Chapter 10
Livestock Farming Constraints in Developing Countries—From Adaptation to Mitigation in Ruminant Production Systems

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Abstract The livestock sector's relationship with climate change is complex. The sector is a major contributor to agricultural greenhouse gas emissions, whereas it is subject to climate change and must adapt to ensure its survival. The diverse range of livestock farming systems worldwide provides a range of greenhouse gas emission mitigation options. Moreover, livestock production contributes to a significant and increasing extent to food systems and to agricultural systems in developing countries (manure, transportation, savings, income). In this sense, their integration in climate-smart agricultural systems is essential, especially since these regions are undergoing major changes in their demographic, environmental and consumption patterns. Livestock farming is thus a crucial adaptation mechanism for poor and vulnerable people living in changing environments who are subject to a range of risks.

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10.1 Background

Livestock farming systems are undergoing major changes in developing countries in response to many interdependent ecological, economic, social, political, security and health factors. Among these factors, the increased demand for animal products due to global population growth and changes in middle-class income and consumption patterns in emerging countries should play a major role. However, the productive features of livestock farming and agriculture overall are now being widely revamped. The multiple services provided by livestock farming activities, i.e. not simply ensuring peoples' food security, are now a key consideration. In developing countries, livestock farming systems are less productive—per head and per hectare with regard to products for human consumption—than in developed countries, but they offer many socioeconomic services that are just as important, such as building economic capital, social status, organic manure production and animal draught (Alary et al. 2011). Their positive impact on ecosystems should also be taken into account. Grasslands, for instance, have a very high greenhouse gas (GHG) mitigation potential (4 % of anthropogenic emissions) by sequestering and storing carbon dioxide (CO_2) in soil (Lal 2004; *in* Blanfort et al. 2011). The contribution of pastoralism to the ecosystem balance and sustainability in drylands is another prime example. It opens landscapes, hampers scrub encroachment, stimulates plant growth, fertilizes soil, increases nutrient cycling, participates in seed dissemination and enhances rainwater infiltration over large territories where it is the main economic activity.

The sector's global emissions amount to 7.1 Gt CO_2 equivalent (CO_2-eq), or 14.5 % of anthropogenic emissions (Gerber et al. 2013), mainly in the form of methane (CH_4), nitrous oxide (N_2O) and CO_2 (Fig. 10.1).

These emissions are gradually being taken into account in agricultural development policies in developed countries, while in developing countries they are often seen as being of lower priority than the fight against hunger, malnutrition, poverty and economic development. Yet the focus nowadays is on producing more,

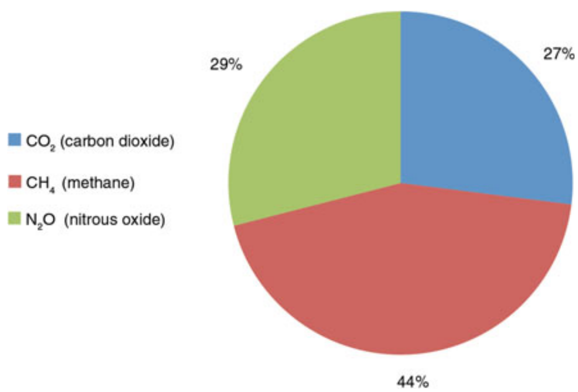

Fig. 10.1 Global emissions per type of greenhouse gas in the livestock farming sector

while improving the productivity of the production systems, but more sustainably and by taking climate change into account—in both developing and developed countries—in terms of adaptation and mitigation. Livestock farming is vital in the design of climate-smart agricultural systems because of the complex interactions between climate change and livestock farming systems in developing countries, associated with their obvious contribution to household food security and addressing the future demand for animal products.

10.2 Producing References on Livestock Farming Systems in Developing Countries

Few references are available on the specific contribution of livestock farming systems to GHG emissions in developing countries. An analysis on trends in major world regions (Gerber et al. 2013) showed that sub-Saharan Africa, given its low productivity, and Latin America and the Caribbean, due to the conversion of primary forests into grassland and cropland devoted to producing livestock feed, are regions with the highest emissions per produced kg carcass weight (around 70 kg CO_2-eq/kg carcass). However, these figures overlook some diversity that was highlighted in assessments of different livestock farming systems (Table 10.1).

Table 10.1 Greenhouse gas emissions measured in different livestock farming systems

Study site	Type of system	Greenhouse gas emissions
Democratic Republic of the Congo Lecomte et al. (2014)	Large ranches (50,000 ha)	
	Cattle on natural savannas	80 kg CO_2-eq/kg carcass
	Cattle on intensified *Brachiaria* grasslands	18 kg CO_2-eq/kg carcass
Senegal Assouma et al. (2014)	Silvopastoral systems in Ferlo	
	Fattening cattle	69 kg CO_2-eq/kg carcass
	Dairy cattle	9 kg CO_2-eq/kg milk
	Fattening cattle	28 kg CO_2-eq/kg carcass
	Dairy sheep	11 kg CO_2-eq/kg milk
Brazil Clerc et al. (2012)	*Fazenda*-type suckler cow rearing systems	20–80 kg CO_2-eq/kg carcass

10.3 Potential Greenhouse Gas Emission Mitigation Pathways

10.3.1 Improving Resource Use Efficiency and Livestock Productivity

Enteric CH_4 emissions from ruminant livestock represent around 40 % of emissions of the entire livestock farming sector (Fig. 10.2).

Reducing these emissions is therefore a priority. Pastoral and agropastoral herd feeding is largely based on the intake of resources of low digestibility, leading to high CH_4 emissions. In southern Mali, for instance, natural rangelands represent up to 70 % of the gross energy consumption per head in extensive dairy farming systems (Vigne et al. 2013). One option for reducing CH_4 emissions thus promotes the consumption of more digestible resources with a low methanogenic potential, such as concentrates and crop by-products. This option is especially interesting as it also enhances herd productivity. However, intensification of all of these livestock farming systems through massive inputs of commercial concentrates is not possible in most systems in developing countries. Most of them have already used external inputs to a limited extent, but for further intensification, substantial economic support policies would be necessary, which hardly seems possible (Corniaux et al.

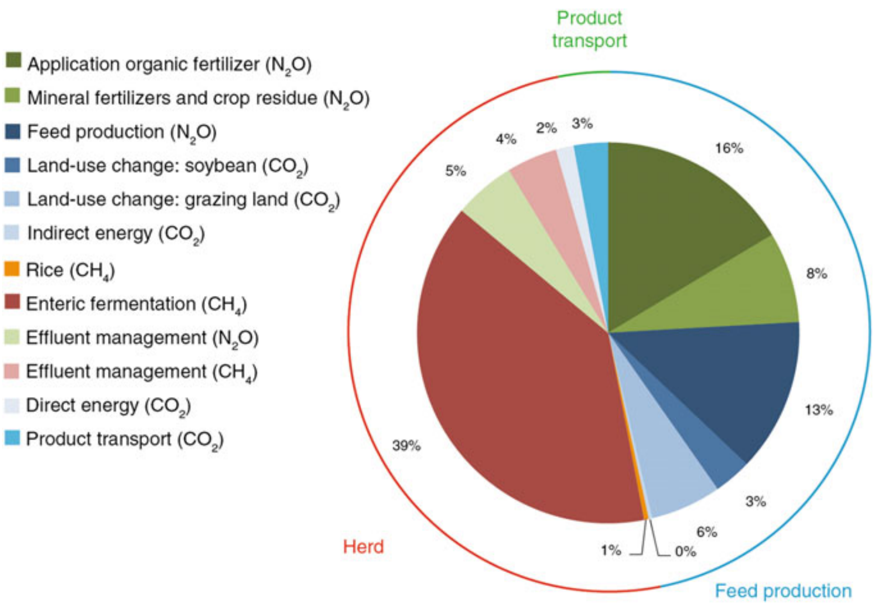

Fig. 10.2 Global emissions of the livestock farming sector per production sector. *CO_2* carbon dioxide; *CH_4* methane; *N_2O* nitrous oxide

Fig. 10.3 Hand milking on a farm in Sikasso, Mali (© M. Vigne/CIRAD)

2012). Other ways of increasing productivity involve improving herd health and access to good quality grassland, especially during the rainy season.

CO_2 and N_2O emissions for the production, processing and transportation of livestock feed represents around 45 % of the total emissions of the sector, a third of which are linked with fossil fuel combustion directly for herd management or indirectly for feed production (Gerber et al. 2013). The promotion of livestock farming systems that make effective use of this resource is a further way of reducing GHG emissions. Vigne et al. (2014) in Mali and Benagabou (2013) in Burkina Faso showed that, in the absence of mechanization, family dairy farming systems (Fig. 10.3) consume less fossil energy per litre of milk produced than more intensive periurban dairy farming systems. In the Democratic Republic of the Congo, Lecomte et al. (2014) demonstrated that the fossil energy efficiency of meat production was higher on intensified *Brachiaria* grasslands than on natural savannas (Fig. 10.4). Nitrogen loss through volatilization during storage and slurry spreading accounted for over 20 % of GHG emissions of the sector. Nitrogen conservation and recycling on the farm are thus important ways to reduce GHG emissions. In southern Mali, an analysis of local management practices regarding produced organic matter revealed that night paddocking of animals along with supplementation with crop residue litter, and the use of manure pits (Fig. 10.5),

Fig. 10.4 Conversion of part of a natural savanna into *Brachiaria* grassland on Kolo ranch, Democratic Republic of the Congo (© A. Duclos/CIRAD)

Fig. 10.5 Manure pit on a family farm at Koumbia, Burkina Faso (© M. Blanchard/CIRAD)

could double the farm nitrogen retention efficiency (Blanchard et al. 2013). Moreover, this crop-livestock integration helps decrease the dependency on industrial chemical fertilizers, which are high non-renewable energy resources consumers and indirect GHG emitters.

10.3.2 Carbon Storage in Rangelands

After oceans and fossil energy reserves, soil is the third largest global carbon stock, far ahead of aboveground plant biomass. Grasslands, which account for 30 % of the land surface, could store 0.3 billion t/year of organic carbon, or nearly 4 % of anthropogenic GHG emissions. However, the carbon sequestration potential would range from 0 to 4 t C/ha/year depending on the ecological zone, soil characteristics, climatic conditions and agricultural practices (Soussana et al. 2010). Agricultural soil management is therefore essential for controlling carbon flows in the fight against climate change (90 % of the emission reduction potential of the agricultural sector, according to Gerber et al. 2013).

The livestock farming development trend in the Amazon region clearly illustrates these new challenges. This development must be planned with a view to forest conservation and GHG mitigation, while maintaining the conventional production functions of livestock farming. Deforestation for the purpose of creating grasslands has significant environmental impacts, while leading to substantial CO_2 local emissions (biomass combustion) and biodiversity loss. Combating deforestation is thus a priority but needs to be accompanied by more sustainable management of cleared areas. In French Guiana, a regional research platform that contributes to the Guianese regional carbon and GHG observatory[1] studies carbon and GHG balances in forests and deforested areas. This CARPAGG (carbon and GHG in grasslands in French Guiana) research project is focused especially on *Brachiaria humidicola* grassland cattle grazing systems resulting from deforestation (Fig. 10.6).

Recent results have shown that the carbon storage function observed in native forests can be re-established in grasslands resulting from deforestation two decades after they have been created. Carbon flow measurements over a 2 year period and a chronosequence study respectively indicated carbon storage levels of 1.8 ± 0.5 and 5.3 ± 2.1 t C/ha/year (Blanfort et al. 2014). The net GHG balance for the 2011–2012 period in a 33 year old grassland with an annual stocking rate of 1.3 animals/ha showed that the grassland was a net carbon sink of −1.2 ± 0.5 t C/ha/year. Grassland ecosystems resulting from deforestation in French Guiana therefore function as carbon storage sinks provided they are preserved for several decades. Prospects for achieving production systems with lower GHG emissions are therefore possible for grassland systems in the humid tropics.

[1] http://www.oredd-guyane.fr.

Fig. 10.6 Cattle grazing on a *Brachiaria humidicola* grassland in the Amazon region, French Guiana (© V. Blanfort/CIRAD)

10.4 Impact of Climate Change on Livestock Farming in Developing Countries

Rising temperatures, changing rainfall regimes and the increased frequency of extreme weather events affect livestock farming systems and their productivity worldwide. These factors influence the different components of the system from the animal to the grazing resources. There are also marked impacts on animal health (Chaps. 9 and 18).

10.4.1 Thermal and Water Stress

Thermal stress following an increase in temperature and humidity variations induces major behavioural and physiological changes in animals, such as reductions in feed intake and movements. Energy and water intake required for body temperature regulation increase at the expense of other functions such as production and reproduction. Vulnerability to thermal stress varies depending on the species, genetic potential, age and nutritional status of the animal, as well as the setting. Local breeds in tropical and subtropical areas seem better adapted to these stresses, but few data are available to confirm this.

Droughts and the simultaneous increase in water needs resulting from the high prevailing temperatures can lead to substantial livestock mortality. Animals adapted to drylands seem less vulnerable, but the heavy losses that occurred over the last 10 years in the Horn of Africa is evidence that all animals are susceptible to these stresses. 38 % of the world's human population currently lives in water-stressed environments and this figure should rise to 64 % by 2025 (Rosegrant et al. 2002), which gives an indication of the potential frequency of such events and their impact on livestock worldwide.

10.4.2 Quantity and Quality of Forage Resources

Climate change has direct effects on fodder resources. CO_2 stimulates photosynthesis. According to Long et al. (2006), an atmospheric CO_2 concentration of 550 ppm as compared to the current 400 ppm rate could lead to a 30 % increase in yield for the most sensitive forage species. This increase in plant biomass will nevertheless only be possible if other climatic factors and soil fertility are not limiting. These factors are well documented for crop species, but not for species found in pastoral areas. An increase in temperature and CO_2 levels also results in higher soluble carbohydrate levels and lower nitrogen levels, in addition to higher lignification, which have an impact on livestock productivity and CH_4 emissions. Climate change will alter the composition of rangelands, especially regarding the proportion of grasses and legumes. More severe climatic conditions will tend to favour plants that are best adapted to extreme conditions.

The current balance regarding animal-plant-environment relationships will thus be upset. The extent of changes in plants available for grazing will determine the type of animal best adapted to the feed supply and could jeopardize the livestock species involved. It might then be necessary to modify livestock farming systems by changing the species (e.g. from cattle to small ruminants and camels), breeds (specialized or rustic), and herd feed management strategy (transhumance, crop and forage stocks, feed supplements).

10.4.3 Land Availability

The migration of herders prompted by the environmental degradation of rangelands upon which their herds previously grazed, concomitantly to population growth under way in many rural areas, has led to land saturation in some regions. This is particularly noticeable in sub-Saharan Africa where Sahelian herds have been moving to sub-humid areas since the 1970s. Historically nomadic herders have been gradually settling in these areas while organizing strategic transhumance movements of their herds to favourable sites. Competition between agricultural and pastoral activities has given rise to conflicts. Extensive livestock farming, which by definition requires considerable land, is thus faced with the reduction, fragmentation or even closure of grazing areas and transhumance corridors due to the planting of food crops, thus blocking access to quality grasslands and water points. While herd mobility is an adaptation to climate change, the structuring of areas concerned by new agreements between users is of equally vital interest.

10.5 Livestock Farming Adaptation Capacities

Livestock farming is a crucial adaptation mechanism for poor and vulnerable people in variable environments where there are many risks. Adaptation is based on the resistance mechanisms of some animals to climatic conditions, diseases and food shortages, on the ability of these animals to make effective use of the diversity of plant species, on the rapidly deployable standing capital function and on mobility (Mandonnet et al. 2011). This mobility is a response to the quest for new rangelands and more favourable climatic areas, marketing chains and feed management between good and harsh years. The diversity of livestock farming systems also enhances the range of adaptation capacities.

Because of the reduction in rangelands in some areas and the increased demand for animal products, there is growing interest in zero grazing systems as an adaptation alternative. Livestock productivity may be improved through these systems by controlling the livestock rearing conditions. For instance, Vigne et al. (2014) in Mali and Benagabou (2013) in Burkina Faso demonstrated that periurban dairy farming systems produced at least tenfold more milk than extensive family farming systems.

In mixed systems, forage production could have a larger share in the cropping plan as an adaptation to future climatic conditions. In food cropping systems, although crop farmers are generally hesitant to convert areas devoted to food crops into feed crops, this would reduce the dependence on grasslands. Research on grass-legume crop associations have been conducted in several countries to cope with the cyclical drought risk in southern Europe. Initial results show that certain crop combinations lead to a 12 % increase in total nitrogen levels in comparison to monospecific crop plots. Improved crop-livestock integration is also a key feature to study with regard to these systems. Silvopastoralism is an interesting option for systems with forage crop areas. The presence of trees in grasslands can indeed enhance grassland productivity, especially by delaying the impact of the dry season, and improving the comfort of animals by providing shade.

Finally, the grazing calendar of pastoral and agropastoral systems using natural areas will have to be adapted to cope with changes in productivity and in the composition of pastoral areas, and also with the decrease in available area. In Burkina Faso, an analysis of herd grazing practices revealed that adaptation strategies are already being applied to deal with these new constraints, especially conflicts (Vall and Diallo 2009). In North Africa, adjustments in herd management, enclosed grazing areas and replanting of natural forage cover are under way especially to enhance the long-term persistence of the vegetation and soil regeneration (Huguenin 2011). In the Mediterranean region, adaptation of sheep farming during drought periods has helped overcome veterinary problems (Box 10.1).

There are also some common adaptations to different types of system. The status of rustic breeds, which are less productive but better adapted to harsh conditions, must be reconsidered, especially to achieve a trade-off between livestock productivity aimed at fulfilling household food security needs and adaptation to climate change. Moreover, by diversifying species on individual farms, it is possible to take advantage of the specific adaptation capacities of each species and to improve the resilience of the system (Nozières et al. 2011).

Box 10.1. Adaptation of livestock farming in the Mediterranean region.
Pascal Bonnet, *Véronique Alary*, *Ibrahim Daoud*

In arid northwestern Egypt, the coastal strip gets around 150 mm/year of rainfall. This is the cradle of *wadi* agriculture (olives and figs) and renowned sheep farming (Barki breed). A drought affected the area from 1995 to 2010, which precisely confirmed the model simulations and predictions carried out with regard to the susceptibility of the area to become a hotspot of climate change (Lacetera et al. 2013). The ELVULMED project coordinated by CIRAD investigated how Bedouin livestock farming coped during this period of profound territorial economic transformation via different forms of adaptation of production systems and commodity chains (Bonnet et al. 2014). Livestock feed resources were diversified, livestock farming practices changed and the livestock farming territory increased in size, with the emergence of new forms of livestock feed management, increased animal mobility and forage diversification.

Before the drought, transhumance started from the northern coastal rainfed agriculture zone and proceeded toward the natural grasslands in the south, to the edge of the desert. It became more complex with complementary west-to-east movements starting in February-March from the agricultural *wadis* towards the edge of the Nile Delta, where irrigation was making new land available for agriculture. These lands provided new forage reserves for some livestock farmers, enabling them to graze their herds more or less temporarily before returning to the original breeding lands. This new form of to-and-from mobility had direct impacts on herd health, with veterinary services and livestock farmers having to adapt. Animals temporarily residing in these irrigated areas were exposed to new diseases and feed resources, and some animals returning from the Delta showed symptoms for which farmers and veterinary services in the original areas were unfamiliar.

Livestock farmers and veterinary services were surveyed on how these changes were perceived and on adaptations. Changes in practices leading to intensification of the livestock farming system (use of richer fodder) and exposure to new pathogens or parasites resulted in the emergence of 'enterotoxemia' type syndromes (caused by *Clostridium chauvei*, often due to contamination of forage and rumen acidosis) and various forms of blood (theileriosis and babesiosis) and digestive (nematodes, trematodes such as liver flukes) parasitism. Fifty percent of livestock farmers surveyed noted a moderate increase in internal and external digestive parasitism. This new livestock mobility also led government services to fear the spread of some major communicable infectious diseases such as foot-and-mouth disease, outbreaks of which have increased in the region, particularly in the Nile Delta and Libya.

Veterinary services and livestock farmers have analysed the change of situation and incorporated new intervention strategies, in turn modifying the health system (Chap. 18). Livestock farmers have often resorted to the private sector via veterinary pharmacies and self-medication to treat parasitic blood diseases (increased use of albendazole and multivalent covaccines for enterotoxemia). With these changes, State veterinary services increased vaccinations against foot-and-mouth disease and sheep pox. Team training was increased on managing diseases that were previously overlooked in the area, particularly hitherto unknown parasitism in wet grasslands. The province also began developing preventive strategies targeting specific areas in order to create a sanitary cordon between the west and the Delta to block the spread of certain infectious diseases, including pox. This involved a dual adaptation of the health system—via the market with livestock farmers resorting to private health care and via the State with amendments in the public vaccination application regulations.

10.6 Conclusion

There are many complex interactions between livestock farming systems and climate change over and above the issue of GHG emissions. Livestock farming is directly and indirectly impacted by this change, which threatens the sustainability of the systems and increases the vulnerability of millions of people on all continents. Livestock farming systems and homestead practices are highly diversified. Just with regard to the cattle farming sector, between industrialized systems in developed countries (animals fed crops), and extensive agropastoral and family systems in developing countries (animals fed almost exclusively by grazing natural seasonal rangelands), there is a highly diversified range of livestock systems that differ markedly in terms of GHG emissions, susceptibility to climate change and contributions to food security and income.

The knowledge gained so far is sometimes not sufficient to understand the changes induced or necessitated by climate change in terms of adaptation, mitigation or food security. Livestock herd demographic models such as Dynmod (Lesnoff 2010) can be used to simulate the impact of successive droughts on herd productivity dynamics, etc. Innovations should, however, also be proposed.

With regard to reducing GHG emissions, innovations involve carbon sequestration in soil and grasslands, the reduction in input and feed consumption, improved productivity of the most extensive systems, treatment of slurry and its subsequent integration in agricultural activities. With regard to adaptation to climate change, it is necessary to consider a range of different aspects, such as forage crops, animal genetics, animal health, animal housing. Social and political sciences should also be mobilized since new regulations for the management and sharing of pastoral areas are required to ensure the mobility and integration of livestock farming activities and farmers in changing societies.

For climate-smart livestock farming, it is essential to combine these approaches so as to be able to formulate proactive long-term public policies. This requires structured discussions between producers, livestock and crop farmers, private companies in the various commodity chains, policy makers and civil society. Research and development institutions are essential in this dynamic process. They must explain the issues and propose technical and institutional solutions that apply to the entire production chain and territory. This should be done from a short-term perspective, by providing support for decision making on the most frequent and intense crises, and from a long-term perspective, by forecasting trends and proposing measures that may be applied without social cost. For instance, the development of an information and early warning system to characterize and monitor pastoral dynamics in the Sahel (SIPSA) is particularly relevant for understanding the current dynamics and supporting decision making to cope with the different crises affecting the region (Touré et al. 2012).

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