Livestock and climate change: Animal Change project summary and key policy challenges

ANIMAL CHANGE

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ANIMAL CHANGE, 2015

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Preparation

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Key messages

AnimalChange has constituted a unique opportunity to concentrate scientific effort on the livestock and climate change nexus and confront outcomes with policy makers and stakeholders.

AnimalChange confirmed the key role livestock can potentially play in mitigating climate change through the development of more productive and resilient – climate smart – food systems.

The project revealed that, in the short term, the European livestock sector can make a limited contribution to EU GHG emission reduction efforts, by curbing overall direct emission intensity by about 15 to 20 percent between 2005 and 2025. Production systems are already relatively efficient and marginal adjustments such as feed supplementation, biogas and energy use efficiency measures can only generate limited mitigation gains.

The short-term mitigation potential is estimated to be substantially greater outside the European Union, with a conceivable reduction of emission intensities of one-third, as well as greater efficiency gains (e.g. through feed balancing and animal health improvements). Mitigation potential is also greater in the European Union over the long term, leading to a 30 to 50 percent reduction by 2050, as the livestock system transforms and taps into new technologies and practices, such as legume introduction in grasslands, geographical relocation, or transformation of grass-protein in bio-refineries.

Efforts to address climate change in the EU livestock sector are being made, especially through research and private sector-led gains in efficiency. These should be strengthened and complemented with targeted public policies to enhance livestock sector's contribution to reducing GHG emissions within agriculture and within the Effort Sharing –mechanism to achieve economy-wide mitigation objective set by the European Union as part of the "20-20-20" targets of its climate and energy package.

In the short term, adaptation efforts in the European Union may focus on extreme weather events and emerging diseases. Over the longer term, as average temperatures, rainfall and CO2 concentration in the atmosphere evolve and impact grass and crop yields, geographical distribution of livestock and feeding strategies will also need to evolve.

The project revealed potential synergies in mitigation and adaptation (e.g. legume introduction in pasture), but also identified substantial economic and social risks arising from allowing producers and consumers to carry the entire adaptation burden. More research and policy work is therefore needed in the area of risk analysis as well as technical and institutional management of climatic risk.

Pursuing mitigation and adaptation objectives may amplify the existing dichotomy between industrialized and grass-based production systems and accelerate consolidation trends in the sector. Project findings urge public policies and multi-stakeholder initiatives to address these issues and prevent negative economic, social and equity outcomes.

The project calls for the following efforts to help promote the transition to a climate smart livestock sector:

- Awareness raising, information and technology transfer, which are still primary drivers of efficiency gains and adaptation
- Research in the areas of:
  - Farm and system-level modelling integrating biophysical processes, economics and behavioral barriers to mitigation and adaptation
  - Piloting of integrated mitigation and adaptation packages
  - Soil carbon sequestration practices, including assessing its potential and developing monitoring methods

KEY MESSAGES: OPTIONS AND NEEDS FOR CLIMATE SMART LIVESTOCK DEVELOPMENT

<table>
<tr><th></th><th>Short term</th><th></th><th>Longer term</th></tr>
<tr><td rowspan="2">EU</td><td>Options
Technology and practice fixes to improve efficiency – 15% to 20% reduction in emission intensity (2005–2025)
Design management plans for extreme weather events
Control of emerging animal diseases</td><td rowspan="4">Global</td><td rowspan="2">Options
30% to 50% reduction in emission intensity (2005–2050) and increased resilience through:
Re-carbonation of pasture and agricultural soils
Changes in spatial distribution of production
Agroforestry
Biochemistry and protein extraction from grass
Improve and/or reduce intensive production based on ruminant species
Improve resilience of grasslands (legume introduction)
Transformation of feeding strategies among mixed and industrial systems to minimize risks of shortages
Control of emerging animal diseases</td></tr>
<tr><td>Requirements
Awareness raising
Incentives: price premiums, energy prices, subsidies for clean technology
Monitoring and reporting methods and data</td></tr>
<tr><td rowspan="2">Non-OECD countries</td><td>Options
Feeding, health and husbandry improvement – 30% to 40% reduction in emission intensity (2005–2025)
Water management (for livestock and irrigation)</td><td rowspan="2">Requirements
Functioning markets
Realistic emission reduction ambitions for agriculture/livestock
Incentive: offset market for agriculture/livestock
Monitoring and reporting methods and data for soil carbon
Investment</td></tr>
<tr><td>Requirements
Awareness raising
Piloting and demonstration of workable and profitable technical packages
Support to investment and insurance
Secure land and water access rights
Secure mobility (drylands)</td></tr>
</table>

- GHG emission accounting and reporting methods
- Coordination of mitigation objectives at supply chain and national levels
- Public policies providing effective incentives (e.g. NAMAs, development assistance, carbon markets)
- Multi-stakeholder engagement towards continuous improvement of mitigation and adaptation performance.

1. Livestock and climate change

Climate change is probably the most serious environmental challenge facing humanity and threatening the well-being of future generations. Tackling climate change has now become extremely urgent with little time remaining to achieve the necessary climate targets (Stocker, 2013). Moreover, delays in global emission reduction increase the efforts needed to achieve stabilization within tolerable levels. At present, the impacts of climate change on agri-food systems will likely be costly but "manageable" in the years leading up to 2050; however, if no action is taken the following period from 2050 to 2080 will be much more challenging (Nelson *et al.*, 2010). The urgent need to reduce greenhouse gas (GHG) emissions and adapt to climate change constitutes an unprecedented challenge for the international community, but one that can be addressed with the right policies. Governments must support innovation and investment to reduce emissions, improve resilience and increase productivity, while accounting for all emissions along the supply chain.

Food security remains an issue for about 805 million people or about 11.3 percent of the global population (FAO, IFAD and WFD, 2014), most of whom are located in least developed countries. For these people, livestock play a critical role in improving food security, supplying protein and micro-nutrients, contributing to agriculture productivity and providing income opportunities. However, livestock products are also among the frequently over-consumed food items[1] causing obesity and associated health issues among about approximately 1 billion people. These demands on the sector are estimated to drive a production increase of about 70 percent over the next four decades, especially in developing countries and among intensified production systems (Alexandratos and Bruinsma, 2012).

Livestock impact climate change. The livestock sector is estimated to contribute a significant share of global GHG emissions, accounting for approximately two-thirds of direct agricultural emissions (FAOSTAT, 2015) and about 14.5 percent of total human-induced emissions when supply chains are considered (Gerber *et al.*, 2013). Box 1 discusses the uncertainties in assessing GHG emissions from livestock supply chains. Feed production and processing and enteric fermentation in ruminants constitute the two main sources of emissions, representing 45 percent and 39 percent of global livestock sector emissions, respectively. Manure storage and processing represent 10 percent of emissions, the remainder being attributable to processing and transportation of animal products. Technologies and practices that help reduce emissions exist but are not widely used due to a number of reasons, such as adoption costs and conflicting objectives and standards (e.g. animal welfare). Those that improve production efficiency at animal and herd levels, including feeding, breeding, health and reproduction management, also have productivity co-benefits (Havlík *et al.* 2014). Globally, GHG emissions from livestock could be reduced by one-third if less efficient producers would adopt the best practices of their peers in the same production system and region (Gerber *et al.*, 2013). In addition, the livestock sector could benefit from carbon-offset programmes that represent potential additional income.

Climate change impacts the livestock sector. Direct impacts on production range from extreme climatic events, droughts and floods, to thermal stress and reduced yields or water availability. Climate change also affects the sector indirectly through productivity and quality of forage and animal diseases, modifying the patterns of affected areas and livestock vulnerability (Box 2). Nearly 2 billion people depend on livestock for a living, including 1 billion poor on <US$1.25/day (FAO, 2009). A large proportion of low-income livestock keepers are highly vulnerable to climate change. Even in EU countries endowed with greater means to adapt, climate

[1] There is no universal recommendation on livestock product intake, but recommended daily protein intake ranges between 50 g and 60 g for adults (EFSA, 2012).

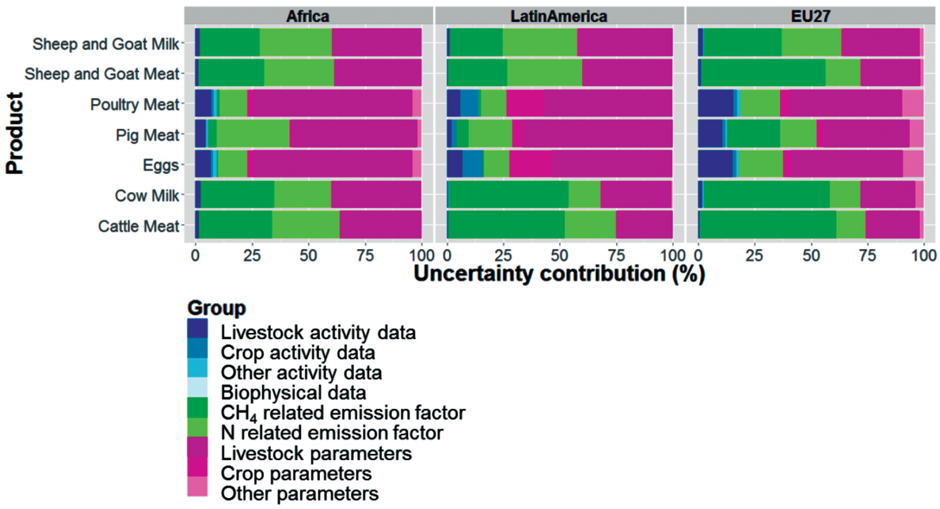
BOX 1. Uncertainties in assessing GHG emissions from livestock supply chains

The assessment of GHG emissions from livestock production is subject to various uncertainties, which have not yet been well quantified at large spatial scales. AnimalChange assessed uncertainties in the relationship between animal production (milk, meat and eggs) and CO_2, CH_4 and N_2O emissions in Africa, the European Union and Latin America using the MITERRA-Global model. The uncertainties in model inputs were derived from time series of statistical data, literature reviews or expert knowledge. These model inputs and parameters were further divided into nine groups based on type of data and affected greenhouse gas. The uncertainty of the final model output and the uncertainty contribution of each group of model inputs were quantified using a Monte Carlo approach, taking into account spatial and cross-correlations.

GHG emissions and their uncertainties were determined per livestock sector, product and emission source category. The uncertainty of total GHG emissions from livestock sectors is higher in Africa and Latin America than in the European Union. The uncertainty of CH_4 emissions is lower than for N_2O and CO_2. The type of data that contribute most to the uncertainty of total GHG emissions for ruminant products are CH_4 emission factors, livestock parameters (e.g. excretion, feed share) and N emission factors (mainly N_2O). For poultry meat, pig meat and eggs, uncertainty in livestock parameters, N emission factors, crop parameters and other emission factors and parameters (e.g. CO_2 emission from fuel use and fertilizer production) contribute most to uncertainty of total GHG emissions (see figure). The reliability of GHG emissions from livestock sectors is relatively high (low uncertainty) at the continental level, but could be low at country level.

The analysis of uncertainties among livestock GHG emissions can be used to guide improvements in national GHG emission inventories, for example, by improving data collection for certain activity data or country-specific emission factors, especially those that contribute most to uncertainty. Improved reliability of estimated GHG emissions, both now and in response to management actions, is likely to encourage actors such as governments, sector representatives and farmers to implement activities to reduce GHG emissions.

Contribution of different groups of data to uncertainty in GHG emissions from livestock supply chains

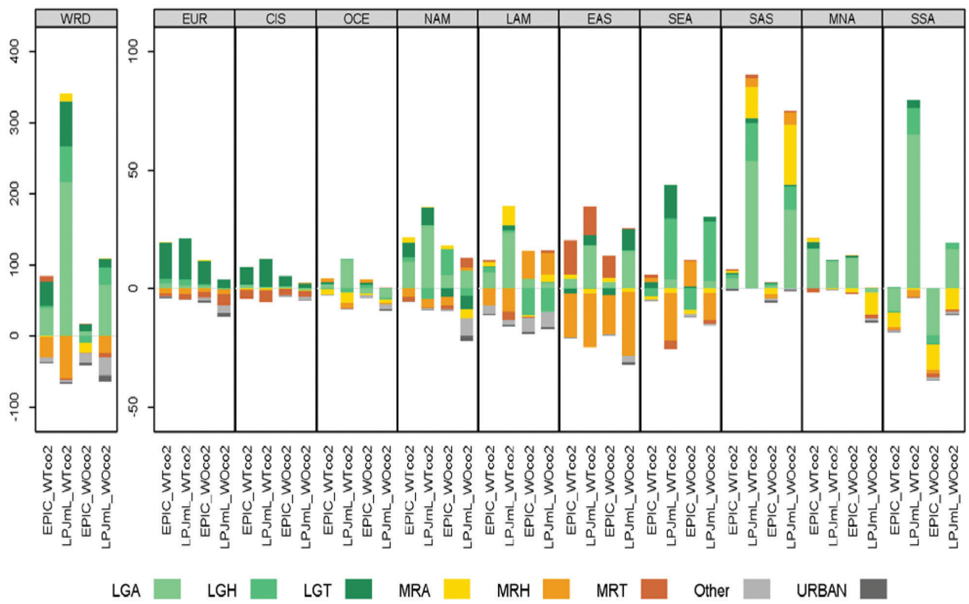


change is likely to have an increasing impact. For example, livestock producers suffered heavily from the heat wave that affected the European Union in 2003, through direct productivity loss of grasslands and increased cereal prices. Fodder deficit varied from 30 percent (Austria, Germany and Spain) to 40 percent (Italy) and up to 60 percent in France, while cereal production across the European Union fell by more than 23 million tonnes, compared to 2002 (GRID, 2004). Intensive operations are also affected, both directly through temperatures and indirectly

BOX 2. Impact of climate change on livestock

Two major observations can be made about the impacts of climate change on crop and grass yields: (i) crop and grass yields are systematically higher when direct CO2 fertilization effects are considered than if they are not accounted for, and (ii) grass yields are more favoured or less negatively affected than crop yields. This difference between crop and grass is a significant determinant of the structural development of livestock production systems structure development. Globally, ruminant herds in grazing systems are projected to be bigger by 2050 than in the absence of climate change, pointing to a potential slow down or even reversal of the current trend towards more intensive mixed systems. However, the structure of production systems still largely depends on climate change impact scenarios. Havlik *et al.* argue that the restructuring of livestock production systems represents a powerful adaptation option; however, the precision of climate change impact projections needs to be narrowed because of the significant risks of maladaptation.

Climate change impact on ruminant numbers across different livestock productions systems by 2050 (million TLUs)



Source: Havlik *et al.*, 2015.

through commodity prices. With intensive dairy and pig systems, heat stress and increased mortality occur at moderate air temperatures, starting above a threshold of ca. 20 °C, especially in conditions of high air humidity. These productivity losses for the European agriculture are yet to be fully quantified and projected into the future, in order to enable the sector to better adapt.

Integrating climate change mitigation and adaptation for livestock is a challenge. To address this, AnimalChange, a project funded by the European Union, brought together researchers from 25 organizations in 13 EU member states and five non-EU countries (Brazil, Kenya, New Zealand, Senegal, South Africa) for a period of four years. The project led to significant technical findings for mitigation and adaptation at animal and farm level. It also produced cost and benefits assessments of interventions and tested scenarios at regional and global level to evaluate policy options. In the first year of the project, AnimalChange established a Policy Committee composed of EC and national governments representatives to communicate research findings to various policy-making arenas. The Committee met once a year and was joined by the Stakeholder Platform, which represents the interests of the livestock sector stakeholders (private sector and NGOs) in the project.

This Executive Committee of AnimalChange developed this report in collaboration with the Policy Committee and the Stakeholder Platform, with contributions from project participants including scientific committees and an ethics advisor. It aims to consolidate the policy-relevant results of the project and propose a vision for climate smart livestock. It presents an assessment of current initiatives followed by a proposal containing potential options over the short and long term. It identifies roles for main stakeholders including the European Commission, national and local governments, private sector and academia. Key results from AnimalChange underpinning the paper are presented in boxes.

2. What is being done?

A number of policy approaches already exist to address climate change with respect to livestock systems, and are being implemented at least partially at different levels (e.g. the consumer, private sector, EU member state or global level; see Table 1). This section does not aim to provide a catalogue of policy instruments, but rather to highlight the main existing initiatives.

2.1 MITIGATION

At global and EU level, significant emphasis is being placed on **Research and Development** to inform negotiation and political processes and prepare for long-term change in livestock systems, by achieving fundamental reductions in emissions and ensuring resilient production growth. One such example is research into "zero methane cows" (see Box 3). Research bodies are also organizing to deliver findings at an international level. Several EU countries are participating in the Global Research Alliance on Agricultural Greenhouse Gases (GRA), one of the main research initiatives at global level, which focuses on the identification and development of technologies and practices to increase food production without increasing emissions. In addition, a dedicated livestock research group is focusing on options to reduce the GHG emission intensity of livestock production systems[2] and increase the quantity of soil carbon stored in grazing lands, with support of a cross-cutting group on soils. At EU level, efforts in research and development will continue as part of the Horizon 2020 programme on sustainable livestock and the European Innovation Partnership on Agricultural Productivity and Sustainability.

Awareness about the contribution of livestock to climate change has grown rapidly among the general public and consumers, fuelled by communication campaigns organized by concerned civil society organizations and extensive media coverage. These campaigns often associate the climate change message with other concerns, such as animal welfare, human health and water resource protection (Laestadius *et al.*, 2013). Rather than focusing on improvement in production practices, they often highlight a need to reduce consumption of animal products.

Campaigns arguing for the reduced consumption of animal products, and meat above all, are particularly visible and generally target OECD countries, with a special focus on Canada, the United Kingdom and the United States. Two broad types of message are put forward: meatless days[3] and reduced portions in favour of a "less but better" approach to meat consumption (Linnea *et al.*, 2014). The impact of such campaigns on public policies is relatively limited because governments are generally reluctant to engage in diet recommendations, but they have the potential to influence consumption patterns.

Consumer concerns also constitute a strong incentive for the **private sector** to address questions of sustainability. The last ten years have seen a rise in private sector initiatives linked to developing responses to sustainability challenges, with the livestock industry playing an increasing role in the development of mitigation strategies. In some cases, the private sector has even taken a leadership role in identifying the environmental impacts of production and related mitigation options. The International Dairy Federation's Common Carbon Footprint Approach for Dairy is one such example (IDF, 2010). National dairy associations have followed suit, for example, in France, Ireland and the United Kingdom.

The meat industry is also engaging progressively in this manner, shown for example by approaches undertaken by the US Cattleman Association and the US National Pork Board. The Beef Carbon project, a collaborative effort between France, Ireland, Italy and Spain, is another example, which aims to present options for farmers to reduce emissions by 15% in 10 years. In

[2] The amount of GHG emissions generated per unit of animal product delivered by the production unit.

[3] For example, "Meatless Mondays" in the United States and Oxfam's "4-a-day" campaign for the replacement of red meat and dairy with vegetables one day a week.

BOX 3. Towards the zero methane cow

Jamie Newbold, Aberystwyth University

Methane is a normal product of ruminal fermentation and represents a pathway for the disposal of metabolic hydrogen produced during microbial metabolism. It has been suggested that rumen function will be disrupted if methane production is inhibited without the provision of alternative hydrogen sinks (McAllister and Newbold, 2008), which implies that methane production is unavoidable in ruminant production systems. However, recent work by AnimalChange and Mitsumori *et al.* (2012) suggest that methane production in sheep, goats and cattle can be significantly decreased with little effect on rumen function and diet digestibility. Indeed, studies on the rumen transcriptome suggest that the methane-inhibited rumen adapts to high hydrogen levels by shifting fermentation to alternative H sinks and direct emissions of H2 from the rumen.

Given that methane emissions seem to be avoidable, attention should focus on the means by which this might be achieved. Progress is being made in understanding the genetic basis of variation in methane emissions between animals (Pinares-Patiño *et al*., 2013), however the greatest progress has been in the areas of diet and dietary additives to mitigate against ruminal methane emissions (Gerber *et al*., 2013), with decreases in excess of 60 percent reported in cattle fed specific dietary additives (Haisan *et al*., 2014). Data from the AnimalChange programme and elsewhere suggest that, in many cases, additives enhance capacity to mitigate against ruminal methane production. On this basis, a combination of approaches might result in a zero methane cow. However, while perhaps technically possible, the zero methane cow presents a number of practical issues:

1. Nutrition: the combination of multiple additives, while potentially possible under experimental conditions, may prove impractical due to difficulties in formulation, including the inevitable dilution of nutritional value as additives account for an increasing share of the diet. Clearly, there is a need for increased research into additives that are effective at low levels of dietary inclusion.
2. Delivery: dietary additives may be applicable to housed ruminants but are far less applicable to extensively raised animals. Significant effort needs to be dedicated to delivery systems for extensively raised animals.
3. Developing a convincing economic model: taken as a whole, current research suggests that measurable production responses to methane mitigation are unlikely to occur. Thus, alternative methods to incentivize the use of what are likely to be expensive additives to decrease ruminal methane production need to be developed.

Ireland, the National Beef Quality Assurance Scheme has incorporated a carbon audit since 2011 to estimate the greenhouse gas emissions generated on participating farms.

Large private companies in the sector have also engaged voluntarily in emission reduction schemes. For example, Fonterra is aiming to reduce emissions intensity along its supply chains by 20 percent by 2020, and Arla has set itself a target of a 25 percent reduction within the same timeframe.

Further down the food chain, **retailers** have also taken important strides in driving improved environmental performance. Walmart's Global Sustainable Agriculture Goals is one such retailer programme that claims substantial progress towards efficient and sustainable livestock supply chains. The Nature Conservancy, a leading conservation organization, Marfrig Group, one of the world's largest food producers, and Walmart Brazil have also announced a sustainability programme targeting beef operations in south-eastern Pará, Brazil. These developments are motivated mostly by changing consumer preferences and the increasing awareness of stakeholders along the livestock supply chain.

All these initiatives increase the need for **harmonized methods and data** quantify emissions along the life cycle of livestock products. To this end, multiple stakeholders developed the Livestock Environmental Assessment and Performance Partnership (LEAP)[4] to produce environmental sustainability metrics, including GHG emissions.

[4] See www.fao.org/partnerships/leap/en/

Governing bodies, both at EU and member state level, have put in place policies that contribute to reduced emission intensities in European livestock farms. The most important policy to date is the Nitrates directive, which has led to increased nutrient efficiency and reduced Nitrous oxide emissions alongside with nitrates reduction. Policies directly or indirectly addressing climate change have also been developed and have contributed to reducing the sector's emissions by 24% in relation to 1990 base year The Effort Sharing Decision for non-Emission Trading Scheme sectors (including agriculture, transport, waste and buildings) sets national emission targets for 2020, expressed as percentage changes from 2005 levels. The average tar- get for the European Union is -10 percent, but national targets range between 20 percent and +20 percent (EC, 2009), for example: Denmark and Ireland (20 percent), the Netherlands and the United Kingdom (16 percent), France and Germany (14 percent), Hungary (+10 percent) and Bulgaria (+20 percent). However, no specific target was set for agriculture, neither at EU nor at country level.

There is also a frequent disconnect between governmental strategies that set to reduce total emissions from a specific country or region and the retailers/industry initiatives that focus on the reduction of emissions intensities along supply chains.[5] There is a need therefore to link these initiatives to maximize the potential for data capture, as well as to ensure that individual farmers are recognized in relation to mitigation of GHG emissions.

The new **Common Agricultural Policy** (CAP) offers a number of instruments to help **find adequate solutions to the challenges** described above. It recognizes that given the pressure on natural resources, agriculture has to improve its environmental performance through more sustainable production methods. Farmers also have to adapt to challenges stemming from climate change, and pursue mitigation and adaptation actions. Sustainable management of natural resources and climate action therefore represents one of the main objectives of the future CAP, with proposals to achieve improved sustainability by combining the complementary effects of various instruments.

The CAP introduces the cross-compliance mechanism, representing the compulsory basic layer of environmental requirements and obligations to be met in order to receive full CAP funding. These obligations include, inter alia, specific rules for the maintenance of soil organic matter.

From 2015 onwards, the CAP has introduced a new layer, the greening. This "green payment" is granted for three practices, namely crop diversification, ecological focus areas and permanent grassland, and accounts for 30 percent of the direct payment budget.

Rural development, or second pillar, will continue to play a pivotal role in achieving the environmental objectives of the CAP and combating climate change. The rural development policy objectives are translated into priorities at the EU level, of which one directly addresses climate change: "Promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in the agriculture, food and forestry sectors". A number of measures, though not specific to climate, are beneficial to climate: agri-environmental measures, support for organic farming, Natura 2000 areas, sustainable forest management, investment aid beneficial for the environment or climate, and – as a basic measure – support for Areas facing Natural Constraints. Member States prepare their rural development programmes (118 for the period 2014-2020) which are adopted by the Commission.

These measures are accompanied by related training measures and other support from the Farm Advisory System, to help farmers implement solutions adapted to their specific situations.

Climate change mitigation and adaptation is a cross-cutting objective in rural development policy (second pillar) and rural development programming shall contribute to the common objectives of the CAP, including climate change mitigation and adaptation, environmental enhancement, and innovation. To this effect, at least 30% of the EU contribution to rural development programmes must be reserved for measures that are beneficial for the environment and climate, e.g. agri-environmental-climate measures, support for organic farming, Natura 2000 areas, sustainable forest management, and support for Areas facing Natural Constraints.

[5] Accounting at supply chain level aggregates emissions from different activities (e.g. including crop production) along supply chains that may run across national boundaries. In contrast, national inventories prepared in the context of the UNFCC account for direct emissions (i.e. enteric methane and manure) that occur within national boundaries.

At a cross-sectoral level, the European Union has agreed that at least 20 percent of the €960 billion allotted for the 2014–2020 period should be spent on climate change-related action. This represents about a threefold increase from the 6-8 percent share in 2007–2013. This increase was achieved by integrating emission mitigation and climate adaptation actions into all major programmes, in particular, regional development, energy, transport, research and innovation, and the CAP. From 2014 onwards, climate-related expenditure from the EU budget is tracked in accordance with specific methodologies to ensure visible and solid mainstreaming and progress towards reaching objectives.

Information about climate change impacts, monitoring of climate events, weather forecasts and early warning systems have also been developed at the EU level to support adaptation to climate change.

Finally, the European Union is also investing in developing regions for climate change mitigation and adaptation. Various initiatives are being launched within the framework or related to the United Nations Convention on Climate Change (UNFCCC), in particular, the Global Research Alliance on Agricultural Greenhouse Gases (GRA), the Global Alliance on Climate Smart Agriculture (GACSA), and the Climate and Clean Air Coalition (CCAC).

2.2 ADAPTATION

Adaptation efforts currently fall mostly on the shoulders of producers and the private sector at large. This includes a range of short-term reactions such as choices of crop or livestock species, and practice shifts in management and farm investments.[6] Farmers are currently bearing the cost of these short-term autonomous adaptation reactions. It should, however, be noted that, compared to other regions, EU farmers are supported by a range of general safety nets and direct payments that indirectly ease adaptation costs. In addition, insurance may also contribute to coping strategies, although at a cost to producers.

The EU Strategy on adaptation to climate change includes research and development on climate change adaptation (Seventh Framework Programme FP7 and new Horizon 2020) and mainstreaming into sectoral policies, including the CAP. The proposed regulations for the CAP 2014–2020 accord adaptation greater prominence with “the sustainable use of natural resources and climate action” cited as a core objective.

A key deliverable of the EU Strategy was the web-based European Climate Adaptation Platform (Climate-ADAPT), launched in March 2012. It incorporates the latest data on adaptation action in the European Union, together with policy support tools, including information on expected climate change in Europe, current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies, and potential adaptation options and tools to support adaptation planning.

National public policies also support farmers through advisory services, information and training. For example, the Scottish Climate Change Adaptation Programme, Climate Ready Scotland, offers skills development programmes to farmers and land managers to increase the adaptive capacity of Scottish farming. In addition, the ClimateXChange centre of expertise, also based in Scotland, is establishing a range of case studies, on-farm demonstration sites and networks to support knowledge transfer.

Finally, emergency funds have been made available to help address the impacts of heat waves, often combined with tax rebates and rescheduled loan payments. For example, in June 2011, the French government allocated a budget estimated at €500 million to supported farmers affected by a severe drought, through land-tax exemption and a one-year delay in loan repayments. In the United States, the IRS grated tax relief to livestock farmers who were forced to destock after the 2014 drought.

[6] Examples include tillage, fertilizer application, crop calendars and grazing dates, irrigation infrastructure, plantation of hedgerows.

TABLE 1. Matrix of main existing policy instruments by type of approach and level of implementation

	Policies/regulations	Research and development	Extension and agricultural support	Financial incentives	Market instruments	Advocacy
Global level	• United Nations Framework Convention on Climate Change (UNFCCC) • Kyoto Protocol • Clean Development Mechanism (CDM) • Green Climate fund	• Global Research Alliance (GRA) • Livestock Environmental Assessment and Performance (LEAP) • Global Methane Initiative (GMI) • Agricultural Model Intercomparison and Improvement Project (AgMIP) • Inter-Sectoral Impact Model Intercomparison Project (ISI–MIP) • Research Program on Climate Change, Agriculture and Food Security (CCAFS)	• Climate and Clean Air Coalition (CCAC)	• Green Carbon Fund (GCF) • Global Environment Facility (GEF)		
EU and member states	• EU 2020 package and 2030 framework • Effort Sharing Decision for non-ETS sectors, including agriculture • National targets for agriculture • National policies for mitigation and adaptations	• AnimalChange • Horizon 2020 • Agriculture, Climate Change and Food Security, Joined Programming Initiative (FACCE JPI) • European Innovation Partnership (EIP) • National funding for research	• Climate-ADAPT • Information, monitoring, forecasts, early warning • National funding for knowledge transfer • Investments in non-OECD countries	• CAP greening and 2d pillar measures	• Voluntary labelling	
Private sector (producers, processors and retail sector)	• Farm-level quality assurance schemes including carbon audits • Farm-level GHG mitigation programmes • Sectoral road maps in the dairy sector • Corporate carbon foot printing	• R&D and innovation	• Voluntary schemes and knowledge extension for efficiency gains	• Risk insurance		• Corporate communication and awareness raising
NGOs and consumers		• Research grants				• Consumer campaigns, dietary choices • Pressure on the private sector

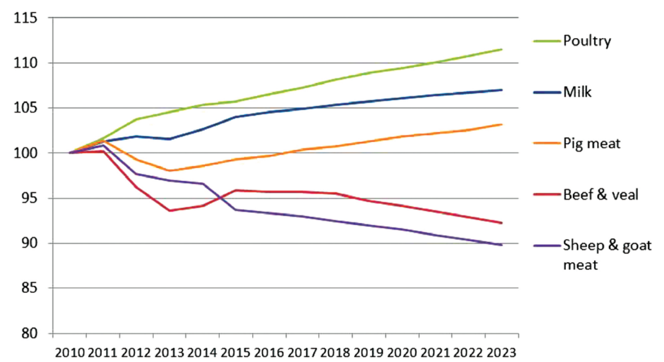
3. Is it enough?

3.1 LIVESTOCK SECTOR TRENDS IN THE EUROPEAN UNION UNDER BUSINESS AS USUAL

The future of livestock emissions will depend on the combined effect of emission intensity and production trends. Under a business as usual outlook, global average emission intensity of livestock products is expected to decrease slightly as more efficient practices are adopted (Capper, Cady and Bauman, 2009) and the majority of growth takes place in commodities with relatively low emission intensities. **On a global scale, it is therefore unlikely that endogenous emission intensity reductions will fully offset the increase in emissions related to growth in the livestock sector.** It is possible, however, that reductions in emission intensity may be able to fully offset trends in output, especially in regions with low expected production growth (Schulte and Donnellan, 2012). This is particularly true in the European Union where a reduction in ruminant meat is expected (Figure 1).

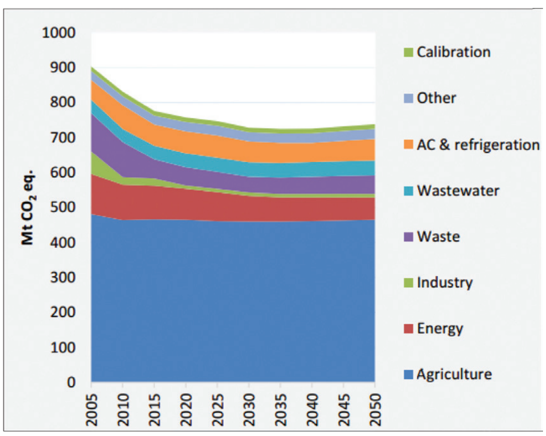
While emissions reductions are expected in the industry and energy sectors, emissions from agriculture are projected to remain almost stable by 2050, as shown by the European Commission's projections of non-CO_2 emissions (Figure 2).

FIGURE 1. Livestock production projections in EU-28 (index 100 in 2010)



Source: European Commission, DG Agri.

FIGURE 2. Non-CO_2 GHG emissions by major sectors in EU-28 from 2005 to 2050



Source: EC, 2013.

As a result, under a business as usual scenario, agriculture emissions would increase from about half to about two-thirds of EU non-CO_2 emissions over the 2005–2050 period.

It also seems that endogenous adaptation has not allowed the EU livestock sector to deal successfully with major climatic events, such as the heat waves and droughts of summer 2003 and 2011 (IPCC, 2014). Grass-based production was severely affected through fodder productivity loss, water shortages and animal mortality, despite large imports of hay and straw in the affected regions. Furthermore, emerging diseases related to climate change-driven spatial shifts in ecosystems are affecting the sector. This is the case of bluetongue, a virus which has now moved into sheep herds across Europe, as climate change allowed its vector, previously confined to lower latitudes, to move into Europe (IPCC, 2014).

This broad-brush description of the sector needs to be nuanced in view of regional differences. The sector is still expected to grow and transform in eastern and south-eastern Europe. Despite structural issues, which limit the uptake of technologies, these transformations provide substantial opportunities for mitigation and adaptation throughout Europe even though margins for development and efficiency gains may vary. Regarding climate change adaptation, trends in temperature and grass and crop productivity are projected to be detrimental in southern Europe, while northern regions may actually see an improvement of production conditions for grass and forage crops.

3.2 LIMITATIONS ON CURRENT PROGRESS

While there exist a range of technologies that reduce emissions from livestock production, (Box 3) their cost limits widespread adoption. Henderson *et al.* (2015) estimate that the most promising practices for reducing enteric CH_4 emissions and for sequestering soil C in grazing lands could abate up to 379 MtCO_2-eq yr^{-1} of emissions, which is equivalent to 11 % of annual global ruminant GHG emissions. Around two thirds of this potential possible at a carbon price of $20 t$CO_2$-eq^{-1}, a price level that has been observed in Kyoto-compliant carbon markets in the past, but distinctly above current market price.

In addition, voluntary schemes put in place by the private sector, based on knowledge extension for efficiency gains throughout livestock supply chains, are facing a number of barriers to adoption, including institutional and behavioral barriers. García de Jalón, Silvestri et al. (2015) identified seven main behavioral barriers ranging from personal beliefs (more difficult to overcome) to limitations in knowledge (easier to overcome) (Box 4).

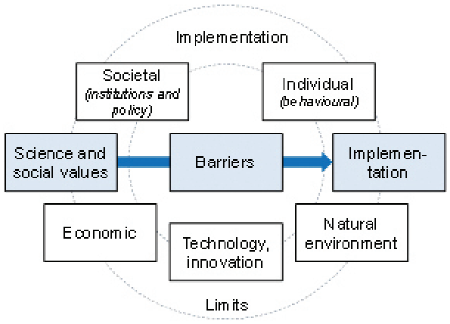
Engagement by governments in the development of mitigation policies has been limited and the recent economic crisis has further diverted public policies away from this objective. At the global, EU and national levels, limited progress has been made in setting targets and reducing emissions. A lack of coordination between sectors, especially between energy and agriculture, seems to further hinder the effectiveness of national mitigation policies. For example, trade-offs between the development of biofuels or biogas production and sustainable livestock production have been observed in the European Union, but are not fully addressed by public policies. The October 2014 Council Conclusions state that ‘the multiple objectives of agriculture and land use sector with their lower mitigation potential should be acknowledged, as well as the need to ensure coherence between food security and climate change objectives.’

Despite public and private support for efficiency gains in livestock production, both within the European Union and in developing countries, it is understood that current efforts must be substantially increased if the sector globally is to contribute to reducing GHG emissions.

BOX 4. Barriers to the adoption of mitigation and adaptation practices

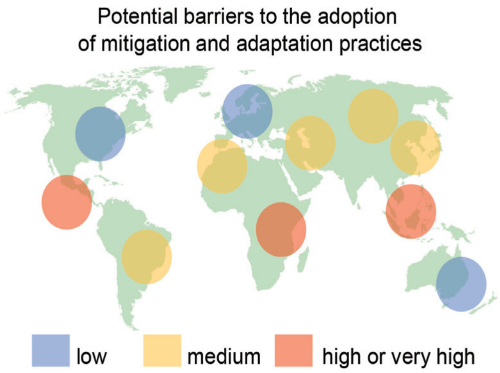
Ana Iglesias and Silvestre García de Jalón, UPM

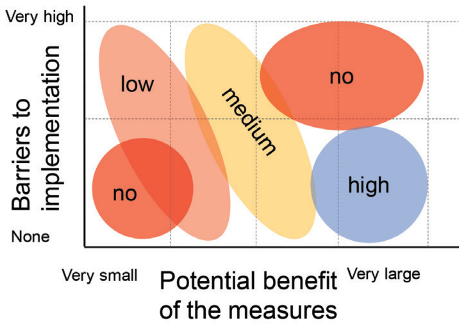
Overcoming barriers to the adoption of mitigation and adaptation practices is a critical part of breaking the link between climate damage and economic growth. The difficulties encountered in effectively implementing adaptation measures are usually explained by a range of limiting factors linked to development, implying that least developed countries may have more barriers than countries with larger financial and social capitals. However, high socio-economic indicators may not automatically translate into successful mitigation or adaptation to climate change. Therefore, effective mitigation and adaptation design must be informed about the views of local communities and their priorities. García de Jalón, Barnes *et al.* (2015) and Iglesias and García de Jalón (2015) examined barriers to adoption by testing the role of society and individual choices. These studies found scenarios of water scarcity and drought to be a useful means of communicating future climate change, and drought has proved to be a efficient scenario for motivating the definition of adaptation needs and barriers.



García de Jalón, Barnes *et al.* (2015) argue that five types of capital (i.e. natural, physical, financial, human and social) may determine the uptake of adaptation strategies among farm households. Using data collected from 1 536 farm households, they assess the adoption of farm-level adaption measures in nine countries of sub-Saharan Africa. The results show while that increased use of fertilisers and agrochemicals is the most frequently adopted option, few households are able to invest in more costly approaches such as introducing or improving irrigation systems.

Overall, all kinds of capital, except natural capital, seem to positively influence the adoption of adaptation measures. Physical capital is the most powerful predictor of adaptation and could be considered a prerequisite for adoption. The adoption rate of most adaptation strategies seems to be higher in farms located in regions less suitable for agriculture or with a lower natural capital. The results suggest that policy recommendations for improving adoption of adaptation measures would need to integrate sustainable agriculture with rural development policies, aimed at improving the basic needs of farm households.





4. Towards climate smart livestock?

4.1 THE SHORT TERM: WITHIN 10 YEARS

Analysis of the results of the AnimalChange project (Box 5) and existing foresight studies and plans[7] indicate that the EU livestock sector could **curb its direct GHG emission intensity by about 15 to 20** percent **between 2005 and 2025**.[8] In other terms, and taking into consideration projected livestock sector growth, the sector is not likely to contribute to its full potential to the 20 percent decrease in greenhouse gas emissions between 1990 and 2020 – which is the objective set by the European Union in the "20-20-20" targets of the Climate and Energy Package (EC, 2015) for the entire economy, to be partitioned between the different contributors. Other sectors of the economy will thus need to contribute more to the effort sharing if the economy-wide objective is to be met.

Acknowledging regional differences, fulfilling this mitigation potential will require the EU livestock sector to boost efficiency gains through a range of practices. Natural resource use efficiency could improve with optimization of nitrogen inputs, animal nutrition balancing, genetic improvement, as well as improvements in grassland management, carbon sequestration and improvements in manure management, driven by financial interests in achieving efficiencies in energy and fertilizer use, consumer demand and targeted public policies. Waste reduction and recycling of energy and nutrient from effluents would also contribute to reducing overall emission intensities.

Efficiency gains in other regions, such as sub-Saharan Africa and South America, will probably be higher than in the European Union, with greater potential in low productivity systems (Gerber *et al.*, 2013; Herrero *et al.*, 2013, Havlík *et al.*, 2014). On a global scale, adoption of currently available and profitable technologies is estimated to be able to reduce emission intensities by about one-third of current levels (Gerber *et al.*, 2013). While significant, this reduction is still unable to fully compensate for the effect of growth in the sector.

At the same time, risk management is expected to improve and the sensitivity of the livestock sector to climatic events is expected to reduce. This can be achieved via improved water management, breeding in forage species, seeding mixtures, crop and grazing calendars, and feed storage, as well as through livestock mobility in extensive systems and the use of private or public insurance schemes. (For examples of improvements to forage species to heighten resistance to drought, see Box 7.) However, adoption of adaptation practices remains uncertain and will depend largely on the capacity of producers to identify and adopt new practices, as well as on their investment decisions, which will balance immediate costs with longer-term benefits.

4.2 THE LONGER TERM: BY 2050

In the longer term, a more profound restructuring of livestock supply chains can be expected, which will represent significant potential for mitigation and adaptation. Although consumption is not expected to rise significantly in the European Union, the global market will continue to grow and EU production will contribute to supplying this demand.

Mitigation effects in the order of magnitude of 30 to 50 percent can be expected

Globalized supply chains provide an opportunity to relocate production where it is most efficient in terms of natural resources and adaption to local climatic conditions. This can generate greater

[7] These include the UK Roadmap for the dairy sector, the French "Carbon dairy" project, and the Teagasc roadmap for Irish beef and dairy and case studies published by the FAO (Gerber *et al.*, 2013).

[8] This estimated emission intensity reduction does not capture the full technical mitigation potential of the sector, which if achieved would result in greater net reductions of emissions.

BOX 5. Efficiency and productivity gains

1. Modelling of options at farm and regional levels and gains in productivity

Nicholas John Hutchings and Maria Stienezen, Aarhus University

FarmAC is a farm-scale livestock developed by AnimalChange. It has been applied to farms in Africa, Brazil and the European Union. In Europe, the model was implemented for a sample of mixed dairy farms (France, Italy and the Netherlands) and grass-based dairy farms (the Netherlands). Mitigation measures tested (e.g. cover cropping, feed supplementation, reduce age at first calving) only had a marginal effect on emissions since modeled farms were already functioning near optimum. More substantive measures (e.g. biorefinery, housing all dairy cattle and scrubbing the ventilation air) could not be modeled because of a lack of adequate data.

A much more significant technical mitigation potential was modelled for Brazilian and Senegalese farms through gains in efficiency. However, data and knowledge caveats limit the validity of results. In particular, carbon and nitrogen flows could only be partially modelled, although they are critical for the long-term sustainability of these farms.

2. Mitigation technical case studies

Anne Mottet, Benjamin Henderson, Carolyn Opio, Alessandra Falcucci, Giuseppe Tempio and Pierre Gerber (FAO), and Silvia Silvestri and Sabrina Chesterman (ILRI)

Packages of mitigation techniques can bring large environmental benefits, as illustrated in the six case studies modelled in the Global Livestock Environmental Assessment Model (GLEAM), developed by FAO (Mottet et al., submitted). Using feasible technical interventions in livestock production systems, the mitigation potential of each of the selected species, systems and regions ranges from 14 to 41 percent. While comparably high mitigation potentials were estimated for ruminant and pig production systems in Asia, Africa and Latin America, significant emission reductions can also be attained in dairy systems with high levels of productivity in OECD countries. Mitigation interventions can lead to a concomitant reduction in emissions and an increase in production, contributing to food security. Output is estimated to increase in each of the six case studies in which mitigation options improve animal performance. Naturally, the absolute mitigation potentials are lower with increased outputs than when output is held constant. Nonetheless, the mitigation options result in a simultaneous expansion in output and a reduction in emissions in five of the six case studies.

Summary of mitigation case studies: impacts of interventions in emissions, emission intensities and overall production

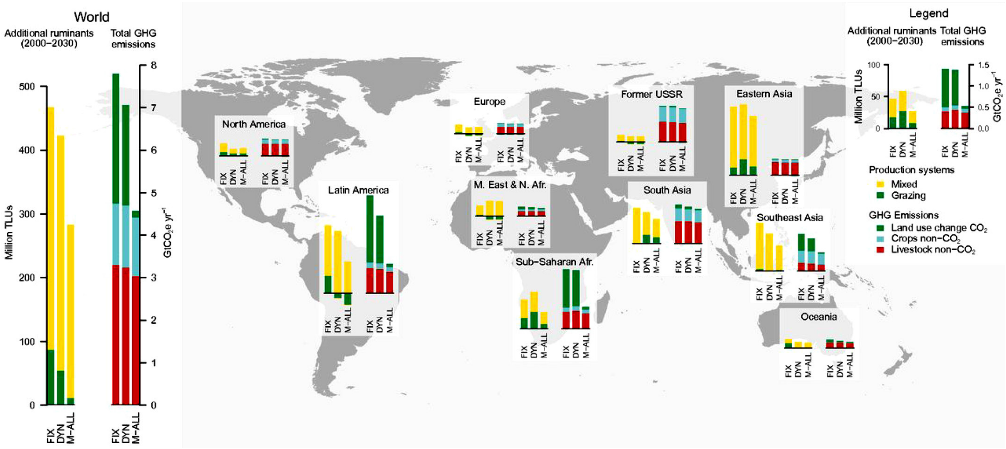
System	Increase in output (Mt FPCM or CW)	Mitigation (absolute potential Mt CO_2-eq or share of baseline emissions)		Emission intensity (kg CO_2-eq/kg FPCM or CW)	
		With constant output	With increased output	Baseline	Mitigation scenario
Mixed dairy South Asia	13 or 24%	120 or 38%	72 or 23%	5.7	3.6
Commercial pigs East and Southeast Asia	3 or 7%	47 to 66 or 20% to 28%	34 to 54 or 14% to 23%	4.7	3.4 to 3.8
Specialized beef South America	2.8 to 5.0 or 27% to 48%	190 to 310 or 18% to 29%	-63 to -65 or -6%	100	72 to 83
Small ruminants West Africa	0.12 to 0.26 or 19% to 40% (meat) 0.03 to 0.10 or 5% to 14% (milk)	8 to 12 or 27% to 41%	2 to 5 or 27% to 41%	36 (meat) 8.2 (milk)	22 to 29 (meat) 5.3 to 6.8 (milk)
Mixed dairy OECD	None	54 to 66 or 14% to 17%	-	1.7	1.4 to 1.5
Mixed dairy East Africa	6% to 18%	13 to 31 or 10 to 24%	6 to 13 or 5% to 10%	10.4	8.0 to 9.4

BOX 6. Restructuring of the livestock sector can substantially contribute to GHG mitigation

Havlík *et al.* analysed how autonomous re-allocation of ruminants could contribute in the medium future to GHG emissions reduction. The ruminants were re-allocated from GHG-intensive extensive grazing systems to more GHG-efficient mixed systems with animal diets supplemented by concentrates, as a special case of intensification within currently available technologies.

Allowing ruminant production systems to restructure according to future relative profitability of the different systems (DYN scenario) would itself reduce emissions from the whole AFOLU sector by 736 $MtCO_2$-eq per year by 2030, compared to a reference scenario where production systems remain unchanged from 2000. This represents a reduction of some 9 percent. The largest share of the reduction comes from avoided land use change (deforestation). The authors also considered a moderate climate change mitigation policy including pricing emissions at US$10 per tCO_2e, which corresponds to scenarios ending with radiative forcing of $4.5W.m^{-2}$ by the end of the century (or global warming of 2.4 °C). Under such a policy, transition in livestock production systems could play an important role as well – contributing up to 21 percent of the total calculated reduction in the AFOLU sector of 3.2 $GtCO_2e$ per year. Ruminant herd expansion would occur almost exclusively in the more GHG efficient mixed crop-livestock systems.

Change in ruminant numbers (2000 to 2030) and total annual GHG emissions from agriculture and land use change (2010 to 2030) globally and by region



Notes: Fixed system scenario (FIX), dynamic production system scenario (DYN), mitigation scenario with dynamic production systems and a carbon price of US$10 per tCO_2e applied to emissions from both agricultural and land-use change sectors (M-ALL). *y*-axis scales are the same in all graphs. TLU = tropical livestock unit (i.e. an adult animal of 250 kg weight).

Source: Havlik *et al.*, 2014.

mitigation and adaptation benefits than short-term upgrading of local production practices (Box 6).

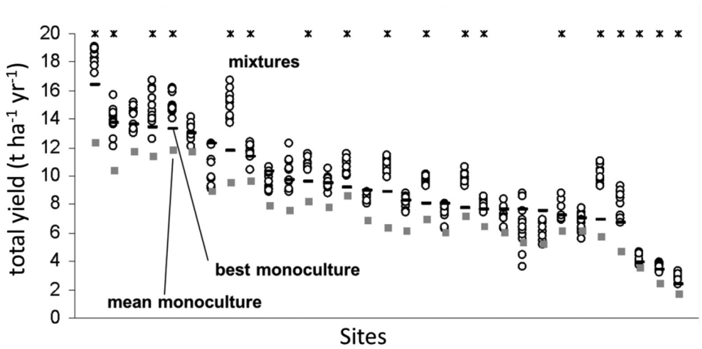
Profound production system transformations can be achieved over the long term, for example, through a **shift in feed sources**. The EU livestock sector is highly dependent on imports of protein feed at present. The main source is soy cake from South America, a product that comes results in high (although reducing) GHG emissions from land use change (Gerber *et al.*, 2013). Increasing EU self-sufficiency in protein feed, for example, by further relying on current European protein feed resources (e.g. by-products from 1st generation biofuels), introducing legumes on pastures for ruminant, cropping protein feed, or processing grass into protein feed for monogastrics in bio-refineries, could arguably reduce emissions from land use change, while improving productivity and resilience (Box 7). These options would offer a range of co-benefits, including the substitution of synthetic fertilizers with biological N fixation (achieving additional mitigation) and the possibility to improve nutrient cycling and feed transport efficiency by considering geograph-

BOX 7. Key outcomes on legumes and drought in grassland systems

Across a wide geographical scale, four-species grass-legume mixtures (two grasses and two legumes) generally outperformed the average for monocultures, both in terms of forage yield (Figure a) and weed suppression. Mixtures outperformed the best-performing monoculture at more than 60 percent of sites. Across Europe, total nitrogen yield in the forage acquired by mixtures was up to 70 percent higher than in grass monocultures. Mixtures with a one-third proportion of legumes attained ~95 percent of the maximum level of total nitrogen yield (Fig. b). Legumes in four-species grassland mixtures were associated with improved resistance of yield to a nine-week drought (Fig. c).

The use of grass-legume mixtures can contribute substantially to resource-efficient agricultural grassland systems over a wide range of productivity levels, implying important savings in nitrogen fertilizer use and associated greenhouse gas emissions. Overall, attainment of these benefits is most effective in mixed swards with a legume proportion of 30–50 percent. Preliminary results indicate that legumes in grassland mixtures can contribute to the resistance of yields to drought events. Overall, this indicates considerable potential for legumes in grassland as a practical option to contribute to climate change mitigation and adaptation. For further details on the diverse potential of legumes, see Lüscher *et al.* (2014).

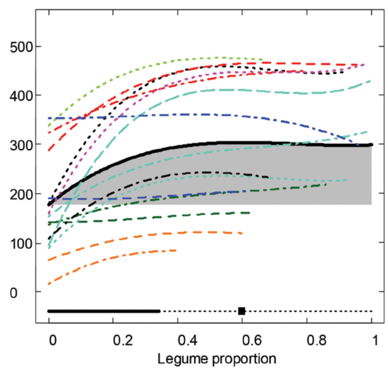
FIGURE A. Annual yield (dry matter) from experimental grassland field trials with monocultures and mixtures of grasses and legumes



Notes: Open circles represent each of 11 mixture communities of varying legume proportions. Horizontal bars represent the yield of the best-performing monoculture. Boxes represent mean monoculture performance. Asterisks indicate sites where the yield of mixtures was significantly greater than the best monoculture yield.

Source: Finn *et al.* (2013).

FIGURE B. Total nitrogen yield (Ntot) as affected by legume proportion in grassland mixtures

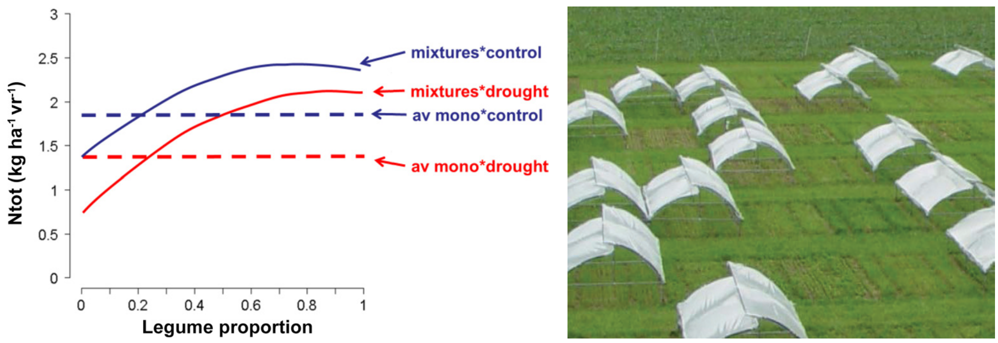


Notes: The bold black curved line displays the predicted Ntot across all sites, and coloured curved lines display predicted Ntot for individual sites over the range of legume proportion. The shaded area indicates N yield gain in mixture as compared to grass monocultures across sites. The vertical bold red line indicates the predicted N yield gain for a mixture with a grass:legume ratio of $\frac{1}{3}$:$\frac{2}{3}$. At this point, about 95 percent of maximum Ntot was attained. The horizontal bold line at the bottom indicates the range of legume proportion for which Ntot across all sites was significantly smaller ($P \leq 0.05$) than at maximum (■).

Source: Suter *et al.* (2015).

BOX 7. ***cont.***

FIGURE C. Yield of mixtures and monocultures under control (blue lines) and nine-week drought (red lines) treatments



Notes: Mixture yield increased with the proportion of legumes. Although mixtures yielded less under drought than under control, their yield advantage compared to monocultures was so great that at >= 50 percent legume, the mixture yield in the drought treatment was comparable to that of the average yields of monocultures in non-drought conditions.

ical criteria when deciding on the longer term farm competitiveness and sustainability.

There is also transformational potential in **grasslands**. Their potential for carbon sequestration and soil recarbonization, if correctly managed, can prove significant and could generate important mitigation and adaptation benefits in the mid to long term (Henderson *et al.*, 2015; Box 8). They also contribute to reducing GHG emissions from producing, harvesting, processing and transporting feed. In addition, enhancing grass in feed baskets makes sense economically, considering the relative costs of feed materials. The increased potential for grassland productivity in western and northern Europe will create opportunities for an extended grazing season in winter, but will also come with increased risks of herbage deficits in summer.

Changes of land use and substitution of crops with high inter-annual yield variability wheat or maize) for crops with lower productivity but more stable yields (e.g. pasture or sorghum) could significantly contribute to long-term adaptation (Olesen and Bindi, 2002). Other examples of system transformation for long-term adaptations include new land management techniques to conserve water or increased irrigation use efficiencies, agroforestry, and more drastic changes such as the abandonment of agriculture land, with in some cases undesirable outcomes for livelihoods and the environment. Relocations and changes in the balance between grass-based and mixed crop-livestock systems may occur over the long term. Although trade-offs with long-term mitigation strategies may occur locally (e.g. change of species and impact on productivity), synergies exist and should be sought, especially with regard to feed resources and consequent land use. Other objectives, such as animal welfare will also impact these trends and may compete with mitigation.

In the mid to long-term, pursuing mitigation and adaptation objectives may amplify the existing dichotomy between industrialized and grass-based production systems. The former aim for capital intensive technologies (e.g. precision crop and livestock farming, high-tech buildings, methane trapping, feed additives, bio-refineries) and the latter focus on lower tech but equally knowledge-intensive practices, such as sylvo-pastoral management, mobility, grazing schedules, grass composition and pasture restoration. In both situations, information technology and improved weather forecasting are poised to play a growing role in management decisions.

Although quite promising from a mitigation and adaptation perspective, these transformational changes and globalized scenarios raise important questions of food sovereignty, in a context of increasing volatility of prices, speculation and trade policies. They also raise major social issues for producers facing increased competition and workers facing loss of employment in livestock supply chains.

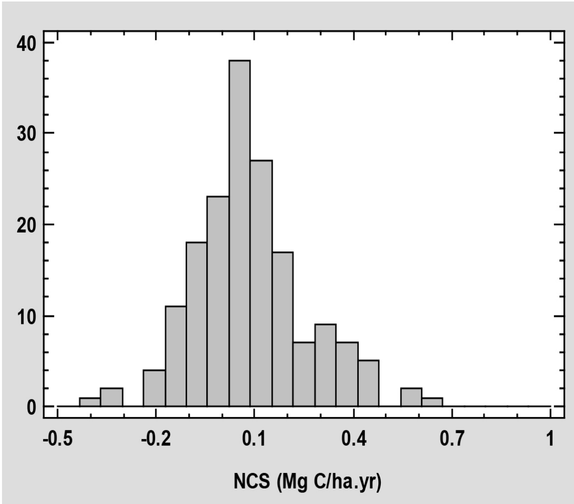
Over the longer term, development of a climate smart livestock sector will likely follow a few key trends:

- The mix of animal products and the geography of livestock supply chains shifts in a manner whereby natural resource use efficiency is increased, without triggering issues

BOX 8. C sequestration in grasslands

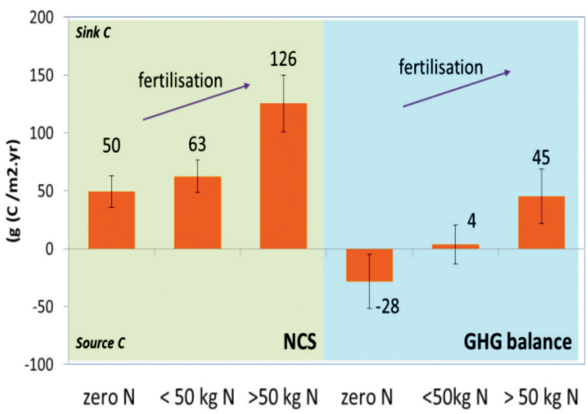
Grassland management has significant potential to mitigate livestock greenhouse gas emissions at a low (or even negative) cost, by combining moderate intensification and the restoration of degraded pastures. For EU-27 pastures in animal feed-producing areas, a synthesis of eddy flux covariance data showed that grasslands provide on average (172 site years) a mean net carbon storage (NCS) of 0.71 ± 0.13 Mg C/ha.yr (with 95 percent of sites being between 0.3 et 0.7Mg C/ha.yr). This carbon sink activity is largely controlled by climatic and management factors (i.e. fertilization and herbage use), where climate is optimal for grassland canopy photosynthesis between 11 °C and 1 280 mm yr^{-1}.

FIGURE A. Net Carbon Storage (NCS) in 27 EU pastures



Under optimal climatic conditions, grasslands are likely to be carbon neutral (in CO_2 equivalents, accounting for enteric CH_4 and soil N_2O emissions) when fertilized and managed moderately (i.e. below a critical herbage use by grazing and cutting). Herbage use efficiency (ratio of herbage use to above-ground net primary productivity) favours carbon sink activity between 0.2 to 0.05 to with and without manure and fertilizer application, respectively. In contrast to manure application, mineral N fertilizer supply leads to minor changes in critical herbage use values.

FIGURE B. Effect of fertilization on Net Carbon Storage (NSC) and GHG balance in grasslands



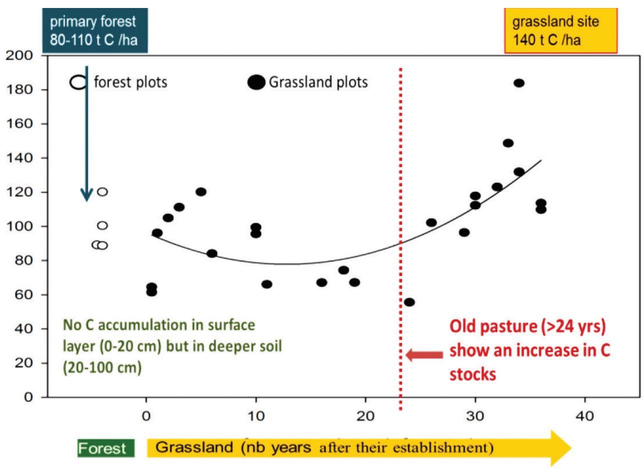
About 15 percent of the Amazon has recently been converted into pastures, resulting in a large carbon loss (ca. 200 tonnes of carbon per hectare). The carbon balance of tropical pastures following deforestation has been studied across the coastal area of French Guiana. Eddy covariance flux measurements and a

BOX 8. *cont.*

chronosequence study of the soil carbon content showed that sown Brachiaria pastures tend to function as a carbon sink, with intensity increasing with pasture age, ranging from 1.8 tC ha^{-1} yr^{-1} in young pastures up to 5.3 tC ha^{-1} yr^{-1} in pastures older than 24 years. Cattle grazing induced an emission of CH_4 and N_2O by 0.9 tCO_2-C equivalents ha^{-1} yr^{-1}, which was lower in CO_2 equivalents than the soil carbon sequestration rate. Carbon was sequestered mostly in deep soil layers (0.2-1 m) with sequestration apparently favoured by the development of legumes and other C3 species (Figure c).

These results suggest that Amazonian pastures can become a carbon sink, provided that sustainable pasture management is applied. Nevertheless, the carbon gain is much lower than the large carbon loss induced initially by deforestation. Attention has to be paid to grasslands installed on organic and drained soils, as these tend to lose carbon over time, whatever management is applied. Concerning management per se, climate and the inter-annual variability of climate (e.g. dry and wet seasons) play a major role in the choice of management practices (i.e. mowing vs. grazing, winter vs. summer grazing) and subsequent carbon storage potential. For example, grazed grasslands increase carbon sink activity by 2 percent with an increase in annual precipitation of 10 mm. Under mowing, mean annual temperature seems more important than precipitation. With respect to climate seasonal variation, under dry warm periods and high intensity of herbage use, grasslands are likely to become a source of carbon. For management in general, a number of paired sites also show high carbon sink activity under grazing compared to mowing, underlining the importance of regulating/preventing grasslands from high (frequent) biomass removal. In addition, grasslands may be set aside (i.e. grazing exclosure) or periods of herbage use (grazing and mowing) may be reduced/moved to counteract grassland degradation and improve carbon storage.

FIGURE C. Effect of age of pasture on soil carbon stock



of food sovereignty and equity.

- Resilience against climate change (drought and heat waves, water shortage, diseases and pests) is built into production systems.
- Feed for livestock is produced with a low carbon footprint (including soil C), and maximum use is made of safe by-products from the food and bio-energy industries.
- Ruminant production maximizes the use of grass, using management practices that maximize carbon sequestration and minimize greenhouse gas emissions. These include grazing and harvesting practices, as well as strategic supplementation with concentrate.
- The livestock sector innovates and is connected to technology developments, especially in the areas of alternative feed resources for pigs and poultry (e.g. bio-refineries) and resource use efficiency.

5. Conclusion: what could be done in the European Union?

5.1 SHORT TERM: ACCELERATING EFFICIENCY GAINS AND BUILDING RESILIENCE

Increased efficiency gains can help the livestock sector reduce its contribution to climate change over the short term. This calls for specific interventions.

Significant mitigation potential is achievable through the **transfer of existing technologies** that increase production efficiency (Box 9). Policies targeting knowledge transfer are therefore particularly important. For example, extension activities and tools should be used to facilitate change in practices by providing access to knowledge and improved practices and technologies. These may include the strengthening of extension services; the establishment of demonstration farms, farmer field schools and farmer networks to promote peer-to-peer knowledge transfer; the organization of sector roundtables and the brokering of linkages among sector participants. Extension activities need a coherent and integrated approach to building sector capacity in order to ensure the successful application of existing and new mitigation practices.

Research and development will play an important role, first by reducing uncertainties in the quantification of GHG emissions from livestock supply chains and then by developing new mitigation strategies. Further international standardization of methodologies and metrics for assessments are needed and multistakeholder and global initiatives such as the Livestock Environment Assessment and Performance (LEAP) partnership, which gathers partners from the private sector, governments and civil society organizations, and research and international organizations, are essential to achieving this objective.

Research also needs to continue to generating knowledge and evidence about technologies and practices, based on producers and society needs, giving farmers and practitioners greater confidence about the effectiveness and impact of their mitigation efforts (Box 10). Three main areas of research have been identified:

- Strengthen farm system modelling and its integration with economics and barrier assessment. This would result in powerful decision support tools for farmers and extension workers. It might be combined with pilot projects to test the effectiveness and feasibility of novel technologies and practices in different agro-ecological and socioeconomic contexts, which is important for implementing this strategy, and could possibly demonstrate the feasibility of "zero-carbon" farms.
- Analyse the potential for restoring degraded lands by increasing pasture productivity at scale, and thereby sequestering carbon. This process is underway in Latin America, but untapped potential might also exist in other regions, such as Central Europe and possibly the sub-humid areas of Africa (Henderson *et al.*, 2015).
- Significant additional research is also needed to further assess the costs and benefits of mitigation practices at farm-level, so as to help policy-makers understand which policy options are best placed to incentivise uptake. Only a handful of GHG mitigation assessments have explored the economics of practices that improve production efficiency (including USEPA, 2006; Smith *et al.*, 2007; Moran *et al.*, 2010; Schulte and Donnellan, 2012; Whittle *et al.*, 2013). While a significant portion of these practices are estimated to be profitable, findings vary considerably, depending on which mitigation options are assessed and which species and regions they are applied to.

Revision of inventories and measurements/reporting/verification (MRV) are needed to reflect mitigation efforts already underway in the livestock sector. At present, too many inventories are still based on simplified emission factors (e.g. IPCC Tier 1) that do not capture

BOX 9. Quantitative analysis of mitigation options in Europe

Franz Weiss, JRC

Three policy scenarios were tested in Europe using the CAPRI model:

Scenario 1: Farmers are forced to implement mitigation measures at their own cost. The full mitigation potential of the measures are achieved but farmers might decide to reduce production wherever costs are too high.

Scenario 2: Farmers are offered a subsidy covering 100 percent of the marginal costs for implementation of the mitigation measures.

Scenario 3: Farmers are offered a fixed subsidy of €50 per kg CO_2-eq emission reduction. They can choose the set of mitigation measures implemented according to profitability.

Results indicate that the total mitigation potential of the considered technologies might be around 10 percent of baseline emissions from the agricultural sector in the European Union for scenarios 1 and 2. Full mitigation potential comes at a high cost, but substantial emission reductions might be achieved at a reasonable cost, under scenario 3. The analysis also highlighted the high public investments required to overcome capacity and information constraints, in addition to private adoption costs.

Results are presented relative to the maximum technically feasible implementation share and for total EU27, Shared Socio-economic Pathway number 2 (SSP2) and the projection year 2030. Overall mitigation effects are lesser compared to those presented in Box 5, because of the reduced number of mitigation practices included in this modeling exercise. For example, change in animal feed ration and improvement in animal health were not included here because of data constrains.

	Other cattle	Poultry	Temporary grassland
Anaerobic digestion	21.8%	no	no
Low nitrogen feed	5.3%	0.5%	no
Feeding lipids	15.0%	no	no
Feeding nitrate	19.8%	no	no
Fertilizer reduction	no	no	0.4%
Increased legume shares	no	no	4.3%

Results are presented relative to the reference scenario and for total EU27 and SSP2 for the year 2030.

	Scenario 1	Scenario 2	Scenario 3
CH_4 emissions from enteric fermentation	86.7%	89.6%	95.3%
CH_4 emissions from manure management	81.0%	83.5%	84.8%
N_2O emissions from manure management	68.6%	71.9%	77.5%
N_2O emissions from manure application	92.0%	97.8%	99.2%
N_2O emissions from grazing	99.3%	101.1%	98.3%
N_2O emissions from mineral fertilizer application	98.4%	97.1%	98.2%
Total agricultural emissions (CO_2eq)	90.1%	92.5%	95.0%
CO_2 emissions from fossil fuel burning saved	-2.6%	-2.6%	-1.6%
Beef production	101.4%	103.8%	98.6%
Milk production	99.2%	101.4%	99.6%
Pork production	97.8%	102.0%	99.5%
Sheep and goat meat production	105.3%	102.8%	98.8%
Poultry meat production	101.3%	104.7%	99.8%

improvements in management practices, such as feed balancing and supplementation or animal health (see Box 3). These assessments do not provide adequate incentives to practice change in the sector, nor can they support the assessment of mitigation potential.

BOX 10. Mitigate: an online meta-analysis database of mitigation strategies for enteric methane emissions

The animal science sector has seen a proliferation of potential mitigation strategies, aimed at tackling emissions from enteric fermentation in ruminant livestock production. By bringing together data from studies on the many mitigation options available through a structured meta-analytical approach, it is possible to evaluate the technical mitigation potential for these broad strategies, as well as explore the many factors influencing the technical potential of CH_4 mitigation strategies. Such quantification of different mitigation strategies will allow for better estimation of mitigation potential on different levels (animal, farm and sector scale) in modelling efforts. In addition, quantification is important to determine which strategies show the best potential to lower methane emissions and can therefore be instrumental in policy recommendations.

A database has been established through an extensive structured search of published literature on the topic. For each relevant paper identified, a range of metadata have been extracted including information on the study design, mitigation strategy, animal husbandry, diet and methane emissions. The studies are classified by distinct categories to facilitate use by all stakeholders interested in utilizing the data. The creation of a database with multiple levels of classification also provided a flexible platform for future meta-analyses at many levels of aggregation. Studies can be aggregated at the level most appropriate for specific modelling exercises or policy recommendations. To date, 320 papers have been added and the database continues to grow. This comprehensive database is being made available online through a user-friendly web interface (http://mitigate.ibers.aber.ac.uk). The website provides a facility for open access to the database, as well as future updates as more research is published on the topic. It is hoped that as the database becomes more widely publicised, more research will become available, particularly from currently underrepresented regions or concerning mitigation strategies that have not yet been fully explored or tested in vivo.

MitiGate
Gateway to ruminant CH_4 mitigation

Source: Veneman *et al.*, 2013: 199.

In addition, there is often confusion between GHG emissions accounting at supply chain level versus national level. The difference between the two approaches is growing as livestock supply chains become more complex and international. Designing emission accounting rules to reflect mitigation strategies along supply chains presents challenges, but avoids the current risk of leakage associated with placing emission reduction targets on domestic direct emissions. For example, following this approach, a livestock producer changing feeding practices would see him/herself assigned the emission increase/reduction taking place at feed production level, even if carried out outside the production unit and possibly even abroad. However, crediting domestic sectors with emission changes located abroad would be complex in the context of international frameworks.

Development Assistance. For the livestock sector, mitigation potential is greater outside the European Union and adaptation needs are also probably more urgent. There is a role for the European Union to play in terms of transfer of technologies practices, including infrastructure development and strengthening of supporting technical institutions. Generally, innovation is driven by entrepreneurs pursuing market opportunities (World Bank, 2011). Moreover, knowledge and technologies seem to work best when their introduction is complemented by infrastructure and institutional development, partnerships and policy support (Spielman and Pandya-Lorch, 2009).

Financial instruments, such as low interest loans and microfinance schemes, may be needed to complement extension policies and support the adoption of new technologies and practices. These instruments are needed where practices require upfront investments and adoption is constrained by ineffective or missing capital markets and financial services - a common constraint on technology use in developing country contexts. These types of instruments may therefore be required even where mitigation options are profitable and producers are willing to bear the costs related to technology transfer.

There are also other barriers to adoption, including producer aversion to change and actual or perceived increased risks associated with adoption, as well as opportunity costs for adopting mitigation practices instead of other investments that farmers may be contemplating. These factors will increase the minimum rate of return producers would be willing to accept before investing in mitigation practices and require higher levels of support and incentives.

5.2 PREPARING FOR LONG-TERM STRUCTURAL CHANGES AND SOIL CARBON SEQUESTRATION

Global policy dialogue will be essential to transcend limited win-win options and achieve ambitious adaptation and mitigation targets. Due to the size and complexity of the livestock sector, the design and implementation of cost-effective and equitable mitigation strategies and polices can only be achieved in the long term through **concerted action by all stakeholder groups** (including producers, industry associations, academia, the public sector and intergovernmental organizations). Multi-stakeholder groups will be particularly aware of the potential social and economic risks associated with sector transformation as fostered by the need to respond to climate change.

Moreover, given the global public good nature of climate change and the sector's socio-economic challenges, collective global action is both welcome and needed. Because of the increasing global economic integration of livestock sector supply chains, unilateral action to mitigate GHG emissions will be much less effective than internationally coordinated efforts, although they may have a net positive effect depending on the time of intervention (Cohn *et al.*, 2014). Indeed, unilateral approaches could have an effect opposite to that intended (Golub *et al.*, 2012). O'Brien *et al.* (2012) showed that the adoption of a confinement dairy system in Ireland reduced national GHG emissions relative to a grass-based dairy system, but emissions increased when considered at global level. In addition, unilateral policies invariably raise issues about competitiveness and fairness for sectors exposed to international trade. While the main official mechanism for international and multi-sectoral action on GHG mitigation is provided by the UNFCCC, important mitigation efforts are also being carried out at local industry scales, often led by the private sector. There is a need for more support from global initiatives focused on specific livestock issues to effectively integrate and mainstream the mitigation and development objectives pursued by sector stakeholders. Initiatives such as the Global Agenda for Sustainable Livestock draw on the differing strengths of each stakeholder group to build the trust and cohesion essential for concerted international action along the entire supply chain.

Carbon markets, in which carbon emission permits and reductions can be traded, have been established by a number of countries and jurisdictions to curb GHG emissions. The Emissions Trading System in the European Union is an effective example, but does not include agriculture. Carbon markets currently provide very limited mitigation incentives for the sector, mostly due to the difficulty in developing specific MRV systems that incentivise mitigation and are accurate, equitable, cost-effective and manageable at the same time. However, continued research and development to improve measurement and farm-scale accounting methodologies and the ongoing evolution of market-based instruments could increase the role of carbon markets over the long term.

Given that the viability of mitigation and adaptation through land management practices depends on being able to establish them on a landscape scale, **institutional innovations** for equitably aggregating the contribution of individual households are needed, in ways that allow both the community and individual households to derive benefits from the soil (Wilkes *et al.*, 2011). Land tenure can also present significant challenges for changing practices in grasslands, particularly in many rangeland areas that are communally managed without clear ownership or access entitlements. In these situations, difficulties can arise in establishing improved management practices and ownership of soil carbon assets, as well as ensuring ongoing monitoring of practices to manage non-permanence risks. Policies based on extension and financial and regulatory incentives will also play an important role in stimulating the adoption of grazing management practices. Again, the economic attractiveness of the various practices for enhancing resilience and soil carbon stocks will help to inform which combination of policies is best placed to support these practices.

Nationally Appropriate Mitigation Actions (NAMAs) are rapidly emerging policy frameworks for voluntarily GHG emission reduction actions, in the context of sustainable development. While the entry point is mitigation, NAMAs can also support adaptation co-benefits. To date, however, the inclusion of agriculture and the livestock sector, in particular, has been limited. As of April 2015, 101 entries were registered in the UNFCCC NAMA registry of which only 13 were related to agriculture. Brazil, Costa Rica and Uganda are among the few countries to have developed NAMAs that centrally address livestock emissions. However, several other countries are engaged in the development of livestock NAMAs, and as experience grows and more sources of bilateral and multilateral funding become available, it is likely that NAMAs will become a major policy instrument to achieve climate benefits in the sector over the mid to long term (FAO, 2015).

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