Food and Agriculture Organization of the United Nations

OPTIONS FOR LOW-EMISSION DEVELOPMENT IN THE TANZANIA 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 Tanzania. The overall objective of this study is to support Tanzania in identifying low-cost strategies to reduce enteric methane emissions while contributing to the country' short- to long-term social and economic development and increasing resilience to climate change.

Benefits of moving towards a climate-resilient dairy sector

Tanzania has taken steps to chart a path towards tackling climate change and achieving sustainable development. The Government of Tanzania has developed a number of high level policy initiatives, including the Tanzania Vision 2025[1] and more recently the National Climate Change Strategy[2] which are the overarching policy documents setting out development and climate change objectives. The Tanzania Vision 2025 is the national long-term development policy that aims to transform Tanzania into a middle-income country providing a high quality of life to all its citizens by 2025 in a clean and secure environment. The National Climate Change Strategy seeks to enable Tanzania to effectively adapt to climate change and participate in global efforts to mitigate climate change with a view to achieve sustainable development in line with the national development plan by the Tanzania Vision 2025, and national sectoral policies.

Despite ongoing transformation of the Tanzania's economy, agriculture remains a crucial sector supporting the livelihoods of more than 70 percent of the population. Within the agriculture sector, dairy farming is one of the most important economic sectors in Tanzania and is critical to rural incomes, employment, nutrition and food security, and resilience of more than 2.3 million dairy cattle holdings. Considering the economic importance of dairy farming to contribute to short- to long-term social and economic development, as well as the impact of the sector on climate change and the environment, Tanzania has identified the dairy sector as a priority and has set policies targeting to develop the sector through a sustainable path.

The Tanzanian Livestock Master Plan (TLMP)[3] projects to increase total milk production by 77 percent and increase the contribution of the dairy sector to gross national product by 75 percent by 2021/2022. 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.

Adopting a low-carbon and climate resilient growth pathway for the dairy sector could benefit Tanzania in several ways:

- The dairy industry is the most important livestock sub-sector, contributing to 30 percent of agricultural Gross Domestic Product. The dairy sector currently provides income and employment to about 2.3 million farmers and livestock keepers. Milk production in Tanzania is predominantly managed by traditional farmers representing 97 percent of the national dairy herd, and producing

[1] National Vision 2025 (http://www.mof.go.tz/mofdocs/overarch/vision2025.htm)
[2] National Climate Change Strategy. 2012. Republic of Tanzania.
[3] Michael, S., Mbwambo, N., Mruttu, H., Dotto, M., Ndomba, C., da Silva, M., Makusaro, F., Nandonde, S., Crispin, J., Shapiro, B., Desta, S., Nigussie, K., Negassa, A. and Gebru, G. 2018. Tanzania Livestock Master Plan. Nairobi, Kenya: International Livestock Research Institute (ILRI).

70 percent of the milk in the country. Amongst these dairy farmers are some of the poorest and most marginalized such as women. 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 especially considering the importance of the dairy sector to rural livelihoods and its potential role in poverty reduction.

- Milk is one of the most nutritionally complete foods; it is rich in high quality protein providing all ten essential amino acids and is an excellent source of calcium and vitamin B2, vitamin A, and a fair source of vitamin D. Current per capita consumption of milk and milk products in Tanzania is on average 40 litres of milk per year - very low compared with the World Health Organization's recommendation of 200 litres per year.
- Dairying represents one of the fastest returns for dairy farmers in the developing world. It provides milk for home consumption, regular cash flow from milk sales to farmers, especially to women, enhances household nutrition and food security and creates off-farm employment. In Tanzania, dairy animals are one of the most valuable assets for rural households playing many functions such as traction, nutrient value and risk management.
- The dairy industry has been earmarked as the priority area for investment and development in the livestock sector. The main set policy target is to increase milk production by 77 percent by 2022, leading to 1,002 million litres of milk surplus over the projected domestic milk demand. This milk surplus could reduce the country's dependence on imported milk products and being used domestically for new and additional industrial uses, or being exported as milk powder or UHT milk to raise foreign exchange earnings.
- The current productivity of dairy animals in general is low and highly influenced by seasonality. For example, on average, milk yields range from 0.6 to 0.8 litres per cow per day in the traditional systems during the dry and wet season, respectively, and from 6.5 to 12.3 litres per cow per day in improved systems during the dry and wet season, respectively. Milk yields are low and largely variable mainly because of poor and limited feed availability, disease and poor management.
- Given the dependence of the country on agriculture and natural resources, Tanzania is also highly vulnerable to climate change ranking as the 24th most vulnerable country in the world[4]. Tanzania agriculture has faced the effects of extreme weather events and impacts of a changing climate, including: flooding, droughts, widespread crop failures, livestock deaths and intensification of climate sensitive diseases[5].
- The impacts of climate change have also influenced the country' social stability. Limited pasture and water availability coupled with land tenure issues have incited tension and land based conflicts between pastoralists and farmers.

Future climate change will continue to impact the agricultural sector in general, but will be especially acute for Tanzania's smallholder farmers and pastoralists. Thus developing adaptation solutions are needed to reduce its vulnerability.

Emissions and emission intensities from the dairy production

The dairy cattle sector produces about 1.4 million tonnes of milk; of this 70 percent of the milk is from the traditional systems, while 30 percent is produced by improved systems.

Milk production from the dairy cattle sector in Tanzania emits about 28.8 million tonnes CO_2 eq. Within this, enteric methane represents about 91.4 percent of the total GHG emissions from dairy production, equivalent to 8.2 million tonnes CO_2 eq. Emissions associated with the management of stored manure (CH_4 and N_2O) contributes an additional 2.3 million tonnes CO_2 eq., 8.2 percent of the total GHG emissions from the dairy cattle sector. Traditional dairy systems are responsible for the bulk of the emissions; 97 percent of the total GHG emissions associated with the dairy sector. On the other hand, improved systems contribute 3 percent to the total GHG emissions.

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

[5] Shemsanga, C., Omambia, A.N., Gu, Y. 2010. The Cost of Climate Change in Tanzania: Impacts and Adaptations. Journal of American Science, 6(3):182-196.

At national level, the emission intensity of milk produced in Tanzania is on average 19.9 kg CO_2 eq./kg FPCM. Average emissions ranged from 20.3 to 28.8 kg CO_2 eq./kg FPCM for traditional systems, while in improved systems they ranged from 1.9 to 2.2 kg CO_2 eq./kg FPCM. In both systems, emissions intensity were lowest in temperate highlands and highest in the semi-arid zones.

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 methane 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 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 (Box 1).

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

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

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

A team of national experts identified key areas to address low productivity in dairy systems including: (i) improving the quality and availability of feed resources; (ii) strategic feeding and supplementation to address the feed seasonality constraints; and (iii) improved herd management and animal health interventions. Within this broad categorization, 6 single interventions and 1 'package' consisting of combination of single interventions were assessed in this study.

Mitigation of enteric methane results in 4 to 56 percent increase in milk production

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 scope to reduce emission intensities; methane emission intensity (kg CO_2 eq./kg FPCM) can be reduced by 2 percent to 35 percent, the magnitude of impact will varies depending on the intervention and production system assessed. All interventions returned a positive productivity outcome with increases in milk production ranging between 4 percent and 56 percent.

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

Applying 'packages', i.e. combinations of interventions, aimed at improving feed availability and quality (establishment of fodder gardens, and maximizing use of crop residues), improving herd health (vaccination against East Coast Fever) and improved genetics (superior bulls in traditional systems and artificial insemination in improved systems) can result in a reduction potential of 27 to 67 percent in methane emission intensity. With these combinations of technologies, an increase in milk production of 29 to 59 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.

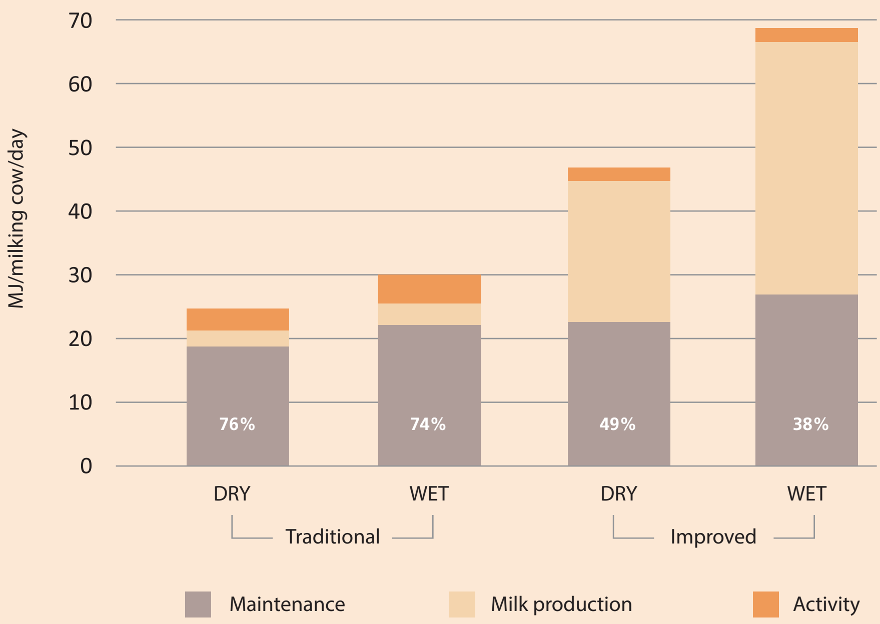
Box 1: Productive efficiency and dilution of the maintenance requirements

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

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

As shown in the Figure below, the average maintenance energy requirement for milking cows in traditional and improved systems during the dry and wet season, is 19.0, 22.0, 22.4 and 26.1 MJ per day, respectively. Assuming milk composition remains constant, the nutrient requirement per unit of milk production also does not change, but the total energy cost for lactation increases as a function of milk production. It can therefore be thought of as a 'variable cost' of dairy production. A dairy cow in the improved system during the dry season requires more nutrients per day than a low producing dairy cow; the cow with a daily milk output of 6.5 kg per day is using 49 percent of consumed energy for maintenance whereas a cow in the traditional system during the dry season (0.6 kg per day) is using 76 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 6.5 kg milk per day in the improved system during the dry requires 7.1 MJ/kg milk, whereas a cow yielding 0.6 kg per day in traditional dairy systems in the same period of the year needs 44.7 MJ/kg milk.

Energy requirement for milking cows in dairy systems in Tanzania



Source: GLEAM, 2018

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

Reduction of enteric methane emissions is profitable for farmers

A key incentive to farmers for adoption of new technologies and practices 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 analysis considered the characteristic of the dairy value chain and each production system, but did not include livestock products and co-benefits that cannot be quantified in monetary terms. 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 0.2 to 0.73 in traditional systems and from 2.4 to 2.9 in improved systems. It is important to highlight, that in the particular case of traditional systems, the BCR was less than 1 also for the baseline scenario. These data indicate that in traditional systems the application of mitigation options do not bring direct economic benefits, however these systems provide farmers with other benefits that have not been considered in the conventional benefit-cost ration.

Prioritization of interventions for reducing enteric methane

A preliminary ranking of interventions per production systems to identify interventions with high mitigation potential, increased production and high economic return was undertaken to provide an indication of what is workable. Putting the mitigation potential, productivity increase and returns to farmers allows for a first-order prioritization of interventions. Out of the 6 interventions assessed, four (legume intercropping, establishment of intensive fodder gardens, improving dairy breeds and East Coast Fever control) were considered relevant for improved systems. The same interventions are also relevant in terms of productivity and emission reduction potential for traditional systems, but all interventions, as well as in the baseline scenario, presented a benefit-to-cost ratio of less than 1. These results can be explained by the low productivity level of traditional systems, household milk consumption, limited access to formal markets and overall socio-ecological purpose of this production system. Interventions excluded from the prioritization process intervention did not meet the threshold methane reduction target of more than 10 percent.

Improving dairy breeds in improved systems ranked high on the productivity criteria and moderate on the methane reduction and economic criteria. East Cost Fever control ranks low on the productivity and enteric methane mitigation criteria. The interventions (all related to feed) assessed presented similar benefits (ranging from low to moderate) in terms of methane reduction, milk yield increase and financial returns to farmers.

Mitigation options for traditional systems

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

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

CHAPTER 1

A climate resilient dairy sector for ensuring food security

In 1999, the Tanzanian government developed the "National Vision 2025" envisioning to change the country from a least developing to a middle income country where present generations would be able to derive benefits from the rational use of natural resources of the country, without compromising the needs of future generations. This plan envisioned to turn Tanzanian economy into a strong, competitive economy that would provide improved socio-economic opportunities, public sector performance and environmental management based on sustainable development principles.

Today, Tanzania remains strongly committed to sustainable development principles and climate change action. Tanzania has made an ambitious commitment to curb its greenhouse gas (GHG) emissions by 2030. In its Intended Nationally Determined Contribution (INDC) to the UNFCCC, Tanzania communicated its plans to cut emissions by 10 to 20 percent by 2030 relative to the business as usual (BAU) scenario (about 138 – 153 MtCO_2 eq.).

On one side, 70 percent of the Tanzanian population depends directly on land and natural resources for their livelihoods. On the other one, 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. Given the importance of the livestock sector, particularly the dairy sector, for generation and provision of rural incomes, employment, nutrition and food security, and resilience of more than 1.7 million households, as well as its impact on GHG emissions and use of natural resources, the Tanzanian government has proposed a Livestock Modernization Initiative and a Livestock Master Plan seeking to support the progressive and adaptive development of the livestock sector based on economic, social and environmentally sustainability principles.

The Tanzania Livestock Modernization Initiative (TLMI)[6] intends to increase food and nutrition security and food safety, create employment opportunities and contribute to the national economy, social stability and preserve the environment. The initiative is composed of 13 key strategic areas and has as an overall objective to promote technological transfer, deliver livestock inputs and services, implement policies and regulations, improve market and marketing systems and empower livestock farming communities and the private sector.

The Tanzanian Livestock Master Plan (TLMP) projects to increase total milk production by 77 percent and increase the contribution of the dairy sector to gross national product by 75 percent during the 2017–2022 period through the increase in the number of crossbred dairy cows by 281 percent and cow milk yield by 42 percent. The TLMP seeks to transform the dairy cattle sector enabling the transition of traditional farming systems into market-oriented improved family farms. The government expects to invest US$ 101 million in feed improvements, veterinary services, diseases control and genetic improvement, as well as in the development of strategies to strengthen marketing and processing capacity of the dairy sector.

The adoption of improved technologies and practices provides opportunities for sustainable intensification consistent with food security and development goals, climate change adaptation and mitigation needs, thus enhancing development with considerations of environmental, social, and economic issues.

This report presents the findings and recommendations from an initial assessment of the dairy cattle

[6] Tanzania Livestock Modernization Initiative, 2015 (http://livestocklivelihoodsandhealth.org/wp-content/uploads/2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf).

sector of Tanzania. It is undertaken in collaboration with the Ministry of Agriculture and Food Security, Tanzania and the Tanzania Dairy Board 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 (CH_4) 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 emissions can potentially be reduced. This analysis is meant to inform where emissions reductions can be made and to systematically explore mitigation 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 Tanzania can implement in the short-to-medium term geared towards improving productivity in dairy cattle production systems, reducing enteric methane emissions and fostering economic development.

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

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

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

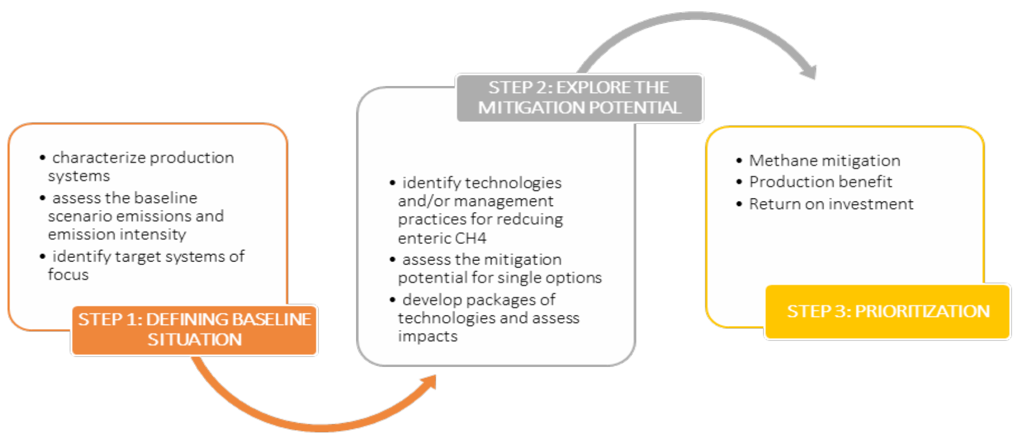
3) Prioritization of interventions. Prioritization of interventions is undertaken by drawing on modeling results (of emission intensity reductions and productivity impacts), and a cost-benefit analysis. It assesses productivity impacts, the potential profitability for farmers in adopting implementing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

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

The analysis focuses on the dairy cattle sector, a strategic sector in Tanzania 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, the cultural and social value of cattle for pastoralists and livestock keepers, as well as the increasing demand for dairy products in urban and peri-urban areas, are the criteria that have supported this choice.

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

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



Box 2: Absolute emissions versus emission intensity

The primary determinants of enteric methane emissions are feed intake, and fermentation characteristics of that feed in the rumen. In general, management practices that increase the proportion of the energy in the feed that is directed to produce milk or gain weight rather than to maintain the animal, reduce the amount of methane per unit of animal product produced (emissions intensity). Higher individual animal productivity generates more animal product and more methane per animal but as a smaller proportion of the feed consumed is used to maintain the animal emissions intensity is reduced.

The same amount of animal product can be produced with fewer methane emissions if producers keep fewer animals. More intensive production provides flexibility to control emissions and generally improves profitability. However, increasing feed intake per animal will always lead to an increase in total farm methane production unless the total number of animals is reduced.

In low and medium-income countries, the concept of emission intensity remains the most attractive mitigation route because it allows for the harnessing of synergies between food security and development objectives and climate change mitigation goal. Emissions intensity reductions will reduce absolute emissions below the business-as-usual.

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[7] (GLEAM) to provide a broad perspective of opportunities and attainable goals in terms of productivity gains and emission intensity reduction in the dairy sector (Box 3). The scenario analysis uses the outputs of the biophysical analysis combined with information taken from published literature, existing studies and expert knowledge on potential impacts of each intervention on herd performance and production to quantify the emission intensity reduction potential.

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

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

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

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

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, production, and feed inputs (including the relative contribution of feed types–forages, crop residues, and concentrates–to animal diets) for each livestock species, country, and production system. The production parameters and data in GLEAM have been drawn from an exhaustive review of the literature and validated through consultation with experts during several joint projects and workshops. The relationships between GHG emissions and production have also been cross validated for ruminants across a range of regions and studies, and published reports on GLEAM have also been through rigorous peer review (Opio *et al*., 2013; Gerber *et al*., 2013). GLEAM works at a resolution level of 1 km^2, the spatially explicit GLEAM model framework allows the incorporation of heterogeneity in emissions, emission reductions and production responses.

The model was further developed to meet the needs of this study. The dairy production systems in GLEAM were further refined to reflect the specificities of the dairy cattle production systems in Tanzania 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.

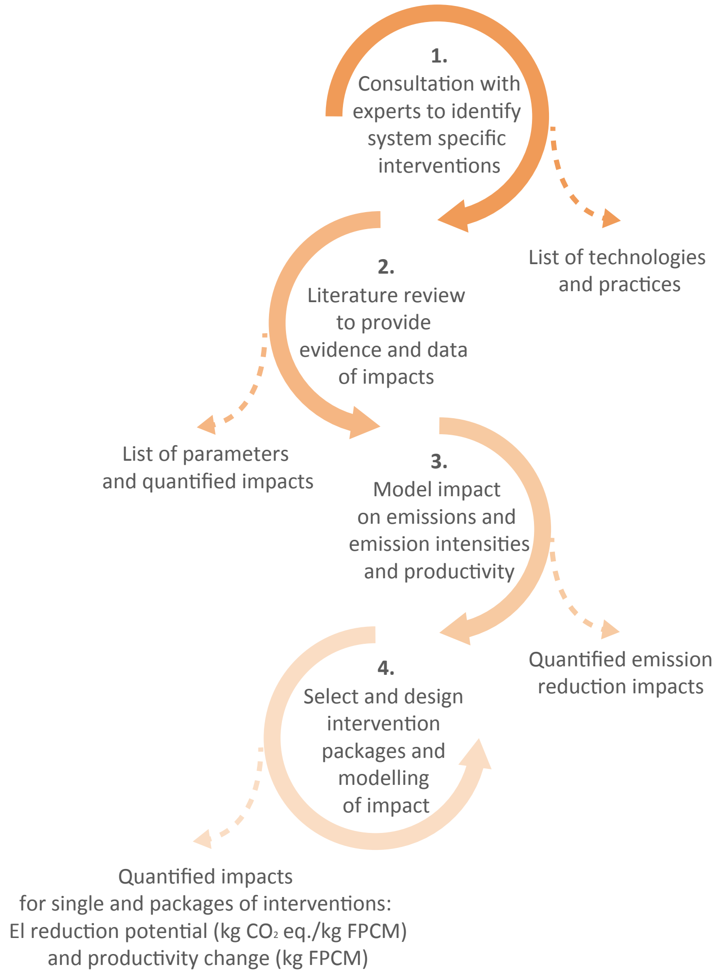
Sources:

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

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

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

Figure 2.2: Process for exploring mitigation impacts



CHAPTER 3

Overview of dairy production

The dairy industry is largest agricultural sub-sector in Tanzania. It contributes 30 percent to agricultural Gross Domestic Product (GDP) and 1.8 percent of total national GDP. The sector currently provides income and employment to about 1.7 million households across the dairy value chain. In terms of nutrition and food security, per capita consumption of milk in 2014 was 40 litres and demand for dairy products is projected to continue to grow rapidly as a consequence of population growth.

Tanzania's population is expected to increase from the current 57 million to 83 million in 2030, of which more than one-third will be urban residents[8]. Driven by future population growth, increased incomes, urbanization, a scenario analysis based on the current level of dairy investments shows that there will be a milk production-consumption gap of about 5.8 million litres in 15 years[9].

Tanzania has outstanding natural resources for livestock development including resilient livestock breeds, extensive rangelands and diverse natural vegetation. Of 88.6 million hectares of land resources in the country, two thirds are suitable for grazing[10]. Despite these resources, the livestock sector is performing well below its potential. The sector's production has grown at a rate of 6.3 percent since 2000; however, large part of this growth is due to increase in livestock numbers (4.3 percent) rather than productivity gains (1.8 percent). The sector is severely constrained by low livestock reproductive rates, high mortality and high disease prevalence.

Tanzania has the second largest national livestock population in Africa. Recent data estimate 27 million cattle, of which 19.7 million are dairy animals. Total milk production from dairy cows in 2014 was about 1.4 million tonnes. Most of the milk production in Tanzania is directed for household consumption. From the milk that is marketed, 97.6 percent is sold directly to neighbors, middleman and collective bulking centers and only 2.4 percent of the marketed milk is in the form of processed products.

The distribution of dairy farming in Tanzania is largely explained by the agro-ecological zoning (Map 3.1) and proximity to markets and feed resources. Milk production takes place in all parts of the country, but it is highly concentrated around Lake Victoria, Northern and Central Tanzania and Southwest region (Map 3.1). Herd size distribution also varies geographically, with larger holders concentrated in the Northern and Western regions, and smaller holdings prevalent in the Southern and Southern Highlands regions[11].

Milk production in Tanzania is predominantly managed by traditional farmers (pastoralists, agro-pastoralists and smallholder mixed farmers) which represents 97 percent of the total dairy herd and produce about 70 percent of the milk in the country. Milk yield per cow, and by extension the total amount of milk produced, fluctuates greatly during the year due to a long dry season that often limits feed and water availability for the animals.

- Traditional dairy farming involves open range free grazing by the cattle, often with low levels of feed supplementation. Tanzania Shorthorn Zebu is the main breed kept by traditional farmers constituting 99 percent of the national herd. Most of the milk produced in these systems is directed for household consumption and cattle plays an important cultural and social role.
- Intensive dairy farming are composed of rural smallholder farms, urban and peri-urban smallholder farms and medium to large-scale farming.

[8] UN Population Projections (https://esa.un.org/unpd/wup/CD-ROM/) and World Urbanization Prospects (https://esa.un.org/unpd/wup/CD-ROM/)

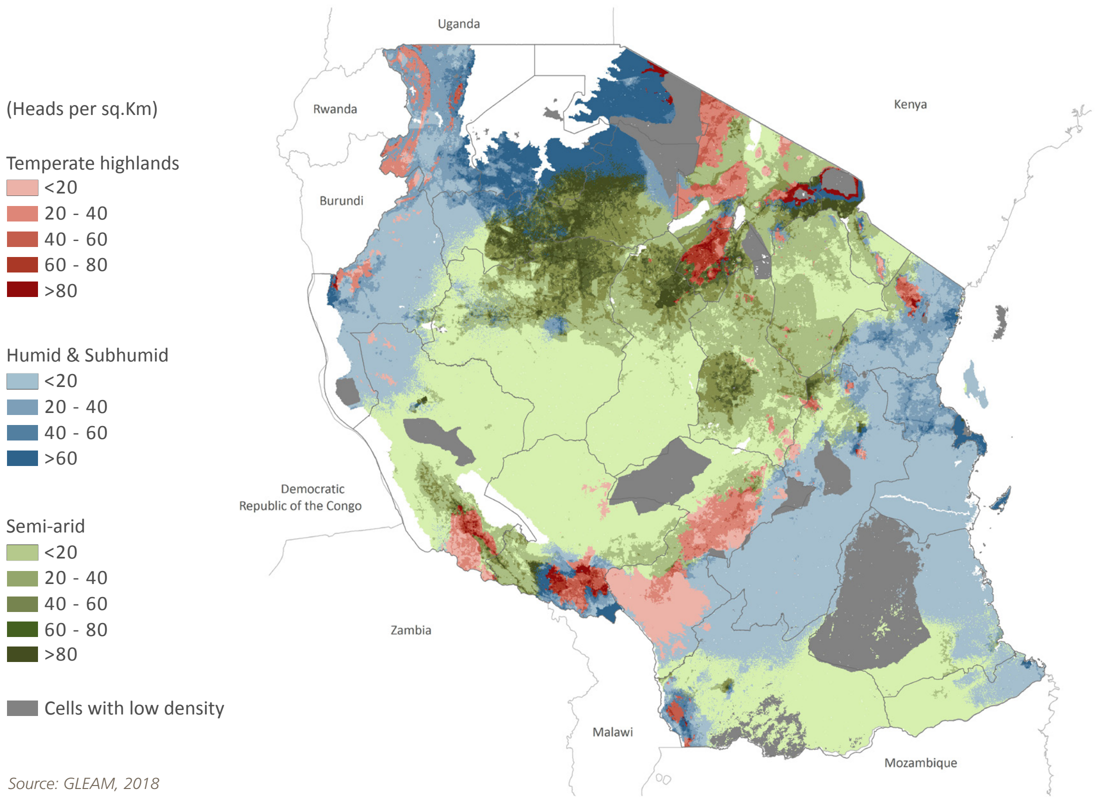
[9] Michael, S., Mbwambo, N., Mruttu, H., Dotto, M., Ndomba, C., da Silva, M., Makusaro, F., Nandonde, S., Crispin, J., Shapiro, B., Desta, S., Nigussie, K., Negassa, A. and Gebru, G. 2018. Tanzania Livestock Master Plan. Nairobi, Kenya: International Livestock Research Institute (ILRI).

[10] Tanzania Livestock Modernization Initiative, 2015 (http://livestocklivelihoodsandhealth.org/wp-content/uploads/2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf).

[11] Covarrubias, K., Nsiima, L. and Zezza, A. Livestock and livelihoods in rural Tanzania - A descriptive analysis of the 2009 National Panel Survey.

Cattle are usually kept under semi-zero grazing and are fed with cultivated fodder, crop residues, cut and carry forages and limited concentrate. Despite the number of animals in improved systems being low, representing only 3 percent of the national dairy herd, improved systems contribute to 30 percent of the total milk produced in Tanzania and have rapidly expanded in the latest years. Table 3.1 summarizes the key features of the two systems.

Map 3.1: Geographical distribution of dairy cattle herd across production zones



Source: GLEAM, 2018

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

Production System		Characterization
Traditional	Diet	Natural pastures with productivity and availability highly affected by seasonality; supplementation of crop residues after crop harvest
	Genotype	Tanzania Shorthorn Zebu breeds
	Productivity	Milk yield per lactation: 200 litres per cow
	Reproductive strategy	Natural breeding, average calving interval 18-24 months, calving occurs during the wet season
Improved	Diet	Cut and carry (local fodder); supplementation with crop residues, leaves from fodder trees and limited concentrate and supplementary feeds
	Genotype	Crosses of exotic breeds and local cattle (Tanzania Shorthorn Zebu)
	Productivity	Milk yield per lactation: 1,500 to 2,000 litres per cow
	Reproductive strategy	Artificial insemination is advocated, but natural breeding is practiced in most of the farms

CHAPTER 4

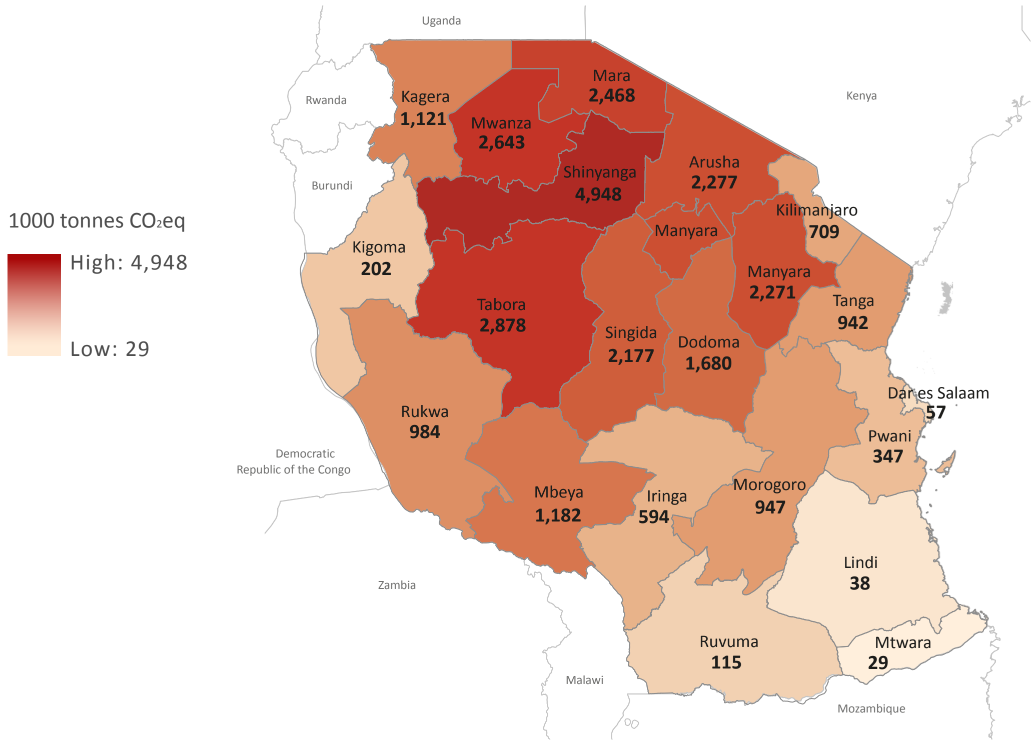
Emissions and emission intensities

Milk production from the dairy cattle sector in Tanzania emits about 28.8 million tonnes CO_2 eq. More than 89 percent of the total emissions are produced by traditional systems located the Semi-Arid (54 percent) and Humid & Sub-Humid (35 percent) regions. 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 95.5 percent, while the nitrous oxide (N_2O) and carbon dioxide (CO_2) contribute 4.2 percent and 0.3 percent of the total emissions, respectively. Approximately 91.4 percent of the emissions arise from methane produced by the rumination of cows and 8.2 percent from the management of stored manure (CH_4 and N_2O). Emissions arising from other sources make a negligible contribution to overall emissions.

Production system contribution to the total GHG emissions

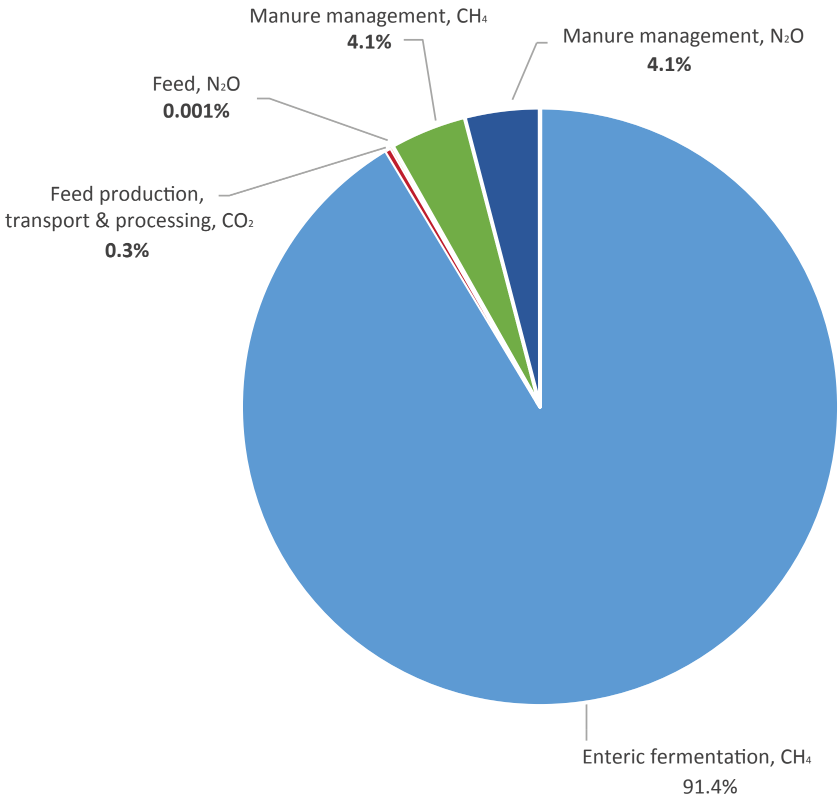
Within the dairy cattle sector, the traditional dairy production system, which produces 70 percent of the national milk, is responsible for 97 percent (28.8 million tonnes CO_2 eq.) of the total GHG emissions. The improved dairy system contributes to 3 percent of the sector's emissions (Figure 4.2).

Map 4.1: Regional distribution of total GHG emissions from dairy cattle



Source: GLEAM, 2018

Figure 4.1: Share of total emissions by emission source



Source: GLEAM, 2018

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

Across all production systems methane emissions from enteric fermentation comprise the bulk of emissions ranging from 87 to 93 percent of the total emissions. Traditional and improved systems have very similar emission profiles; enteric methane and methane emissions from manure management dominate both profiles (Figure 4.2).

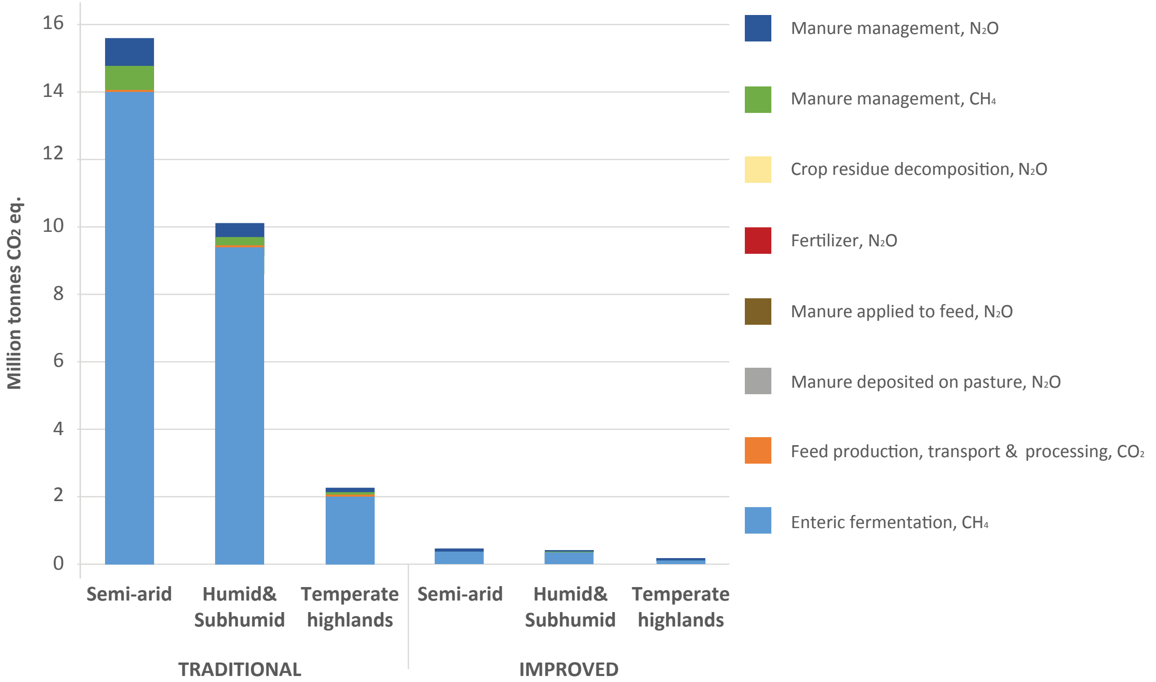
Greenhouse gas emissions per kg of fat and protein corrected milk (FPCM)

At national level, the emission intensity of milk produced in Tanzania is on average 19.9 kg CO_2 eq./kg FPCM. Average emissions ranged from 20.3 to 28.8 kg CO_2 eq./kg FPCM for traditional systems, while in improved systems they ranged from 1.9 to 2.2 kg CO_2 eq./kg FPCM. In both systems, emissions intensity were lowest in temperate highlands and highest in the semi-arid zones (Figure 4.3).

Variability in emission intensity within dairy production systems

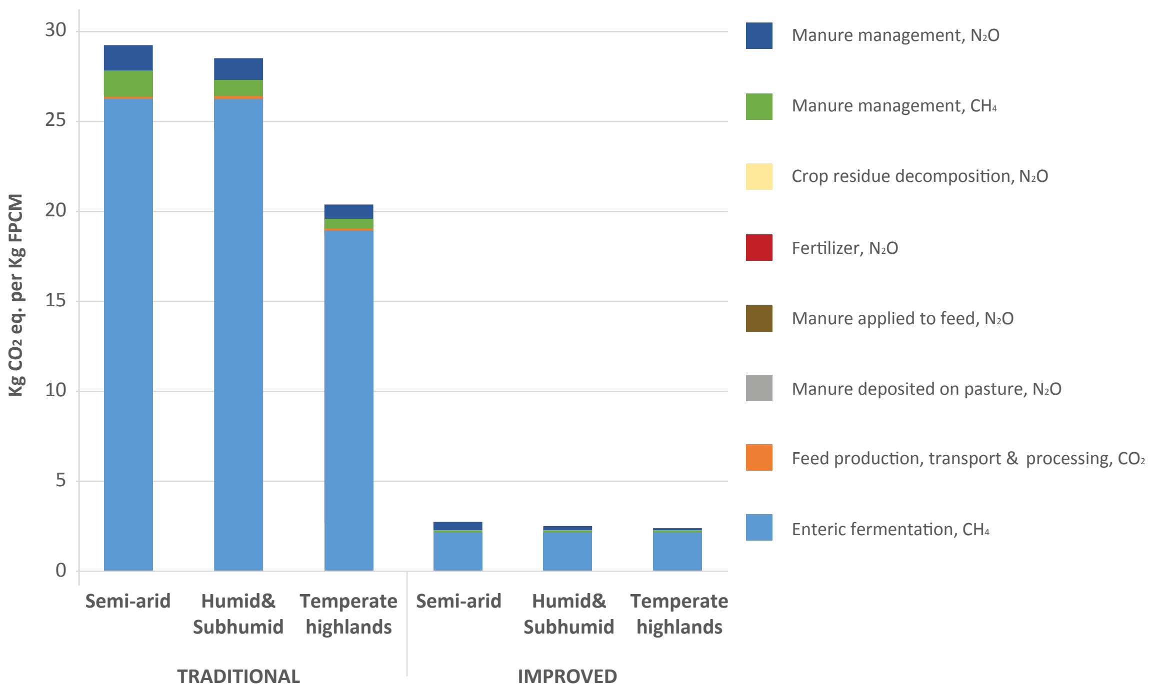
At production system level, there is a wide variation in emission intensity which is closely related to seasonality, productivity level, feeding and management practices adopted by each production system (Figure 4.4). At production system level, the highest variability in emission intensity is observed for traditional systems with a range from 16 to 42 and 14 to 35 kg CO_2 eq./kg FPCM during the dry and wet season, respectively (Figure 4.4). In improved dairy systems, almost all producers are spread over a smaller range of values (from 2 to 4 and 2 to 3 kg CO_2 eq./kg FPCM during the dry and wet season, respectively), indicating less variation in emission intensity. The existence of a wide variability is strong indication of the potential for reductions in GHG intensity of milk through the adoption of practices associated improvements in efficiency.

Figure 4.2: Absolute emissions and sources of emissions by production system and agro-ecological zone



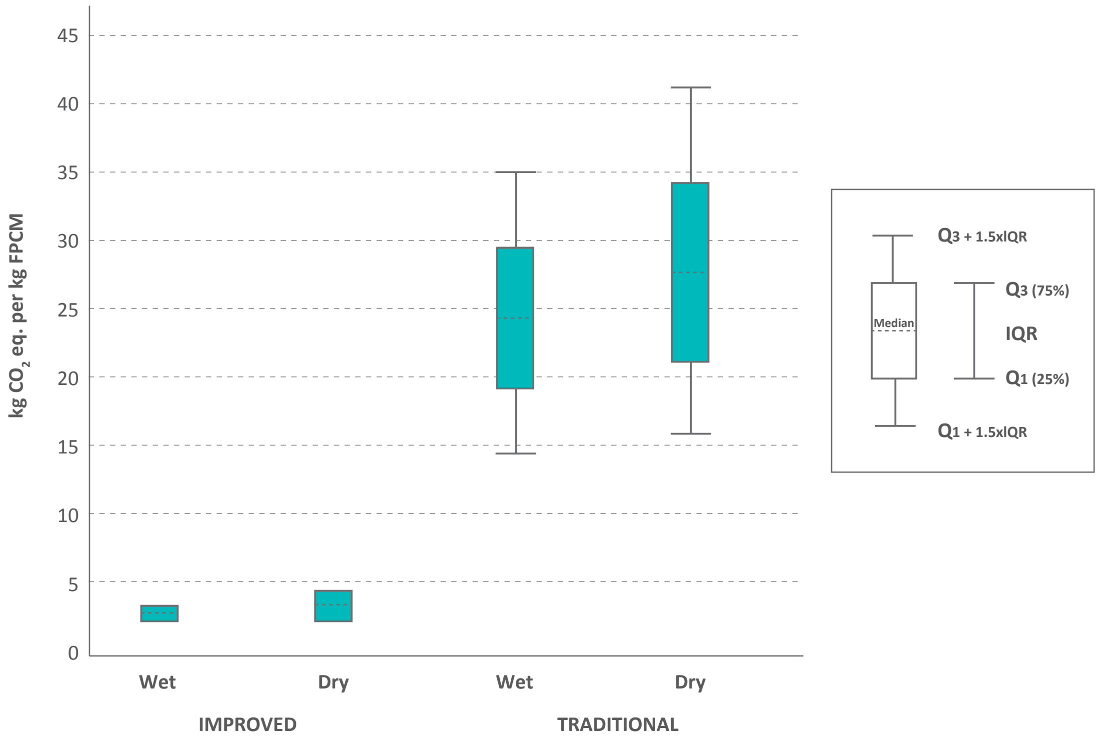
Source: GLEAM, 2018

Figure 4.3: Emission intensity per kg FPCM by production system and agro-ecological zone



Source: GLEAM, 2018

Figure 4.4: Variability in milk emission intensity across production systems and seasons



Source: GLEAM, 2018

Note: The figure shows the variation in emission intensity measured as GHG emissions per kg fat and protein corrected milk (FPCM) at the production zone level. The upper whiskers show the 90th percentiles of emission intensity for each system; the upper box edges show the 75th percentiles; the dotted line show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles.

Determinants of emissions and emission intensities

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

- **Inadequate and poor quality feed.** An inadequate supply of quality feed is the major factor limiting dairy production in Tanzania. Feed resources, are either not available in sufficient quantities due to the long dry season period, or even when available, they are of poor nutritional quality. Across all systems, fodder availability is inadequate and prices are too high for smallholder dairy farmers and livestock keepers to access. This problem is compounded by seasonal changes in pasture conditions, with poor productivity during dry seasons. High milk fluctuations arise because most farmers and livestock keepers depend on rain for 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 from 51 to 58 percent across production 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 cattle. Animal health affects emission intensity

through the "unproductive emissions" related to mortality and morbidity. Animal mortality rates are high (ranging between 15 percent and 25 percent for calves) regardless of the system. Many of the health problems result from poor animal condition as a consequence of inadequate nutrition, but also from the limited access to animal health services. Major animal diseases include East Cost Fever, contagious bovine pleuropneumonia (CBP), brucellosis, rinderpest, ticks and internal parasites. Morbidity has an indirect effect on emission intensities through slow growth rate, reduced mature weight, poor reproductive performance and decreased milk production.

- **Reproductive efficiency.** Reproductive efficiency affects emission intensity by influencing the portion of the herd that is in production (e.g. milked cows and young stock fattened for meat). It is also a key parameter to the economic performance of dairy systems. Improvements in reproductive performance is a major efficiency goal of the dairy industry. However, achieving this goal is currently hampered by a number of factors, particularly feed availability and quality. Poor reproductive performance of the dairy herd is manifested in a number of parameters such as low fertility rates (55 percent to 65 percent), delayed time to reach puberty and age at first calving (2.5 and 3.8 years in improved and traditional systems, respectively), long calving intervals, short productive life (due to culling for infertility or sterility) and high calf mortality (15 percent to 25 percent).
- **Better management of genetics.** About 97 percent of the cattle population in Tanzania are indigenous. While adapted to feed and water shortages, disease challenges, and harsh climates, the productivity of these breeds is generally low. Milk production is as low as 0.5 to 0.8 litres per cow per day over a lactation period of 200 days. 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.

CHAPTER 5

Exploring the mitigation potential in dairy cattle production

The analysis of current production of milk in Tanzania shows that improved management practices and technologies that increase milk production per cow can reduce the GHG emissions intensity of milk production. This approach to mitigation is compatible with the national objective of increasing overall milk output for improved nutrition and food security. The abatement technologies and practices assessed in this study were selected for their potential impact on enteric methane. This is not a purely technical process but incorporates other factors such as existing 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 greenhouse gas emission intensity while taking into account the feasibility of implementation and their potential economic benefits at the farm level. Box 4 summarizes the criteria used to identify interventions that were included in the analysis.

Enhancing animal productivity has several dimensions including animal genetics, improved feeding, reproduction, health and overall management of the herd. The interventions evaluated ranged from improved feeding practices to better herd health and management. These comprised: legume intercropping, urea treated crop residues, establishment of fodder banks, maximize the use of crop residues during the dry season, improving dairy breeds and East Coast Fever control. 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, the use of crop residues treated with urea was applied only to a proportion of lactating and replacement heifers during the dry season in selected agro-ecological zones.

Box 4: Criteria for selection of interventions

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

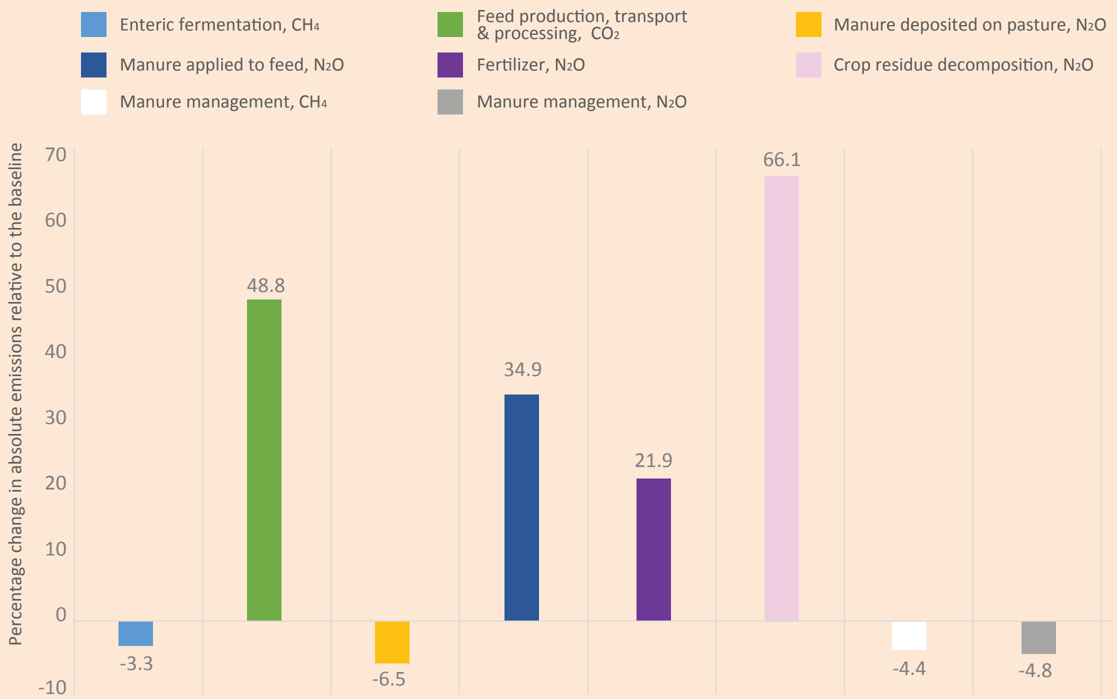
Improving production efficiency is a strategy that farmers can implement to decrease methane emissions. Enhancing animal productivity has several dimensions including animal genetics, feeding, reproduction, health and overall management of the herd.

Reduction in enteric methane emission intensity. Many measures that have the potential 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. Therefore, in a business-as-usual scenario where productivity is not constrained, it is expected that both absolute GHG and enteric emissions will increase under a mitigation scenario.

Moreover, the impact of the interventions on GHG emission profile varies depending on the intervention, and consequently, the mitigation response by source of emissions are not always linearly connected. The figure below demonstrates some of these impacts. The impacts from maximizing the supplementation of crop residues during the dry season were evaluated for dairy cattle in Traditional systems in the arid region. Reductions in enteric methane emissions was found to be marginal because, although, increasing overall diet digestibility with crop residues would result in lower enteric methane production, the intervention actually would increase dry matter intake as a consequence of improved digestibility and palatability of the diet, hence counterbalancing the effects of lower enteric methane production. This increment in dry matter intake 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, this intervention however translate into a decrease in emission intensity resulted from increased milk production (see Figure 5.1). This intervention, in particular, slightly reduced both absolute enteric emissions and emissions intensity, but some practice changes, however, can result in an increase in absolute enteric emissions and reduction in emission 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: location of interventions should be informed by location-specific determinants e.g. soil type, technical and financial capacity, and potential to enhance other benefits, e.g. raising income of target population (poverty reduction).

Impacts of maximizing the use of crop residues on total emissions



Source: GLEAM, 2018

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

Intervention	Objective and constraint addressed	Mitigation mechanism
Legume intercropping	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
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.
Intensive fodder gardens establishment	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
Improving dairy breeds	Improve production and reproductive traits	Enhanced animal productivity and reduced GHG emission intensity
East Coast Fever control	Control a disease that affects both physical and financial performance of dairy herds	Enhanced animal productivity and reduced GHG emission intensity
Maximize the use of crop residues	Minimize quantitative and qualitative deficiency of basal diet to address feed seasonality and quality constraints	Supplementary source of roughage during the dry season to improve energy intake and sustain productivity

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 Figure 5.1. Overall, the analysis shows that there is a high potential to reduce emission intensities; methane emission intensity (kg CO_2 eq. /kg FPCM) can be reduced by 3 percent to 35 percent, the magnitude will vary depending on the intervention and production system assessed.

All interventions returned a positive productivity outcome with increases in milk production ranging between 4 to 56 percent in traditional systems and 5 to 38 percent in improved systems.

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 grasses 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.

The feed and nutrition related interventions (legume intercropping, use of urea treated crop residues, intensive fodder gardens establishment and maximize the use of crop residues) resulted in a reduction in emission intensities between 8 to 35 percent and 3 to 21 percent in traditional and improved systems, respectively.

Legume intercropping is the simultaneous seeding of legumes seeds with grass species on the same piece of land. Legume intercropping can mitigate the risk of forage failure and contribute to soil fertility enhancement trough the biological fixation of atmospheric nitrogen. On the animal production side, legume intercropping can improve both forage supply and protein content of the forage. Natural pastures which commonly form the bulk of roughage for dairy cows, are generally low in crude protein, especially during the dry season. Feeding lactating animals and heifers with a legume-grass mix thought the year has the potential to reduce enteric methane emission intensity by 28 and 12 percent in traditional and improved system, respectively.

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, hence limiting intake. Treating crop residues with urea solution improves the nutritive value by increasing the digestibility, palatability and crude protein content. The intervention was applied in traditional systems (in all agro-ecological zones, except in the Arid areas) and in improved systems (in the Semi-Arid and Temperate highlands) where use of crop-residues is common. Feeding urea-treated crop residues in traditional and improved systems results in a reduction in methane emissions by 8 and 3 percent, respectively. A conservative approach was adopted to reflect the current low adoption rates due to knowledge, high cost of urea and technical barriers, e.g. fear of ammonia poisoning and lack of technical skills in mixing and treatment of residues. Despite the low digestibility, the use of crop residues can help to minimize the feed gap in traditional systems in the Arid Zone where the diets are based exclusively on poor quality natural grasses.

The establishment of fodder gardens managed intensively is a practice appropriate to areas where forage production is scarce and not readily available and farmers have to "cut and carry" forage in a daily basis to feed the animals. Intensive fodder gardens are an ideal solution to supplement dairy animals with a constant supply of high quality forage, especially during the dry season. The provision of a constant supply of high quality forage to lactating animals and heifers resulted in the reduction in enteric methane emission intensity of 30 and 13 percent in traditional and improved system, respectively.

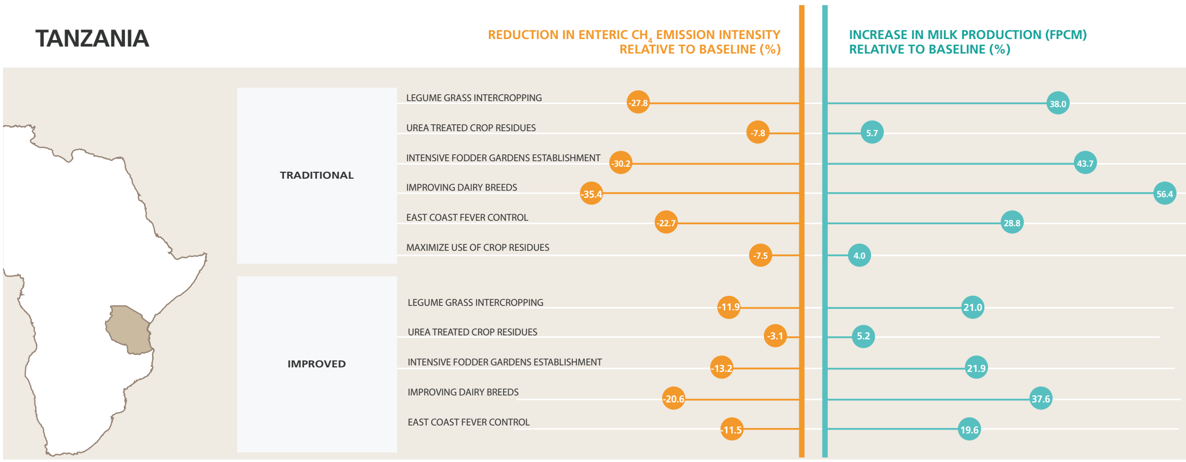
The use of improved breeds with higher milk yield potential results in 35.4 and 20.6 percent reduction in emission intensity in traditional and improved dairy systems, respectively. The impacts on emission intensity are achieved through reductions in number of replacement breeding animals, improvements in reproductive performance of the herd (age at first calving) and through increased milk production via a combination of higher milk yields per day and longer lactation periods.

In Tanzania, East Coast Fever has substantial effects on cattle health and the livelihoods of rural farmers. East Coast Fever reduces the offtake of animal protein and decreases milk production. The control of East Coast Fever in cattle was applied to both the traditional (excluding the Semi-Arid areas with less than 10 heads/km^2) and improved system and resulted in a reduction of emission intensity between 12 to 23 percent relative to the baseline.

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 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.

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



Source: GLEAM, 2018

The design of the mitigation package was carefully carried out based on a conservative approach that considered the particularities of and constraints within each production system and agro-ecological zone. For instance, given that potential of adopting mitigation practices by smallholder farmers and pastoralists is limited by environmental and socio-economic barriers, the mitigation package was applied to only 30 percent of the animals in each production system, reflecting a 30 percent technological adoption rate.

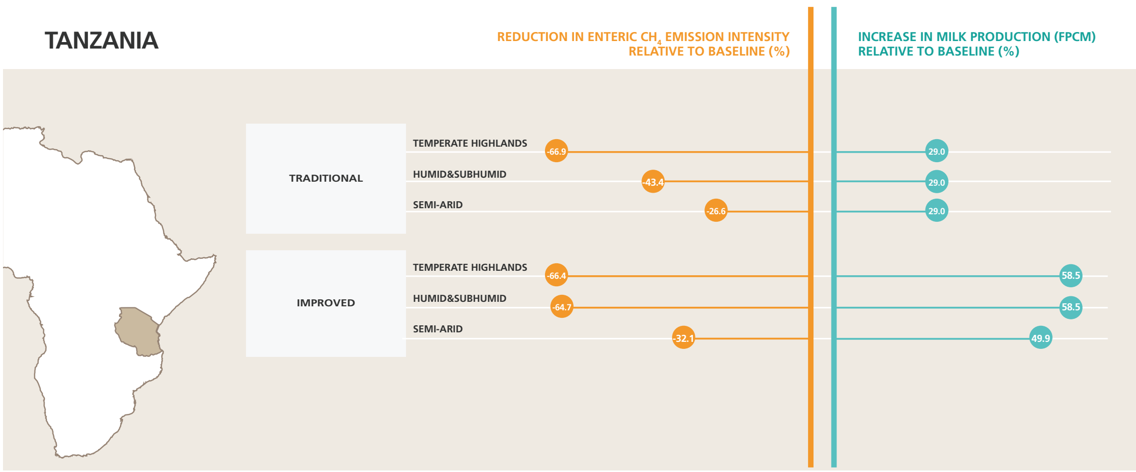
With the exception of traditional systems located in the arid zone, the establishment of intensive fodder gardens was applied to all production systems, for a period of 120 days (dry period). In traditional systems in the arid zone, the use of crop residues was applied for the whole year.

Considering that improved systems already use superior genetics, improving dairy breeds through the crossing of local breeds with high productivity breeds was only applied in traditional systems, while artificial insemination was applied in improved systems.

Regarding the application of the animal health intervention, it was observed that a large area of Tanzania is susceptible to Theileria parva-group parasites (the causative agent of East Coast Fever), excluding the very dry areas. Analyzing the distribution of the dairy cattle herd in Tanzania, we observed that animal distribution follows the same distribution pattern of Theileria parva parasites. Additionally, it has been observed that indigenous breeds, such as Tanzania Shorthorn Zebu, are tolerant to tick infestation and ECF infection[12]. Combining all this information, our approach was to apply the control of East Coast Fever to all animals in both production systems, except the animals in traditional systems in the semi-arid areas with less than 10 heads/km^2.

Applying combinations of interventions aimed at improving feed availability and quality, herd health, and herd management can potentially result in a reduction potential of between 27 and 67 percent in emission intensity relative to the baseline emission intensity. With these combinations of technologies, an increase in milk production between 29 and 59 percent can be achieved compared to the baseline (Figure 5.2).

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



Source: GLEAM, 2018

[12] Laisser, E.L., Chenyambuga, S.W., Karimuribo, E.D., Msalya, G., Kipanyula, M.J., Mwilawa, A.J., Mdegela, R.H., and Kusiluka, L.J. 2017. A review on prevalence, control measure, and tolerance of Tanzania Shorthorn Zebu cattle to East Coast fever in Tanzania. Tropical Animal Health and Production, 49, 813-822.

CHAPTER 6

Prioritization of interventions to address enteric methane

Having identified and assessed the mitigation of potential these technologies, interventions can be prioritized for wider dissemination and adoption. Prioritization should not only consider enteric methane mitigation potential but also the productivity benefits, income advantages to farmers and other co-benefits that are likely to provide additional incentives for farmers to adopt mitigation interventions. A key incentive to farmers for adoption is increased revenue and/or reduced costs. To better understand the implications for farmers, a cost benefit analysis was conducted to assess the profitability of each intervention. The benefit-cost ratio is the ratio between the present value of the benefit stream and the present value of the cost stream. It provides an indication of how much the benefits of an intervention exceed its costs. The results from the cost-benefit analysis are presented in Box 5.

Box 5: Assessing the costs and benefits of mitigation interventions

The benefit-cost ratio (BCR), i.e. the ratio of the present value of the benefits to the present value of the costs. Costs were calculated as production costs (baseline scenario) plus costs involving the implementation of the mitigation strategy while benefits were calculated as total revenue from milk and meat output within a year. The analysis considered the characteristic of the dairy value chain and production systems, such as: milk sales and milk prices in the formal and informal markets, household consumption, milk price fluctuation due to seasonality, animals and meat sales, manure management, etc. The benefit-cost ratio indicates the overall value for money of the interventions. If the ratio is greater than 1, benefits of the interventions outweigh the costs. In this study, the BCR for different mitigation options ranged from 0.24 to 0.66 in traditional systems and from 2.39 to 2.91 in improved systems.

The benefit-cost ratio analysis reveals that in traditional systems, both the baseline scenario and mitigation options present economic returns of less than 1. These results can be explained by the low productivity of traditional systems, household milk consumption, and restricted access to formal markets, which limits the outputs (milk and meat) available for commercialization. In improved systems, all interventions assessed were cost-beneficial, that is, adopting mitigation practices would increase farm profitability. However, the magnitude of the impacts varied considerably among interventions. This variability can be explained by how the interventions were modelled in the economic analysis (intervention cost, duration of intervention period, rate of adoption, animal response, etc.).

Benefit-cost ratios of mitigation interventions

Intervention	Traditional	Improved
Baseline	0.25	2.23
Legume intercropping	0.41	2.51
Urea treated crop residues	0.40	2.39
Establishment of intensive fodder gardens	0.62	2.57
Improving dairy breeds	0.66	2.91
East Coast Fever control	0.49	2.62
Maximize use of crop residues	0.24	**

Note: ** intervention not applied; Source: Authors own calculations

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).

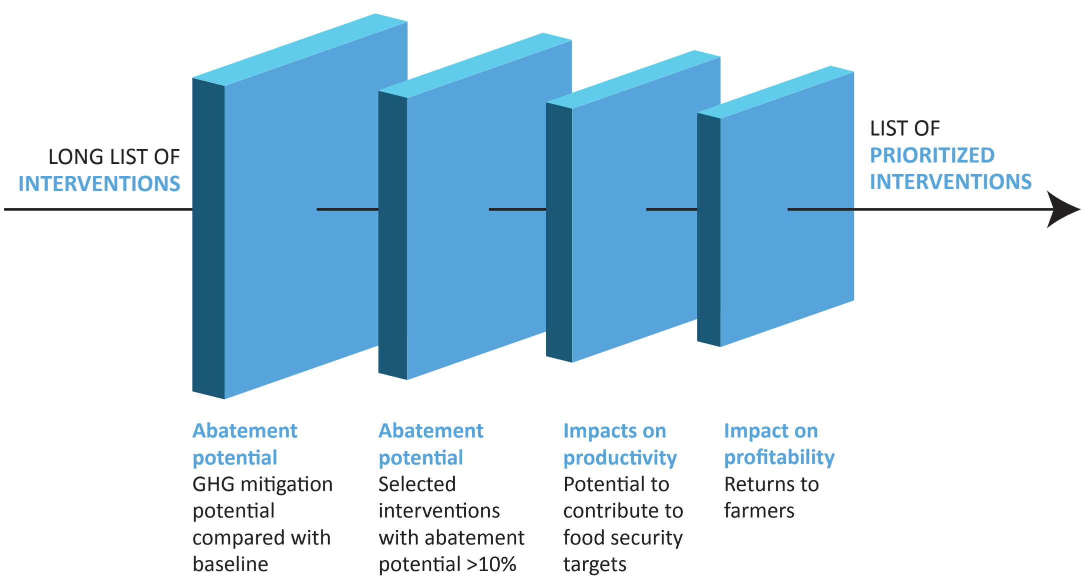
For ease of interpretation a 'coloured light' system was developed for assessing impact where red was 'high', blue 'medium' and yellow 'low'. As the impact of an individual practice varies by system, practices were prioritized separately for each system. The values associated with the high, medium and 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. The outcomes of the prioritization process are shown in Table 6.1.

Comparison of individual interventions

Across the two production systems, two interventions (urea treated crop residues and maximize use of crop residues) resulted in methane emission reductions of less than 10 percent and hence were excluded from the prioritization. Moreover, all interventions applied in traditional systems presented a benefit-cost ratio of less than 1 indicating that economic benefits of the interventions are lower than the production and intervention costs for these systems. 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. Table 6.1 summarizes the impacts of the individual interventions within each production system.

In improved systems, out of the 5 interventions assessed, four were considered relevant including legume intercropping, establishment of intensive fodder gardens, improving dairy breeds and East Coast Fever control. The use of improved breeds had the highest potential impact on all of the assessment criteria which is achieved through a combination of increased daily milk yield, increased lactation length and a reduction in age at first calving. The impact of legume intercropping and establishment of fodder gardens was considered low for methane reduction and moderate for milk production. Despite the benefits of these two feeding strategies, they resulted

Figure 6.1: Initial prioritization process of technical interventions



in an increase in enteric methane emissions because feeding better quality feed rations increased dry matter intake as a consequence of the improved digestibility and palatability of the diet. East Cost Fever control ranks low on the productivity and enteric methane mitigation criteria. One of the reasons for the low returns in productivity and methane reduction is the low adoption rate applied for this intervention scenario. The adoption rate tried to reproduce the challenges faced by Tanzanian dairy farmers, such as limited availability of vaccines and farmer access to the technology.

Although the use of improved and higher yielding cattle clearly stands out as an intervention that should be prioritized, achieving that potential may not in fact be easy. Exploiting superior genetics will mean that other facets of the system will also need to change, in particular improved diet (both quantity and quality), disease control, etc. The gains from feeding interventions and disease control, although ranked lower than improvements in genetics on their potential, may well be easier to achieve in practice.

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 two dairy systems. Results of an assessment of this package, which comprised interventions aimed at improving herd health, genetics and nutritional status of the dairy herd, are shown in Table 6.2.

There is a clear benefit from introducing a package of interventions since in all systems enteric methane reduction and milk production increase were ranked high in the two systems. The financial implications of the package of interventions were less than 1 in traditional systems and moderate in improved systems.

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

Intervention	Legume intercropping	Urea treated crop residues	Establishment of intensive fodder gardens	Improving dairy breeds	East Coast Fever control	Maximize use of crop residues
TRADITIONAL						
Methane reduction	● Medium	**	● High	● High	● Medium	**
Production increase	● High		● High	● High	● Medium	
Economic benefit	● Less than 1		● Less than 1	● Less than 1	● Less than 1	
IMPROVED						
Methane reduction	● Low	**	● Low	● Medium	● Low	
Production increase	● Medium		● Medium	● High	● Low	
Economic benefit	● Medium		● Medium	● Medium	● Medium	

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

Assessment criteria:

Methane mitigation:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Production increase:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Economic benefit:	● Low: < 2	● Medium: > 2 <3	● High: >3	● Less than 1

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

	Traditional	Improved
Methane reduction	● High	● High
Production increase	● High	● Medium
Economic benefit	● Less than 1	● Medium

Assessment criteria:

Methane mitigation:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Production increase:	● Low: >10 <25	● Medium: >25 <50	● High: >50	
Economic benefit:	● Low: < 2	● Medium: > 2 <3	● High: >3	● Less than 1

Box 6: Are pastoralism and mitigation mutually exclusive?

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

In this study, the application of mitigation options in traditional systems was carefully carried out based on a conservative approach that considered the particularities and limitations of these systems.

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

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

CHAPTER 7

Un-locking the potential of 'no regrets' opportunities

Traditional dairy systems will continue to be a dominant agricultural production system in Tanzania. Dairy farming is a part and parcel of many such systems, and is an important livelihood option to increase household income of dairy farmers. This study reveals that pathways for enhancing productivity and achieving emission reductions exist for both traditional and improved dairy systems.

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

The results presented in the preceding sections indicate that there are significant opportunities for growth on a low carbon path for the dairy sector and that economically viable opportunities exist (in varying degree and circumstances).

Increasing individual animal productivity arising from the adoption of better feeding practices, improved health and herd management, can 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 pastoralists and smallholders who generally tend to keep animals for other functions such as a symbol of wealth, traction, nutrient value and risk management. Particularly in 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.

It is important to note that the costs and benefits (and profitability) of the technology are only one part of the picture: adoption also depends on policy incentives, technical support, farmers' capacity, and other factors. According to a national survey[13], Tanzanian rural livestock farmers use basic husbandry practices, with only 26 percent of livestock keepers adopt breeding or mating strategies, 38 percent vaccinate their animals and 35 percent treat their animals against parasites. Moreover, only 20 percent of livestock producers are able to access extension services. Access to extension services enhance rural household livelihoods, farms that did have access to extension services had greater net annual income per live animal (42 percent) than farms that did not utilized livestock extension services.

Putting in place an enabling environment with supportive policies and programs to overcome the market, regulatory and institutional barriers is essential for mitigation potential to be realized. A better understanding of the barriers to adoption is also required before designing interventions are farm level and contributing to the design of policies and programs that can support practice change at scale.

[13] Covarrubias, K., Nsiima, L. and Zezza, A. Livestock and livelihoods in rural Tanzania - A descriptive analysis of the 2009 National Panel Survey.

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

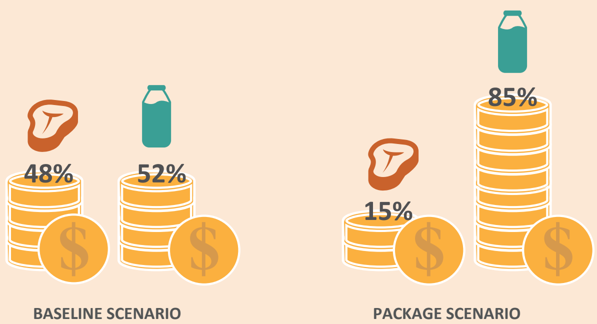
Box 7. Impact of interventions on farm revenue profile

The analysis of farm revenue profiles at the baseline level reveals that most part of the income from traditional production systems are originated from meat (animal sales) rather than milk (see Figure below). Several technical and economic aspects can be attributed to this outcome. First, overall milk productivity is low and it is highly affected by seasonality, with farmers receiving lower milk prices during the wet season when milk productivity is higher, while during the dry season, when milk prices go up, farmers cannot cope to sustain the herd productivity due to low feed quality and feed availability. Second, traditional farmers count on on-farm milk production for household consumption and therefore less milk is available for sale. Finally, the milk produced in traditional systems is less likely to reach formal markets, usually being commercialized at lower prices and being more vulnerable to price variability and market constrains (transportation, hygiene, volume, refrigeration, etc.).

Increasing milk productivity through the application of mitigation practices can boost overall farm income and particularly increase the contribution of milk sales to the total revenue profile. In traditional systems, as an example, where the benefit-cost analysis included milk and meat sales as farm output products, milk contributes to only 52 percent of the farm revenue profile in traditional systems, while meat contributes to 48 percent of the total farm revenue. The analysis of the farm revenue profile after the application of the package shows that under the intervention scenario, 86 percent of the farm revenue would come from milk, while the contribution of meat sales to revenue profile would be reduced to about 15 percent.

Since milk is a daily source of food and income, the application of mitigation practices can empower traditional livestock farmers to make decisions about whether milk surplus will contribute to increase household food security or enhancement farm income.

Sources of farm revenue



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