the process of feed energy utilization by the animal. Changes in the efficiency of feed energy utilization therefore influence enteric methane emissions of animals. The

[4] The economic impacts of climate change. https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/4e25a04e8c9d92-economics-of-climate-change-in-kenya-factsheet.pdf

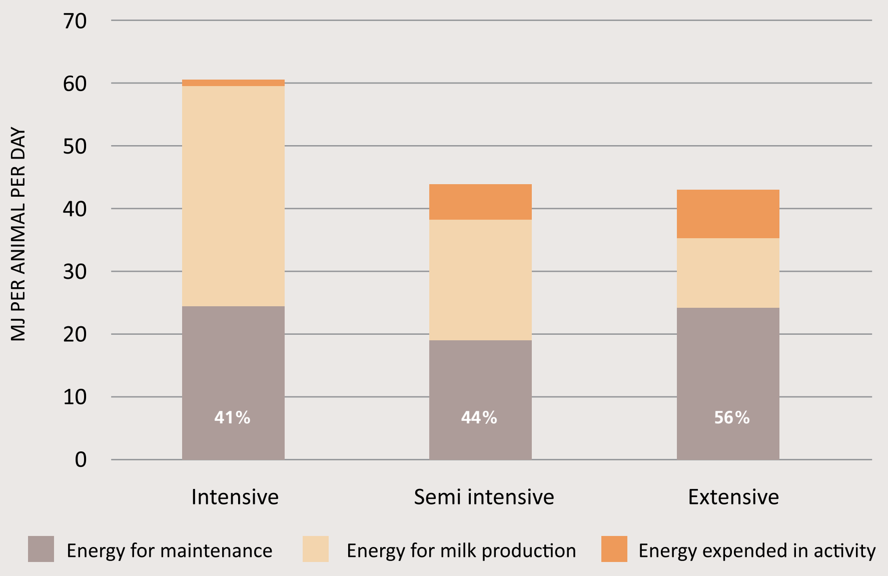
efficiency of feed energy utilization depends on the type of animal, the type or quality and quantity of feed, environmental conditions, etc. The way feed energy is partitioned between the different body functions (maintenance and production) also explains the variation in emission intensity.

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 CH_4 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 300kg, 212kg and 294kg milking cows in intensive, semi-intensive and extensive systems is 27.8, 21.4 and 27.4 MJ per day. The total energy cost for lactation increases as a function of milk production. A high-producing dairy cow requires more nutrients per day than a low producing dairy cow; the cow with a daily milk output of 12 kg per day is using 41 percent of consumed energy for maintenance whereas the low producing cow (2 kg/day) is using 56 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 12 kg milk/day in Intensive systems requires 5.2 MJ/kg milk, whereas a cow yielding 2 kg/day in extensive dairy systems needs 30.4 MJ/kg milk.

Energy requirement for milking cows in dairy systems in Kenya



Source: GLEAM, 2017

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

Research shows that there are several technologies that if comprehensively applied throughout the sector can 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 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 Kenya.

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 genetics and animal health interventions. Within this broad categorization, 10 single interventions and 1 'package' consisting of combination of single interventions were assessed in this study.

Significant gains can be realized: between 21-36 percent in emission intensity reduction

This work shows that significant reductions in methane emission intensity 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 (kg CO_2 /kg FPCM) can be reduced by 7–45 percent, the magnitude of impact varies depending on the intervention and production system assessed. All interventions returned a positive productivity outcome with increases in milk production ranging between 4–80 percent.

Many of the biological effects are interrelated and interdependent and, accordingly, the changes in enteric CH_4 emissions per unit of milk (kg CH_4/kg FPCM) are not additive. The decreases in CH_4/FPCM range are modest because the range of alterations was restricted to what might reasonably be implemented or expected to occur in dairy production. In addition, the implementation of many of the approaches is limited to lactating dairy cattle for practical or economic reasons and, thus, the reductions in enteric CH_4 are modest.

The use of a combination of feed practices (combining use of non-conventional feed resources, feed conservation and feeding of high energy/protein and an additional one including the use of non-conventional feed resources and feed conservation) returned the highest impacts on methane and milk production. The two interventions were designed to evaluate the impacts of feed management practices that improve consistency and minimize variability. The use of non-conventional feed resources, feed conservation and feeding of high energy/protein resulted in 26–28 percent reduction in methane emission intensity and 34–36 percent increase in milk production. Strategic supplementation with sweet potato vines and sorghum silage in intensive and semi-intensive systems reduces enteric methane emissions by 48–50 percent and results in milk production increases between 93–97 percent.

Applying combinations of interventions 'packages' aimed at improving feed availability and quality (establishment of fodder grasses and legumes, use of conserved silage and UMMB); improving herd health (vaccination against East Coast Fever) and improved genetics (artificial insemination) can potentially result in a reduction potential of 21–36 percent in emission intensity relative to the baseline emission intensity. With these combinations of technologies, an increase in milk production of 31–35 percent can be achieved compared to the baseline. 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.

Reduction of enteric methane emissions will pay for itself

A key incentive to farmers for adoption is increased revenue and/or reduced production costs. To better

understand the implications for farmers, a cost benefit analysis was conducted to assess the profitability of adopting mitigation intervention. The benefit-cost ratio (BCR) indicates the overall value for money of the interventions. Generally, if the ratio is greater than 1, benefits of the interventions outweigh the costs. In this study the, the BCR for different mitigation options ranged from 1.1 to 5.8 indicating that benefits exceed economic costs for the different options considered.

Prioritization of interventions for enteric methane

A preliminary ranking of interventions per production systems to identify interventions with high emissions reduction potential, increased milk production and high economic return for farmers was undertaken to provide an indication of which interventions can deliver win-win outcomes. Out of the 10 interventions assessed, 6 were considered relevant for the intensive and 9 for semi-intensive systems. Four of the five interventions selected for extensive systems were included in the prioritization process.

In the intensive system, vaccination against East Coast Fever, use of urea treated crop residues, and combined feeding practices returned high productivity and profitability impacts. While in the semi-intensive systems, combining strategic supplementation feeding practices had important impacts on all three criteria.

Reducing enteric CH_4 would in many cases be profitable.

Reducing enteric CH_4 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. Economically attractive measures are those that have a negative cost or savings meaning there is a net financial benefit.

The interventions assessed all have negative net costs (i.e. net benefits) resulting in an abatement potential of 15.9 million tonnes CO_2 eq. Putting the reduction potential and net costs together allows a first order prioritization of low carbon interventions. All other things equal, the objectives would be to promote interventions with high reduction potential and a net economic benefit.

CHAPTER 1

Green growth options for the dairy sector

In Kenya, where about 75 percent of the population depends directly on land and natural resources 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 the country. In 2010, the Government developed the National Climate Change Response Strategy to propose a cross-governmental strategy to respond to climate change challenges[2]. Kenya has recognized the importance of green growth for achieving its Vision 2030[3] goals and also as an element of the implementation of the Kenya Constitution 2010 that, under the 'Bill of Rights', guarantees every citizen a clean and healthy environment. In 2013 Kenya launched the National Climate Change Action[4] which provides a vision for low carbon and climate resilient development pathway.

Kenya envisions being a middle income country with citizens enjoying high quality of life and a sustained annual economic growth rate of at least 10 percent by the year 2030 according to the National Development Blue Print "The Kenya Vision 2030".

The agriculture sector has been identified as one of the key sectors to contribute to the projected annual 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 the most vulnerable to the impacts of climate change and extreme weather events. Enhanced temperatures and change in precipitation regimes have led to reduced suitability of agro-based enterprises; reducing productivity of crops, livestock and fisheries due to temperature and water stresses; and rising production costs. The increase in frequency and intensity of extreme weather events such as droughts and floods have led to loss of investments, incomes and livelihoods, the destruction of agro-based infrastructure as well as increased frequency of weather related disasters. Due to these challenges, the government recognizes the need to develop interventions that make agriculture more resilient to climate change and extreme weather events while minimizing its contribution to greenhouse gas emissions.

Kenya seeks to undertake an ambitious mitigation contribution towards the 2015 Paris Agreement. Kenya therefore seeks to abate its GHG emissions by 30 percent by 2030 relative to the BAU scenario of 143 Mt CO_2 eq. and in line with its sustainable development agenda. For the agricultural sector (crops and livestock), these actions will be pursued under the banner of climate smart agriculture[5]. The livestock sub-sector contributes 90 percent of the emission from the agriculture sector mainly from enteric fermentation. The NDC Livestock development is identified as a key priority area is action. More specific to the dairy sector the government of Kenya recognizes that the agricultural sector has the potential to reduce GHG emissions through efficient dairy production systems[6].

This report presents the findings and recommendations from an initial assessment of the dairy cattle sector of Kenya. It is undertaken in

[2] Government of Kenya. 2010. National Climate Change Response Strategy. Nairobi: Ministry of Environment and Mineral Resources, Government of Kenya.
[3] Government of Kenya. 2007. Kenya Vision 2030. Nairobi: Government of Kenya.
[4] Government of Kenya. 2013. National Climate Change Action Plan 2013-2017. Nairobi: Ministry of Environment and Mineral Resource, Government of Kenya.
[5] Government of Kenya: Kenya's Intended Nationally determined contribution. http://www.environment.go.ke/wp-content/uploads/2015/07/Kenya_INDC_20150723.pdf
[6] Government of Kenya. 2014. National Climate Change Framework Policy. 2014

collaboration with the State Department of Livestock in Kenya, 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 ruminant 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.

CHAPTER 2

Objectives and approach

This study seeks to identify and evaluate low-cost options that Kenya 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.

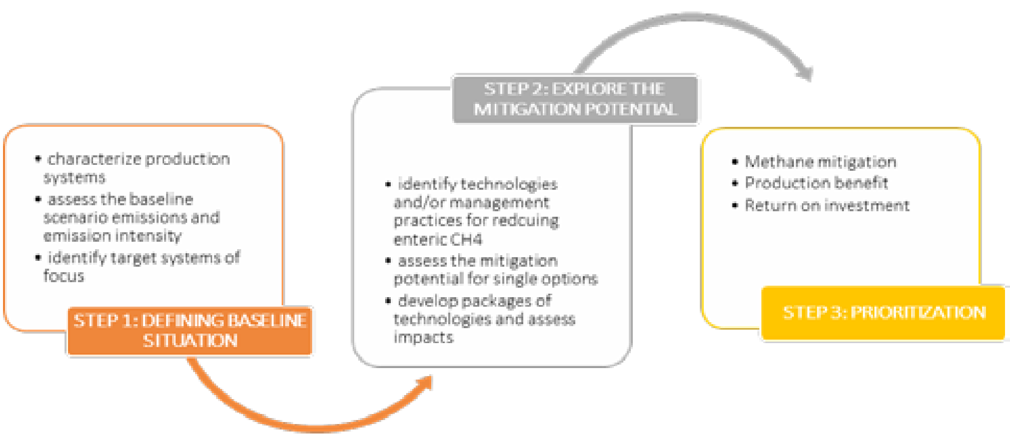
3) Prioritization of interventions. Prioritization of interventions is undertaken by drawing on modeling results (of emission intensity reductions and productivity impacts), and a cost-benefit analysis. It assesses productivity impacts, the potential profitability for farmers in adopting implementing 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 1).

The analysis focuses on the dairy cattle sector, a strategic sector in Kenya 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.

Smallholder dairy development presents a promising option to boost rural incomes, improve

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 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 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 the business-as-usual.

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

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 definition level of 10 square kilometers, 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 Kenya 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 eq. 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: http://www.fao.org/gleam/en/;

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

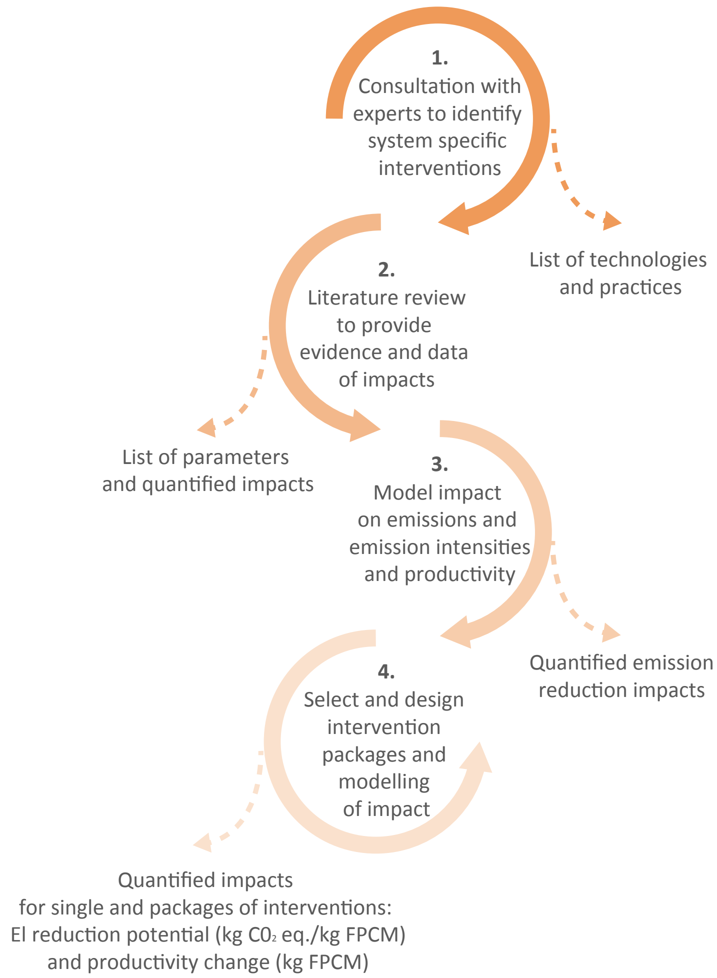
FAO. 2013a. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment, by C. Opio, P. Gerber, A. Mottet, A. Falcucci, G. Tempio, M. MacLeod, T. Vellinga, B. Henderson & H. Steinfeld. Rome.

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 (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 2). 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

Figure 2.2: Process for exploring mitigation impacts



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 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

The dairy industry is Kenya's single largest agricultural sub-sector in Kenya. It contributes 14 percent to agricultural Gross Domestic Product (GDP) and 3.5 percent of total national GDP. The sector currently provides income and employment to about 2 million people[8] across the dairy value chain. In terms of nutrition and food security, current per capita consumption of milk is 115 litres and demand for dairy products is projected to continue to grow rapidly as a consequence of population growth.

Kenya's population is expected to increase from the current 48 million to 65 million in 2030, of which more than one-third will be urban residents[9]. With this future population scenario, per capita milk consumption is projected to reach 220 liters by 2030. Demand for chilled, high quality processed milk is expected increase, with growth in demand projected at 5 percent per year, and total milk demand reaching 12 billion liters by 2030[10]. Growth in the formal sector is expected to be more rapid, partly due to the shifting structure of consumer demand, and partly due to initiatives to regulate milk quality in informal markets.

Total milk production from dairy cows in 2014 was about 3.4 billion litres. In the last decade, milk production has grown at an annual average rate of more than 3 percent. Of the milk produced, about 42 percent is consumed at household level, and 58 percent is marketed. Of the marketed milk, 70 percent is sold through the informal sector, in which brokers link producers and consumers of unprocessed milk. The rest of the marketed milk passe through formal marketing channels, involving transport to chilling and bulking centers and processing facilities, where it is processed into a wide range of dairy products for retail in the country's urban centers. The main products are fresh pasteurized, UHT and fermented milk, and milk powder, with smaller markets for cheese, ice-cream, cream, butter and ghee. Between 2008 and 2015, the formal sector has been growing at an annual rate of 6.3 percent.

Milk production in Kenya is predominantly managed by small-scale farmers, who own one to three dairy animals, and produce about 70 percent of the milk in the country.[11] Smallholders engaged in milk production represent about 35 percent of the rural households and 26 percent of total households in Kenya. However, small-holder producers should not be considered as one homogeneous group. They vary in their motivations for keeping dairy cows; from providing milk for household consumption, to dairying as a supplementary source of income alongside other cash/subsistence crops or the main source of income for the household. Other reasons for owning dairy cows include status, a store of wealth and a valuable source of organic manure for the crop production or sale.

Dairy production in Kenya is highly concentrated in the high-potential highland areas, where temperature is moderated by altitude, receive a greater and more reliable rainfall than medium-potential areas that are predominantly found at lower altitudes. These factors largely explain the current distribution of dairy farming in Kenya, as forage production is related to rainfall, disease risk is reduced at higher altitudes and market demand arose from emerging consumption centers located in the highlands. Dairy production takes place in three types of production systems: intensive, semi-intensive and extensive (Map 3.1). The differences between the systems are in their sizes

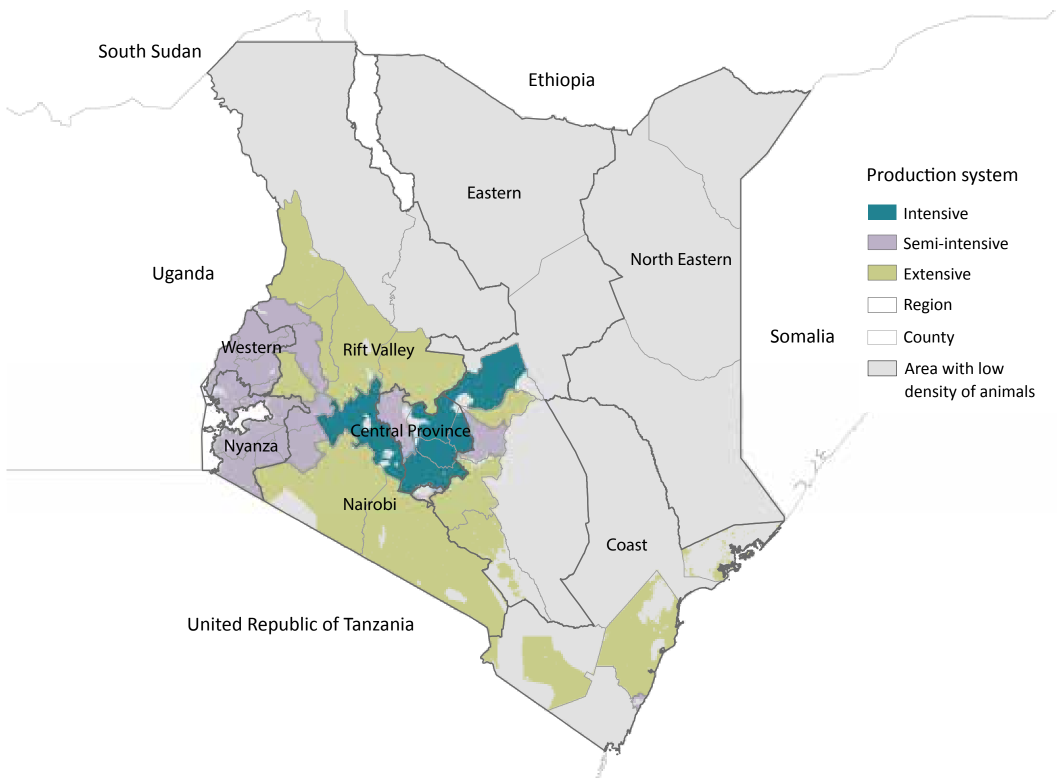
[8] Kenya Dairy Board, 20129 Government of Kenya. 2007. Kenya Vision 2030. Nairobi: Government of Kenya.
[9] UN Population Projections (https://esa.un.org/unpd/wup/CD-ROM/) and World Urbanization Prospects (https://esa.un.org/unpd/wup/CD-ROM/)
[10] National Dairy Development Policy (2013)
[11] FAO. 201. Dairy development in Kenya, by H.G. Muriuki. Rome. http://www.fao.org/docrep/013/al745e/al745e00.pdf

of operation, level of management and use of inputs. The production systems are influenced by the agro-climatic characteristics of the area, land productivity potential and prevalence of animal diseases. In areas of high population density, this has allowed the development of highly intensive smallholder dairy production systems typified by the 'zero-grazing' practice of confining and stall-feeding cattle with crop residues and planted fodder, particularly Napier grass and concentrates. In areas of greater land availability, such as parts of Rift Valley Province, less intensive feeding practices of combined grazing and stall-feeding, or free grazing only on unimproved natural pasture in the more marginal areas, are employed. The choice of the feeding system is normally motivated by a desire to optimize the limiting resource. In areas of high population density, land tends to be the limiting factor whereas in open grazing, labour is the limiting factor. Expenditure on purchased feeds and concentrates are higher in zero-grazing system than in open grazing.

Map 3.1 illustrates the distribution of the three production system across the territory.

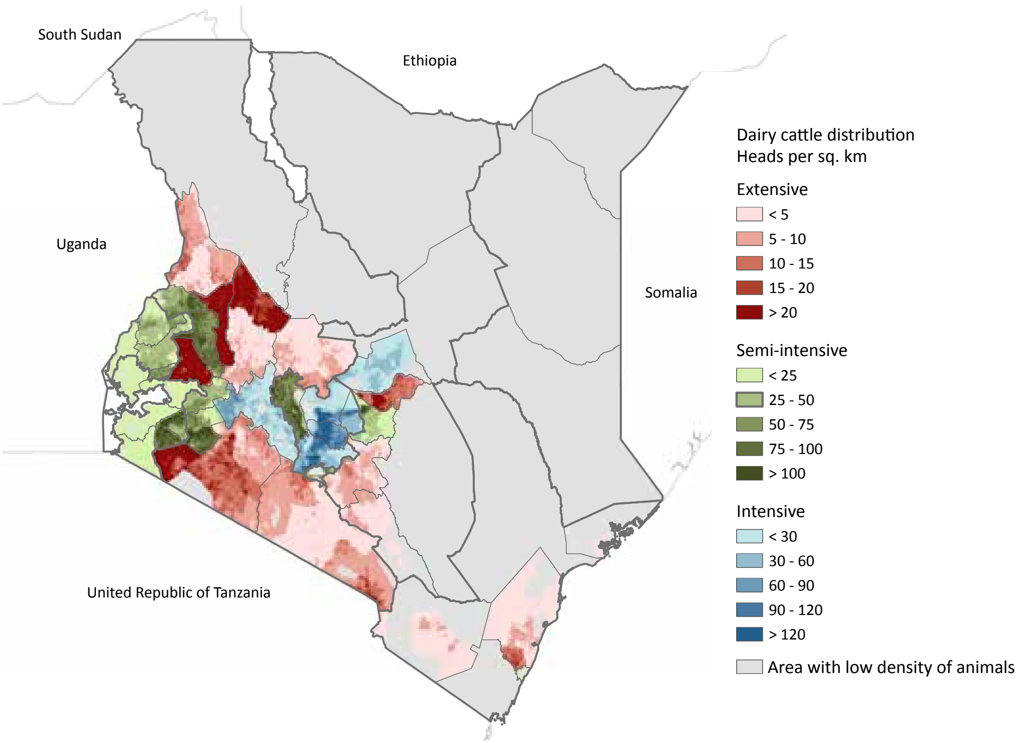
- Intensive dairy production which is often practiced under zero grazing conditions involves confining cattle to a limited physical space where they are managed, fed, watered and milked. This system is mainly practiced in high-potential areas of Central Kenya where high population growth has resulted in reduction of land-holding sizes and also by urban and peri-urban farmers.
- Extensive production systems involves open range free grazing by the cattle, often with no supplemental feeds and animals are predominately local zebus with low milk productivity. It is practiced where grazing land is available and there is little use of purchased inputs. In Kenya, it is practiced in most parts of the Rift Valley, where farmers own large tracts of land.

Map 3.1: Geographical distribution of dairy cattle production systems



Source: GLEAM, 2017

Map 3.2: Dairy cattle production system distribution



Source: GLEAM, 2017

- Semi-intensive systems fall somewhere in the middle and involves the combination of the two approaches above. This system is characterized by a lower human population density compared to the intensive system, dairy rely on mainly grazing which is usually supplemented with cultivated fodder and/or purchased feed. In these systems cross-bred cattle are usually kept.

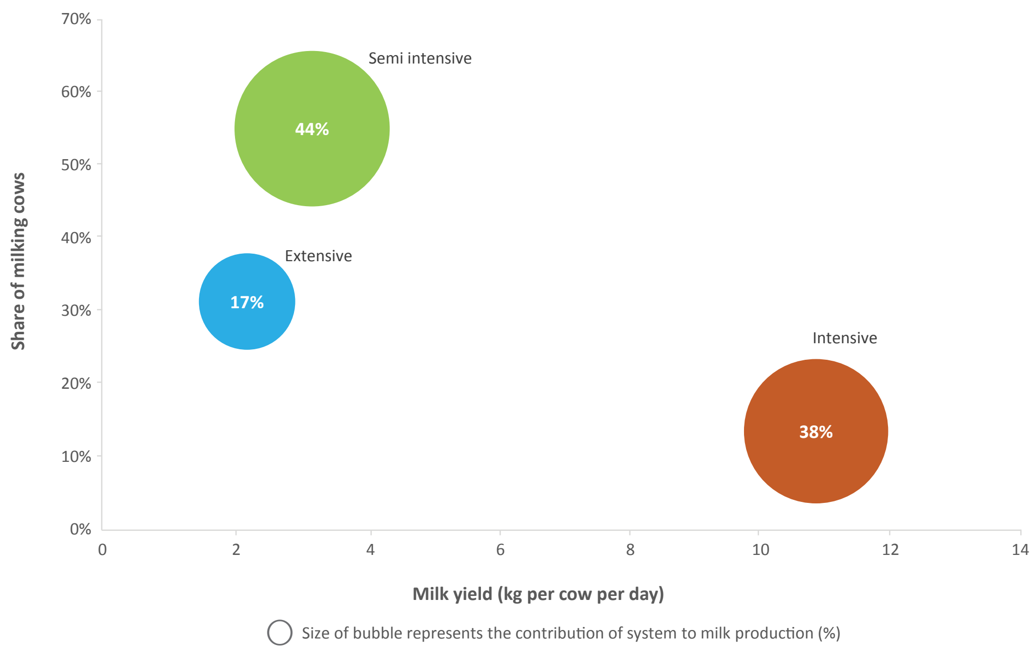
A summary of key features of these production systems is provided in Table 3.1.

Map 3.2 illustrates the distribution of dairy cattle herd across the Regions. Milk production in Kenya is mainly concentrated in the Rift Valley, Central Province and Western region. About 63 percent of the total milk is produced Rift Valley and Central Province on less than 17 percent of the country's land area.

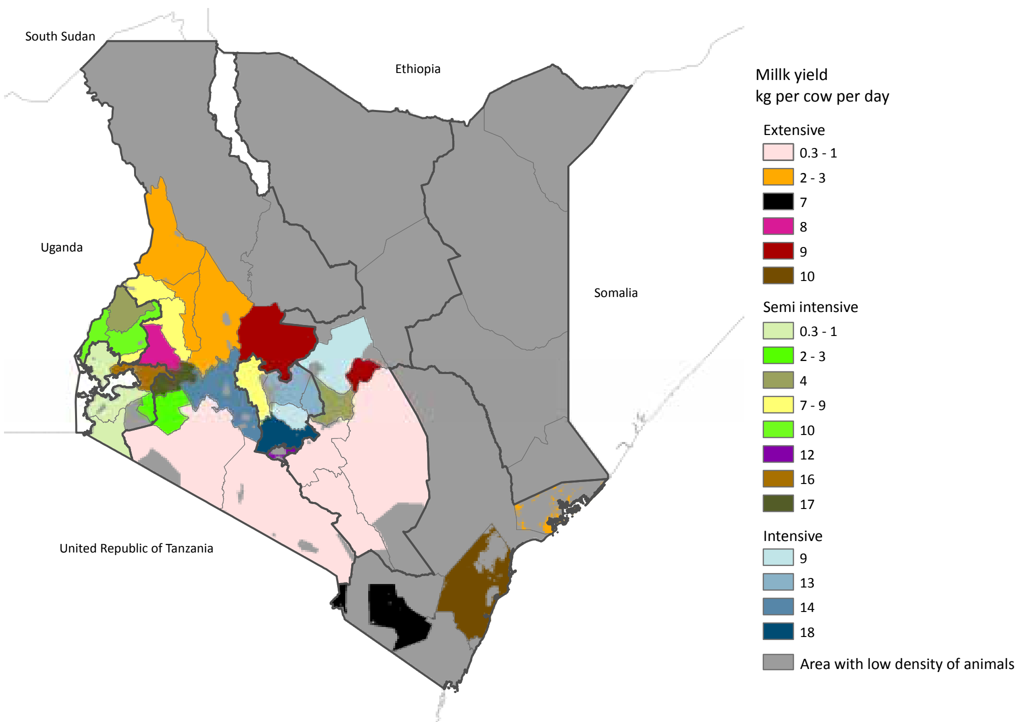
The dairy cattle sector produces about 3.4 million litres of milk. The semi-intensive dairy system produces the largest share of milk, contributing 44 percent of total milk supply from 55 percent of milking animals.The intensive and extensive dairy systems contribute 38 percent and 17 percent of the total milk, respectively, with 14 percent and 31 percent of the milking cows, respectively (Figure 3.1).

The productivity of dairy cows in Kenya is highly variable (Map 3.3).

Figure 3.1: Milk yield and contribution to milk production by production system



Map 3.3: Milk yield by production system



Source: GLEAM, 2017

Table 3.1: Summary description of dairy cattle production systems in Kenya

Production system		Characterization
Stall feeding	Diet	The main source of feed is fodder especially napier grass *(Pennisetum purpureum)* and crop residues from maize and bananas due to limited grazing land. Sometimes supplementation from sweet potato vines is also used. The feedstuffs are either purchased or grown in the farms.
	Genotype	The exotic dairy breeds; Friesian and Ayrshire are dominant in these regions.
	Health	Mortality is approximately 12% for mature cows, and 13% for mature bulls 15% and 14% for female and male calves, respectively
	Reproductive practice	The age at first calving can be assumed to be at 29 months with a calving rate of 52% and a calving interval of about 20 months[5]. Natural mating is the most widespread option of reproduction whereby few farmers own bulls and hire them for servicing cows. The bull to cow ratio is 1:76. Artificial insemination (AI) is sometimes used especially by financially able farmers. The cow replacement rate is assumed to be 50%.
	Diet	Major source of feed is from grazing natural pastures of unimproved annual and perennial grasses mainly kikuyu grass *(Pennisetum clandestinum)* and rhodes grass *(Chloris gayana)*. These grasses are of low quality during the dry season. However, supplementation with fodder such as Napier grass, sweet potato vines and crop residues e.g. maize stover, legume residues (from pigeon pea, cowpea, green gram and beans) are also used especially during periods of harvesting.
	Genotype	The indigenous zebu cow is the most popular breed. However exotic breeds (Friesian Ayrshire, Jersey and Guernsey) and crossbreds of exotic and zebu are also found in this system.
	Health	Approximately 14% for mature cows and 10% for mature bulls, 13% and 19% for female and male calves, respectively.
	Reproductive practice	The age at first calving can be assumed at 31 months with a calving rate of 51%. Natural mating is the most widespread method with a bull to cow ratio of 1:22. AI is sometimes used by financially able farmers and the cow replacement rate is 89%.
Extensive	Diet	Animals in the system are primarily fed on natural unimproved grass
	Genotype	The small East African Shorthorn Zebu, crosses between Zebu and the dual-purpose Sahiwal breed and zebu X Boran are the dominant cattle breeds in these system.
	Genotype	The mortality rate of both mature bulls and cows is assumed to be 13%15% and 21% for female and male calves, respectively
	Reproductive practice	Age at first calving is about 4 years with a calving rate of 64.3%. Natural mating is the sole method of reproduction with the ratio of bull to cow at 1:20 and the cow replacement rate is 78%. There is no controlled breeding and reproduction is primarily influenced by the bimodal rainfall regime and the resultant seasonality in feed supply.

CHAPTER 4
Emissions and emission intensities

Milk production from the dairy cattle sector in Kenya emits about 12.1 million tonnes CO_2 eq. by the dairy cattle sector. More than three-quarters of the total emissions are concentrated in two regions with the highest share of the national dairy herd: Rift Valley (52 percent), and Central Province (24 percent).

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 95.8 percent, while the nitrous oxide (N_2O) and carbon dioxide (CO_2) contribute 3.4 percent and 1 percent of the total emissions, respectively.

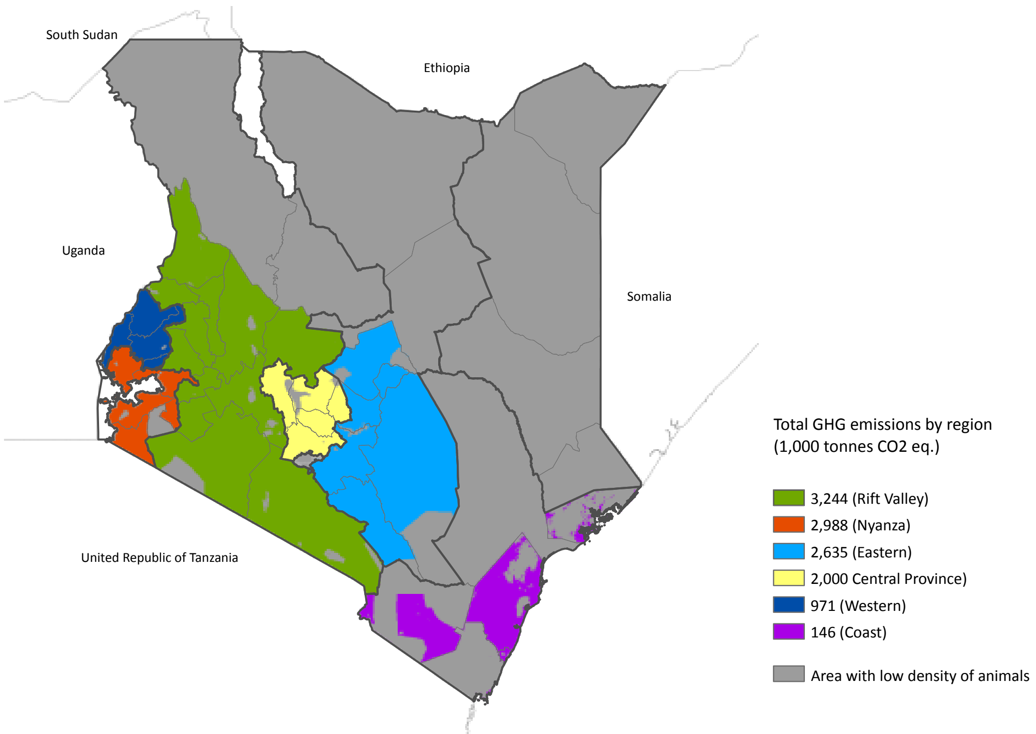
Approximately 88 percent of the emissions arise from methane produced by the rumination of cows and 11 percent from the management of stored manure. Emissions arising from other source make a negligible contribution to overall emissions.

Production system contribution to the total GHG emissions

Within the dairy cattle sector, the semi-intensive dairy production system which produces 44 percent of the national milk, is responsible for 48 percent (5.7 million tonnes CO_2 eq.) of the total GHG emissions. The extensive and intensive production system contribute 32 percent and 21 percent of the emissions, respectively (Figure 4.2).

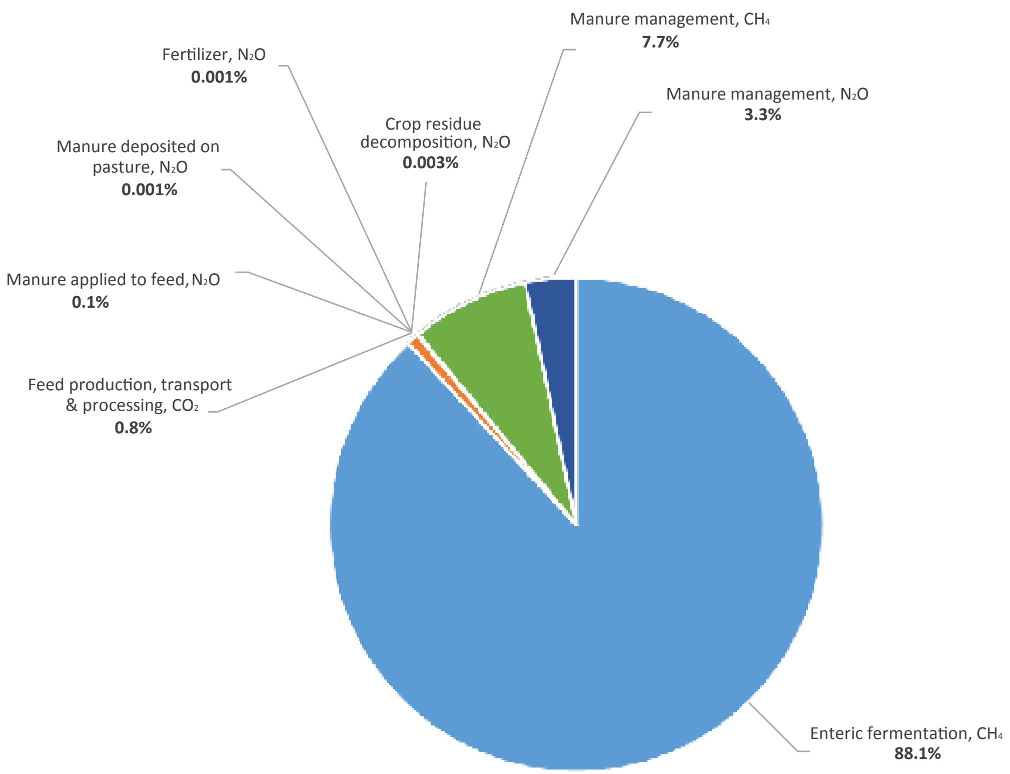
Across all production systems, methane emissions from enteric fermentation comprise the bulk of

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



Source: GLEAM, 2017

Figure 4.1: Share of total emissions by emission source



Source: GLEAM, 2017

emissions ranging from 56–77 percent of the total emissions. Extensive and semi-intensive systems have very similar emission profiles; enteric methane and N_2O emissions from manure deposited on pasture dominate both profiles. Emissions from manure management especially methane is important in intensive systems mainly because a large part of the manure produced is managed in liquid form (Figure 4.2).

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

At national level, the emission intensity of milk produced in Kenya is on average 3.8 kg CO_2 eq./ kg FPCM; the highest values were estimated for extensive grazing systems and the lowest in intensive systems. Emissions were on average, 7.1, 2.1, and 4.1 kg CO_2 eq./kg FPCM for the extensive, intensive, and semi-intensive systems, respectively (Figure 4.3).

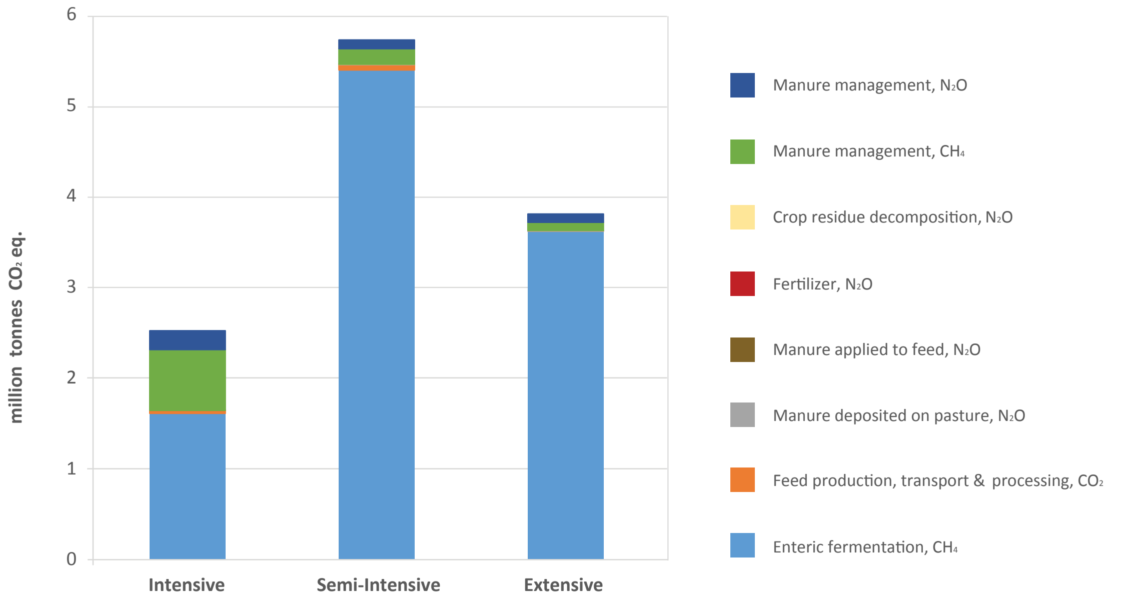
Variability in emission intensity within dairy production systems

At production system level, there is a wide variation in emission intensity which is closely related to the diversity the production and management practices in the dairy production systems. At production system level, the highest variability in emission intensity is observed for the extensive systems with a range from 2 to 50 kg CO_2 eq./ kg FPCM (Map 4.2). In intensive dairy systems, the variation in emission intensity are narrow. 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.

Determinants of emissions and emission intensities

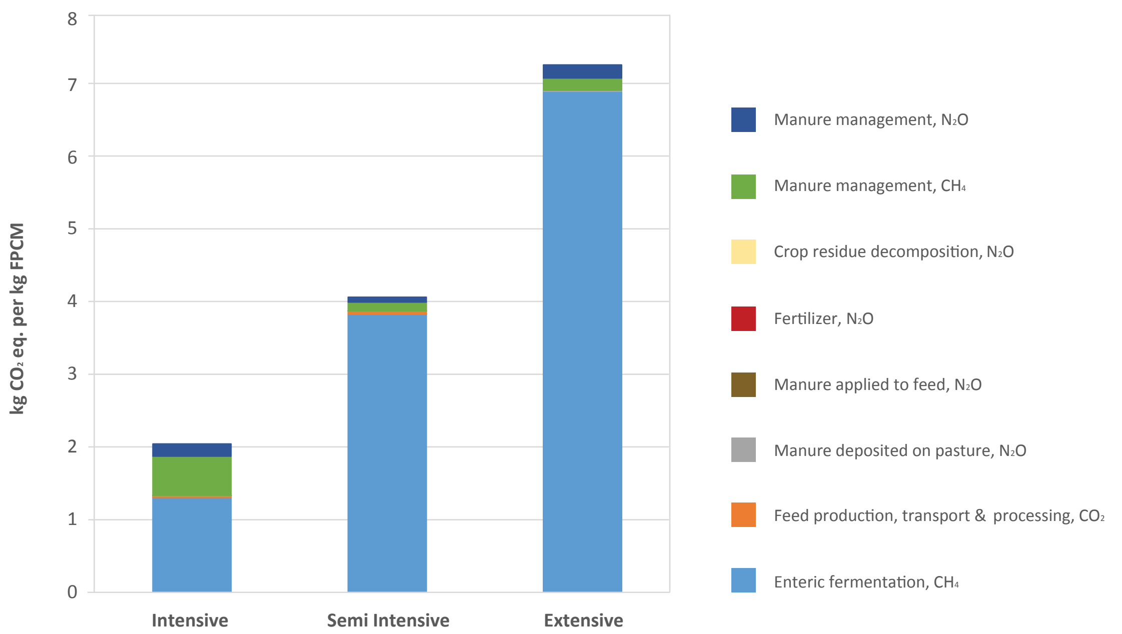
A number of factors influence emissions and emission intensities from dairy production in Kenya:

Figure 4.2: Absolute emissions by production system and emission source



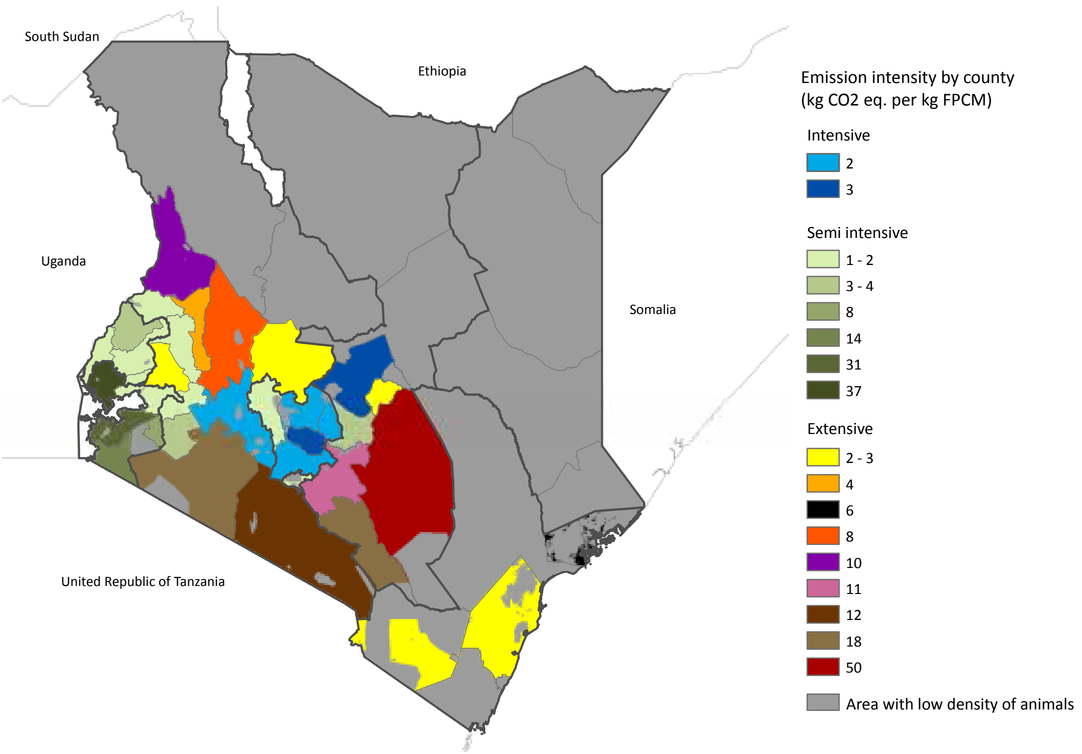
Source: GLEAM, 2017

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



Source: GLEAM, 2017

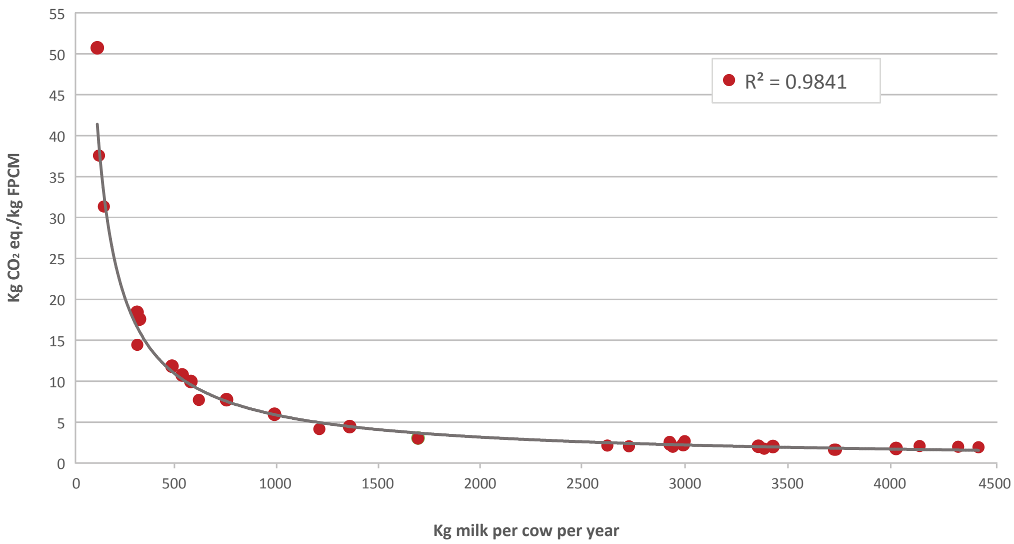
Map 4.2: Variability in milk emission intensity



Source: GLEAM, 2017

- **Inadequate and poor quality feed.** An inadequate supply of quality feed is the major factor limiting dairy production in Kenya. Feed resources, are either not available in sufficient quantities due to fluctuating weather conditions or even when available are of poor nutritional quality. While the small-scale of dairy farm operations and the lack of broad-based use of modern farm technologies/ practices and improved breeds explain a great deal of the productivity gap, a notable factor is the lack of access to feed. Across all systems, fodder availability is inadequate and prices are too high for smallholder dairy farmers to access. This is constraining their milk output and their ability to expand production. This problem is compounded by seasonal changes in pasture conditions, with poor productivity during dry seasons. High milk fluctuations arise because most farmers depend on rain-fed feed production and rarely make provisions for preserving fodder for the dry season. In addition to seasonality of feed supply, the diet is 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 between 59 percent in semi-intensive systems to 66 percent in intensive systems. These constraints explain the low milk yields and short lactations, high mortality of 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 diseases, tick-borne diseases, internal and external parasites affects the performance of dairy animals and herd. Animal health affects emission intensity through the "unproductive emissions" related to mortality and morbidity. Mortality rates are high (ranging between 7–21 percent) regardless of the system. Many of the health problems result from poor animal condition as a result of inadequate nutrition, but also disease. 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

Figure 4.5: Variation in greenhouse gas (GHG) emission intensity of milk in relation to milk productivity per cow (kg milk per cow per year). Each dot represents a county



Source: GLEAM, 2017

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, often inherently more susceptible to diseases compared to the indigenous cattle. This also partly explains the lower calving rates (52 percent) in the intensive systems.

- **Reproductive efficiency.** Reproductive efficiency affects emission intensity by influencing the portion of the herd that is in production (e.g. number of lactating and dry cows in the herd). 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 Kenyan dairy herd is manifested in a number of parameters such as low fertility rates (50 percent), delayed time to reach puberty and age at first calving (2.7 and 4 years in semi-intensive and extensive systems, respectively).
- **Better management of genetics:** Enhancing the genetic potential of the animal is critically important, but 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, or climatic challenges. In intensive systems, farmers generally rely on exotic breeds such as Friesian and Ayrshire which are high yielding animals with high feed requirements, have a high demand for clean water, susceptible to disease and other climatic stressors.

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 Kenya (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 R^2 value describes the proportion of the variation in values that is explained by the trend. In other words, an R^2 value of 0.98 means that 98 percent the variation in emissions intensity is explained by milk production per cow.

CHAPTER 5

Exploring the mitigation potential in dairy cattle production

The analysis of current production of milk in Kenya shows that improving 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 CH_4. This is not a purely technical process but incorporates other factors such as existing national priorities. As such other considerations 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, 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 GHG 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 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: fodder cultivation, supplementation with concentrates, leguminous shrubs, and urea-treated straw, urea-molasses multi-nutrient blocks (UMMB), use of conserved fodder, disease control (East Coast Fever and internal parasites) and use of improved genetics (artificial insemination). 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 judgement of their specific operating requirements and likely impact on performance. For example, all feed-related interventions were applied only to a proportion of lactating and replacement heifers while the vaccination against East Coast Fever was applied to all animals in all systems in the Coastal Province and Rift Valley.

Quantitative summary of mitigation outcomes from the application of single interventions

The potential outcomes (emission reductions and improvements in productivity) from the application of the single interventions evaluated in this study are presented in Figures 5.1 and 5.2. Overall, the analysis shows that there is a high potential to reduce emission intensities; methane emission intensity (kg CO_2/kg FPCM) can be reduced by 7 percent to 45 percent, the magnitude will vary depending on the intervention and production system assessed (Figure 5.1). The productivity outcomes are presented in Figure 5.2; all interventions returned a positive productivity outcome with increases in milk production ranging between 4.3–80 percent.

Forage legumes and multi-purpose fodder tress 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. Most small-scale dairy farmers graze their

Box 3: Criteria for selection of interventions

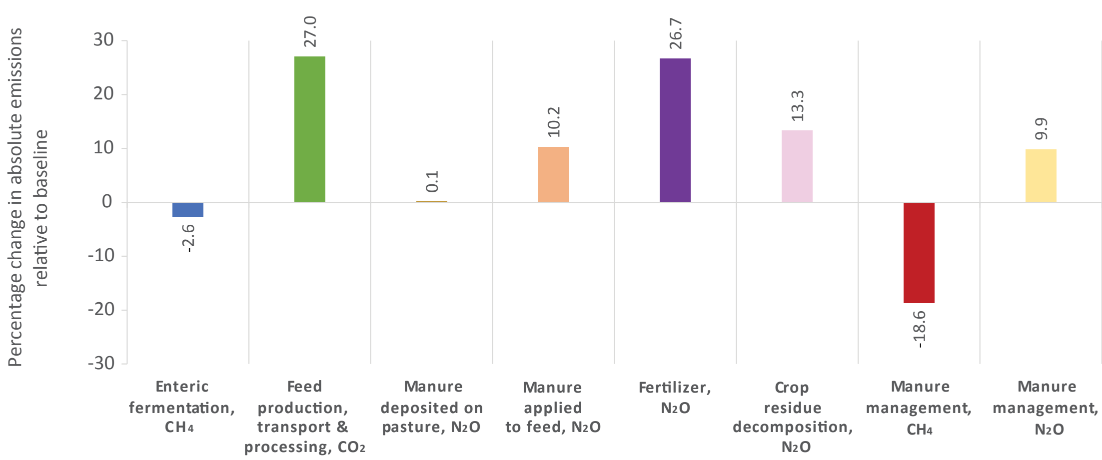
Three principal criteria were used to identify interventions for analysis in the study; the potential for improving production efficiency, technical feasibility of adoption by farmers and the potential to reduce enteric methane emission intensity.

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 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 impacts from the application of urea to diets with crop residues were evaluated for dairy cattle in semi-intensive systems. Reductions in enteric methane emissions was found to be marginal because feeding urea treated straw increased dry matter intake as a consequence of improved digestibility and palatability of the diet. The total daily methane emissions (g/day) increase with higher levels of milk production. This is logical since more feed is being consumed and processed in the rumen. Increased dry matter intake in-turn results in an increase in feed-related emissions. From an emission intensity perspective, these interventions however translate into a decrease in emission intensity resulting from increased milk production (see Figure 5.1). Some practice changes however can result in a decrease in both absolute enteric emissions and emissions intensity.

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: selection of interventions should be informed by location-specific determinants e.g. soil type, and potential to enhance other benefits, e.g. raising income of target population (poverty reduction), biodiversity conservation, and ecosystem services provision.

Impacts of feeding urea-treated crop residues on total emissions



Source: GLEAM, 2017

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

Intervention	Objective and constraint addressed	Mode of action
Fodder cultivation: establishment of fodder grasses and legumes	Minimize quantitative and qualitative deficiency of basal diet to address feed seasonality and quality constraints	Improvements in digestibility lead to increased DMI, energy availability, milk yields and decrease CH_4 emissions per unit of product.
Supplementation with leguminous fodder shrubs (Calliandra, Leucaena, etc.)	Minimize quantitative and qualitative deficiency of basal diet to address feed seasonality and quality constraints	Lower CH_4 observed with legumes is attributed to lower fiber content and faster rate of passage of feed through the rumen.
Supplementation of basal diets with high protein/energy concentrates	Supplementation of diet with good-quality concentrates helps overcome problem of palatability and digestibility	High-quality (more energy-dense or more digestible) diets provide more energy for production as a proportion of the gross energy intake (GEI) and dilutes the costs of maintenance than low-quality diets; therefore less CH4/FPCM is generated
Supplementation: Use of non-conventional feed resources e.g. sweet potato vines	Improve the quality of low basal diets and addresses feed availability during periods of scarcity	Promotes high dry matter intake and have a faster rate of passage through the rumen
Supplementation: Urea-treated crop residues	Improve 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.
Supplementation: Urea-molasses multi-nutrient blocks (UMMB)	Improve 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 utilization of the diet
Feed conservation (use of silage)	Improve the quality of low basal diets and addresses feed availability during periods of scarcity	Promotes high dry matter intake and have a faster rate of passage through the rumen
Vaccination against East Coast Fever	Improve health status of animals, increase productivity and reduce economic losses for farmers.	Enhanced animal productivity and reduced CH_4/FPCM
Deworming (Helminthes control)	Improve health status of the herd by addressing internal parasites that affect efficiency. Addresses high morbidity, low milk production and milk wastage in dairy systems	Maximizes feed energy use by eliminating internal parasites, enhanced animal productivity and reducing emission intensity
Use of Artificial insemination (AI)	Improve production and reproductive traits. It addresses low productivity of local indigenous cattle.	Poor fertility causes livestock producers to maintain more animals per unit of production and keep more replacement animals to maintain the herd. When fertility is improved by using AI, the productivity of animals is improved and emissions reduced.

animals on unimproved, natural grass. Napier grass which commonly forms the bulk of roughage for dairy cows, is generally low in crude protein, especially so during the dry season. Although crop residues may be added to Napier grass-based diets, they are not sufficient and balanced to support high levels of milk production. Commercial protein sources that could supplement these roughages are too costly for many smallholder dairy farmers to afford on a regular basis and in adequate quantities. Production and utilization of forage legumes is a low-cost method for improving both the quantity and quality of livestock feeds on smallholder farms. Legumes can also concurrently enhance soil fertility for companion fodder grasses and subsequent cereal crops thereby reducing the cost of livestock feed and crop production for resource poor farmers. Fodder trees are an ideal solution to supplement dairy animals with high quality feed especially during the dry season. Feeding lactating animals and heifers on fodder legumes (desmodium) and fodder-trees (calliandra) returned 18 percent and 8 percent reduction in enteric methane emissions, respectively.

Improving feed availability and quality will be a key strategy to realize the largest proportion of the desirable animal productivity levels. Feeding is the major constraint to achieving the targeted milk production because of heavy reliance on rainfed forage and pasture production. However during

the dry season, feed availability reduces and animals are forced to survive on scarce, low quality mature grass and crop residues. In addition, there is low adoption of alternative feeding strategies such as 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 constraint of seasonality of feed: 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. Crop residues can be used to bridge the feed gap however, 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, health of animals and increases the environmental impact. Treating crop residues with urea solution improves the nutritive value by increasing the digestibility, palatability and crude protein content. The intervention was applied in intensive systems where use of crop-residues is common. Feeding urea-treated crop residues in intensive and semi-intensive systems results in a reduction in methane emissions by 13.4 percent and 26 percent, respectively. 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 (sweet potato vine silage) results in similar reductions in the intensive and semi-intensive systems: 10.3 percent and 9.3 percent, respectively.

Strategic supplementation of critical nutrients stimulates intake of feed in ruminants and increases the efficiency of production in systems where animals rely are on low quality diets. Urea-molasses multi-nutrient blocks (UMMB) provide both energy and nitrogen to the microorganisms in the rumen and thus improve the digestion of crop residues such as straw. It provides a readily available source of energy, protein and minerals for the dairy animal. Supplementation with UMMB resulted in similar methane reductions of 10.8 percent and 10.7 percent in the semi-intensive and extensive dairy production systems, respectively.

Dairy farmers tend to compensate for some of the shortages by purchasing concentrate feeds, however evidence from a number of studies indicates that the large majority of farmers feed a low, flat rate of concentrates throughout lactation, typical quantities being 2 kg/day. This often results in under-nutrition in the early part of lactation and can have a negative effect on milk production later in lactation. The intervention evaluated was the feeding of 8 kg concentrates/day for the first 12 weeks of lactation rather than the general practice of feeding a flat rate of 2 kg/day. This intervention resulted in a reduction in enteric CH_4 by 6.5 percent, 12.3 percent and 10.6 percent in intensive, semi-intensive and extensive systems, respectively. And a corresponding increase in milk production by 4.3 percent, 12.4 percent and 10.2 percent.

It may be possible to combine some of the feeding and nutritional management approaches to reduce enteric CH_4/FPCM. Two combinations of feeding practices (combining use of non-conventional feed resources, feed conservation and feeding of high energy/protein and an additional one including the use of non-conventional feed resources and feed conservation) were evaluated. Both returned the highest impacts both in terms of CH_4 emission reductions and productivity impacts. The use of non-conventional feed resources, feed conservation and feeding of high energy/protein resulted in 20–45 percent reduction in methane emission intensity and 23–80 percent increase in milk production. Strategic supplementation with sweet potato vines and sorghum silage in intensive and semi-intensive systems reduces enteric methane emissions by 10–25 percent and results in milk production increases between 9–32 percent (Figure 5.1).

Tick-borne diseases constitute the largest component of all animal diseases that impact negatively on the dairy industry. East Coast Fever (ECF) is a disease of importance to dairy farmers in Kenya. Prevalence is high in areas with extensive free grazing pastures and in semi-intensive paddock grazing herds in lowland areas where risk reaches 30 percent per year and account for over half of all clinical cases. Risks in the highlands particularly in stall-fed dairies are less than 3 percent per annum[12]. The impact of tick-borne diseases is through high mortality rates. Decreasing mortality and morbidity rates has a significant effect on CH_4 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. Disease challenges also translate into metabolic changes such as reduced feed intake as well as increased requirements for maintenance energy that in turn increase GHG emissions. In Kenya, 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 in all production systems.

From various studies, the three main diseases that affect dairy in Kenya are, ECF, internal parasites and diarrhea[13]. In addition, high helminth burden has been shown to increase the risk of ECF death. Helminthes are internal parasites that consume nutrients meant for animals. They cause direct losses through mortalities especially in calves. Diarrhea in calves has been reported to be the most important cause of calf morbidity, reduced growth rate, and delayed age at first calving and cause of mortality. In older animals, this results in reduced reproductive efficiency, milk production and high economic losses through purchase of drugs and forgone profits.

Interventions to vaccinate against East Coast Fever result in 18.5 percent, 14.2 percent and 17 percent reductions in enteric CH_4 in extensive, intensive and semi-intensive systems, respectively. These impacts are achieved through decreased mortality rates, live-weight gain and increased milk yield. Deworming on the other hand resulted in reductions of 8 percent, 10 percent and 20 percent in intensive, semi-intensive and extensive dairy production systems, respectively.

The use of improved breeds with higher milk yield potential results in 12 percent, 16 percent and 7 percent reduction in emission intensity in intensive, semi-intensive and extensive livestock systems (Figure 5.1). The impacts on emission intensity are achieved through reductions in number of replacement breeding animals and male animals needed for reproduction, 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).

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

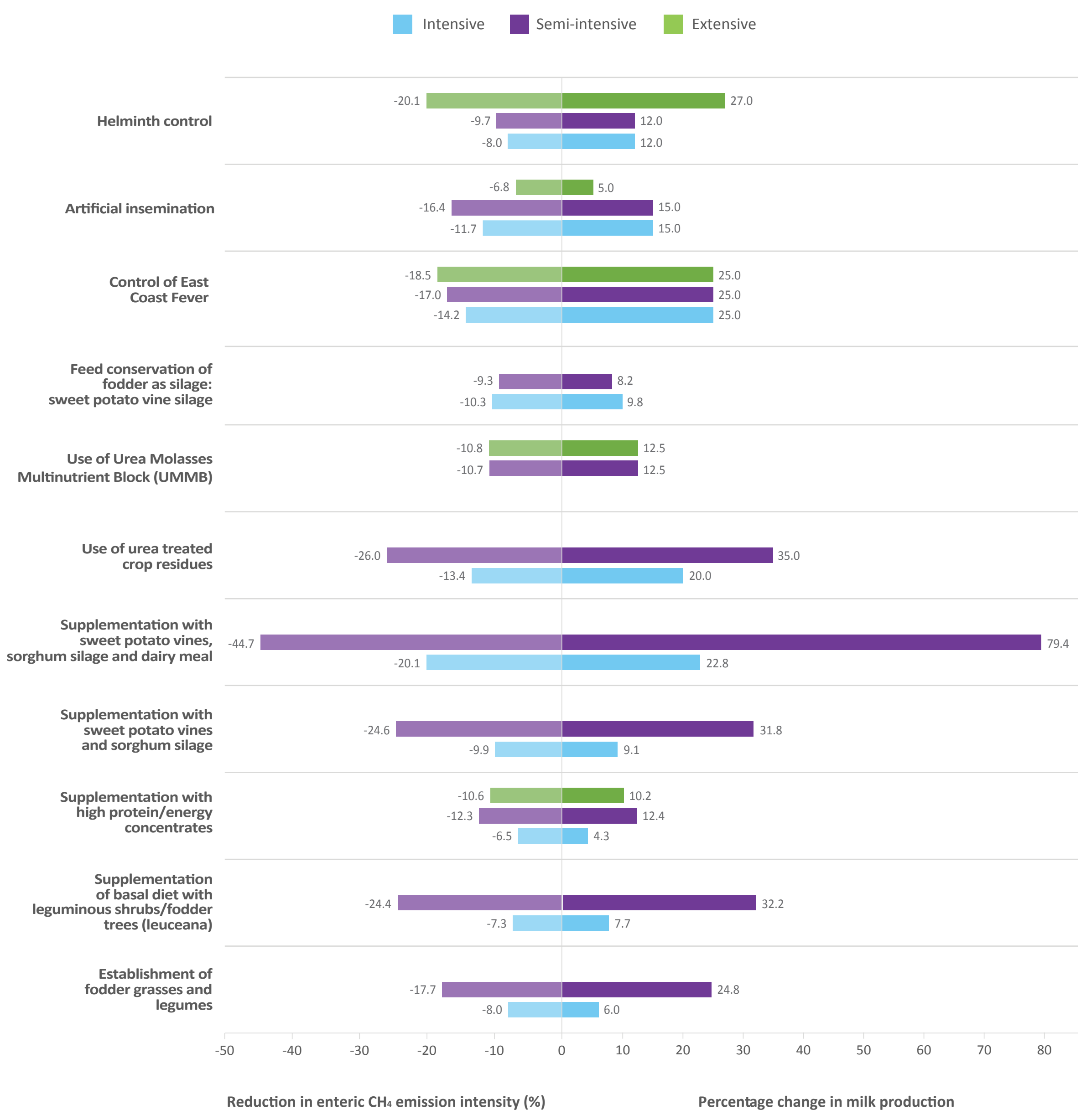
Significant reductions in emissions can be achieved through a combination of herd and health management, nutrition and feeding management strategies, and improved genetics. The reality is that farmers are likely to combine technologies and will select the combination of technologies that will maximize a number 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 (establishment of fodder grasses and legumes, use of conserved silage and UMMB); improved herd health (vaccination against East Coast Fever) and improved genetics (artificial insemination) can potentially result in a reduction potential of 21–36 percent in emission intensity relative to the baseline emission intensity. With these combinations of technologies, an increase in milk production of 31–35 percent can be achieved compared to the baseline (Figure 5.2).

[12] Government of Kenya: Kenyan Dairy Master Plan (http://kdb.co.ke/press/publications/reports/5-kenya-national-dairy-master-plan/file.html)

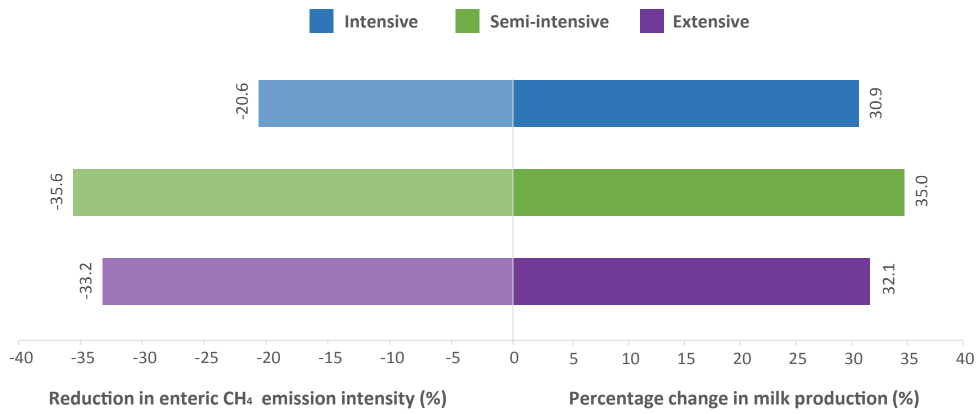
[13] Phiri, B. J., Benschop, J., & French, N. P. (2010). Systematic review of causes and factors associated with morbidity and mortality on smallholder dairy farms in Eastern and Southern Africa. Preventive veterinary medicine, 94(1), 1-8.; Njehu, A., Omore, A. O., Baltenweck, I., & Muriithi, B. (2011). Livestock disease challenges and gaps in delivery of animal health services. https://cgspace.cgiar.org/bitstream/handle/10568/3746/EADD_baselinebrief_4.pdf; Thumbi, S. M., de Clare Bronsvoort, B. M., Poole, E. J., Kiara, H., Toye, P. G., Mbole-Kariuki, M. N., ... & Steyl, J. C. (2014). Parasite co-infections and their impact on survival of indigenous cattle. PloS one, 9(2), e76324. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0076324

Figure 5.1: Impacts on Enteric CH_4 emission intensity reduction and milk production relative to baseline emissions



Source: GLEAM, 2017

Figure 5.2: Package of mitigation options (Establishment of fodder grasses and legumes, sweet potato vine silage, UMMB, control of East Coast Fever, UMMB and use of artificial insemination)



Source: GLEAM, 2017

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 production 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 4.

Box 4: 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 output within a year. 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 costs. In this study the, the BCR for mitigation options ranged from 1.1 to 5.8 (table below) indicating that benefits exceed economic costs for the different options under consideration.

Benefit-cost ratios of mitigation interventions

Intervention	Intensive	Semi-Intensive	Extensive
Establishment of fodder grasses and legumes	4.9	1.6	1.1
Supplementation with leguminous shrubs/fodder trees	5.2	1.8	**
Supplementation with high protein/energy concentrates	4.9	1.6	**
Supplementation with sweet potato vines and sorghum silage	5.2	1.8	1.2
Supplementation with sweet potato vines, sorghum silage and dairy meal	5.8	2.5	**
Feed conservation: sweet potato vine silage	5.0	1.5	**
Urea treated crop residues	5.6	1.9	1.4
Supplementation: Urea-molasses multi-nutrient blocks (UMMB)	**	1.6	**
Artificial Insemination	5.1	1.5	1.3
Helminth control (deworming)	5.1	1.5	1.2
Control of East Coast fever	5.8	1.7	**

Note: ** intervention not applied

Source: Authors, 2017

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 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. It does not signal potential since even practices ranked 'low' against all three criteria reduced enteric methane emissions, increased output and returned a net financial benefit. The outcomes of the prioritization process are shown in Table 6.1.

Comparison of individual interventions

With the exception of urea-treated crop residues (in semi-intensive systems) and the use of urea molasses multi-nutrient blocks (UMMB) in extensive systems that resulted in methane emission reductions of less than 10 percent, the remaining interventions assessed, in addition to decreasing enteric methane production, resulted in increased milk production and returned a positive benefit-cost ratio. 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 within each production system.

In intensive dairy systems, 6 interventions were included in the prioritization process. Of these 4 interventions had a low methane emission reductions but generally a high impact on milk production and farm profitability. While 2 interventions (use of conserved fodder and supplementation with sweet

Figure 6.1: Initial prioritization process of technical interventions

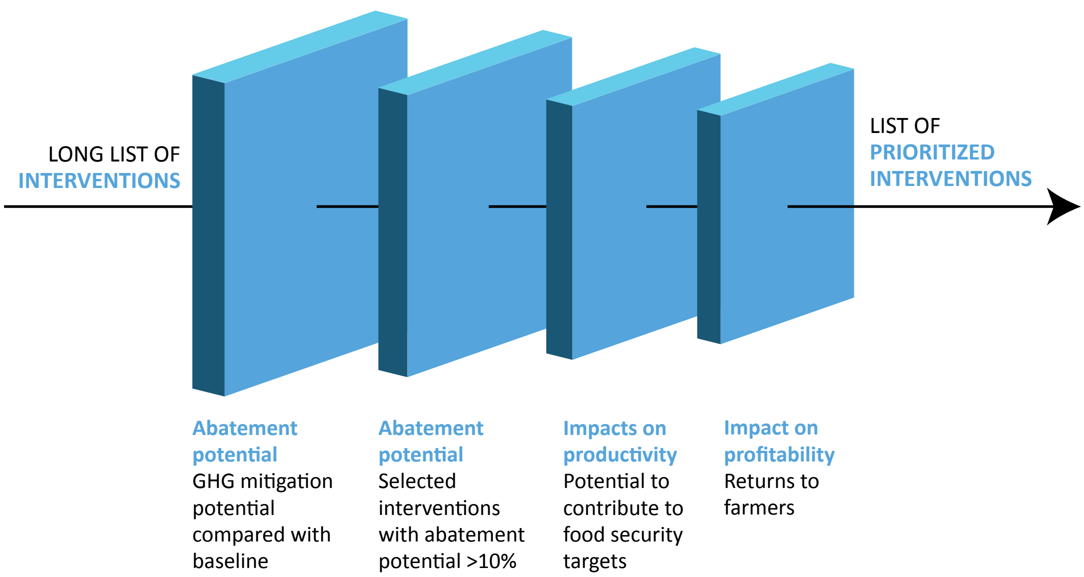


Table 6.1: Results from the prioritization of single interventions for dairy cattle production systems

Intervention	Establishment of fodder grasses and legumes	Supplementation with leguminous shrubs/ fodder trees	Supplementation with high protein/energy concentrates	Supplementation with sweet potato vines and sorghum silage	Supplementation with sweet potato vines, sorghum silage and dairy meal	Use of urea treated crop residue	Use of Urea Molasses Multinutrient Block (UMMB)	Feed conservation of fodder as silage	Control of East Coast Fever	Artificial Insemination	Helminth control
INTENSIVE DAIRY SYSTEMS											
Methane reduction	**	**	**	Low	Low	Low		Low	Low	Low	**
Production increase				Low	High	High		Low	High	Medium	
Economic				High	High	High		High	High	High	
SEMI-INTENSIVE DAIRY SYSTEMS											
Methane reduction	Low	Low	Low	Low	Medium	Medium	Low	**	Low	Low	Low
Production increase	High	High	Medium	High	High	High	Medium		High	Medium	Medium
Economic	Low	Low	Low	Low	Medium	Low	Low		Low	Low	Low
EXTENSIVE DAIRY SYSTEMS											
Methane reduction			Low				Low		Low	**	Low
Production increase			Medium				Medium		High		High
Economic			Low				Low		Low		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 · Medium: >10 <15 · High: >15
Economic benefit: Low: <2 · Medium: >2 <3 · High: >3

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

Common intervention 'package'	Methane reduction	Production increase	Economic benefit
Intensive dairy systems	Low	High	High
Semi-intensive dairy systems	Medium	High	Low
Extensive dairy systems	Medium	High	Low

Assessment criteria:

Methane mitigation: Low: >10 <25 · Medium: >25 <50 · High: >50
Production increase: Low: >10 · Medium: >10 <15 · High: >15
Economic benefit: Low: <2 · Medium: >2 <3 · High: >3

potato vine and sorghum silage) had low impacts on both methane and milk production and a high impact on financial returns to farmers (Table 6.1).

Within the intensive dairy production system, it is striking that all 6 interventions give considerably higher financial returns to farmers even in situations where the increase in milk production was considered low (between >10 percent <25 percent).

In the semi-intensive systems, combining feeding strategies returned the highest impacts on all three criteria (high for the supplementation with sweet potatoes vines and sorghum silage and moderate with the supplementation with non-conventional feed, conserved feed and high protein/energy feed). These combinations were designed to address two main nutritional constraints faced in milk production including feed seasonality and poor feed quality. The high impact achieved from combining options reinforces the benefits of combining interventions. With the exception of combined feeding strategy, the rest of the single feed interventions were ranked low on profitability criteria.

Five interventions were considered for extensive dairy systems and of these four, the control of East Coast Fever, helminth control, supplementation with UMMB, and supplementation with concentrates had had a more than 10 percent impact on methane emissions. These four interventions however scored low against two of the three criteria.

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 nutritional status of the dairy herd, are shown in Table 6.2.

There is a clear benefit from introducing a package of interventions. In the intensive, methane reductions are low while impacts on milk production and economic returns to farmers are ranked high

In extensive and semi-intensive systems, enteric methane reductions were moderate while milk production was ranked high. For both systems however, the package of interventions has low benefits with regard to profitability.

CHAPTER 7

Un-locking the potential of 'no regrets' opportunities

Smallholder dairy systems will continue to be a dominant agricultural production system in Kenya. Dairy farming is part and parcel of many such systems, and is an important livelihood option to increase household income of dairy farmers in Kenya. This study reveals that pathways for enhancing productivity and achieving emission reductions exist in all the three systems however the greatest opportunities for immediate mitigation and productivity increases at scale lie in the semi-intensive and intensive dairy systems.

The results presented in the preceding sections indicate that there are significant opportunities for growth on a low emissions path for the dairy sector and that economically viable opportunities exist within all production systems. 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.

Increasing individual animal productivity as a consequence of better feeding practices, improved 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 animals for other functions such as traction, nutrient value of manure and risk management. Particularly in the extensive 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 smallholder 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 that 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 household expenditures will decline. This is because functioning markets provide signals for investment decisions as well as opportunities for long term planning.

Increases in milk productivity can result in benefits not only at farm-level (income, food security and nutrition) but also across the dairy value chain. These productivity improvements are also likely to spur development across the dairy value chain.

Beyond the production constraints, the Kenyan dairy sector is characterized by a number of systemic barriers, including, poor infrastructure, limited incentive for farmers to enter formal market value chain, etc.

The market challenges include unstable milk supply with cycles of abundance and scarcity, high cost of milk processing, poor milk quality and safety, etc . Despite these challenges, the growth in demand for high quality milk and diverse dairy products in both the domestic and regional markets, are opening investment opportunities. Medium and large-scale farms and entrepreneurial smallholders can benefit from delivering milk to expanding diverse, well-structured and trusted formal markets. Other market opportunities are offered by a growing demand for equipment for milk handling, bulking, chilling, processing and dispensing by various enterprises. The Government of Kenya and many county governments are investing in local milk-chilling and -processing equipment to drive growth of the dairy market.

- ***Introducing better animal feeding practices to small-holder farmers will help stabilize shifts in milk production volume.*** The yield per cow and by

extension the amount of milk produced in Kenya fluctuates greatly during the year. This has a great effect on the processors' ability to absorb all the milk produced at any time during the year, with a period of surplus followed shortly by that of low milk volumes. Improvements in milk supply will address constraint of milk fluctuations; currently, milk fluctuates between dry and rainy seasons, resulting in capacity utilization of only 40–50 percent. considerable seasonal variations in milk production between Kenya's rainy and dry seasons causes market disruption and swings in producer prices that deter planning and investment. Farmers can mitigate these effects through the use of drought-resistant crops and feed preparation and storage methods such as silage as described in previous chapters

- ***Poor infrastructure:*** Poor farm-to-market roads in many rural locations greatly increase the cost of milk delivery, the time milk remains unrefrigerated, and its quality. Infrastructural development needs to be considered so as to improve market access. Generally, milk producing areas tend to have poor infrastructure in terms of roads, electricity especially during the rainy season. The infrastructure challenge extends to the lack of milk handling and storage facilities at the farm level, leading to milk spoilage and milk loss at the farm. Poor infrastructure reduces producer's margin as it results in high market transaction costs. On the processing side, infrastructural challenges remain, with limited capacities of dairies to convert excess milk into long life products and limited storage at the dairies.
- ***Limited incentive for farmers to enter the formal market value-chain.*** There is little incentive for most smallholders to supply the formal market as opposed to the informal market. About 70 percent of the milk is marketed through traders, cooperatives, hotels and kiosks. The factors driving the continued importance of the informal market are traditional preferences for fresh raw milk, which is boiled before consumption, and unwillingness to pay the costs of processing and packaging. By avoiding pasteurizing and packaging costs, raw milk markets offer both higher prices to producers and lower prices to consumers[14]. An estimated 84 percent of the milk produced is sold in raw form to consumers, providing instant cash or higher prices to the farmer. This compromises product quality while offering direct competition to the dairy processing industry. Capacity utilization of processing plants remains low (between 40–50 percent) as a result of seasonality and competition with informal market.

The informal market channels are difficult to regulate therefore limiting potential for transforming the dairy sector into a highly commercialized industry. The Kenya Dairy Board recognizes the informal market as a major player in the industry and this is a step towards helping improve its functioning through gradual regulation.

Addressing these issues requires innovations and investments by dairy value chain actors and input and service providers, if this potential is to be unlocked. Development of the entire milk value chain will be important if dairy producers and supply chain actors are to benefit from increased productivity.

[14] Meridian Institute, Dairy Value Chains. https://www.merid.org/~/media/Files/Projects/Value%20Chains%20Microsite/Dairy_Value_Chain_Overview.pdf

CHAPTER 8

Key messages and policy conclusions

This chapter sets out to present key highlights and messages from the analyses. It is not the intention of the chapter to repeat the detailed analysis of previous chapters but rather to draw out some key overarching messages and policy conclusions, both from the perspective of the results process and what is actually required to implement on the ground.

1. The potential for low-cost abatement is sizable

This study helps illustrate how, the dairy sector in Kenya could make substantial reductions in emissions with interventions and investments that in many cases will pay for themselves. The analysis on the dairy sector demonstrates how milk productivity can grow significantly (between 30 percent and 35 percent) while reducing emissions by 20 percent and 36 percent.

More importantly, from the study, low emissions development of the dairy sector can support a range of other national policy goals, including achieving food and nutrition security, economic growth and development, improved livelihoods, and environmental protection. It is this combination of reasons that explains the strong interest of Kenya in low emissions growth and justifies investment in the sector.

However, 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.

2. Kenya is already acting

This study has contributed towards an ongoing nationally-led process of identifying opportunities for green growth as outlined in its National Climate Change Action Plan and Vision 2030. The results and findings of the Kenyan low emission study have directly fed into the design of national policy mitigation action for the dairy sector. Results were used as a reference during the preparation of Kenya's Nationally Appropriate Mitigation Action (NAMA) on dairy (Box 5). The aim of this NAMA is to stimulate dairy development by enhancing dairy efficiency and optimizing energy use along the value chain to reduce GHG emissions. The activities foreseen under the NAMA include assistance and incentives to the private-sector to invest in low-emission, gender-inclusive dairy advisory services aimed at facilitating on-farm adoption of improved production practices and technologies; enabling investments in energy efficiency and renewable energy technologies in milk collection, chilling and processing; and supporting adoption of household biogas technology. The dairy NAMA will reach 227,000 dairy producing households across the country and is expected to yield an additional 6.6 billion litres of milk per annum, reaching over 30 million consumers. Over the 10-year implementation period, the expected total emission reductions from the implementation the NAMA are 8.8 million tonnes CO_2 eq.

3. Many interventions will pay for themselves but barriers need to be addressed

A significant percentage of the emissions savings come at negative cost, meaning they will actually contribute not only reduce GHG emissions, but also save money in the long-term. Figure 8.1 shows that all of the total potential for emissions reduction have positive net benefits (or "negative costs").

All interventions assessed are cost-beneficial (i.e. measure that not only reduce GHG emissions but also save money in the long term) accounting for an abatement potential of 15.9 million tonnes CO_2 eq.

This doesn't imply that this potential will be realized in the absence of incentives.

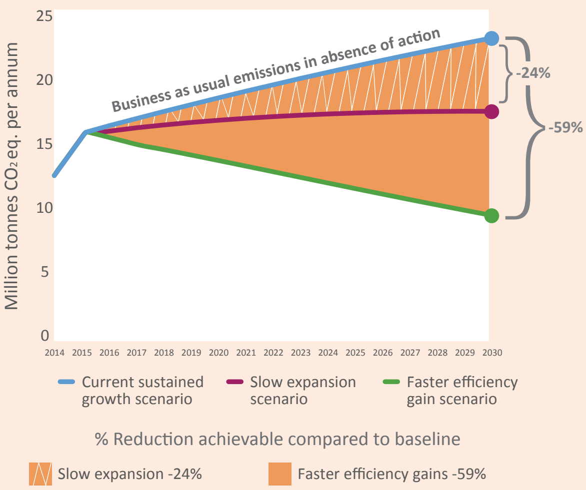
Box 5: Supporting the design of national mitigation policy action for the Kenyan dairy sector

The contribution of the dairy NAMA project to emission reductions at national scale was explored through scenario analysis using the mitigation potential of this study. The analysis uses Kenya's national greenhouse gas inventory and commitments (INDC), and Kenya's Dairy Master Plan (DMP), in which per capita milk demand is forecast to expand from the current levels of 110 kg per person to 220 kg per person in 2030. This target provides the starting point for estimating future emissions and emission reduction potential of the sector. Three scenarios were constructed:

- The *current sustained growth scenario* (i.e. business as usual (BAU), scenario) assumes the absence of specific targeted actions to increase milk productivity. Increase in milk yield per cow from the current national average of 1800 kg per cow is expected to continue to grow at historical rates at 3 percent per annum to 2030 with the dairy cattle herd accounting for 80 percent of the milk produced domestically.
- The *slow expansion scenario* uses the animal productivity targets defined in the DMP, which assumes that in order to meet the 220 kg per capita milk consumption in 2030, dairy cattle milk productivity will have to reach 4500 kg per cow, which implies strategic interventions to improve animal productivity. This scenario recognizes that while growth is realistic, a number of constraints such as land, feed, markets, or policies will limit the achievement of 4500 kg. As such, it is assumed that milk yield in this scenario reaches 4000 kg per cow by 2030, implying annual average growth rates in per cow milk yield of 5 percent.
- The *faster efficiency gains scenario* builds on the slow expansion scenario but assumes faster and greater increases in animal performance. It is assumed that 4500 kg per cow milk yield is achieved earlier in 2025 due to accelerated intervention in the sector, implying annual average growth rates in milk yield of 10 percent.

To derive the total milk demand to 2030, the projected human population[15] was multiplied by the per capita demand for dairy products. This total was then multiplied by a factor of 0.8 to account for the fact that 80 percent of the total domestic milk is produced by the cattle dairy sector. Based on this, total domestic milk demand from dairy cattle sector is expected to increase 3.4 fold, from 3.4 to 11.5 billion litres. Using the average annual milk yield and the total milk demand per year, the total national milking herd required to produce 11.5 billion litres of milk was estimated. Assuming BAU yields per cow, to produce 11.5 billion litres in 2030 will require a national population of 4.1 million lactating cows, which implies an increase in the total dairy cattle herd from the current 4.3 million to almost 7.5 million head in 2030. Emission intensities, absolute emissions and the reduction potential associated with the three scenarios are derived using the Gold Standard Methodology for the Quantification of GHG emission reductions from improved management of smallholder dairy production systems using a standardized baseline[16].

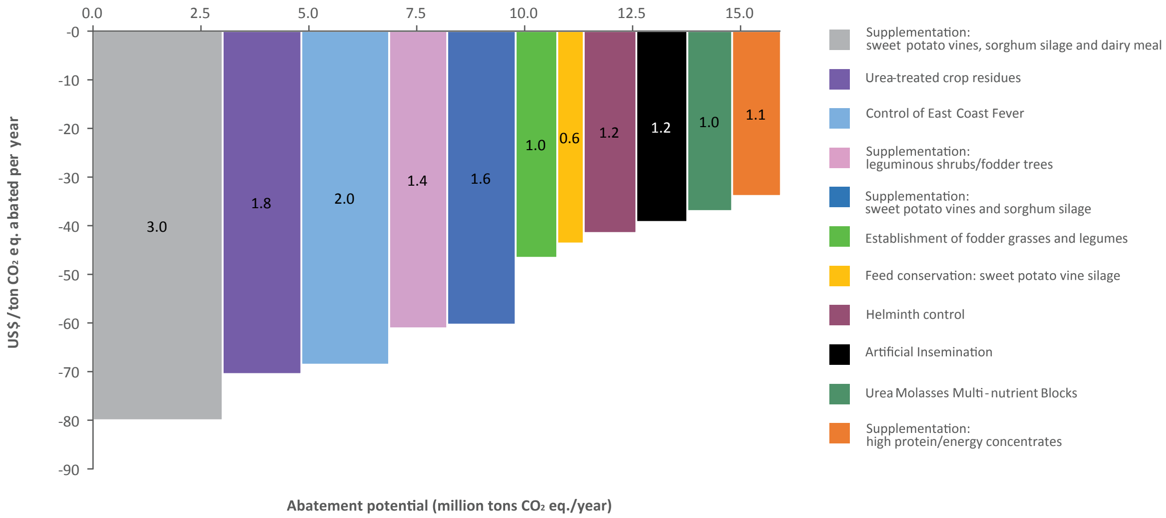
Historical and projected trends in emissions for the Kenyan dairy sector



The figure summarizes the main findings from this assessment. In the BAU scenario, emissions are expected to grow to grow to more than 22 million tCO_2 eq. per year in 2030. Compared to the BAU scenario, absolute GHG emissions (and emission intensities) are projected to decline in both scenarios, reflecting the continued improvements to production efficiency achieved via improved animal productivity. Compared to the BAU scenario, the percentage reduction achievable in 2030 are in the range of -24 percent and -59%.[17] This reduction represents between 13–31 percent of the Kenya's NDC mitigation target of 43 million tonnes CO_2 eq. in 2030.

[15] UN DESA (2015). World Population Prospects 2015 Revision. https://esa.un.org/unpd/wpp/
[16] http://www.fao.org/3/a-i6260e.pdf
[17] These reductions represent the maximum technical mitigation potential achievable if interventions are applied to the entire dairy sector.

Figure 8.1: Abatement cost curve for Kenyan dairy sector



Source: Authors, based on study results

However, it is clear that even win-win interventions still face barriers that require holistic policy action. The reasons for low adoption lie in the numerous barriers that that prevent the uptake of these opportunities. Technology alone is insufficient to achieve the multiple objectives that have been charted out for the Kenyan dairy sector. Polices and incentives are required to minimize risks faced by various stakeholders and attract investment capital to the sector.

4. Action to address methane must continue to support food security goals, economic growth and other sustainable development goals

Over time, the need to integrate climate change policies into national sustainable development strategies has become more evident as these policies can only be effective when embedded within broader strategies designed to make national development paths more sustainable. There is general agreement is that policies pursuing climate change and sustainable development can be mutually reinforcing.

In Kenya, the numbers of smallholders engaged in dairy production is so large that any climate change strategy targeted at the sector needs to prioritize food security and livelihoods. There are about 2 million farmer households in Kenya – about 35 percent of the rural population are engaged in dairy production and women play an important role in milk production. About 70 percent of the milk is produced on smallholder farms, milk not only contributes to household nutrition but the milk sales also contribute significantly to farmers' incomes. Action to reduce enteric methane is thus important as it provides countries, especially the poorest and most vulnerable, a critical opportunity to adapt to the challenges of a changing climate. At the same time, reducing enteric methane can reap food and nutritional benefits including other development benefits (Box 6). This will provide incentive to countries to act responsibly in global climate mitigation, while simultaneously ensuring continued domestic growth.

Several of the negative and low-cost abatement opportunities are of importance to Kenya's stated intent to take a leading global position as a center of 'green' technology, goods and services. Some of Kenya's priorities as outlined in the Dairy Master Plan, such as improving feed availability and quality, disease prevention and control, improved genetics are confirmed by this analysis as having the potential to deliver notable contributions to GHG abatement by 2030.

Box 6: Reducing enteric methane for development and climate goals simultaneously

The exclusive focus on methane in the climate debate is short-sighted, if the analysis is confined only to emissions. The opportunity to mitigate methane is only one reason to reduce emissions; reducing emissions of methane can provide significant development benefits, including improved productivity, food security and livelihoods. This study confirms the often cited multiple synergies that can be achieved by combining measures that address enteric methane with efforts to improve food and nutrition security. The strong correlation between productivity increases and methane mitigation implies large opportunities for low-cost mitigation, and widespread social and economic benefits. The additional benefits and positive economic returns that can be generated by closely aligning emission intensity reductions with productivity gains result in lower abatement costs for producers. Methane production through enteric fermentation is not only of global concern for its contribution to global warming, but also for its wastage of feed energy, an inefficiency that limits the production performance of ruminants. As a result of this process, ruminants lose between 2–12 percent of the gross dietary energy in the form of methane, depending on the quality and quantity of diet. Thus, it is essential to look for options to reduce CH_4 emissions through improving feed conversion efficiency, which also translates into higher productivity and improved food security. Increasing productivity of dairy systems has the potential to benefit millions of poor livestock keepers manifested through higher incomes, improved food security and nutrition wellbeing.

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