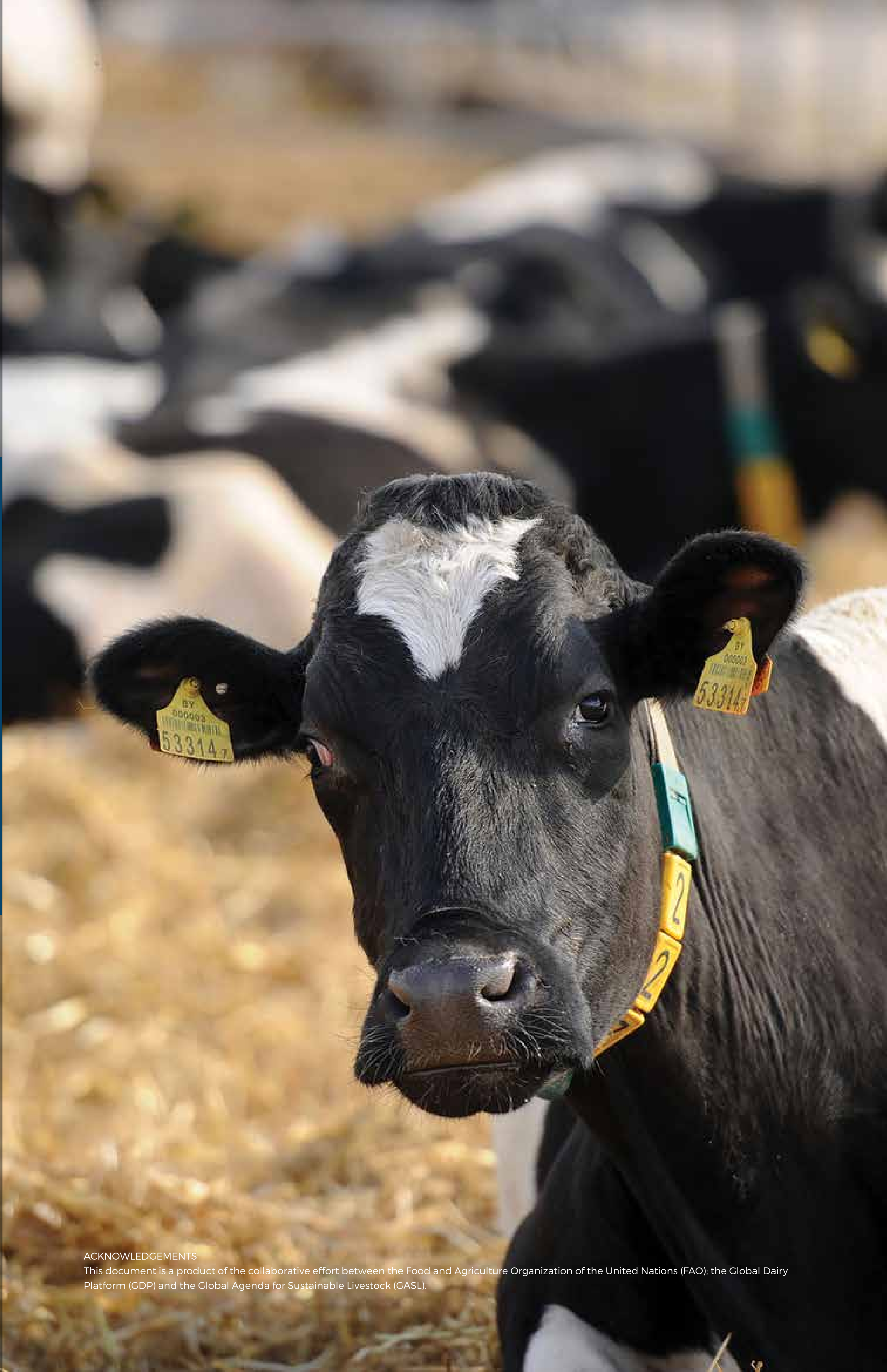
Food and Agriculture Organization of the United Nations

GLOBAL DAIRY PLATFORM

CLIMATE CHANGE AND THE GLOBAL DAIRY CATTLE SECTOR

The role of the dairy sector in a low-carbon future

Global Agenda for Sustainable Livestock



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EXECUTIVE SUMMARY

Climate change along with population growth, poverty alleviation, environmental degradation and global food insecurity is one of the defining challenges of the 21st century. From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impact of climate change is global in scope and unprecedented in scale. What is clear is that if we do not produce win-win solutions then climate change will make all other challenges worse.

The challenge for policy-makers – and for the dairy sector – is how to reduce environmental impacts while continuing to meet society's needs. Dairy products are a rich source of essential nutrients that contribute to a healthy and nutritious diet. With demand for high-quality animal sourced protein increasing globally, the dairy sector is well placed to contribute to global food security and poverty reduction through the supply of dairy products. In so doing, it is essential that sector growth is sustainable in terms of the environment, public and animal health and welfare and in terms of development, poverty alleviation and social progress.

The Climate Agreement adopted at the UN Climate Change Conference of Parties in Paris in December 2015, and supported by 195 countries, provided a timely reminder that all sectors and stakeholders need to undertake immediate actions on climate change.

The world is already experiencing, for example, more frequent floods, storms and droughts, forest fires causing damage to the environment and people's livelihoods. The dairy sector must contribute effectively to the global effort to avoid dangerous climate change, become more resilient and prepare for and adapt to a changing climate.

In order to limit temperature rise, the dairy sector must reduce its greenhouse gas (GHG) emissions and work towards a low-carbon future. The good news is that there are many opportunities within the sector to limit climate change by reducing emissions. While there is some uncertainty about the size and timing of changes, it is certain that it is happening and acting

now to protect our environment, economy and culture will always be worthwhile.

To consider how to deal with climate change, the dairy sector needs to have evidence at hand, presented in a clear and comprehensible way, so stakeholders can see how they can and must contribute.

This report is an attempt to understand the contribution of the dairy sector to global emissions between 2005 and 2015 as a further step towards addressing the challenge of climate change and defining a low-carbon pathway for the sector.

EMISSIONS FROM THE DAIRY SECTOR

This study shows that the sector's GHG emissions have increased by 18 percent between 2005 and 2015 because overall milk production has grown substantially by 30 percent, in response to increased consumer demand. The trends in absolute emissions reflect changes in animal numbers as well as changes in the production efficiency within the sector. Between 2005 and 2015, the global dairy herd increased 11 percent. At the same time, average global milk yield increased by 15 percent. Increased production efficiency is typically associated with a higher level of absolute emissions (unless animal numbers are decreasing). Yet without efficiency improvements, total GHG emissions from the dairy sector would have increased by 38 percent.

So while total emissions have increased, dairy farming has become more efficient resulting in declining emission intensities per unit of product.

Emission intensities, GHG per kilogram of milk, have declined by almost 11 percent over the period 2005-2015. These declines are recorded in all regions reflecting continued improvements to on-farm efficiency achieved via improved animal productivity and better management. There is however a distinct difference in emission intensities between regions: generally, emission intensity of milk production is lowest in developed dairy regions (ranging between 1.3 to 1.4 kg CO_2 eq. kg fat-and-protein corrected milk in 2015) while developing dairy regions such as South Asia, Sub-Saharan Africa, West Asia and North Africa having higher emission intensities (ranging between 4.1 to 6.7 kg CO_2 eq. per kg fat-and-protein corrected milk in 2015).

Large variations in emission intensity was also found within the same regions. This variation is explained by differences in management practices and implies that potential exists to reduce GHG emissions in all regions.

MORE AMBITIOUS ACTION NEEDED NOW

There is a clear case for immediate and more ambitious action. Dairy farmers are already part of the solution to limit climate change, but there is an urgent need to accelerate and intensify the sector's response to avoid climate tipping points. While new research and technologies will continue to be developed, many mitigation options are already available and their adoption can be accelerated. Further delaying adoption will result in a greater amount of emissions overall, given that CO_2 emissions accumulate in the atmosphere for hundreds to thousands of years. Even with implementation of best practice and technologies, it is likely that some residual emissions will remain in the future. The dairy industry will therefore need to also consider how these residual emissions will be offset. Achieving substantial net reductions in GHG emissions from the dairy sector will require action in the three broad areas of 1) improving efficiencies; 2) capturing and sequestering carbon; and 3) better linking dairy production to the circular bio-economy.

These three pathways result in the reduction of:

- emission intensity, the emissions required to produce a kilogram of milk; and
- absolute emissions from dairy production.

REDUCING EMISSION INTENSITY OF DAIRY PRODUCTION

Accelerating the adoption of existing best practices and technologies to further improve production efficiency can help reduce emission intensity. While the largest gains in emission intensity reduction have occurred in low-and-middle income regions with low productivity, the results also show that there still exists a large gap between producers in these regions. This gap provides room to further mitigate emissions within existing systems. In low-and-middle income countries, the concept of emission intensity remains the most attractive mitigation route because it allows for the harnessing of synergies between food security, development objectives and climate change mitigation and adaptation goals.

REDUCING ABSOLUTE EMISSIONS FROM DAIRY PRODUCTION

Absolute emissions reduction will become an imperative as the world moves towards carbon neutrality by 2050. While recognizing the responsibility of the dairy sector to develop in a sustainable manner, the mitigation potential of the sector is limited because, as a biological process, emissions will always be generated. This raises the question of using additional levers to compensate for residual emissions. Some solutions to address the dilemma of increasing emissions are for the sector to focus on enhancing carbon capture and storage in soils and identifying key strategies to promote circular economy opportunities to reduce greenhouse gas emissions. For example, implementing improved grassland management practices that increase carbon uptake by increasing productivity or reducing carbon losses can lead to net accumulation of carbon in grassland soils – sequestering atmospheric carbon dioxide. Furthermore, making the sector more circular would not only lead to more efficient resource use, but also help address climate change. Minimizing the production of new resources, wastage of resources, closing of nutrient loops and extending the lifetime of those already in circulation can have a significant impact on climate.

Strategies can involve, for example, `nutrient recovery technologies' like anaerobic digestion, breaking down manure to produce nutrient-rich products that can be used to replace synthetic fertilizers, which have increased significantly over the past decade and contribute heavily to CO_2 and N_2O emissions. In addition, leveraging possibilities of technology can advance modernization of agriculture by moving to precision farming, for example, including measures for irrigation, fertilization and precision feeding. Closing agricultural product and nutrient cycles also helps maintain soil quality and prevent land-use change elsewhere.

SUPPORTING LOW-CARBON PATHWAYS

There is no single pathway to a low carbon future. The dairy sector has the potential to make the transition to a low-carbon economy by taking mitigation actions. While this will have costs, it will also bring benefits and opportunities that need to be considered. This study is a further step to enable an open dialogue around options, choices and impacts.

Research, policies, regulations, infrastructure, and incentives will all be required to systematically support low-carbon choices. Investment in data gathering and further in-depth analysis will help identify and refine mitigation options, actions and support a transparent debate about longer-term desirable and feasible mitigation pathways.

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1. SETTING THE SCENE

The global demand for food is expected to double by 2050. The UN estimates that the world population is expected to increase from 7.6 billion today, to reach 8.6 billion in 2030, 9.8 billion in 2050 and surpass 11.2 billion in 2100. Agricultural systems throughout the world will have to provide extra food to feed this growing population. This growth will provide opportunities and challenges for the dairy sector. The challenge is to feed the global population with food that is both healthy, nutritious and sustainably produced.

More than 80 percent of the world's population, or about 6 billion people, regularly consume liquid milk or other dairy products. In 2014, the global dairy market was estimated at US $330 billion (FAOSTAT, 2014).

People benefit from consuming milk and dairy products. They are nutrient-dense foods that supply energy and significant amounts of protein and micronutrients, including calcium, magnesium, selenium, riboflavin, and vitamins B5 and B12. They are the fifth largest provider of energy and the third largest provider of protein and fat for human beings and an important source of affordable nutrition to meet recommended levels.

More than one-quarter of 570 million farm-holdings worldwide, or more than 150 million farmers, are estimated to keep at least one milk animal, including cows, buffaloes, goats, and sheep. There are estimated to be 133 million holdings keeping dairy cattle, 28.5 million with buffaloes, and 41 and 19 million with goats and sheep, respectively (FAO, 2016). Farmers often keep mixed herds with more than one species of dairy animal. Cows are by far the most common dairy animal, with farmers in developing countries usually keeping them in herds of two or three animals (FAO, 2016).

In about 25 percent of cattle-keeping households, or in about 35 million farms, dairy cows are directly owned and/or managed by women (FAO, 2016). Dairy often serves as a platform for rural women to consolidate a better place for themselves in their society. As about 22 percent of the world's women of working age are employed in agriculture and about one-fourth of agricultural holdings, headed by both men and women, keep milk animals, about 80 million women are to some extent engaged in dairy farming (FAO, 2016).

The challenges for the dairy sector include bringing milk to the consumer at competitive prices when dairy production is subject to changing weather patterns, changing market dynamics and dairy prices. At the same time, there is a growing emphasis on sustainability. People are concerned about the environment, animal welfare and the quality of their food.

Dairy is essential in the endeavor towards ending hunger, achieving food security and improving the nutritional value of diets in a sustainable manner. The UN Sustainable Development Goals includes several priority areas relevant to agriculture and food production including the zero hunger target by 2030, the sustainable use of natural resources and climate action. By 2050, the planet will need to produce more food, while conserving available land, water and energy resources and reducing GHG emissions. This challenge is exacerbated by the reality that one-third of food produced for human consumption is wasted (FAO, 2011)[1]. Consequently, effective climate change policy measures must address both demand and supply related factors.

The evidence that our planet is warming due to human activity is unequivocal. Global temperature has increased by 0.85 degrees since 1880 (IPCC, 2014)[2]. Global warming is caused by increasing levels of greenhouse gases (GHGs) in the atmosphere. Climate change influences dairy farming in multiple ways (directly, e.g. the performance and well-being of cows, or indirectly, e.g. via impacts on quantity and quality of fodder production).

At the same time, livestock products are responsible for more GHG emissions than most other food sources. In dairy production, emissions are the result of various complex biological processes. For example methane from enteric fermentation where methane is produced as a by-product of the digestion process. Additional methane and nitrous oxide emissions occur throughout the whole process of managing manure from livestock: in pastures and in buildings, during storage and when spreading manure. They are the result of physical, chemical and biological processes which vary in time and space depending on the ambient conditions (e.g. temperature, wind), the surroundings (e.g. soil, type of building) and livestock characteristics (e.g. physiological stage) and farming practices. Other emissions include carbon dioxide largely associated with energy use, production and transport of inputs and land use and land use change.

The Paris Agreement marked a turning point in the international climate negotiations and signifies an intensification of global efforts towards a low emissions future. In November 2016, the Paris Agreement entered into force, having been ratified by nations representing over 55 percent of total GHG emissions. It sets a global aim to limit warming to below 2°C and to pursue efforts to limit it to 1.5°C. To achieve this aim, the Agreement sets a target for a 'balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century'. In looking to meet these goals, countries are expected to continue to take the lead in reducing emissions, reflecting the principle of equity and common but differentiated responsibilities and respective capabilities (UNFCCC, 2015)[3]. To support the transition to these pathways, the Paris Agreement invites countries to develop, by 2020, 'mid-century, long-term low greenhouse gas emission development strategies'.

Under the Paris Agreement, 92 countries have included the livestock sector in their nationally determined commitments (NDCs) as a means to achieve their national reduction targets (Wilkes, 2017)[4]. The sector is thus part of the response to address the impacts of climate change and to limit the rise in global temperature, requiring a transition of the sector to one consistent with a sustainable low carbon and climate resilient development pathway.

This report is an effort to support the dairy sector to chart possible low-emission pathways. It presents findings on emissions and emission intensities of milk production with the aim of assessing whether the sector's performance is consistent with the global reduction needed to realize the Paris Agreement aspirations. These emission trends are analyzed using FAO's Global Livestock Environmental Assessment model (GLEAM); a spatially explicit biophysical model that estimates the impact of the livestock sector on emissions using a life cycle assessment (LCA) approach.

The objective of this work is two-fold:

- First, it seeks to assess the performance of the dairy sector, understand the sector's contribution to global GHG emissions over time and identify emission reduction opportunities that are available to the dairy sector.
- Secondly, to provide information that can support the sector in taking steps towards further addressing emissions from the dairy production as part of its contribution towards the achieving global goals enshrined in the Paris Agreement and 2030 Agenda for Sustainable Development.

[1] FAO. 2011. *Global food losses and food waste – Extent, causes and prevention.* Rome. http://www.fao.org/3/a-i2697e.pdf
[2] IPCC. 2014. *Fifth Assessment Report (AR5) - Summary for policy makers.* https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf
[3] UNFCCC. 2015. *The Paris Agreement.* https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[4] Wilkes, A. 2017. *Measurement, reporting and verification of greenhouse gas emissions from livestock: current practices and opportunities for improvement.* https://cgspace.cgiar.org/bitstream/handle/10568/80890/Livestock%20MRV%20Info%20Note%20May%203%202017.pdf


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2. THE APPROACH

HOW DO WE MEASURE EMISSIONS?

Understanding the contribution of the dairy sector to emissions is a first step towards defining low-carbon pathways. Livestock produce GHG emissions in a number of ways: direct emissions by livestock (from manure and enteric fermentation), and indirect emissions from the production of livestock feed, energy use in fertilizer manufacture, farm operations such as milking, refrigeration, housing, storage and transport, and post-production transportation, processing and retailing.

As part of their international commitments under the Kyoto Agreement, countries are required to report annually on their emissions. The Intergovernmental Panel on Climate Change (IPCC) has defined the guidelines for the reporting of national inventories of GHG emissions. For the agricultural sector, the IPCC defines four groups of activities. For livestock, this comprises of methane emissions from enteric fermentation and methane and nitrous oxide emissions from manure management. Other emissions associated with livestock production are reported elsewhere. For example, in the current accounting procedures, indirect carbon dioxide or nitrous oxide emissions due to production, transport and use of synthetic fertilizer and other production inputs are reported under industry, energy generation and transport sectors. However, the responsibility for resource utilization, and the possible options for mitigation, is a management decision taken at the farm level. It thus reduces the menu of options available to the sector industry to reduce GHG emissions and doesn't provide the right incentives for mitigation to happen.

Furthermore, the IPCC method quantifies GHG emissions using a national sector-based approach. The approach estimates emissions from the production of products within defined national boundaries and emissions from the production of goods exported from a nation, but does not consider emissions from the production of goods imported into a country.

Approaches that can be used to examine the agricultural sector as a whole, evaluate trade-offs between the production of agriculture commodities such as milk and meat are needed in order to evaluate policies and practices designed to reduce the environmental impact of agriculture. One such approach is the life cycle assessment (LCA) that accounts for all GHG emissions associated with the production of a commodity. For livestock, this includes not only the direct emissions from animals but also indirect emissions arising from the production of inputs such as nitrogenous fertilizer and feed, even if the emissions associated with the production of these imported products were generated in other jurisdictions. The LCA approach supports the sector in understanding the source of impacts, identifying areas for improvements and assessing the impacts of best practices on GHG emission. The approach provides a baseline against which to measure improvements over time.

ACCOUNTING FOR EMISSIONS IN THIS STUDY

This study uses the FAO's Global Livestock Environmental Assessment Model (GLEAM)[5], a biophysical model to assess emissions from the dairy cattle sector. The current report provides an assessment of the emissions from the dairy cattle sector for the reference years 2005, 2010 and 2015 analyzing the trends in emissions and emission intensities from milk production. GLEAM 2.0 is a model using a life cycle assessment (LCA) method for the identification of all main emission sources along livestock supply chains; starting from land use and the production of feed through to animal production on farm and finally processing and transportation of products to the retail point.

This study focuses on major GHG emissions up to the farm-gate that make up the bulk of the emissions in livestock systems (Gerber *et al.*, 2013).

The three major GHGs emitted from agri-food systems are covered – namely methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2).

The emission sources considered include:

- (i) on-farm livestock rearing including enteric fermentation, manure deposition by grazing animals, manure management and application of manure to agricultural land;
- (ii) fodder and feed production including application of mineral fertilizer, the cultivation of organic soils, crop residue decomposition and related upstream industrial processes (fertilizer production);
- (iii) on-farm energy consumption related to livestock and feed production and energy consumption for the transport and processing of feed;
- (iv) land use changes (LUC) induced by the production of feed (excluding grassland and grazing); and
- (v) indirect energy related to the construction of animal housing and farm equipment.

Emissions from post-farm gate emissions (transport, processing and distribution to retail) and meat from the dairy sector are excluded.

Emissions are reported as CO_2 equivalent emissions, based on 100-year Global Warming Potential (GWP100) conversion factors. To estimate the impact of climate change, GLEAM 2.0 uses the latest GWP values from IPCC (2014): GWP100 CH_4 = 34 and GWP100 N_2O = 298.

Emission intensities are expressed per kilogram of fat-and-protein corrected milk (FPCM) at the farm gate. Dairy systems generate several saleable products, so the GHG emissions should ideally be allocated across the co-products. Meat from male calves, female calves in excess of replacement requirements, and culled cows is an inevitable and valuable co-product of dairy production. Different allocation methods can be used e.g. mass, biophysical, economic, or system expansion approaches for allocating the total emissions among co-products. This study utilizes a biophysical approach based on protein content to apportion emissions to products (milk and meat).

There are a few caveats to this work. Most importantly, the 2015 analysis of GHG emissions from milk production only considers changes in the dairy herd and milk yield. In the 2015 analysis, it is assumed that production factors such as feed composition, manure management systems are similar to those modeled in 2010. In addition, the analysis does not consider emissions after the farm-gate and emissions associated with the production of meat from the dairy herd. In some regions, beef is closely linked to milk production. The results from this analysis cannot be compared to FAO's previous analysis on GHG emissions because it is based on a revised methodology and dataset captured in the GLEAM 2.0 version.

The objective of this analysis is to assess the GHG contribution of the global dairy sector over time and to better understand where further mitigation potential is for the sector. Whilst the methodology used in this study is scientifically robust, care should be taken if trying to compare these outcomes to individual country or regional studies that may only assess parts of the dairy chain, or have had access to more specific primary data, utilized a smaller sample size or are even reporting for different purposes and as such applying different methodological approaches.

The vital output from this analysis for the dairy sector is the trend over the 10-year period and the knowledge of where to target mitigation actions.

[5] FAO. 2018. *GLEAM Model description*. Rome. http://www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM_2.0_Model_description.pdf

3. TRENDS IN MILK PRODUCTION AND PRODUCTION EFFICIENCY

Almost 666.5 billion kg of milk was produced globally in 2015, 30 percent more than in 2005. Growth in global cow milk production during the decade (2005-2015) averaged 2.8 percent per annum (p.a.). Growth between 2005 and 2010 averaged 2.5 percent p.a., slower than the 3.1 percent p.a. observed during the period 2010-2015. The number of milking cows and milk production per cow (milk yield) also changed. Over the decade, average global milk yield per cow has increased from 2,180 litres in 2005 to 2,514 litres in 2015 (a 15 percent increase) while the number of milking cows increased by 14 percent.

REGIONAL MILK SUPPLIES

Figure 1 illustrates the milk production of 10 regions for 2005, 2010, 2015[6]. Western Europe and North America, (generally considered the traditional dairy cattle regions) in 2015 produced the bulk of milk from the dairy cattle sector; 22 percent and 15 percent, respectively. Despite this, their production shares in global milk production have declined (*Figure 2*). The share of global milk production has increased in other regions such as South Asia, Sub-Saharan Africa (SSA), West Asia and North Africa (WANA) – not surprising since these are currently some of the fastest growing milk-producing regions (*Figure 3*). In East Asia and Central and South America, production shares tended to increase between 2005 and 2010 and decline in 2015. While in the Russian Federation and Eastern Europe, the share declined in 2010, followed by increases in 2015. These shifts ultimately reflect differences in a range of factors across the regions that affect the profitability and productivity of dairy farms. Factors such as varying climate and landscape characteristics, production practices and milk price, etc.

GROWTH IN MILK PRODUCTION

During the decade, highest annual growth in milk production occurred in WANA (4.5 percent p.a.), South Asia (4.0 percent p.a.) and SSA (3.6 percent p.a.). Compared to other regions, in SSA, growth in productivity remains small given that it starts from a very low base. In Oceania, Eastern Europe, Central & South America, and the Russian Federation milk production grew at 3.8, 3.2, 2.9 and 2.3 percent p.a. between 2005 and 2015. Milk production in Western Europe and North America, on the other hand, grew only at 1.5 and 1.6 percent per annum, respectively – which is slower than the 2.8 percent p.a. observed at global level (*Figure 3*).

[6] Regions included in this study: Central & South America (CSA) , East Asia (EA), Eastern Europe (EE), North America (NA), Oceania (O), Russian Federation (RF), South Asia (SA), Sub-Saharan Africa (SSA), West Asia & Northern Africa (WANA) and Western Europe (WE). See **Annex** for countries included in each region.

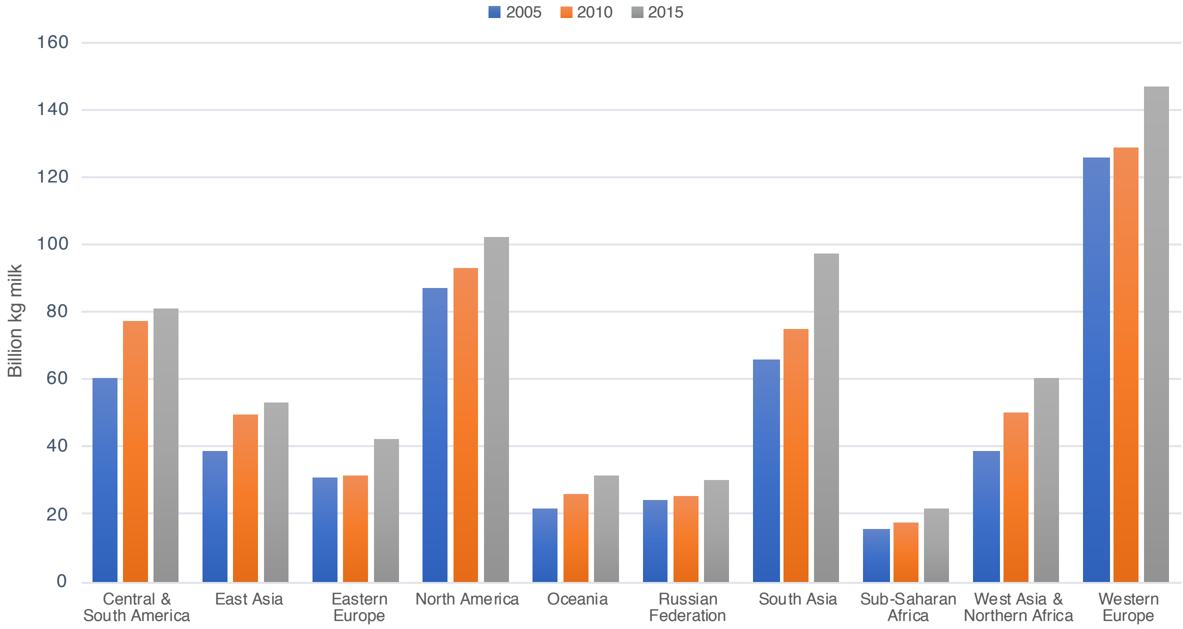


Figure 1: Milk production by region in 2005, 2010 and 2015

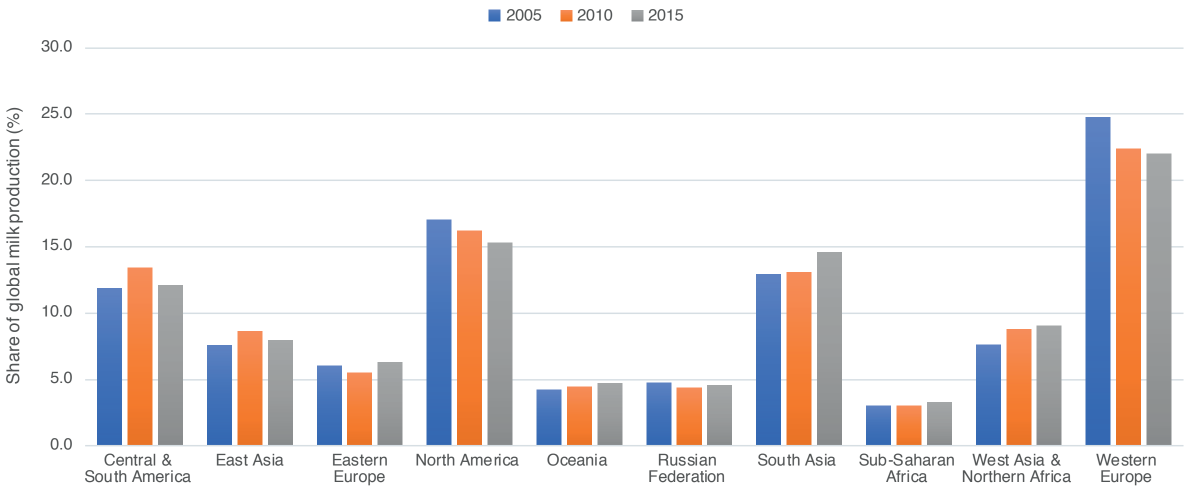


Figure 2: Regional share of global milk production in 2005, 2010 and 2015

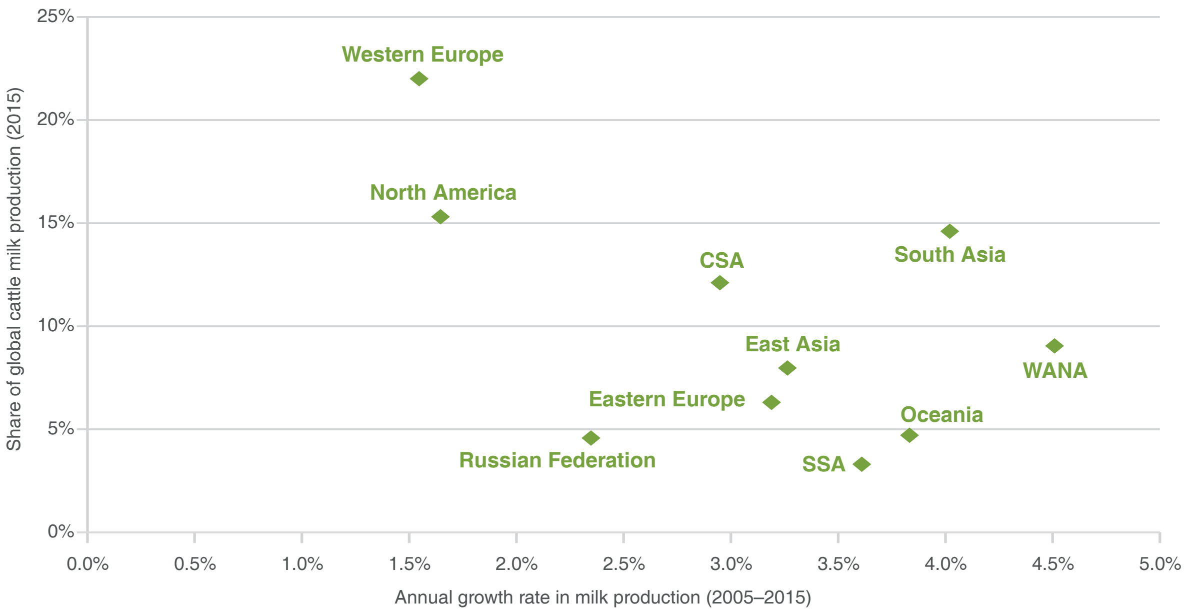


Figure 3: Growth in milk production by region in 2005-2015

SOURCES OF PRODUCTIVITY GROWTH

In the dairy industry, productivity is often considered in terms of milk production relative to a single factor. Commonly used measures include milk production per cow per year (yield), or feed conversion efficiency (milk produced relative to herd feed consumption). While productivity growth has occurred in all regions *(Figure 4)*, this outcome has been achieved in different ways.

The growth in milk production over the decade (2005-2015) has been achieved either through higher yield growth per milking cow, increased number of milking cows or combination of both. Between 2005 and 2015, the global dairy herd[7] increased 11 percent driven mainly by East Asia, SSA, South Asia and CSA where the dairy herd grew by 31, 25, 11 and 10 percent, respectively. In 2015, dairy animals in these four regions accounted for 76 percent of the global dairy cattle herd. A stagnant trend in the dairy herd was observed for Western Europe (+0.1 percent) during this period.

During 2005-2015, growth in regional milk production has been achieved through the following trends (*Figure 5*):

- **Regions with shrinking herds (combined reduction in milking animals and dairy herd) and increases in milk yield:**
  Over the 2005-2015 period, a reduction in the dairy herd was recorded for WANA (-1.4 percent), and Russian Federation (-11.4 percent). At the same time, the number of milking cows also decreased in the Russian Federation (-2.5 percent), and WANA (-4.6 percent). Despite a shrinking number of milking cows and dairy herd, the net effect of the changes in these regions was a significant growth of total milk production, driven largely by changes in milk yield.
  - WANA: increase in milk yield of 4 percent p.a. and a decrease in milking cows of 0.5 percent p.a.
  - Russia Federation: increase in yield of 3.3 percent p.a. and a decrease in milking cows of 0.2 percent p.a.
- **Regions where milk yield expanded faster than the increase in milking cows**:
  In some regions, the surge in milk production has been driven more by the increase in individual cow milk yield than the increase in milking animals.
  - South Asia: increase in yield of 3.6 percent p.a. and an increase in milking cows of 1.5 percent p.a.
  - Eastern Europe: increase in yield of 2.5 percent p.a. and an increase in milking cows of 0.6 percent p.a.
  - Central and South America: increase in yield of 1.6 percent p.a. and an increase in milking cows of 0.8 percent p.a.
  - Western Europe and North America: milk yield grew at 1.0 percent p.a. over the decade, while the number of milking cows increased at 0.3 and 0.4 percent p.a., respectively.
- **Regions where the increase in milking animals expanded faster than milk yield:**
  In East Asia and Oceania and Sub-Saharan Africa much of the gain in productivity growth has been associated with an increasing number of milking cows.
  - Oceania: increase in milking cows of 1.5 percent p.a. and a yield increase of 0.9 percent p.a.
  - East Asia: increase in milking cows of 2.2 percent p.a. and a zero annual growth in milk yield.
  - SSA: increase in milking cows of 3.8 percent p.a. and a slight decrease in yield of 2.5 percent p.a.

These differences in productivity growth rates by region reflect changes in regional industry structure, the extent of uptake of new technologies among farms within a region, and the unique characteristics of each region that affect the types of dairy farming systems.

[7] The dairy herd includes milking cows and replacement stock.

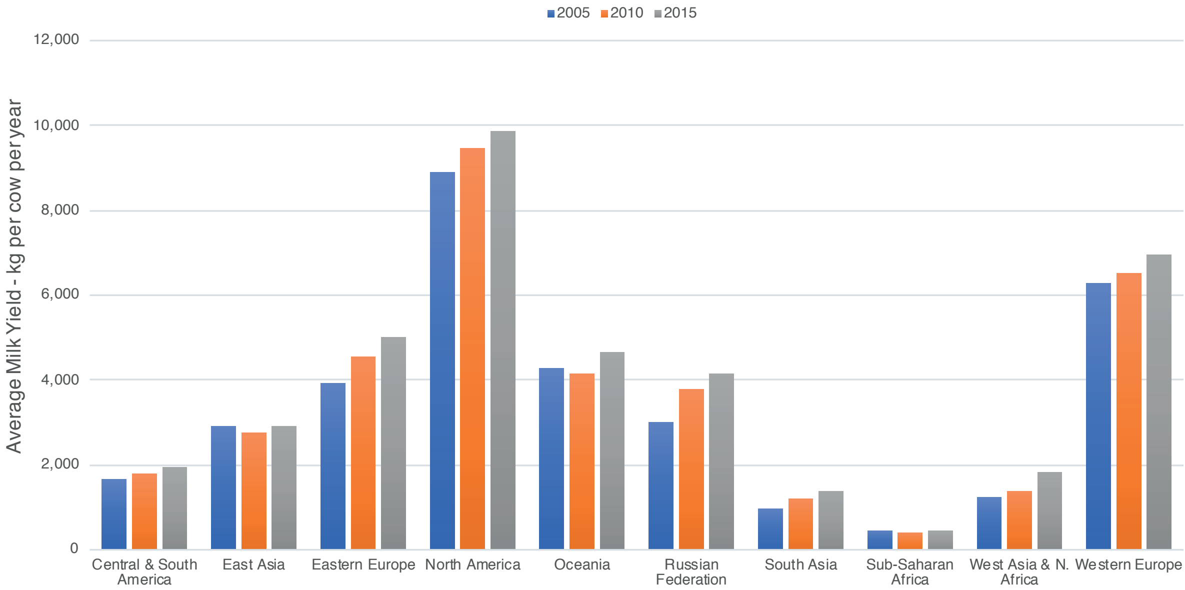


Figure 4: Trends in milk yield by region in 2005, 2010 and 2015

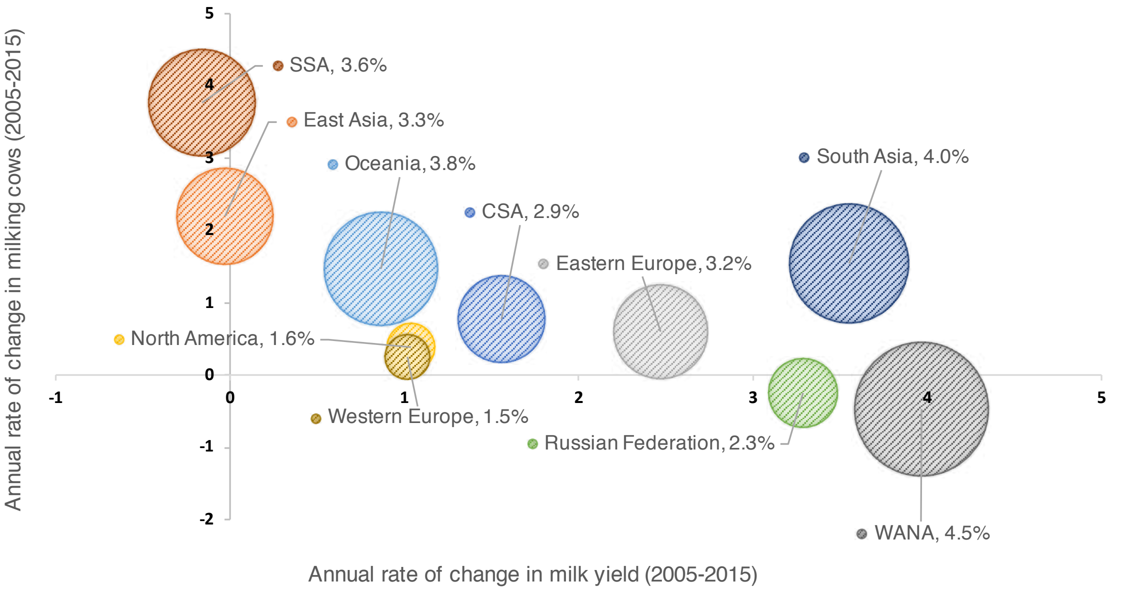


Figure 5: Annual rates of change in milking cows and milk yields (2005-2015, % p.a.)

Note: Size of bubble represents annual growth rate milk production 2005-2015

4. TRENDS IN EMISSIONS FROM THE DAIRY CATTLE SECTOR

Dairy farming is becoming more efficient as a result emissions per unit of product are falling. The emission intensity of milk has declined by about 1 percent per year since 2005. However, this reduction in emission intensity has been more than offset by the increased overall growth in milk output. As a result, absolute emissions are above the 2005 levels.

Dairy production systems are complex sources of greenhouse gas (GHG) emissions, notably of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Using a global life cycle assessment approach, in 2015 the sector is estimated to have emitted 1,711.8 million tonnes of CO_2 equivalent (CO_2-eq.) (*Figure 6*).

Total emissions have increased, by about 18 percent in 2015 relative to 2005 levels, because overall production has grown substantially in response to international demand. In 2015, emissions increased by 256 million tonnes CO_2 eq. (18 percent) above 2005 levels. Of this, 169 and 52 million tonnes CO_2 eq. are related to increase in CH_4 and N_2O emissions, respectively. This is not surprising when one considers the increase in cow numbers and average milk yield growth over the same period. The increased livestock productivity (milk yield per head) achieved since 2005 results in increased individual cow feed intake to meet higher energy demands which in turn results in higher emission rates per cow and increased CH_4 (*Table 1*) and N_2O emissions per animal.

Without gains in productivity (and assuming production grew at the same rate), to deliver the same amount of product, total emissions would have increased by approximately 38 percent rather than 18 percent between 2005 and 2015. As presented in the previous section, these changes in overall production and efficiency have not occurred homogeneously across the regions.

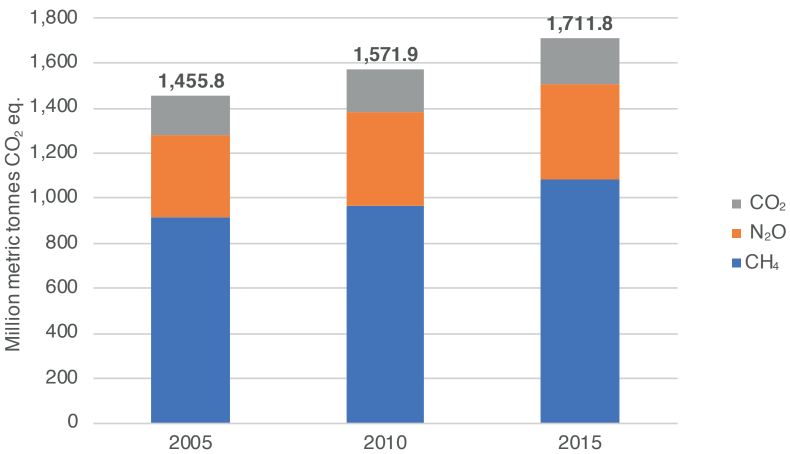


Figure 6: Absolute emissions from dairy cattle sector in 2005, 2010 and 2015 (million metric tonnes, CO_2 eq.)

Region	kg of CH_4 per animal per year		Average milk yield (kg per animal/year)	
	2005	2015	2005	2015
North America	111.0	116.6	8,899	9,867
Russian Federation	64.2	71.8	3,000	4,146
Western Europe	76.3	80.9	6,287	6,957
Eastern Europe	71.2	81.7	3,921	5,005
West Asia & Northern Africa	68.2	72.8	1,240	1,830
East Asia	69.5	69.1	2,915	2,907
Oceania	72.3	81.4	4,274	4,659
South Asia	60.8	62.1	979	1,388
Central & South America	82.2	84.6	1,668	1,947
Sub-Saharan Africa	46.1	46.4	464	457

Table 1: Enteric methane emissions per animal and milk yield

WHERE DO THE EMISSIONS COME FROM?

Dairy farms are a source of GHG emissions, mainly from enteric fermentation (methane) and manure management (methane and nitrous oxide) and feed production, transport and processing (carbon dioxide and nitrous oxide). Methane is produced as a by-product of the digestive process in animals through a microbial fermentation process. The quantity of methane emissions from enteric fermentation is determined by the animal's digestive system, diet and management practices. Livestock manure management produces both CH_4 and N_2O emissions. Methane is produced when manure decomposes under anaerobic conditions. The quantity of manure CH_4 emissions is determined by the type of treatment or storage facility, the ambient climate and the composition of the manure.

Nitrous oxide on dairy farms also comes from nitrogen inputs mostly dung, urine, and nitrogen based fertilizers. N_2O is 298 times more potent than CO_2. A large contribution to N_2O emissions is the excess dietary nitrogen that is excreted in manure and urine. Emissions from fertilizer application occur when nitrogen applied is converted to N_2O either directly through the process of nitrification and denitrification, or indirectly via ammonia gas which is redeposited on to soil and leached.

Carbon dioxide is emitted when various types of fossil fuels are combusted for energy purposes. Energy is used in various processes/activities on the farm e.g. milking, grain drying and field operations, as well as in industrial processes e.g. mineral fertilizer and feed production and in transport and processing of dairy products.

Figure 7 shows the percentage contribution that each source of emissions makes to the overall emissions calculated for 2005 through to 2015. The largest three contributing sources account for the bulk of total emissions from milk production in 2015 and their individual contributions are as follows:

- Methane from enteric fermentation emissions (58.5 percent of total emissions).
- Emissions (CO_2 and N_2O) from feed production, processing and transport (29.4 percent).
- Emissions (CH_4 and N_2O) from manure management (9.5 percent).

These same sources contributed the bulk of emissions in 2005.

Since enteric fermentation contributes more than half the total of emissions, this area represents a potential opportunity for mitigation. Emissions associated with feed production point to a potentially applicable strategy for reducing GHG emission intensity of milk, i.e. improving feed conversion efficiency defined as the amount of feed input for producing a given quantity of milk. Improving feed conversion is an attractive strategy that will not only contribute to reducing emission intensity but also improving farm profitability given that feed costs form a large share of overall farm costs.

Figure 7: Sources of emissions from the global dairy cattle systems in 2005 and 2015

LEGEND:

LUC, emissions from the expansion of cropland for feed production;

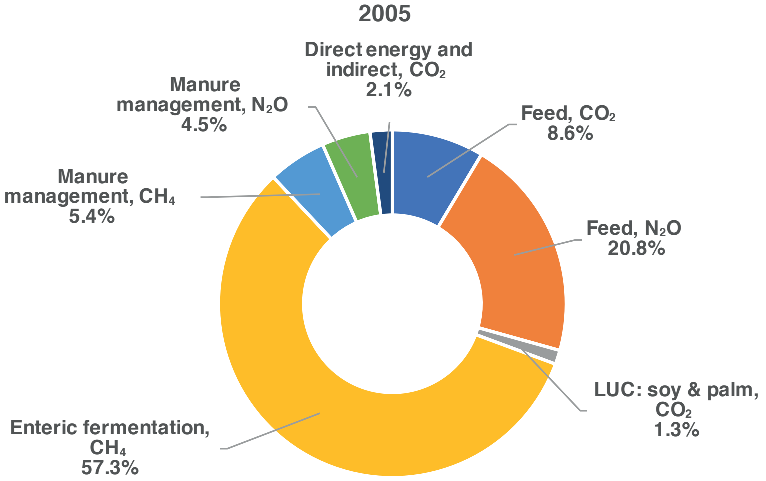
Feed CO_2, emissions from the production, processing and transport of feed;

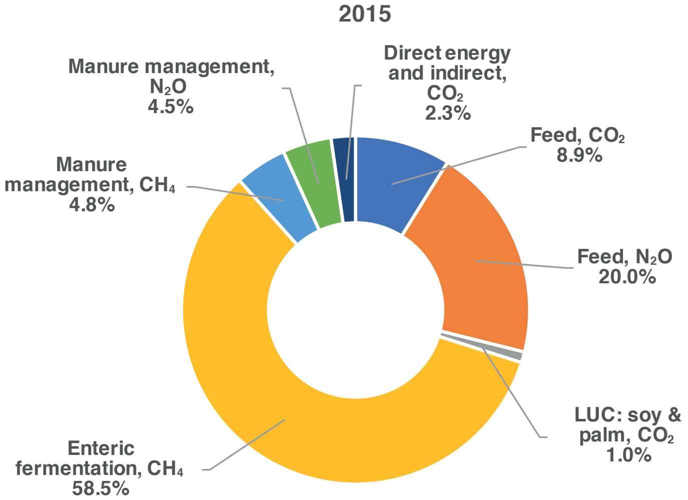
Feed N_2O: direct and indirect emissions from fertilizer application, applied and deposited manure, and decomposition of crop residues;

Direct energy CO_2, emissions from energy use on-farm (milking, heating, ventilation etc.);

Indirect energy CO_2, emissions related to the construction of on-farm buildings and machinery;

Manure management, CH_4 and N_2O emissions from manure storage and processing.





GAINS IN PRODUCTIVITY CAN CONTINUE TO LIMIT THE RISE IN EMISSION INTENSITY

The analysis shows that between 2005 and 2015, emission intensity of milk has decreased from 2.8 to 2.5 kg CO_2 eq. per kg FPCM, an 11 percent decrease over the ten-year period (*Figure 8*).

Emissions per unit of product have decreased, because production has become more efficient. Improved animal genetics and management, combined with better grassland management and feeding practices mean that farmers are adapting resources more efficiently to increase their outputs. For example, the analysis shows that more of the feed consumed by animals is used for production than for animal maintenance; higher milk production (largely driven by increasing milk yields per cow) has contributed towards lowering emission intensities. Higher milk yields imply a shift of the cow's metabolism in favor of milk production and reproduction rather than maintenance, contributing to lower emission intensities. A high-producing dairy cow requires more nutrients per day than a low producing dairy cow; the cow with a daily milk output of 14 kg milk/day uses 47 percent of consumed energy for maintenance whereas a low producing cow (1.4 kg milk/day) uses 75 percent of energy intake for the maintenance. *Figure 9* illustrates the percentage of dietary intake required to meet maintenance energy requirements in milking cows given an average regional milk yield.

The global trend of declining emission intensities is also reflected at regional level (*Figure 10*). Emissions intensities have declined for all regions reflecting continued improvements to on-farm efficiency achieved via improved individual animal productivity. There is however a distinct difference in emission intensities between regions: generally, emission intensities of milk production is lowest in more developed dairy regions (below the global average) while regions like South Asia, SSA and WANA have higher emission intensities (ranging between 4.1 to 6.7 kg CO_2 eq. per kg FPCM in 2015).

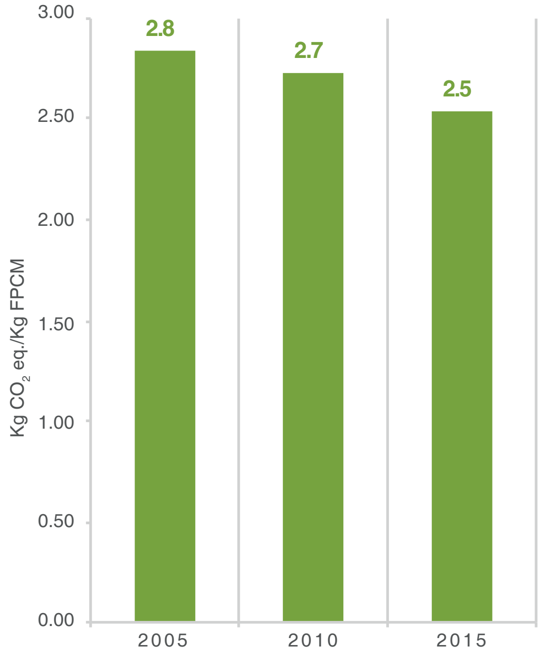


Figure 8: Average emission intensity of milk in 2005, 2010 and 2015

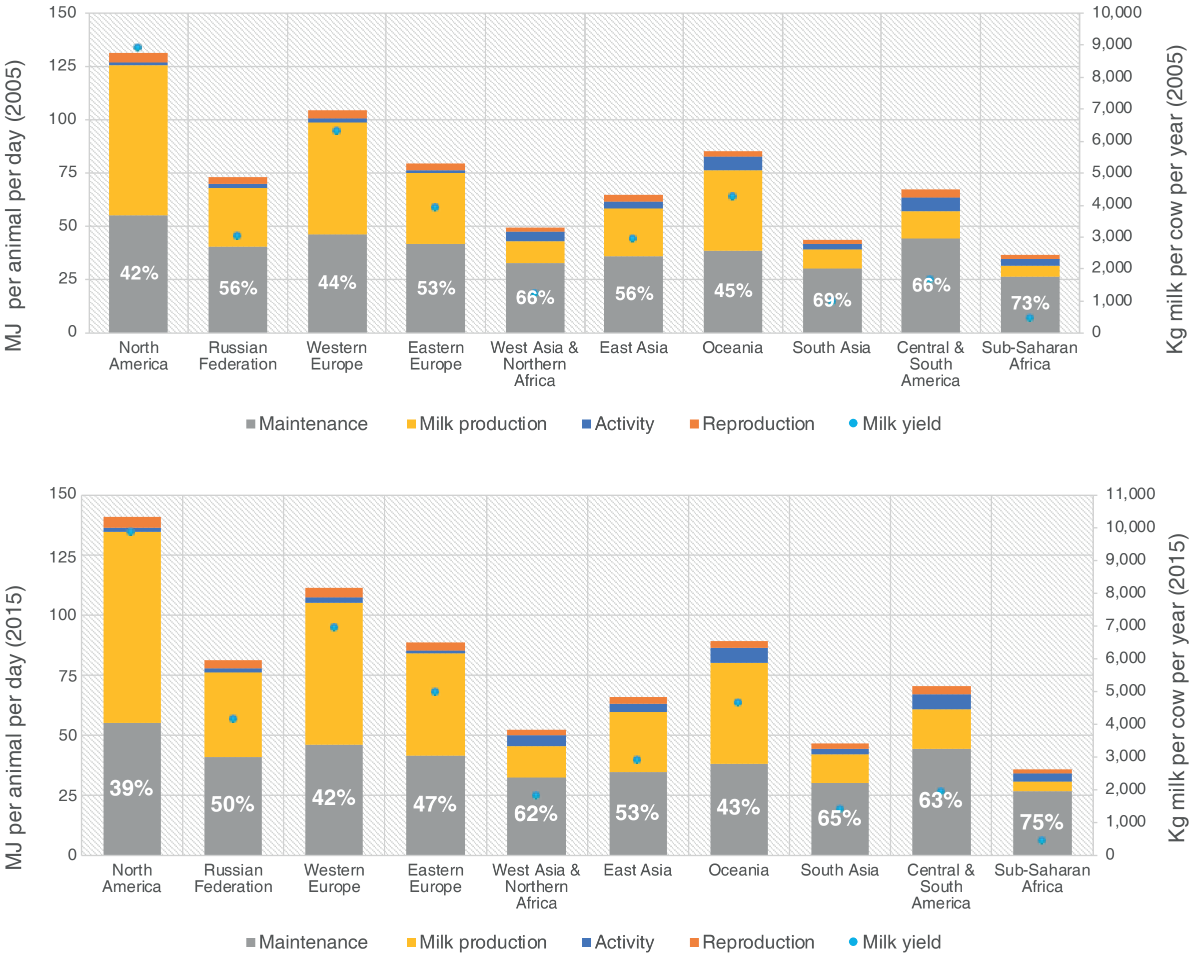


Figure 9: Distribution of feed energy use of milking cows (2005 and 2015)

Note: As a cow eats more and produces more milk, her total energy use, especially milk energy output, increases and the energy needed for maintenance is diluted. This "dilution of maintenance" is the primary reason that efficiency of nutrient use has increased in the dairy industry.

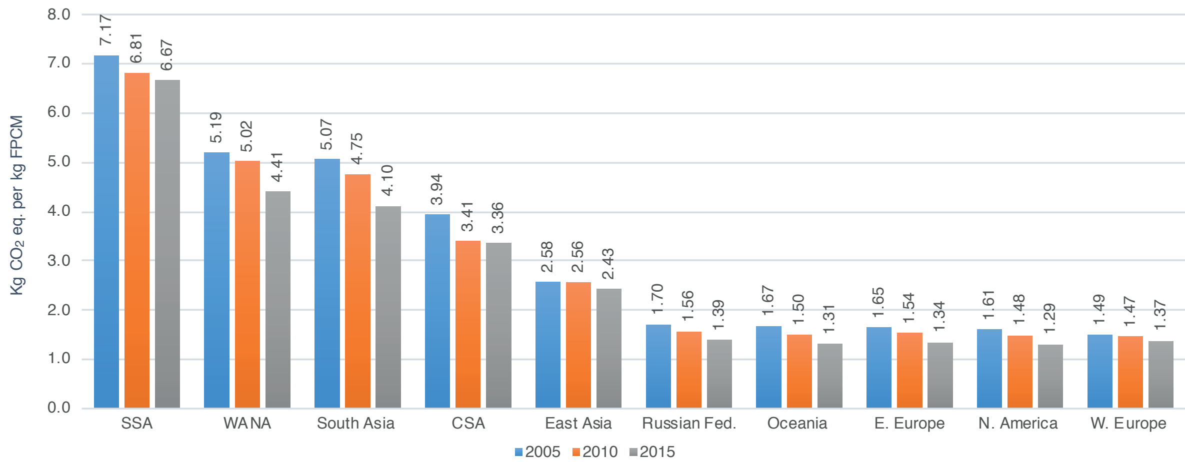


Figure 10: Trends in emission intensity of milk by region (2005, 2010 and 2015)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Within each region, there is a wide variation in emission intensity which is closely related to diversity in the production and management practices (*Figure 11*). The highest variability in emission intensity is observed in the low-and-middle income regions. The existence of a wide variability suggests that opportunities exist for reductions in GHG intensity of milk through the adoption of practices associated improvements in efficiency.

TRENDS IN EFFICIENCY GAINS IN MILK PRODUCTION AND EMISSION INTENSITY

The dairy sector has seen a continued increase in productivity and reductions in emissions intensities driven by efficiency gains in production. These changes are the cumulative benefits resulting from improvements in nutrition, genetics, reproductive performance, disease control, and improved fertilizer practices and enhanced management at herd and animal level. *Figure 12* illustrates how the emission intensity of milk follows a non-linear trend: as milk production increases, the contribution of maintenance emissions decreases relative to production-related emissions. The figure also shows a downward shift of the curve in 2015 which is a reflection of further efficiency gains and lowering of emission intensities. Most of these gains have been achieved in low productivity countries as demonstrated by the gap between the two curves (*Figure 13*). Gains in saved GHG emissions through increased milk yield is marginal for milk production systems with milk yield above 5,000 kg milk per cow per year. The inflection point for this relationship is approximately 1,200 kg FPCM per cow per year; this is the milk yield that should be the minimum performance targeted for sector-wide maximum reduction of intensity globally.

The largest reduction potential for increased milk yield is therefore in systems that yield below 2000 kg FPCM per cow per year. In an extreme case of a very highly productive animal, where almost all emissions arise from the production of milk and animal maintenance becomes negligible, further increasing the amount of production per animal will result in only minor additional reductions in emissions intensity.

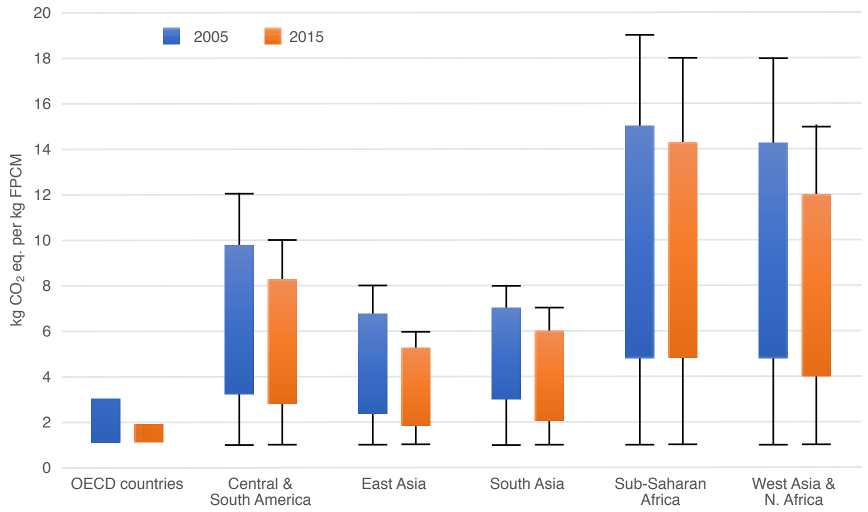

Figure 11. Box plots of the emission intensity of milk (kg of CO_2-equivalent/kg of FPCM)

Note: The shaded area represents 90% of the distribution of the emission intensity of milk within each region

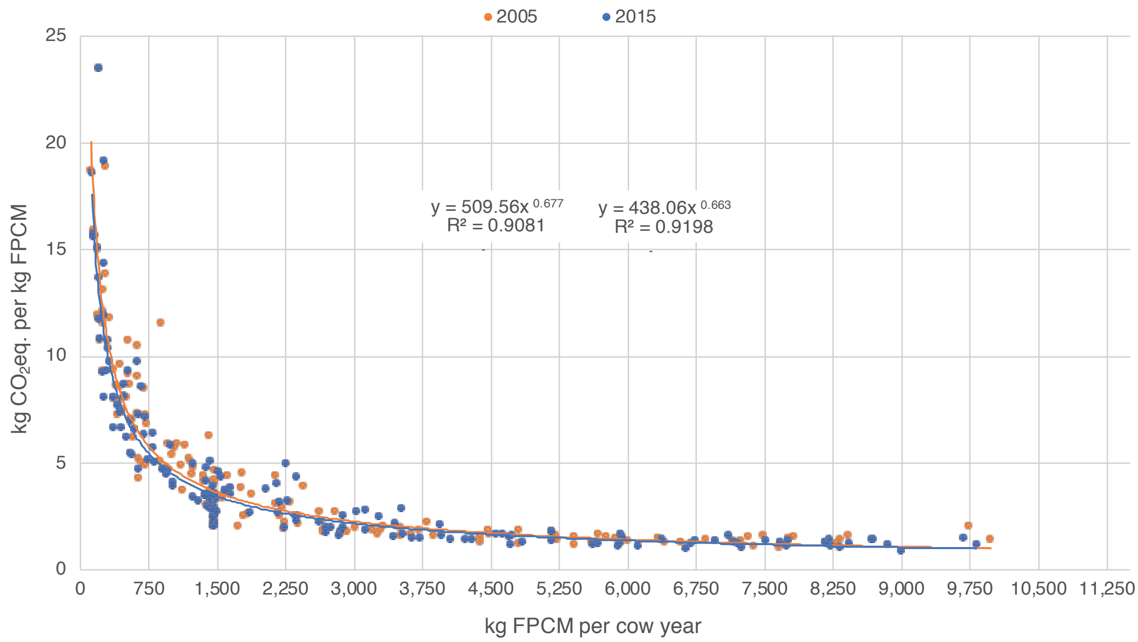

Figure 12: Emission intensity and milk yield

Note: Each dot represents a country. The fitted line clearly indicates an inverse relationship between milk yield per cow and emission intensity, i.e. as milk yield increases there is more milk to spread the emissions over.

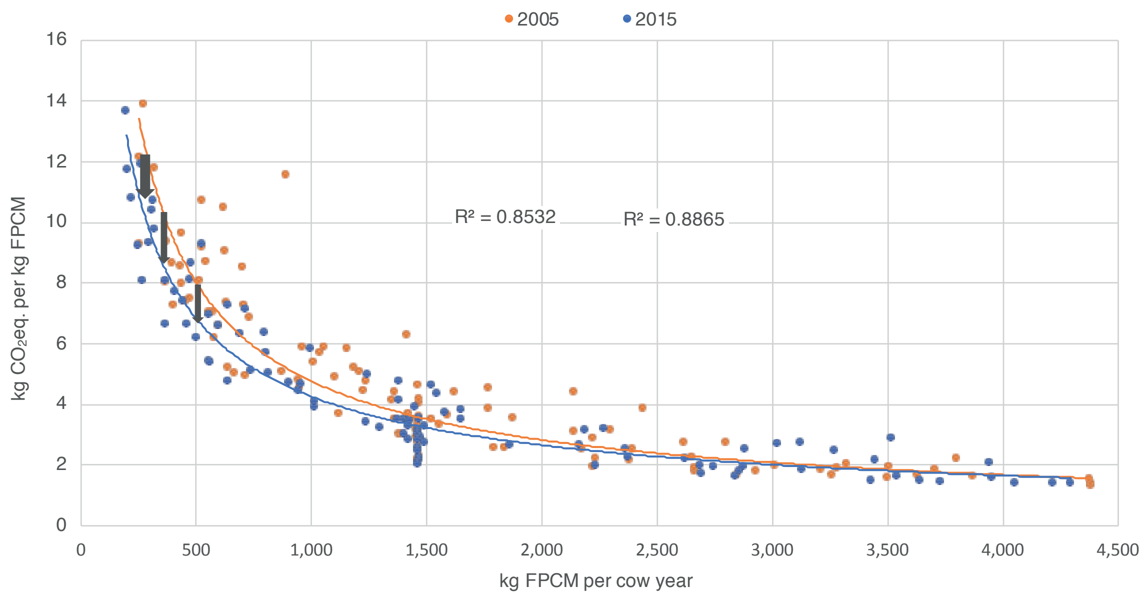

Figure 13: Emission intensity and milk yield (for milk yield levels lower than 4500 kg of milk per cow per year)

Note: Each dot represents a country.

5. HOW CAN THE DAIRY SECTOR PLAY ITS PART?

The dairy sector is already part of the solution to address climate change. However, the sector needs to accelerate its current efforts by: 1) Continuing to improve production efficiency, the sector will also continue to reduce emission intensity of milk. To achieve this, the sector needs to urgently act to realize the existing potentials for GHG emission reduction through technological and farm best practices interventions and solutions; 2) Fostering changes in production practices that protect carbon sinks (grasslands and forest) by targeting drivers linked to degradation of natural ecosystems, agricultural expansion and deforestation; and 3) Reducing its demand for resources by better integrating livestock into the circular bio-economy. This can be achieved by recycling and recovering nutrients and energy from animal waste, or closer integration of livestock with crops and agro-industries at various scales to make use of low value and low-emission biomass.

While there has been a general trend in emission intensity reductions across the regions, reductions in emission intensity have not translated into reductions in absolute emissions. With the exception of the North America, where emission intensity decreased 2.2 percent p.a. while milk production increased by 2.1 percent since 2005 and absolute emissions decreased by 5 percent. The other regions all recorded increases in absolute emissions *(Figure 14)*. For reductions in absolute emissions to occur, the rate at which milk production increases has to be lower than the rate at which emission intensity decreases. Increasing animal productivity usually increases emissions per cow (due to higher feed intake), thus reductions are only achieved if product output is capped.

Earlier sections have described the high variability in emission intensity at global and regional level, highlighting a wide gap between producers. This gap provides room to mitigate emissions within existing systems. *Figure 15 a and b* illustrate the gains that have been achieved in narrowing the emission intensity gap between 2005 and 2015 for two regions. The figures show that narrowing the gap between producers will lower the average emission intensity by bringing the emission intensity of the majority closer to the most efficient. In this context, the dairy sector can positively address climate change in a number of ways. This includes reducing emissions through the adoption of cost effective mitigation measures. However, the mitigation potential of agriculture and food production is challenging compared to other economic sectors. This is because emissions from the agri-food sector stem from biological processes.

A particular challenge in the transfer of technologies and best practices to farmers is the diversity of the production systems, as well as the diversity of the physical environments in which farmers operate – exemplified by the wide distribution in emission intensity observed.

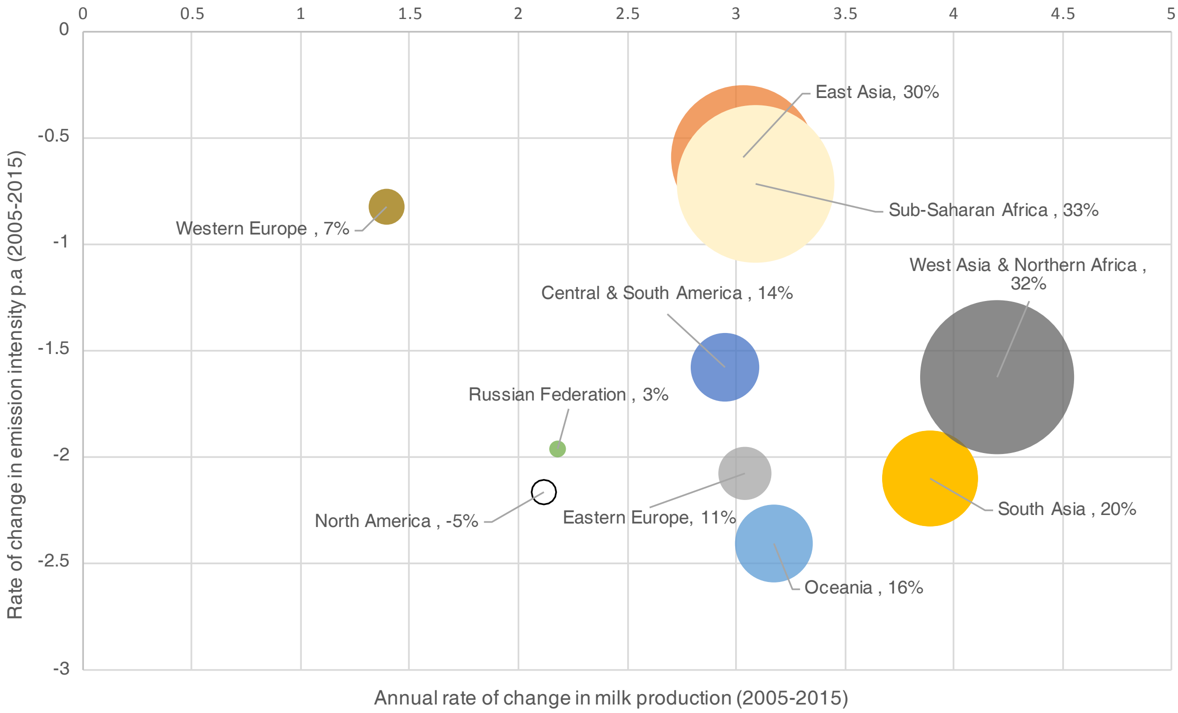

Figure 14: Trends in emission intensity and production by region (%)

Note: Size of bubble represents the percentage change in absolute emissions (2005-2015).

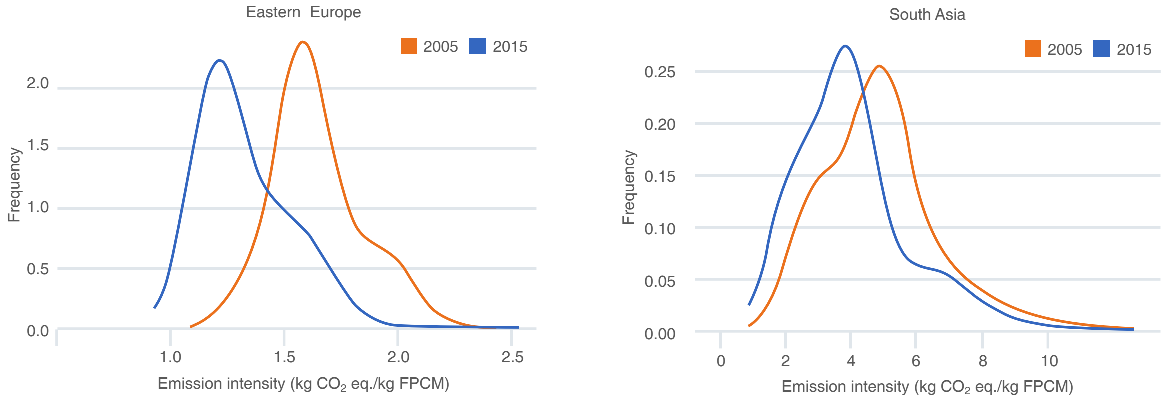

Figure 15 (a, b): Illustration of emission intensity gap in 2005 and 2015 for Eastern Europe and South Asia

Box 1

OPTIONS FOR REDUCING GHG EMISSIONS FROM THE DAIRY SECTOR

The mitigation options outlined below are consistent with improving the efficiency and profitability of the dairy farm. Enhancing animal productivity has several dimensions including feeding, reproduction, health, genetics and overall management of the animal operation. In many parts of the world, particularly in low-and-middle income regions, the single most effective GHG mitigation strategy is to increase animal productivity. Adopting these practices and technologies could significantly reduce the emission intensity of milk.

FEED AND FEEDING MANAGEMENT

- Increase feed efficiency by optimizing the energy and protein content in feed.
- Use of precision feeding techniques to match animal requirements with dietary nutrient supply.
- Use more locally produced feed and source low-emissions feeds such as by-products.
- Store more carbon in the soil by means of better grassland management.

MANURE MANAGEMENT

- Improve manure collection, storage and utilization.
- By using cow manure in biogas systems it is possible to: reduce emissions of GHGs associated with the storage of manure; improve the quality of fertilizer and replace fossil energy sources
- A switch from raw to composted manures can greatly reduce emissions.

FERTILIZER MANAGEMENT (MANURE AND COMMERCIAL FERTILIZER)

- Optimize consumption relative to need.
- Lower manure application rates and the incorporation of manure into soils can reduce emissions while maintaining farm productivity.
- Use commercial fertilizer produced in an environmentally friendly way with a low carbon footprint.
- Spread fertilizer at the optimum time and with the best technology.

ENERGY USE AT THE FARM

- Reduce fossil fuel energy use (e.g. electricity and diesel).
- Increase the use of sustainable energy, e.g. wind energy and biofuel to replace fossil energy sources.

ANIMAL HEALTH AND HUSBANDRY

- Management of herd structures to reduce the number of non-productive animals through improved animal and herd fertility and reproduction is an effective approach to reduce emissions per unit of milk and increase dairy profitability.
- Reducing the prevalence of diseases and parasites would generally reduce emissions intensity as healthier animals are more productive, and thus produce lower emissions per unit of output.
- Improving the genetic potential of animals through planned cross-breeding or selection within breeds, and achieving this genetic potential through proper nutrition.

WHAT PATHWAYS ARE AVAILABLE TO NARROW THE GAP AND LIMIT GROWTH IN EMISSIONS?

Dairy farms are highly variable in terms of landscape, land use, soil characteristics, and farm management practices. They are particularly complex systems with multiple interacting components, and determining the best approaches to reduce GHG emissions will depend on the specific local conditions and objectives of each individual farm including farmer skills and knowledge. There is however considerable scope for reducing emissions and creating off-sets.

The inherent complexity of the sector coupled with the unique challenges of climate change, suggests that it is undesirable to rely and focus on a single pathway to reduce emissions. Reducing the 'emissions gap' through a combination of pathways will also allow the sector to broaden its potential to reduce its impact on global GHG emissions.

Reducing emission intensity through further gains in production efficiency

The best approach to keep reducing emission intensity is for producers to continue to increase their production efficiency as much as possible, and as fast as possible. Production efficiency is minimizing the amount of inputs (e.g. feed) and waste (e.g. GHGs) to produce a given quantity of output. GHG emissions represent inefficiencies in dairy systems. The loss of methane and nitrous oxide into the atmosphere means that energy and nitrogen inputs which could be directed towards production is lost. While some level of emissions is expected, there are many opportunities to reduce GHG emissions, achieve efficiency and ultimately profitability. Feed is the largest single cost to dairy producers and its efficient use will improve net income and reduce potentially negative impacts on the environment. The results for the analysis show how feed conversion efficiency (FCE) across the regions has improved between 2005 and 2015, i.e., with increasing milk productivity per cow relatively lower feed inputs were used to produce 1 kg of FPCM (Figure 16). As a secondary consequence, it also involves a reduction in the amount of greenhouse gases per kg of milk. Over the past decades, farmers have steadily improved feed and nutrition, animal genetics, pasture management, and animal health (Box 1). These options have the potential to provide cumulative gains as is demonstrated by the reduction in emission intensity. In regions where emission intensity is high, future efforts must therefore focus on the promotion of solutions that improve farm profitability performance, while also reducing emission intensity. There are clear relationships between mitigation measures in the area of climate change, food security and other development objectives. These measures need to be maximized in the context of an expanding dairy sector particularly in low-and-medium income regions where emission intensity is high and demand is expected to continue.

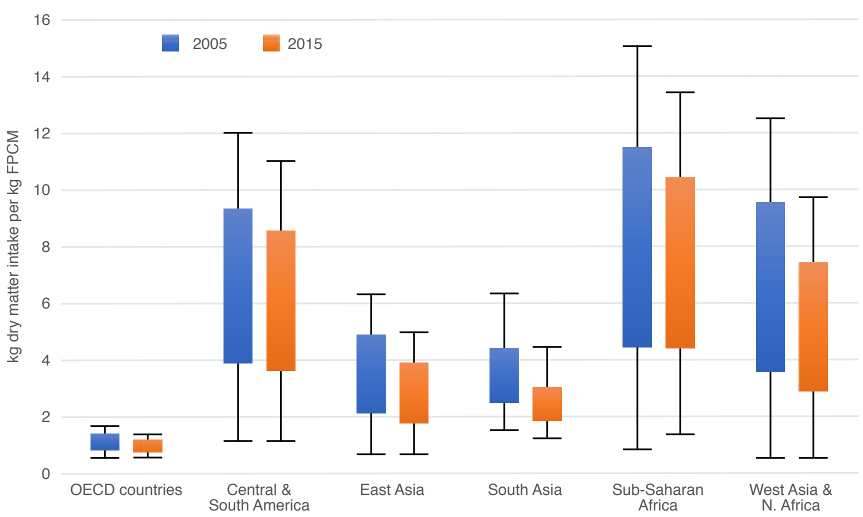

Figure 16. Feed conversion efficiency (FCE) of milking cows

Note: FCE is commonly used to determine how efficiently cows are converting their diet into milk. Put simply, it's a measure of how many kilos of milk are produced by the cow from each kilo of dry matter consumed. Making improvements in FCE will almost always be profitable as it means getting more milk per unit of dry matter fed or alternatively, the same amount of milk could be achieved by feeding lesser amounts of feed.

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Reducing the growth in absolute emissions

As the emissions intensity gap is increasingly narrowed, it will become progressively more difficult to find further solutions and gains in efficiency, unless avant-garde cost-effective scientific breakthroughs (such as methane inhibitors, methane vaccine or lower methane-emitting animals) change the fundamentals of ruminant production.

The scope to make large reductions in the total emissions from the dairy sector without compromising output is limited. Reducing absolute emissions will require a combination of constraining production (appreciating that this would be challenging with increasing consumer demand) and achieving significant breakthroughs in developing new mitigation technologies and strategies. Some solutions to address the dilemma of increasing emissions is for the sector to focus on enhancing and maintaining carbon storage and identifying key strategies to narrow the circularity gap in the sector.

Increasing the quantity of carbon stored in agricultural soils has the potential to offset emissions of GHGs to the atmosphere. Globally, grasslands are estimated to contain 343 tonnes of carbon, nearly 50 percent more than is stored in forests (FAO, 2010)[8]. In practice, enhancing natural sinks over the long run will require tackling the drivers of the degradation or destruction of these ecosystems at all scales. Encouraging more sustainable farming practices and ensuring the conservation of grasslands and forests would most effectively address the twin challenges of deforestation and soil degradation, enabling better carbon storage overall. However, realizing this mitigation potential is technically challenging. The lack of methods and data to account for soil carbon stock changes is an important barrier. This challenge is further compounded by the ecological uncertainties, both on the permanence of these carbon stocks, the complex links between nitrogen and carbon cycles, the risks of non-permanence due to reversal in land use or changes in practices, and regarding the exact impact of climate change on carbon sequestration potential. The potential for carbon sequestration and techniques for achieving it are country/region specific, and differ across soil types, management practices and climate.

The application of circular strategies ensures that less CO_2 is emitted. This can be done by reducing food losses and waste along the supply chain, by improving waste management, or by making optimum use of residue streams. FAO (2011) found that in low-income countries, on average, loss of milk and dairy products during post-harvest handling and storage, as well as during distribution and retail, is relatively high at 7 and 9 percent, respectively. Access to cooling is a particular factor at play here. In sub-Saharan Africa, losses during post-harvest handling and storage was the highest at almost 11 percent. Losses in production are also significant in medium-and high-income countries since disease in dairy cows (mostly mastitis infections) causes approximately 3 to 4 percent decrease in milk yield. However, in high-income countries, waste at the consumption level makes

[8] FAO. 2010. *Challenges and opportunities for carbon sequestration in grassland systems.* Rome. 67pp. http://www.fao.org/docrep/012/i1399e/i1399e.pdf

up the largest proportion of total loss and waste. Circularity may be achieved by managing flows of biomass, nutrients and energy at various scales: within farms, at landscape/regional level, within the food system, and at global scale.

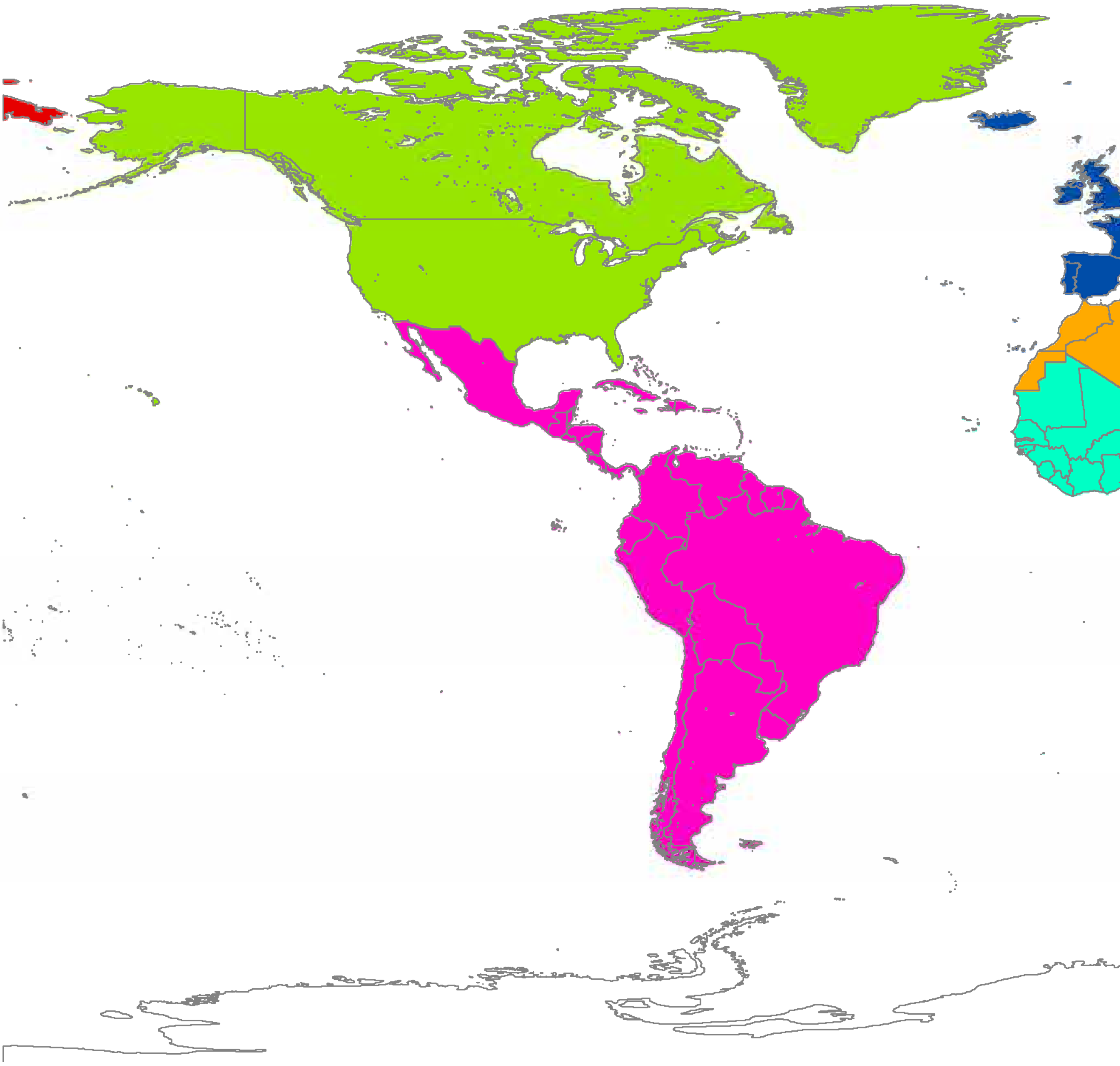
High potential - if enabling environment is implemented

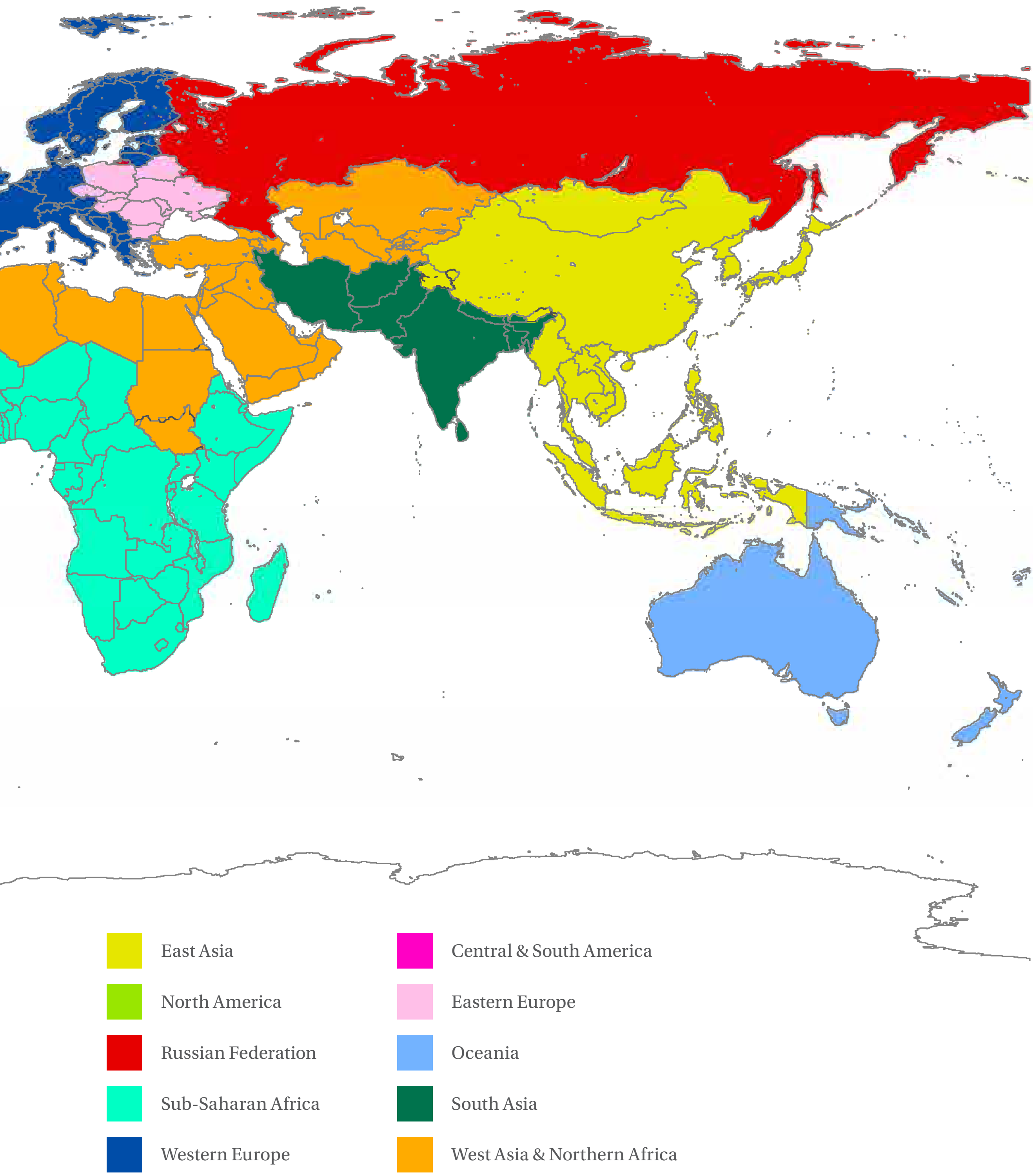
Reducing emissions will depend on a combination of innovative technology and farmers adopting existing best practices. Farm management practices that lower emissions, including some that improve productivity, are known and available. Yet, progress in reducing emissions is affected by the diversity in dairy production systems. Identifying ways to accelerate the rate of progress and overall results needs consideration. Addressing the underlying causes for slow adoption of practices and technologies is vital.

The wide spread adoption of mitigation measures will require significant investment in research and knowledge transfer. Research on climate change mitigation and uptake of more carbon efficient management practices are interlinked. Technology and knowledge transfer efforts must focus on narrowing the spread in emission intensities and bringing the least efficient farmers closer to the most efficient. On the other hand, research on novel GHG mitigation reduction technologies will be important in further reducing emission intensity of farms that are already carbon efficient. However, even if technological breakthroughs occur, it may still take many years for a majority of farmers to adopt them. Both support and incentives will be required to accelerate the adoption of viable new technologies.

Unlocking the potential of the dairy sector requires concerted action by all stakeholders to invest in the sector, support and undertake research, promote innovation and provide incentives to accelerate the translation and implementation of low-carbon efficient technologies and practices. These actions will need to take into account the diversity of the sector and the people that depend on it.

ANNEX

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