Food and Agriculture
Organization of the
United Nations

OPTIONS FOR LOW EMISSION DEVELOPMENT IN THE BANGLADESH 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

OPTIONS FOR LOW EMISSION DEVELOPMENT IN THE BANGLADESH DAIRY SECTOR

Reducing enteric methane for food security and livelihoods

Published by
the **Food and Agriculture Organization of the United Nations**
and
the **New Zealand Agricultural Greenhouse Gas Research Centre**
Rome, 2017

Recommended citation:
FAO & New Zealand Agricultural Greenhouse Gas Research Centre. 2017. *Options for low emission development in the Bangladesh dairy sector – reducing enteric methane for food security and livelihoods*. Rome. 34 pp.

ISBN 978-92-5-109633-8

Contents

Acknowledgements

This document is a product of the collaborative effort between the Ministry of Fisheries and Livestock, Bangladesh, the Bangladesh Livestock Research Institute, (BLRI), Food and Agriculture Organization of the United Nations (FAO); the New Zealand Agricultural Greenhouse Gas Research Center (NZAGRC) and the Climate and Clean Air Coalition (CCAC).

This project was led by a national core team comprising of Khan Shahidul Huque (Bangladesh Livestock Research Institute). The core national team acknowledges the contributions received from stakeholders including: Md. Giasuddin (Bangladesh Livestock Research Institute - BLRI), S. M. Jahangir Hossain (BLRI), Nasrin Sultana (BLRI), Razia Khatun (BLRI), M. S. K. Sarker (BLRI), Sadek Ahmed (BLRI), Md. Lutful Haque (BLRI), S. M. Amanullah (BLRI), Gautam Kumar Deb (BLRI), Nasim Ali Mandal (National Consultant, FAO), Begum Nurun Naher (FAO), K.F.M Jesmin Akhter(MoFL), Delwora Beggum(MoFL), S. A. Chowdhury (DGM), Z. H. Khandaker (Bangladesh Agricultural University - BAU), M. M. Uddin (BAU), Md. Ruhul Amin (BAU), A. Q. M. Shafikur Rouf(BRAC, Md. Abu Hossan Sarker (Department of Livestock Services - DLS), Mr. Samir Kumar Sarker (Rural Development Academy - RDA), M. Salauddin (Milk Vita), Bidyut Kumar Mondal (DGM), and S. M. Rajiur Rahman (EME)

Overall project implementation, guidance and support has been provided by the Project Team including Carolyn Opio (FAO), Henning Steinfeld (FAO), Pierre Gerber (FAO), Harinder Makkar (FAO), Harry Clark (New Zealand Agricultural Greenhouse Gas Research Centre - NZAGRC), and Victoria Hatton (New Zealand Agricultural Greenhouse Gas Research Centre – NZAGRC). Alessandra Falcucci (FAO), Monica Rulli (FAO) and Juliana Lopes (FAO) provided input in the research, modelling and analytical work.

This report has been written by Carolyn Opio (FAO), Harry Clark (NZAGRC), Pierre Gerber (FAO) and Henning Steinfeld (FAO).

Finally, special thanks to the Climate and Clean Air Coalition (CCAC), the New Zealand Government and Food and Agriculture Organization of the United Nations for the funding support.

Executive summary

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

Bangladesh has taken steps to chart a path towards achieving food security and other developmental goals. The Government of Bangladesh has developed a number of high level policy initiatives, including Vision 2021 and the related Perspective Plan[1] which is the overarching policy document setting out economic development objectives. Strategic objectives outlined in the Vision include realizing universal food security, which implies that the country needs to be not only self-sufficient in terms of food production but also manage equitable distribution of nutritious food. Achieving food security is also a key objective of the country's poverty reduction strategy and has been recognized to be the highest risk in the Bangladesh Climate Change Action Plan. Climate change is expected to severely challenge the country's ability to achieve its desired rates of economic growth and its food security goals. Bangladesh is a recognized leader in planning for adaptation, and has developed a Climate Change Strategy and Action Plan[2]. The country has expressed an interest in undertaking mitigation activities that contribute to the country's development goals and that entail adaptation and sustainable development (i.e., environment, economic and social) co-benefits.

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

With this in mind, Bangladesh 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 and to becoming a middle-income country by 2021 as outlined in its Vision 2021.

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

- Dairy production remains one of the most important economic sectors in Bangladesh. The dairy sector contributes considerably to the national Gross Domestic Product (GDP). Dairy accounts for about 12% of agricultural GDP and contributes to the livelihoods of many smallholders through the generation of income, employment and food. There are about 1.4 million family dairy farms, comprising around 7 million people, working very small plots of land and who typically own two cows. Amongst these dairy farmers are some of the poorest and most marginalized such as women. It is estimated that for every million kg of milk produced in Bangladesh, 350 jobs are created compared to EU dairy farmers where the number is 7.6 jobs.[3] 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 technol-

[1] Government of Bangladesh: http://www.plancomm.gov.bd/perspective-plan/
[2] Government of Bangladesh: Bangladesh's Climate Change Strategy and Action Plan 2009
[3] Actionaid, 2011. http://www.actionaid.org/sites/files/actionaid/milking_the_poor.pdf

ogies and use of incentives is expected to significantly increase milk yields with net benefits in the short –to– medium term.

- Milk is one of the most 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. Milk is therefore a crucial source of nutrition in a country which has one of the highest rates of under-nutrition in the world; 33% of the children under 5-years of age are undernourished[4] and 26 million people are undernourished[5]. The Bangladesh Vision 2021 has set a target to increase per capita consumption of milk to 150ml per day per person. Current consumption of milk and milk products in Bangladesh is low; the average Bangladeshi consumes 91ml of milk per day.
- 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 Bangladesh, dairy animals are one of the most valuable assets for rural households playing many functions. Dairy animals also provide farmers with draught power and manure for fertilizer.
- Milk demand, measured by per capita consumption, is increasing by 4% per year, which is higher than the growth in milk production (3.6%). Currently, the productivity of dairy animals in general is low, which results in a shortage of supply of dairy products and a dependence on imports. The country is producing milk well under the requirement and 18% of the demand is being met from import of milk powder from the international market. For example, in cattle systems, milk yields range from 2.6 litres per cow per day in subsistence systems to 6.9 litres per cow per day in commercial systems. Milk yields are low and largely variable mainly because of poor feed resources and poor genetics and disease. Currently, only 4 million animals out of a total cattle population of 24 million actually produce milk.
- Given the dependence of the country on agriculture and natural resources, Bangladesh is also highly vulnerable to climate change. With nearly 80% of the population living in rural areas, approximately 70 million people are employed in agriculture while another 56 million are employed in the non-farm sector (which is primarily driven by agriculture). Trends in erratic rainfall, flooding, sea level rise and increased salinity, and increasing temperatures therefore directly affect agricultural production and yields, food security and the livelihoods of millions of people. According to the IPCC, Bangladesh could potentially lose 17% of its land and 30% of its food production by 2050 due to the impacts of climate change.[6] Estimated agricultural GDP losses of 3.1% are estimated annually between 2005 and 2050 – amounting to USD 36 billion in lost economic value.[7]

Emissions and emission intensities from the dairy production

The national dairy population is estimated to be 23.44 million cattle and 1.45 million buffalo; with dairy cattle producing 4.7 million litres of milk and buffalo producing 0.08 million tonnes. For cattle, the subsistence dairy cattle production system produces the largest share of milk production, contributing 77 percent of total milk supply from cattle. While in the buffalo dairy sector, the extensive and semi-intensive system contribute 41% and 59%, of the 0.08 million tonnes of milk, respectively.

The dairy cattle sector in Bangladesh is responsible for about 52.2 million tonnes CO_2 eq. The GHG profile is dominated by methane (79%) while the contribution of nitrous oxide (N_2O) and carbon dioxide (CO_2) is almost 3% and 18% of the total, respectively). Milk production from buffalo adds another 1.3 million tonnes CO_2.

At national level, the emission intensity of milk produced from dairy cattle and buffalo in Bangladesh is 11.1 and 3.2 kg CO_2 eq./kg fat-and-protein corrected milk (FPCM), respectively; the highest values were found for the subsistence and extensive systems. Emissions were on average, 12.7,

4 FAO, 2016. Country fact sheet on food and agriculture policy trends. http://www.fao.org/3/a-i5890e.pdf
5 FAO: State of food insecurity in the world, 2015 http://www.fao.org/3/a-i4646e.pdf
6 Journal of Ecology and the Natural Environment: Impact of Climate Change in Bangladesh: The Role of Public Administration and Government's Integrity. May 2012.
7 FAO: State of food insecurity in the world, 2015 http://www.fao.org/3/a-i4646e.pdf

and 5.6 kg CO_2 eq./kg FPCM for the subsistence and commercial dairy cattle systems and 4.4 and 2.3 kg CO_2 eq./kg FPCM for the extensive, and semi-intensive dairy buffalo systems, respectively.

Options for improving productivity and enteric methane mitigation

Improving animal and herd productivity is one of the key pathways to reduce enteric CH_4 emissions per unit of product. Reducing enteric CH_4 via increasing productivity is economically viable in most situations; several activities that reduce methane emissions have low or negative economic cost when considering the increase in production.

Research shows that 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 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 Bangladesh.

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, 7 single interventions and 1 'package' consisting of combination of single interventions were assessed in this study. The impacts of these interventions were only tested for the dairy cattle sector.

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

This work shows that significant reductions in methane emission intensity can be realized through the adoption of existing and proven technologies and practices. The application of single mitigation practices (e.g. improved feed quality, improved herd health and) can result in reductions in emission intensity (Kg CO_2/kg FPCM) ranging from 3% to 36%, depending on the intervention and production system. Deworming in commercial dairy systems increased emission intensity by 1% compared to the baseline. This increase is explained by the reductions in mortality rates and a resulting increase in animal numbers. The impacts achieved are modest because a cautious approach was adopted in the applicability of the interventions. Given the resource constraints faced by the sector, many of the interventions were applied to a subset of the animals (i.e. lactating animals). All interventions returned a positive productivity outcome with increases in production ranging between 4% - 15%.

Applying a combination of interventions aimed at improving fertility and reproductive status of the herd; improving feed availability and quality and herd health can potentially result in a reduction potential of 17% and 17.5% in emission intensity relative to the baseline emission intensity. With these combinations of technologies, an increase in milk production of 27% and 24% (in subsistence and commercial systems, respectively) can be achieved compared to the baseline situation.

Prioritization of interventions for enteric methane

A preliminary ranking of interventions per production systems to identify those with high reduction potential, increased production and high economic return was undertaken to provide an indication of what is workable. Out of the 7 interventions assessed, 4 were considered relevant for the dairy cattle system including supplementation of diet with urea and molasses, feeding a balanced feed ration, fodder cultivation and udder health management. Balancing feed rations based on available feed resources returned the highest impact on all three criteria in both subsistence and commercial dairy systems.

CHAPTER 1

A climate-resilient and low-carbon growth pathway

Bangladesh is working to achieve a low-carbon as well as more resilient development pathway. As one of the countries most vulnerable to disaster risks and climate change, a high poverty rate and high population density, the Government of Bangladesh has taken significant steps to include these issues within its national plans. With this in mind, its Intended Nationally Determined Contributions (INDC) has put forth adaptation and mitigation actions that Bangladesh can take to tackle its growing emissions and to play its role in global efforts to limit temperature rise to two degrees. With respect to Bangladesh's contribution to global efforts to counter climate change, this INDC sets out a number of mitigation actions that will help limit the country's GHG emissions. These mitigation actions will play a key role in realizing the transition to a low-carbon, climate-resilient economy as outlined in its Vision 2021.

Vision 2021 has the goal to turn Bangladesh into a middle income country and enhance the agricultural sector through increasing productivity of its all sub-sectors (crop, fisheries, livestock and forestry). The livestock sub-sector was identified as deserving special attention for its economic, cultural and religious importance. The livestock sector plays a key role in Bangladesh; it supports millions of landless people, is a livelihoods options for the rural poor families and is potentially important for poverty reduction; income generation, contribution to food and nutrition security. In this context, the target of the government of Bangladesh is to promote development of livestock sector. A set of specific targets have been established for the dairy sub-sector under the Vision 2021, among which, the need to increase per capita consumption of milk to 150 ml per day from the current 91 Ml. In a "business as usual" situation, assuming current growth continues, we estimate that the dairy sector will have to produce about 8.9 million tonnes of milk to meet this target of 150ml per day per person. In the absence of targeted interventions to increase milk productivity, this will also signify a 60% increase in milking animals. For a country that has one of the lowest percentages of land in the world and could potentially lose 17% of its land due to climate change, while at the same time contending with, demographic pressures, the costs of pursuing a "business as usual" path is clearly unsustainable. In recognition of the need to tackle climate change, Bangladesh's climate action plan on mitigation has identified the reduction of methane from cattle as a potential area to target for emission reductions.

The adoption of improved technologies and practices provides opportunities for selective intensification consistent with food security and development goals, climate change adaptation and mitigation needs, thus enhancing development with considerations of environmental, social, and economic issues. At the same time, Bangladesh will be significantly impacted by climate change and adaptation solutions are needed to reduce its vulnerability. Bangladesh is one of the most climate-vulnerable countries in the world, and is expected to become even more so as a result of climate change. Climate change and variability have already had an impact on the lives and livelihoods of people living in coastal areas and in arid and semi-arid regions of Bangladesh. Floods, tropical cyclones, storm surges and droughts are becoming more frequent and will be more severe in the coming years and decades.

This report presents the findings and recommendations from an initial assessment of the dairy sector of Bangladesh. It is undertaken in collaboration with the Ministry of Fisheries and Livestock, the Bangladesh Livestock Research Institute (BLRI) 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. To that end, this report examines dairy production to assess the scale of enteric methane emissions, and identify cost-effective interventions through which methane can potentially be reduced. This analysis is meant to inform where reductions can be made and to systematically explore emission reduction opportunities with the objective to translate emission savings into benefits for producers.

CHAPTER 2

Objectives and approach

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

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

1) Definition of the baseline scenario. Including the selection and characterization of production system, estimation of GHG emissions and emission intensity, and identification of key 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 and cost-benefits analysis. It assesses productivity impacts, the potential profitability for farmers in adopting implementing the selected interventions and identifies the implementation barriers.

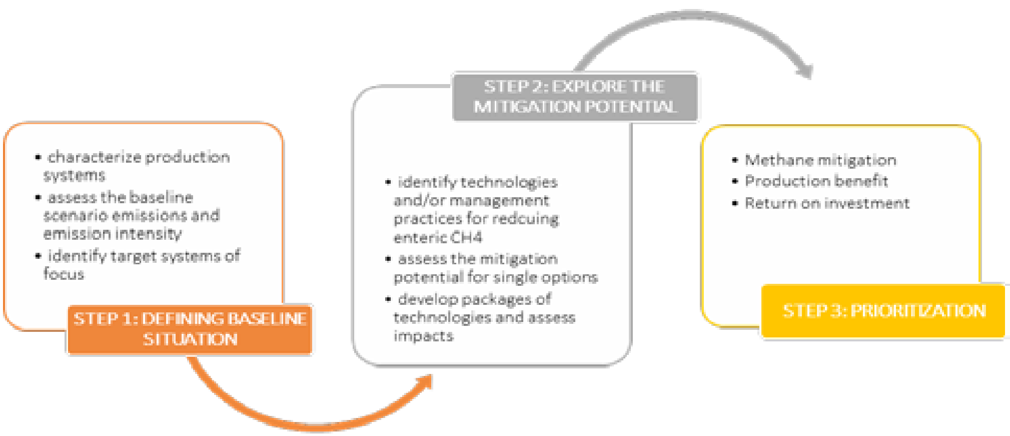
A key focus of this work is on interventions that reduce emission intensity while maintaining or increasing production such that climate change and productivity improvement can be pursued simultaneously (Box 1).

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

The 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.

The study undertakes biophysical modeling and scenario analysis using the Global Livestock

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



Box 1: Absolute emissions versus emission intensity

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

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

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 1 km2, the spatially explicit GLEAM model framework allows the incorporation of heterogeneity in emissions, emission reductions and production responses.

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

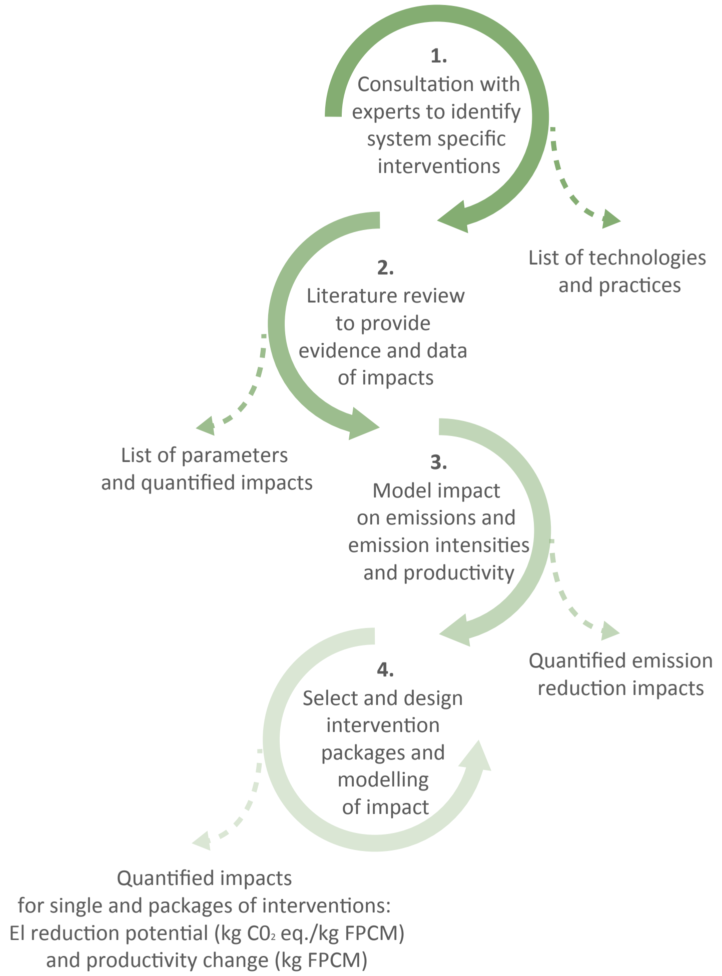
The GLEAM framework is used to characterize the baseline production and GHG emission output of dairy production systems. Emissions and emission intensities are reported as CO_2 eq. emissions, based on 100-year global warming potential (GWP100) conversions factors as reported by the IPCC in its 5th Assessment Report (AR5).

The abatement potential for each practice was calculated by estimating the changes from the baseline GHG emissions, following the application of each 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 as elaborated in the supplementary information.

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

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

Figure 2.2: Process for exploring mitigation impacts



Environmental Assessment Model (GLEAM) to provide a broad perspective of opportunities and the 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 yield and their feasibility in terms of political, social, institutional, and other preconditions. The interventions identified are presented individually and with a subset evaluated as a 'package', in order to demonstrate to stakeholders how a combination of interventions would impact the emission 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.

CHAPTER 3
Overview of dairy production

Milk production is one of the most important economic activities in Bangladesh, contributing around 2.7 percent to the national GDP, providing 3.6 million households with supplementary income. Bangladesh has 23.4 million cattle and 1.45 million buffalo. According to the Bangladesh Bureau of Statistics (BBS) in 2011 there were about 4.2 and 0.3 million milking cows and buffalo, respectively. Bangladesh dairy industry is mainly dominated by local.Out of 4.2 million milking cows, around 90% are local breeds and the rest are crossbreeds.

Bangladesh, like other South Asian countries, has a dairy system characterized by small-scale operation more than 70% of the dairy farmers are smallholders producing 70–80% of the country's total milk.

Simplistically, dairy production in Bangladesh takes places in three broad types of systems; traditional subsistence, extensive, and commercial.

Traditional/subsistence systems reflect small-scale farm holdings often associated with informal milk marketing systems, inconsistent in price and demand of milk. Rural dairy farmers, irrespective of land categories and regions, keep both crossbreds and local animals and a major part of their annual income depends on dairy systems. Shared family labor of both men and women manage them, feed mostly with fibrous and cereal by-products and cut and carry grasses. Production and supply mismatches and seasonal availability of feeds and fodders affect their annual plane of nutrition and cows often failed to optimize their production potentials due to poor metabolizability of their diets.

The extensive farming system is emerged gradually centering some communal grazing lands and formal market outlets operated by both cooperatives and/or private marketing organizations. The animals are allowed pasturing during cool and dry period of a year but, their grazing period is shortened by the inundation of pasture land with flood water and/or seasonal cropping, while animals are stall fed on farm with fibrous and cereal crop by-products. The average herd size is relatively larger and consists proportionately more of crossbreds than traditional dairy systems. Their feeding plane of nutrition varies in different seasons. Similar to traditional dairy, farmers irrespective of land categories keep dairy animals and, sometimes, it is a major source of their annual income.

The commercial dairy systems are more intensive and characterized by relatively high input use and output levels. It is increasing gradually due to the disappearance of grazing lands and demand of milk and milk products. Substantially higher amounts of concentrate feed (resulting in higher costs) along with straws and green grasses are used in commercial dairy herds, consist proportionately more crossbred cows than others. Typically, both family and hired labor are employed, the latter to a larger extent than in the other production systems. The farms have favorable access to the consumer markets, and rely mostly on formal market channels for delivering milk to the capital and other bigger cities.

For the purposes of this work, two broad classifications were adopted for dairy systems: subsistence and commercial for the dairy cattle systems and extensive and semi-intensive for the buffalo dairy systems. As with all generalizations, there are invariably exceptions. These systems can be further classified into semi-intensive/stall feeding, grazing/extensive, semi-extensive/extensive, and tethering (Table 3.1).

Table 3.1: Summary of dairy production systems

Production system		Characterization
Semi intensive/stall feeding	Feed-base/diet:	Zero grazing. Purchased concentrate and rice straw (sometimes treated with urea and molasses), green fodder.
	Genotype	Crossbred cows and local high milk producing cattle (like Prabna)
	Productivity	Crossbred cows yield higher milk daily (7.3 L/cow/day) compared to local cattle (2.5 L/cow/day), and their average lactation length was 265 days compared to 222 days of local cattle.
	Reproductive practice	Artificial insemination is widely used.
Grazing/extensive	Feed-base/diet:	Grazed near river banks on arable land using different legumes e.g. Vigna sinensis, Lathyrus sativus. Jumboo, Napier and German grasses are cultivated.
	Genotype	98% of cows are crossbreeds, 2% are local.
	Productivity	Practiced by cooperative dairy farmers. Average milk production is 3.29-7.88 litres per cow/per day. Based largely on access to grass.
Semi extensive/extensive	Feed-base/diet:	Fodder is cultivated. Cattle are grazed part of the day and stall fed. Some concentrates are used, cut and carry, cultivated grasses and rice straw. Calves are fed crop by-products (bran, rice maize, oil cake and molasses). About 51%, 43% & 5.3% of the dairy farmers feed their animals in stalls, stall cum open or open feeding system, respectively.
	Genotype	Indigenous breeds.
	Productivity	Average milk production ranges between 2.08-6.39 litres per cow/per day.
Tethering	Feed-base/diet:	Fed on crop residues, kitchen waste and left-overs from fruit and vegetables. Cut and carry of natural grass when available.
	Genotype	Local indigenous breeds.
	Productivity	Herd size between 1 - 6 cows. Average milk production ranges between 2.08-6.39 litres per cow/per lactation. Produces more than 65% of the countries milk.
	Reproductive practice	Natural mating is used with a trend toward artificial insemination.

CHAPTER 4
Emissions and emission intensities

Milk production from the dairy sector (including cattle and buffalo) in Bangladesh produced 53.5 million tonnes CO_2 eq. in 2008; dairy cattle contributed the bulk (52.2 million tonnes CO_2 eq.) and contributed. Map 4.1 illustrates the distribution of total emissions from cattle across the regions with a 61% of the emissions concentrated in 3 regions of Dhaka, Rajshahi and Rangpur.

The activities and processes that contribute towards greenhouse gas emissions from dairy cattle are shown in Figure 4.1. The GHG profile is dominated by methane from enteric fermentation and manure management (79%) while the contribution of nitrous oxide (N_2O) and carbon dioxide (CO_2) is 3% and 18% of the total, respectively.

The contribution to methane emissions from buffalo is even higher; 96% (91% from enteric fermentation and the rest from manure) and a negligible contribution of 1% from CO_2 and 3% from N_2O (Figure 4.2). The low contribution from CO_2 and N_2O is explained by the low use of external inputs such as off-farm feed, use of fertilizer and energy in production.

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

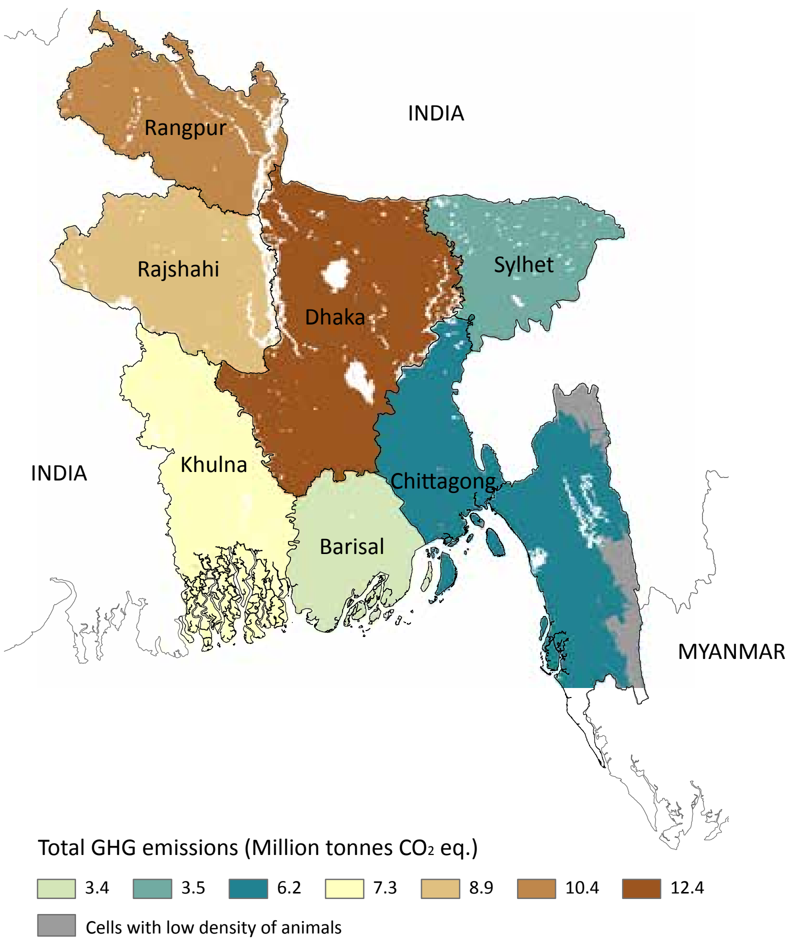


Figure 4.1: Share of total emissions by source, from dairy cattle production systems

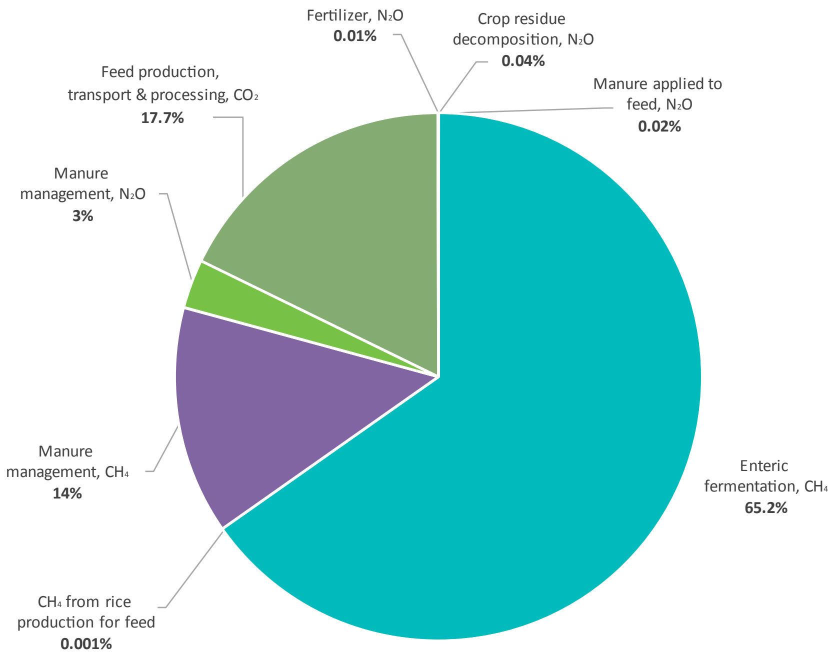
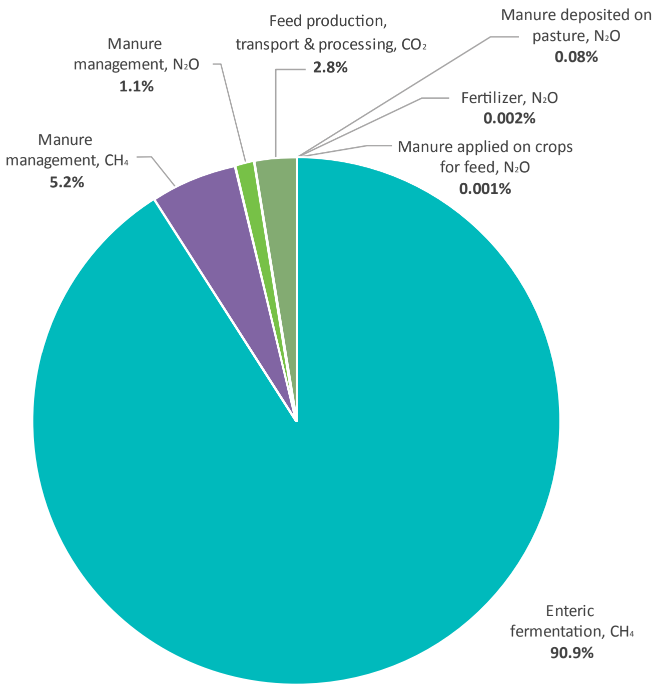


Figure 4.2: Share of total emissions by source, from dairy buffalo production systems

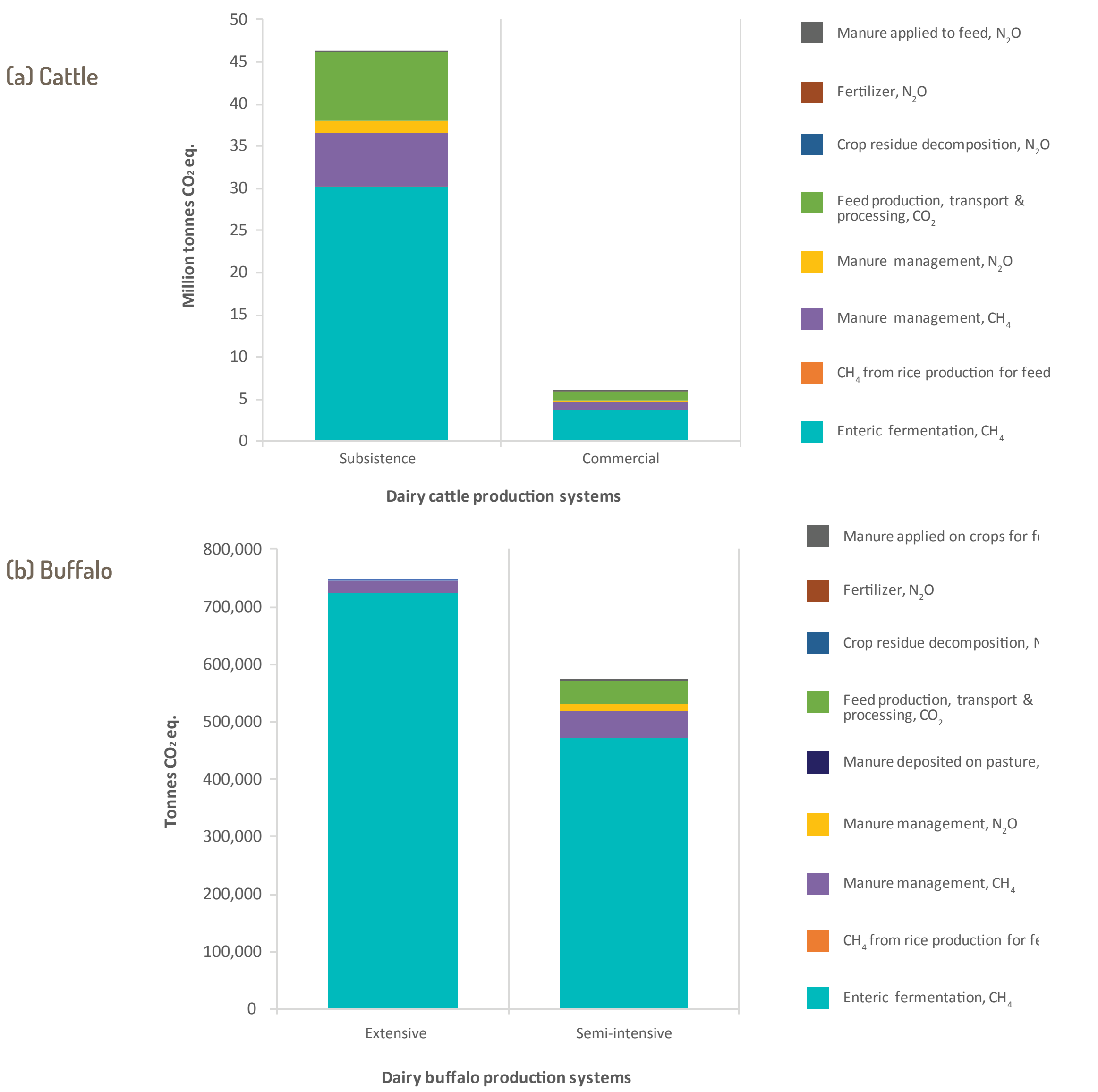


Contribution of production systems to milk production and total GHG emissions

Within the dairy cattle sector, the subsistence dairy production system which produces 77% of the national milk produced by cattle, is responsible for 89% (46.2 million tonnes CO2 eq.) of the total GHG emissions produced by cattle. The commercial production system produces 11% of the emissions (Figure 4.3a) . In both dairy cattle systems, 3 main activities and processes contribute the bulk emissions: enteric fermentation, methane and nitrous oxide from stored manure and CO_2 emissions from feed production. CO_2 emissions from feed production, transport and processing are important in dairy cattle production systems where a large part of the feed ration comprises largely of crop residues and agro-industrial by-products (between 85 and 88 percent of the ration). Due to land constraints, grass (cut and carry and cultivated) makes up only 15% of the feed ration.

Within the buffalo sector, the extensive system and semi-intensive production systems each contribute 56% and 44% of the total emissions associated with milk production from buffalo. In extensive systems, almost all emissions (97%) are associated with enteric fermentation. Compared to the semi-intensive systems, no or limited external inputs are going into the production process (Figure 4.3b) and hence profile is dominated by emissions associated with the animal (enteric methane and emissions from manure).

Figure 4.3: Absolute emissions by production system and source of emissions

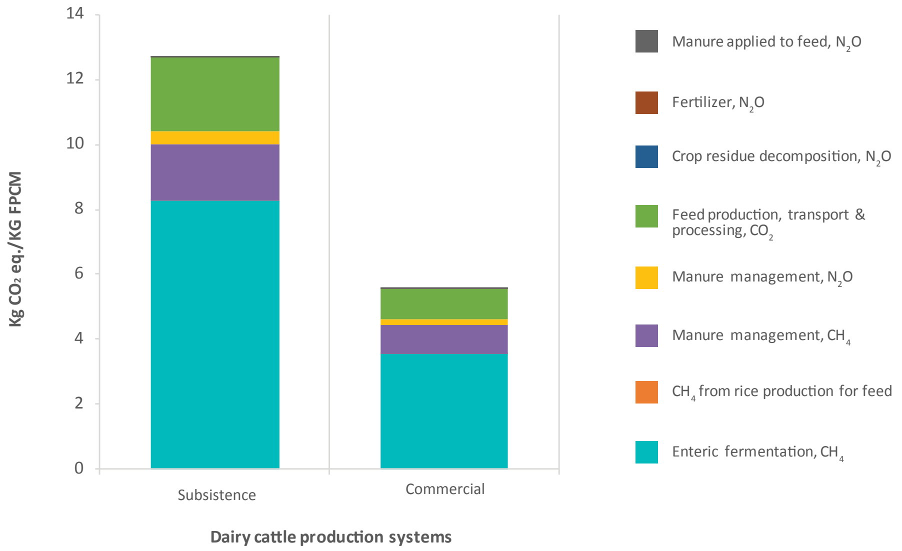


Greenhouse gas emissions per kg of fat-and-protein corrected milk (FPCM)

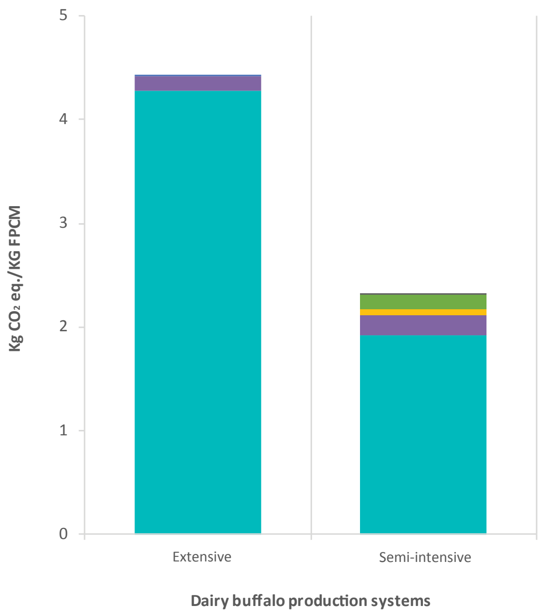
At national level, the emission intensity of milk produced from dairy cattle and buffalo in Bangladesh is on average 11.1 and 3.2 kg CO_2 eq./kg FPCM, respectively; the highest values for the subsistence and extensive systems. Emissions were on average, 12.7, and 5.6 kg CO_2 eq./kg FPCM for the subsistence and commercial dairy cattle systems and 4.4 and 2.3 kg CO_2 eq./kg FPCM for the extensive, and semi-intensive systems, respectively (Figure 4.4).

Figure 4.4: Greenhouse gas emissions per kg of fat-and-protein corrected milk (FPCM)

(a) Cattle



(b) Buffalo



Determinants of emissions and emission intensities

Dairy production in Bangladesh is characterized by low productivity levels mainly due to genetic and nutritional constraints, poor management, and disease control.

Feed constraints: The traditional feeding system for dairy cattle is based on the use of rice straw, natural grasses supplemented with a little or no concentrates. Depending on the production system and animal category (lactating/non-lactating), between 56% - 75% of the ration is made up of crop residues. The quantity and quality of fodder available from natural pasture shows seasonal fluctuation. There is an acute shortage of feed supply during the dry season and the available feed during this period is of very poor quality. Average digestibility of feed rations are very low and range between 45%-55%. Under these circumstances, malnutrition induces a number of problems.

Nutritionally, these feedstuffs are unbalanced in terms of their mineral and protein content.

Poor nutrition results in low production and reproductive performance, slow growth rate, loss of body condition and increased susceptibility to diseases and parasites. Thus, effective utilization of the available feed resources (agricultural and agro-industrial by-products, natural pastures and browse) and appropriate supplementation of poor quality natural pasture and crop residue-based diets appear to be the necessary steps to alleviate the nutritional problems of dairy animals.

The Animal health: The prevalence of various animal diseases, such as tick-borne diseases, internal and external parasites affects dairy production. Animal health affects emission intensity through the "unproductive emissions" related to mortality and morbidity. Methane emissions produced during the period the animal is grown to the productive phase are a net loss if the animal dies before its productive value is harvested or its value is greatly reduced when its productive potential is reduced due to poor health. Calf mortality is high in all systems, where mortality ranges between 10%-20%. Many of the health problems result from poor animal condition as a result of inadequate nutrition, but also from the limited access to animal health services. Morbidity has an indirect effect on emission intensities through slow growth rate, reduced mature weight, poor reproductive performance and decreased milk production. This is particularly true for improved exotic dairy cattle breeds which are often inherently more susceptible to diseases compared to the indigenous cattle.

Reproductive inefficiency: Reproductive efficiency affects emission intensity by influencing the portion of the herd that is in production (e.g. milked cows and young stock fattened for meat). It is also a key parameter to the economic performance of dairy systems. Improvements in reproductive performance is a major efficiency goal of the dairy industry. However, achieving this goal is currently hampered by a number of factors, particularly feed availability and quality. Poor reproductive performance in the Bangladesh dairy herd was manifested in a number of parameters such as low fertility rates (45-47%), delayed time to reach puberty and age at first calving (37 and 43 months in subsistence and commercial dairy systems, mixed respectively).

The proportion of lactating cows ranges between 29% and 36% which implies a large proportion of the dairy herd comprises of non-productive stock (bulls, replacements and dry cows).

Poor genetics and a low number of improved genotypes: Out of 4.9 million milking cows, 4.2 million are local breeds and 0.7 million are crossbreeds. While adapted to feed shortages, disease challenges, and harsh climates (hot and humid temperatures, the productivity of the local breeds is generally low. Average milk production in cattle dairy systems ranges between 2.6 to 6.9 litres per cow per day. In such situations, the classical approach to increase milk production is through genetic improvement by crossing local breeds with improved breeds. However, in a country with feed constraints, unless feed management is improved, these animals will be unable to fully express their potential genetic superiority.

CHAPTER 5

Exploring the mitigation potential in dairy cattle production

The analysis of current production of milk in Bangladesh shows that management practices and technologies that increase milk production per cow will reduce the GHG emissions intensity of milk production. This approach to mitigation 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. Another consideration taken into account during the selection of target interventions was the need to integrate mitigation with a number of key developmental goals for the dairy sector, such as its role in promoting food security, rural and overall economic development. Mitigation options were evaluated only for the dairy cattle sector which contributes the bulk of emissions.

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 intensity while taking 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. The interventions evaluated covered areas ranging from improved feeding practices to better herd

Box 3: Criteria for selection of interventions

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

Improving production efficiency 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 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. Some practices 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: location of interventions should be informed by location-specific determinants such as geophysical aspects like soil type, and potential to enhance other benefits, e.g. raising income of target population (poverty reduction), biodiversity conservation, ecosystem services provision.

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

Practice	Objective	Constraint addressed	Mode of action
Fodder cultivation	Minimize quantitative and qualitative deficiency of basal diet	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 of straw/ fibrous crop residues with urea and molasses/Feeding of Urea molasses straw (UMS)	Improve the utilization of low quality roughages	Low quality of basal diet	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
Ration balancing	Increase efficiency of dietary nutrient use by providing critical nutrients that are deficient in the diet and therefore balancing nutrient availability with animal requirements	Energy, protein and other mineral constraints	Alters rumen fermentation towards more production of microbial protein and lower volatile fatty acid production. Improves efficiency of nutrient utilization, improves productivity and reduces methane emissions
Use of pre & post-partum balanced diets	Provide diets with adequate amounts of macro and micronutrients prior to calving	Improvements in reproductive performance and reduced Incidences of postpartum disorders	Increase in animal productivity (heavier calves at birth, cow's post-partum performance, increased milk yields)
Deworming	Improve health status of herd by addressing internal parasites that affect efficiency	Reduced productive potential due to poor health e.g. Poor growth (calves) and reduced milk production	Maximizes feed energy use by eliminating parasites resulting in enhanced animal productivity and reduced GHG emission intensity
Udder health management (prevention of mastitis)	Improve health status of animals, increase productivity, reduce economic losses for farmers and reduce human health risks	High morbidity, reduced milk production and milk wastage	Enhanced animal productivity and reduced GHG emission intensity
Heat stress management	Improve productive and reproductive performance of animals	Reduced milk production, decreased reproductive efficiency	Enhanced animal productivity and reduced GHG emission intensity

Source: DICOSE, 2015

health and management. These comprised: fodder cultivation, feeding of urea-molasses straw (UMS), deworming, feed ration balancing, use of pre-partum balanced diets, udder health management (prevention of mastitis) and management of heat stress. Interventions were selected to address the key determinants of low productivity and inefficiencies in production cycle such as seasonality of feed resources, low quality of feed and animal health.

Table 5.1 provides a summary of the interventions selected. The strategies were not applied uniformly, but selected for each production system, animal category, and agro-ecological zone using evidence from modelling and field studies and expert judgement of their specific operating requirements and likely impact on performance. For example, all feed related interventions were applied only to a proportion of lactating and pregnant cows while the animal health intervention such as deworming was applied to all animals in the herd.

Quantitative summary of mitigation outcomes from the application of single interventions

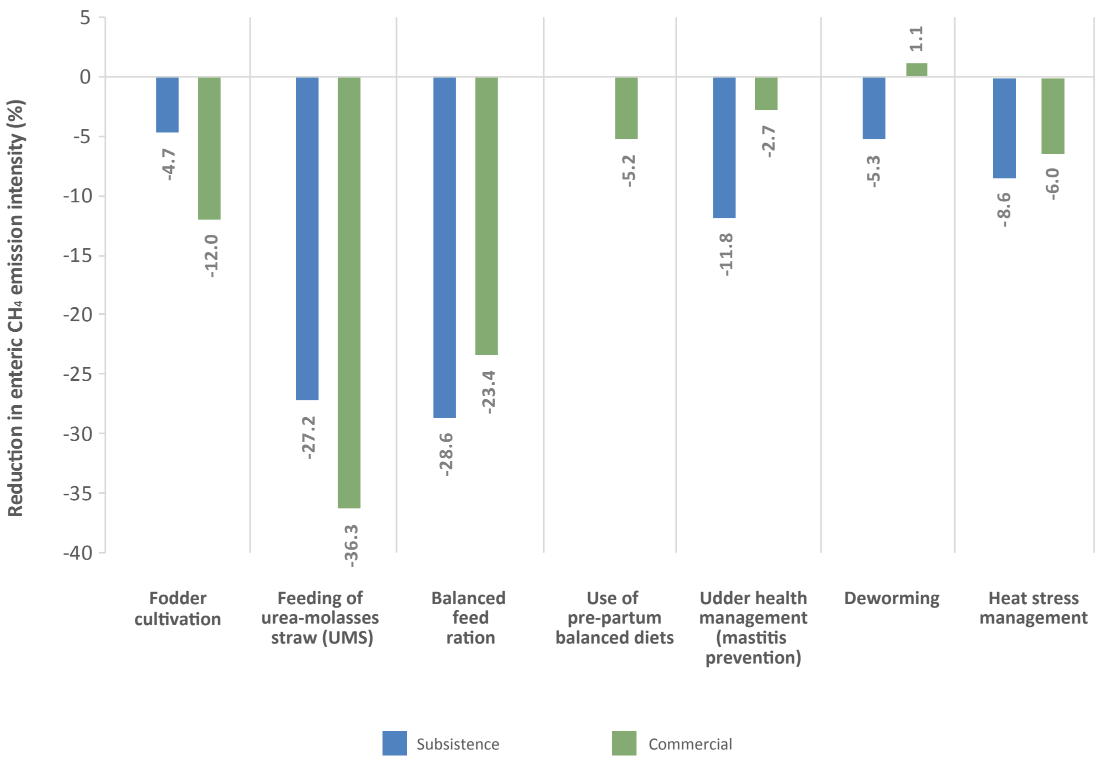
The potential outcomes (emission reductions and productivity) from the application of the single interventions evaluated in this study are presented in Figures 5.1 and 5.2. Overall, the analysis shows that there is a high potential to reduce emission intensities; methane emission intensity (kg CO_2/kg FPCM) can be reduced by 3% to 36%, 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 4.1%-16%.

Feed related interventions resulted in emission intensity reductions ranging between 4.7% and 36%. For most of the interventions (with the exception of feed ration balancing), the largest potential is achieved in the commercial dairy system. Within the feed-based interventions the lowest impacts are achieved for cultivated fodder in subsistence systems. A conservative approach was adopted in the application of this intervention, which was applied to only 50% of the lactating animals in each production system for 6 months. This approach was adopted to take into account the land constraints i.e. limited land available for the production of fodder.

In Bangladesh, dairy cattle are primarily fed on crop residues which form an important part of the diet; between 55% and 75%. Crop residues can be used for feeding dairy cattle but cannot supply adequate nutrients without supplementation. Because of their low digestibility they remain in the rumen for a long time, limiting intake. The other major limitation is they do not contain enough 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. Strategic supplementation of critical nutrients stimulates intake of feed in ruminants and increases the efficiency of production on straw-based diets.

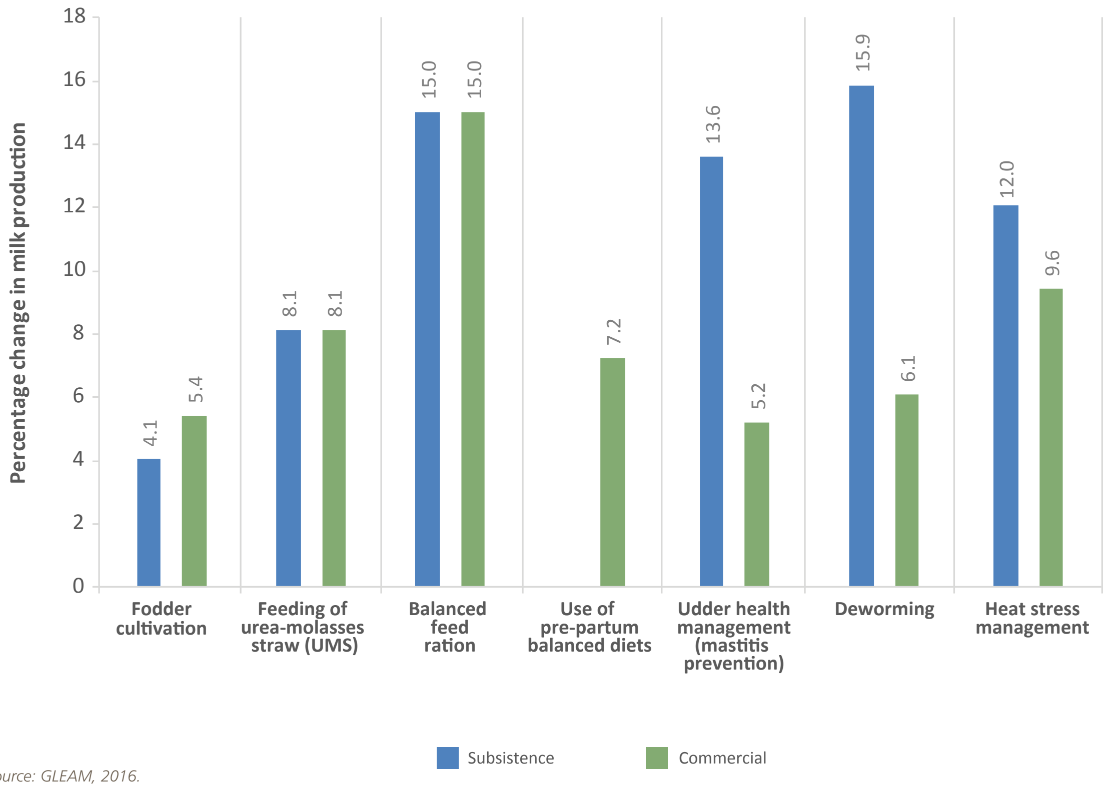
Two interventions (balancing the feed ration and feeding urea molasses straw (UMS) were applied to address the constraints described above. Urea-molasses straw (UMS) provide both energy and nitrogen to the microorganisms in the rumen and thus improve the digestion of crop residues such as straw. It is a readily available source of energy, protein and minerals for the dairy animal. Feeding

Figure 5.1: Enteric CH_4 emission intensity reduction potential relative to baseline emission needs updating intervention



Source: GLEAM, 2016.

Figure 5.2: Impact of single interventions on milk production relative to baseline scenario



Source: GLEAM, 2016.

of UMS resulted in methane reduction of up to 33% in local cattle. Feed ration balancing produced significant reductions in methane emissions; 29% and 23% in the subsistence and commercial dairy production systems, respectively.

In Bangladesh, poor fertility is a major problem; the average fertility rate of 45% and 47%. Adequate nutrition before the calving period is essential for enhancing the reproductive performance in dairy cows. Pre-partum nutritional strategy was tested in commercial dairy systems to improve the reproductive performance of dairy cows. This resulted in methane reductions of 5%. The impact is low because the intervention was applied to a proportion of the animals (15% of the herd).

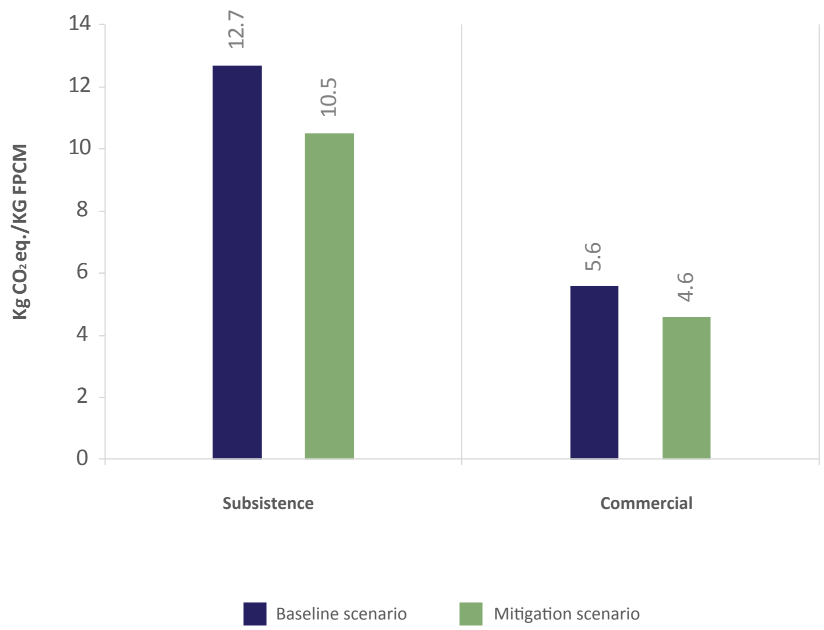
Decreasing mortality and morbidity rates has a significant effect on CH_4 reduction because animals that die or are culled before their first lactation represent a significant loss of energy and resources without any usable food being produced.

The animal health related interventions (mastitis prevention and deworming) result in higher impacts in the subsistence dairy production systems; 12% and 6% reductions, respectively. These impacts are achieved through decreased mortality rates, reduction in the age at first calving, reduction in replacement animals and increased milk yield.

Deworming in commercial systems results in an increase in emissions and emission intensity due to increase in animal numbers resulting from decreased mortality rates.

Heat stress is a major factor that reduces milk production in dairy cows. Up to 10% of the variability in milk production has been attributed to the effect of climatic factors such as temperature. Animals cannot reach their full genetic potential if factors in their environment are limiting. Currently, a wide range in herd average milk yields exists, which reflects the variation in genetic potential and the variation in environment, which is altered by

Figure 5.3: Emission intensity reduction from application of mitigation package (Deworming, balanced feed ration, pre-partum diets and supplementation with urea-molasses multi-nutrient blocks)



Source: GLEAM, 2016.

management practices. Heat stress has adverse effects on the reproductive performances of dairy cattle and buffaloes. Animal responses to heat stress include reduced dry matter intake, decreased average daily gain, decreased milk yield, and decreased fertility and poor reproduction. Management strategies are needed to minimize heat stress and attain optimal dairy animal performance. Managing heat stress in lactating animals resulted in methane reduction of 9% and 6% in the subsistence and commercial dairy production systems, respectively.

The impacts of the single interventions on milk production range between 4.1% and 16%. These changes are modest because the range of alterations was restricted to what might reasonably be implemented by farmers in reality. This conservative approach takes into account the various barriers to adoption that farmers face such as resource (land, feed, capital) constraints. The implementation of many of the feeding and nutritional approaches is limited to the lactating dairy cattle for practical or economic reasons and, thus, the reductions in enteric CH_4 are less on a whole-herd basis.only.

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. Applying combinations of interventions aimed at improving fertility and reproductive status of the herd; improving feed availability and quality and herd health can potentially result in a reduction potential of 17% and 17.5% in emission intensity relative to the baseline emission intensity (Figure 5.3). With these combinations of technologies, an increase in milk production of 27% and 24% (in subsistence and commercial systems, respectively) can be achieved compared to the baseline.

CHAPTER 6

Prioritization of interventions to address enteric methane

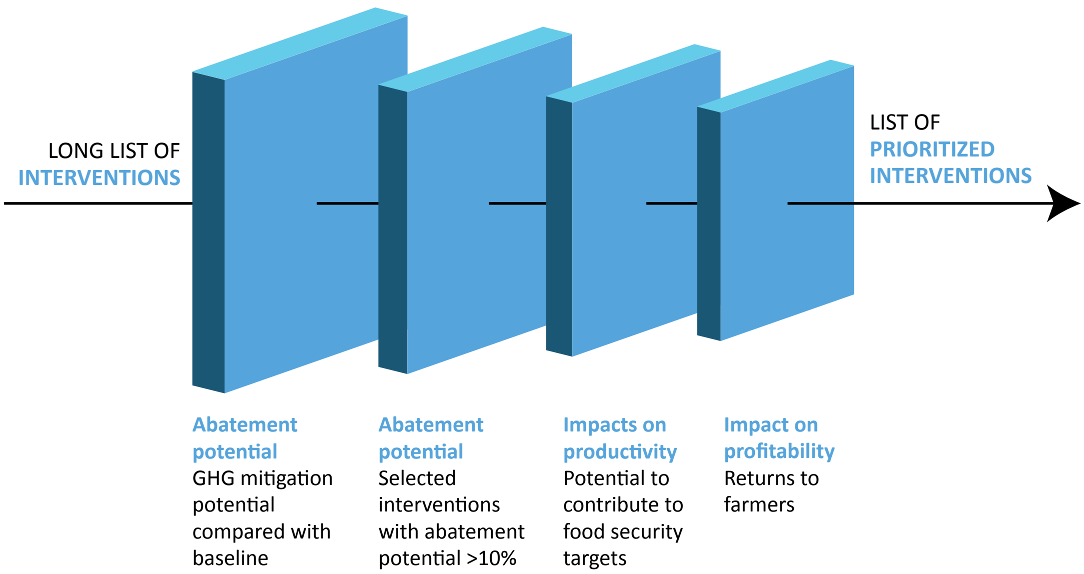
Having identified and assessed the mitigation of potential, these technologies can be prioritized for wider dissemination and adoption. Prioritization should not only consider enteric methane mitigation potential but also the productivity benefits, income advantages to farmers and other co-benefits that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

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%. 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

Figure 6.1: Initial prioritization process of technical interventions



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 deworming that resulted in methane emission reductions in both systems of less than 10%, the rest of the individual 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.

In subsistence dairy systems, out of the 7 interventions assessed, only three were considered relevant including supplementation of fibrous roughages with urea and molasses, feeding a balanced feed ration, and udder health management. Providing a balanced feed ration to lactating cows has the highest impact (ranked moderate) on all of the three assessment criteria. While in the commercial dairy cattle systems, supplementation of fibrous roughages with urea and molasses, feeding a balanced feed ration and fodder cultivation were considered relevant. In both systems, feeding a balanced feed ration to lactating cows has the highest potential impact (ranked moderate to high) on the three assessment 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 two dairy cattle systems. Results of an assessment of this package, which comprised interventions aimed at improving fertility and re-

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

Intervention	Fodder cultivation	Feeding of urea-molasses straw (UMS)	Balanced feed ration	Udder health management
SUBSISTENCE DAIRY SYSTEMS				
Methane reduction		Medium	Medium	Low
Production increase		Low	Medium	Medium
Economic benefit		Medium	Medium	Medium
COMMERCIAL DAIRY SYSTEMS				
Methane reduction	Low	Medium	Medium	
Production increase	Low	Low	Medium	
Economic benefit	Medium	High	High	

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

productive status of the herd; improving feed availability and quality and herd health, are shown in Table 6.2.

There is a clear benefit from introducing a package of interventions since in all systems enteric methane reduction was increased while milk production was increased in all the two systems. The financial implications of the package of interventions were moderate in subsistence systems and high in commercial dairy cattle systems.

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

Common intervention 'package'	Methane reduction	Production increase	Economic benefit
Subsistence dairy systems	● (Medium)	● (Medium)	● (Medium)
Commercial dairy systems	● (Medium)	● (Medium)	● (High)

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

CHAPTER 7

Unlocking the potential of 'no regrets' opportunities

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

- Dairy cattle contributing the bulk (52.2 million tonnes CO_2 eq.), about 97% of the emissions from the dairy sector.
- The milk output is considerably less than it should be; this is confirmed by the wide productivity gaps in these systems;
- Emissions and emissions intensity are highest in dairy cattle systems a systems.

The results presented in the preceding sections indicate that there are significant opportunities for growth on a low carbon path for the dairy sector and that economically viable opportunities exist across all production systems. Feed interventions and improved animal husbandry practices are highly effective in both systems. In terms of prioritization, ration balancing provided the highest return on all three criteria: methane reduction, productivity increase and financial return to farmers. However, to implement the concept of nutritionally balanced rations in smallholder systems is a challenge owing to their lack of knowledge and skills.

Adoption of these interventions however remains low. The explanation lies in a variety of barriers that prevent the uptake of such opportunities and that are not necessarily captured in the cost-benefit analysis performed here. The following are the most commonly cited: opportunity cost of labor, limited knowledge of farmers, access to markets, inputs and services, and environmental constraints.

It is important to note that the costs and benefits (and profitability) of technologies are only one part of the picture: adoption also depends on policy incentives, technical support, farmers' capacity, and other factors. Putting in place 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.

I6822EN/1/04.17