Worldwide growth of animal production and environmental consequences

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Introduction

Ensuring environmental sustainability is one of the Millennium Development Goals to which FAO and its Members are committed. The conservation, improvement and sustainable utilization of natural resources, including land, water, forests, fisheries and genetic resources for food and agriculture is one of the three global goals of FAO's Strategic Framework between 2000 and 2015. In this document, the issue of livestock's impact on the environment is presented.

Driven by growing populations and incomes, the increase in demand for animal products will be stronger than for most food items. Global production of meat is projected to more than double from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050, and that of milk to increase from 580 to 1,043 million tonnes (FAO, 2006). The bulk of the growth in meat and milk production will occur in developing countries, with China, India and Brazil representing two thirds of current meat production and India predicted to grow rapidly, albeit starting from a low base. Among the meat products, poultry will be the commodity of choice for reasons of acceptance across cultures and technical efficiency in relation to feed concentrates. It is expected that intensive systems will contribute to most of the increase in production, as they have done in the past three decades.

The livestock sector has a primary and growing role in the agricultural economy. It is a major provider of livelihoods for the larger part of the world's poor people. It is also an important determinant of human health and diet. Global demand for livestock products is projected to double by 2050 - despite this growth, per capita consumption levels in developing countries will be not more than half the level of developed countries. But already the livestock sector stresses many ecosystems and contributes to global environmental problems. Greenhouse gas emissions from livestock production and their waste, and from pasture expansion into forests and pasture degradation are an important factor in climate change. The presence of livestock in the vast majority of the world's ecosystems affects biodiversity. In developed and rapidly developing countries, it is often a major source of water pollution (Gerber, 2005).

The future of the livestock-environment interface will be shaped by how we resolve the balance of two competing demands: for animal food products on the one side and for environmental services on the other. Both demands are driven by the same factors: increasing populations, growing incomes and urbanization. The natural resource base within which they must be accommodated is finite. Therefore, the continuing expansion of the global livestock sector must be accomplished while substantially reducing livestock's environmental impact.

This paper draws from a report submitted to the 20th session of the Food and Agriculture Organisation of the United Nation (FAO) Committee On Agriculture (COAG), held on 25 to 28 April 2007 in Rome. It summarizes recent studies on these issues and suggests possible lines of action for dealing with the environmental challenges posed by the sector.

Environmental impacts

Land and land-use change: Humanity's largest land use

Livestock's land use includes (a) grazing land and (b) cropland dedicated to the production of feed. Considering both, livestock represent approximately 70 percent of all agricultural land.

The total land area occupied by *livestock grazing* is 3.4 billion hectares equivalent to 26 percent of the ice-free terrestrial surface of the planet. A large part of these areas are too dry or too cold for crop use, and are only sparsely inhabited. While the grazing area is not increasing at a global scale, in tropical Latin America there is rapid expansion of pastures into valuable ecosystems, with 0.3 to 0.4 percent of forest lost to pastures annually. Ranching is a primary reason for deforestation.

About 20 percent of the world's pastures and rangeland have been degraded to some extent, and this percentage may be as high as 73 percent in dry areas (UNEP, 2004). The Millennium Ecosystem Assessment (MEA, 2005) has estimated that 10 to 20 percent of all grassland is degraded, mainly by livestock. However, some of the dryland grazing ecosystems have proved to be quite resilient and degradation has shown to be partly reversible (Steinfeld et al., 2006).

The total area dedicated to *feed crop production* amounts to 471 million hectares, equivalent to 33 percent of the total arable land. Most of this total is located in Organization for Economic Co-operation and Development (OECD) countries, but some developing countries are rapidly expanding their feed crop production, notably maize and soybean in South America. Again, a considerable part of this expansion is taking place at the expense of tropical forests. It is expected that future growth rates of livestock output will be based on similar growth rates for feed concentrate use (FAO, 2006). Without the necessary precautions, intensive feed production can result in land degradation, including soil erosion and water pollution (Steinfeld et al., 2006).

Gaseous emissions and climate change

Recent estimates of global Green House Gas (GHG) emissions from different sources by the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC) and the "Stern Review", show that land use changes due to deforestation result in 18.3 percent of total GHG emission while agriculture accounts for 13.5 percent (of which agricultural soils is 6 percent, livestock and manure 5.1 percent) and the transportation sector 13.5 percent (of which road transport is 10 percent).

Considering different forms of emissions throughout the livestock commodity-chains, GHG estimates for the livestock sector are substantial (Steinfeld *et al.*, 2006). GHG emissions occur at the level of feed production (e.g. chemical fertilizer production, deforestation for pasture and feed crops, cultivation of feed crops, feed transport and soil organic matter losses in pastures and feed crops), animal production (e.g. enteric fermentation and methane and nitrous oxide emissions from manure) and as a result of transport of animal products. Using such methodology, livestock contribute about 9 percent of total anthropogenic carbon-dioxide emissions, but 37 percent of methane and 65 percent of nitrous oxide emissions. The commodity-chain methodology used in this paper is not used by the IPCC and, therefore, emissions may be attributed in a different manner.

Carbon dioxide is released when previously-forested areas are converted into grazing land or arable land for feed. Therefore, expansion of pasture and cropland at the expense

of forests releases significant amounts of carbon dioxide into the atmosphere as does the process of pasture and arable land degradation, often associated with a net loss of organic matter. Carbon dioxide releases resulting from fossil fuel consumption used for the production of feed grains (tractors, fertilizer production, drying, milling and transporting) and feed oil crops need also be attributed to livestock. The same applies to the processing and transport of animal products. Methane is emitted from rumen fermentation and from livestock waste when stored under anaerobic conditions, for example in so-called lagoons. Yet another category is constituted by nitrous oxide emissions from intensive feedcrop production and related chemical fertilizer application.

Regarding polluting gaseous emissions not linked to climate change, livestock waste emits a total of 30 million tonnes of ammonia. Livestock account for 68 percent of total ammonia emissions (Steinfeld et al., 2006).

Technical options are available to mitigate gaseous emissions of the sector. Carbon-dioxide emissions can be limited by reducing deforestation and the sector can contribute to carbon sequestration through a range of practices including: restoring organic carbon in cultivated soils, reversing soil organic carbon losses from degraded pastures and sequestration through agro-forestry. Improved livestock diets as well as better manure management can substantially reduce methane emissions, while careful nutrient management (i.e. fertilization, feeding and waste recycling) can mitigate nitrous oxide emissions and ammonia volatilization. Furthermore, the use of biogas technology is a way to reduce emissions from manure management while increasing farm profit (e.g. savings on energy bill, electricity trading) and providing environmental benefits, such as reduced fossil fuel consumption).

Water

The livestock sector is a key factor in increasing water use and water depletion. The share of livestock sector is about 8 percent of global water use. The major part of this water is used for irrigation of feed crops, representing 7 percent of the global water use. The water used for product processing and drinking and servicing is less than one percent of global water use, but it often is of great importance in dry areas; for example, livestock drinking requirements represent 23 percent of total water use in Botswana.

Important amounts of water are used for irrigating pasture and feed crops, mostly in developed countries. Through the compacting effect of grazing and hoof action on the soil, livestock also have a determining, and often negative, impact on water infiltration and water erosion.

Water quality can be affected by livestock through the release of nitrogen, phosphorus and other nutrients, pathogens and other substances into waterways, mainly from intensive livestock operations. The fact that the livestock sector is industrializing, in a number of concentrated locations, separates the sector from its supporting land base and interrupts the nutrient flows between land and livestock, creating problems of depletion at the source (land vegetation and soil) and problems of pollution at the sink (animal wastes, increasingly disposed of into waterways instead of back on the land).

Livestock have a major role in water pollution though the release of animal manure into freshwater resources. These wastes are not controlled for sediments, pesticides, antibiotics, heavy metals and biological contaminants. Livestock land-use and animal waste-management appear to be the main mechanism through which livestock contribute to the water depletion process.

Multiple and effective options for mitigation exist in the livestock sector that would allow

the reverse of current water-depletion trends. Mitigation options usually rely on three main principles: reduced water use (e.g. through more efficient irrigation methods and animal cooling systems), reduced depletion, (e.g. through increased water productivity and mitigated pollution from waste management and feed crop fertilization) and improved replenishment of the water resources through better land management.

Biodiversity

Livestock affect biodiversity in many direct and indirect ways. Livestock and wildlife interact in grazing areas, sometimes positively, but more often negatively. Livestock help to maintain some of the open grassland ecosystems, but animal disease concerns pose new threats to wildlife.

Pasture expansion, often at the expense of forest, has vast negative consequences on some of the most valuable ecosystems in Latin America, while rangeland degradation affects biodiversity on all continents. Crop area expansion and intensification for livestock feed undoubtedly affect biodiversity negatively, sometimes with dramatic consequences (soybean expansion into tropical forests). Water pollution and ammonia emissions, mainly from industrial livestock production, reduce biodiversity, often drastically in the case of aquatic ecosystems. Pollution, as well as over-fishing for fishmeal as animal feed, affects biodiversity in marine ecosystems.

Livestock's important contribution to climate change will clearly have repercussions on biodiversity, while the historic role of livestock as a driver and facilitator of invasions by alien species continues – in particular by way of introduction of exotic pasture seeds and livestock diseases.

Differences between species, products and production systems

There are huge differences in the environmental impact between the different forms of livestock production, and between species.

Cattle provide a multitude of products and services, including beef, milk, hides and draught power. In mixed farming systems, cattle are usually well integrated in nutrient flows and can have a positive environmental impact. In many developing countries, cattle and buffaloes still provide animal draught for field operations, and in some areas, animal traction is on the increase (parts of sub-Saharan Africa), potentially substituting for fossil fuel use. Livestock also consume crop residues some of which would otherwise be burned. However, cattle in extensive livestock production in developing countries are often only of marginal productivity. As a result, the vast majority of feed is spent on the animal's maintenance, leading to resource inefficiencies and often high levels of environmental damage per unit of output, particularly in overgrazed areas.

The dairy sector is more closely connected to the supporting feed resource than is the case for other forms of market-oriented livestock production. Most milk operations tend to be close to areas of feed supply because of their daily demand for fibrous feed, allowing for nutrient recycling. However, excessive use of nitrogen fertilizer on dairy farms is one of the main causes of high nitrate levels in surface water in OECD countries. There is also a risk of soil and water contamination by manure runoff and leaching from large-scale dairy operations.

Beef is produced in a wide range of intensities and scales. At both ends of the intensity spectrum considerable environmental damage occurs. On the extensive side, cattle are involved in degradation of vast grassland areas and are a contributing factor to deforestation (pasture conversion). The resulting carbon emissions, biodiversity losses and negative

impacts on water flows and quality constitute major environmental impacts. On the intensive side, feedlot size is often vastly beyond the capacity of surrounding land to absorb nutrients (Steinfeld et al., 2006). In the feedlot stage the conversion of concentrate feed into beef is far less efficient than into poultry or pork, and therefore beef has significantly higher resource requirements per kilogram of meat than pork or poultry. However, taking the total life-cycle into account, including the grazing phase, concentrate feed per kilogram of growth is lower for beef than for non-ruminant systems (CAST, 1999).

The production of sheep and goats is usually extensive, except for small pockets with feed lots in the Near East and West Asia, and North America. The capacity of small ruminants, in particular goats – to grow and reproduce under conditions otherwise unsuitable for any form of agricultural production – makes them useful and very often essential to poor farmers pushed into these environments for lack of alternative livelihoods. Because of their adaptive grazing, sheep and goats can affect land cover and the potential for forest re-growth. Under overstocked conditions, they are particularly damaging to the environment through degradation of vegetative cover and soil.

Extensive pig production, based on the use of household waste and agro-industrial by-products as feed, performs a number of useful environmental functions by turning biomass of no commercial value – which otherwise would be waste – into high-value animal protein. However, extensive systems are incapable of meeting the surging urban demand in many developing countries, not only in terms of volume but also in sanitary and other quality standards. The ensuing shift towards larger-scale grain-based industrial systems has been associated with geographic concentration, leading to nutrient overload of soils and water pollution. Furthermore, most industrial pig production in the tropics and sub-tropics uses waste-flushing systems involving large amounts of water.

Poultry production has been the system most subject to structural change. In OECD countries production is almost entirely industrial, while in developing countries it is already predominantly industrial. Although industrial poultry production is entirely based on feed grains and other high-value feed material, it is the most efficient form of production of food of animal origin (with the exception of some forms of aquaculture), and has the lowest land requirements per unit of output. Poultry manure is of high nutrient content, relatively easy to manage and is widely used as fertilizer and sometimes feed. Other than for feed crop production, the environmental damage, though sometimes locally important, is of a much lower scale than for the other species.

In conclusion, livestock-environment interactions are often diffuse and indirect; and damage occurs at both the high and low end of the intensity spectrum, but is probably highest for beef and lowest for poultry.

What needs to be done?

Major corrective measures need to be taken to address the environmental impact of livestock production that will otherwise worsen dramatically, given the projected expansion of the livestock sector. However, growing economies and populations combined with increasing scarcity of environmental resources and rising environmental problems are translating into a growing demand for environmental services, such as clean air and water, and recreation areas. Increasingly, this demand will broaden from immediate factors of concern, such as reducing the nuisance factors of flies and odours, to the intermediate demands of clean air and water, and then to the broader, longer-term environmental concerns, including climate change, biodiversity, etc. At the local level, markets will undoubtedly develop for the provision of such services; this is already the case for water in many places. At the global level, the emergence of such markets is uncertain although promising models already exist, for example carbon trading.

Encouraging efficiency through adequate market prices

Current prices of land, water and feed resources used for livestock production often do not reflect true scarcities. This leads to an overuse of these resources by the livestock sector and to major inefficiencies in the production process. Any future policy to protect the environment will, therefore, have to introduce adequate market pricing for the main inputs, for example, by introducing full-cost pricing of water and grazing fees.

A host of tested and successful technical options are available to mitigate environmental impacts. These can be used in resource management, in crop and livestock production, and in post-harvest reduction of losses. However, for these to be widely adopted and applied, appropriate price signals which more closely reflect the true scarcities of production factors, and correcting the distortions that currently provide insufficient incentives for efficient resource use are required. The recent development of water markets and more appropriate water pricing in some countries, particularly water-scarce ones, are steps in that direction.

Correcting for environmental externalities

Although the removal of price distortions at input and product level will go a long way to enhancing the technical efficiency of natural resource use in the livestock production process, this may often not be sufficient. Environmental externalities, both negative and positive, need to be explicitly factored into the policy framework, through the application of the "provider gets - polluter pays" principle.

Correcting for externalities, both positive and negative, will lead livestock producers into management choices that are less costly to the environment. Livestock holders who generate positive externalities need to be compensated, either by the immediate beneficiary (such as with improved water quantity and quality for downstream users) or by the general public (such as with carbon sequestration from reversing pasture degradation).

While regulations remain an important tool in controlling negative externalities, there is a trend towards taxation of environmental damage and incentives for environmental benefits. It may gain momentum in future, tackling local externalities first but increasingly also trans-boundary impacts, through the application of international treaties, underlying regulatory frameworks and market mechanisms. Government policies may be required to provide incentives for institutional innovation in this regard.

Accelerating technological change

A number of technical options could lessen the impacts of intensive livestock production. Concerning feed cropping and intensive pasture management, good agricultural practices can reduce pesticide and fertilizer losses. Conservation agriculture and other forms of resource preserving technologies can restore important soil habitats and reduce degradation. Combining such local improvements with restoration or conservation of an ecological infrastructure at the landscape level may offer a good way of reconciling the conservation of ecosystem functioning and the expansion of agricultural production. Improvements in extensive livestock production systems can also make a contribution to biodiversity conservation, for example by adopting silvopastoral systems and planned grazing management that limits overgrazing of plants and increases biodiversity and quantity of forage, soil cover and soil organic matter thus reducing water loss to evaporation, runoff and sequestring carbon dioxyde. Options exist to increase production and achieve a variety of environmental objectives.

Improved and efficient production technologies exist for most production systems.

However access to information and technologies and capacity to select and implement the most appropriate ones are restraining factors, which can be reduced through interactive knowledge management, capacity building and informed decision making at policy, investment, rural development and producer levels. Technological improvements need to be oriented towards optimal integrated use of land, water, human, animal and feed resources. In the livestock sector, the quest for optimizing efficiencies will be through feeding, breeding and animal health. Research and management of feed crop production needs to aim at higher yields in more locally adapted eco-friendly production systems and socio-economic research for rural development needs to provide a better understanding of the external factors that enable realization of the improvements in the first two sectors.

Reducing negative environmental and social impacts of intensive production

An estimated 80 percent of total livestock sector growth comes from industrial production systems. The environmental problems created by industrial systems mostly derive from their geographical location and concentration. In extreme cases, size may be a problem: sometimes units are so large (a few hundred thousand pigs, for example) that waste disposal will always be an issue, no matter where these units are located.

What is required therefore is to bring waste generated into line with capacity of accessible land to absorb that waste. Industrial livestock must be located as much as possible where cropland within economic reach can be used to dispose of the waste, without creating problems of nutrient loading - rather than geographically concentrating production units in areas favoured by market access, or feed availability. Policy options to overcome the current economic drivers of the peri-urban concentration of production units include zoning, mandatory nutrient management plans, financial incentives and facilitation of contractual agreements between livestock producers and crop farmers. Regulations are also needed to deal with heavy metal and drug residue issues at the feed and waste levels, and to address other public health aspects such as food-borne pathogens.

Whether industrialized or more extensive livestock production systems, they need to strive to obtain lowest possible emissions with full waste treatment adapted to local conditions. This requires close coordination and integration with other development activities like bioenergy, transport, urban and peri-urban development, forestry and others. Associated additional costs need to be absorbed across various economic sectors.

In parallel, there is a need to address the environmental impacts associated with production of feed grain and other concentrate feed. Feed is usually produced in intensive agriculture, and the principles and instruments that have been developed to control environmental issues there need to be widely applied.

Diversifying extensive grazing with the provision of environmental services

Grazing systems need to be intensified in areas where the agro-ecological potential so permits, in particular for dairy production, and where nutrient balances are still negative. In many OECD countries, excess nutrient loading is a major issue in grass-based dairy farming. Reductions in the number of livestock have been imposed, sometimes with very positive results. However, the vast majority of extensive grazing lands are of low productivity. Grazing occupies 26 percent of the ice-free terrestrial surface but the contribution that extensive grazing systems make to total meat production is less than 9 percent.

In a world with around 9 billion people by 2050 and a growing middle class, there will be a growing demand for environmental services; therefore extensive systems will have

the opportunity to include the provision of environmental services as an important, and sometimes predominant, purpose. This can be facilitated by payments for environmental services or other incentives to enable livestock producers to enhance resource sustainability.

The central argument here is that the opportunity cost for livestock to use marginal land is changing. Livestock used to occupy vast territories because there was no viable alternative use, whereas other usages (e.g. biodiversity conservation, carbon storage, bio-fuels) are now competing with pasture in some regions. Water-related services will likely be the first to grow significantly in importance in future, with local service provision schemes the first to be widely applied. Biodiversity-related services (e.g. species and landscape conservation) are more complex to manage, because of major methodological issues in the valuation of biodiversity, but they already find a ready uptake where they can be financed through tourism revenues. Carbon sequestration services, through adjustments in grazing management or abandonment of pastures, will also be difficult. However, given the potential of the world's vast grazing lands to sequester large amounts of carbon and to reduce emissions, mechanisms must be developed and deployed to use this potentially cost-effective avenue to address climate change.

Suggesting a shift from some of the current negative grazing practices to environmental-service oriented grazing raises two questions of paramount importance: how to distribute profits from environmental services and how to deal with the poor who currently derive their livelihoods from extensive livestock? Their numbers are considerable. Livestock provide an important source of livelihood in poor countries, for example in Mauritania (where it provides 15 percent of GDP), the Central African Republic (21 percent) and Mongolia (25 percent).

Not all environmental services of sustainable livestock production will be easily paid for through immediate product pricing. Alternative employment generation and social safety nets are some of the needs to ensure sufficient knowledge and labour to maintain marginal but important production areas, which however require effective integration/collaboration with other rural development activities, particularly in countries where poverty and lack of public resources and governance result in unsustainable land use. More encompassing external assistance will be required in countries where global assets such as biodiversity, climate and food security are concerned but where the economic potential for other sectors is limited.

The challenge ahead

As an economic activity, the livestock sector generates about 1.4 percent of the world's GDP (2005); it accounts for 40 percent of agricultural GDP. With a 2.2 percent global growth rate for the last ten years (1995 to 2005) globally and 5.5 percent growth rate in developing countries, the livestock sector is growing faster than agriculture as a whole whose share of overall GDP is declining. However, the livestock sector is much more important than its modest contribution to the overall economy would suggest. Livestock provide livelihood support to an estimated 987 million poor people in rural areas (LID, 1999). Livestock products in moderation are also an important element of a diverse and nutrient-rich diet.

These diverse aspects of livestock's importance inform national decision-making for the sector. The different national policy objectives of food supply, poverty reduction, food safety and environmental sustainability take on different levels of importance depending on factors such as stage of development, per capita income and general policy orientation of a country. Furthermore, the objectives of sector policies and the instruments used to achieve environmental goals should be tailored according to the farming systems and relative stakeholders they target.

A key aspect is that, compared to its economic performance, the environmental impacts of the livestock sector are not being adequately addressed. The problem therefore lies mainly with institutional and political obstacles and the lack of mechanisms to provide environmental feedback, ensure that externalities are accounted for and embed the stewardship of common property resources into the sector.

The first challenge, therefore, is to raise awareness among stakeholders of the scale of the environmental problem. Environmentally-motivated action currently focuses on the functions and protection of specific ecosystems. As we have seen, the mobility of the livestock industry allows its relocation without major problems becoming apparent. However, the pressure on the environment is usually shifted elsewhere, and manifests itself in different forms. For example, intensification may reduce pressure on grazing lands but increase pressure on waterways. Thus, another challenge is to add a sector perspective to the analysis of environmental issues.

The complexity of livestock-environment interactions and their many manifestations make concerted actions more difficult. Investment and production choices are driven by a variety of factors, many of which are external to the livestock / agriculture sector as such. This is also true of many other environmental and development issues and is a major reason why environmental policy-making lags behind other areas. In this sense, the livestock sector is driven by its own set of policy objectives and decision-makers find it difficult to address economic, social, health and environmental objectives simultaneously. Frequently they also lack the tools, information access and platforms to initiate and implement such complex decision making processes.

The livestock sector is industrializing at the level of production units and and food chains while also remaining an important livelihood source for large numbers of small-scale and marginalized producers in many parts of the world. The fact that so many people depend on livestock for their livelihoods and health limits the available options to policy-makers, and involves difficult and politically sensitive decisions on trade-offs. Policy-makers therefore need to address the multiple objectives of livestock development: affordable supply of high value food; food safety; and livelihoods and environmental soundnessPerhaps the biggest challenge is therefore to build the institutions and cross-sectoral capacities, both nationally and internationally, to address the complex environmental issues with a sense of urgency, while considering social and public issues.

Reducing livestock's environmental impacts has a net cost that will need to be borne by the sector and the consumers. Addressing the environmental challenge thus raises issues of smallholder competitiveness, reduced purchasing power of the non-affluent consumers and reduced national competitiveness, especially in those countries that do not compensate increasing production costs by increased transfers to producers. Despite these difficulties, the impact of livestock on the local and global environment is so significant that it needs to be addressed with urgency. The challenge for policy makers is to balance the interests of consumers and producers, and to ensure an equitable outcome of this process.

Expecting the livestock sector to deliver on all fronts is ambitious. The policy framework for the livestock sector, as for other areas, is characterized by a large number of trade-offs that need to be balanced at the national and local level. For example, a large commercial expansion of the sector, benefiting from economies of scale and with upgraded food safety standards, creates barriers to smallholder producers. Many simply will not have the financial and technical means to compete and will be forced out of business. Likewise, distortions and externalities can be corrected but the costs of higher input prices and environmental controls will have to be passed on to the consumer, in the form of higher prices for meat, milk and eggs. Balancing these trade-offs and arbitration among stakeholders is a further challenge to policy makers.

Simultaneously with other measures, the reduction of expected demand from the livestock sector would also ease environmental pressure and costs and should find entry into policies in both developed and developing countries while assuring adequate nutritional needs [health] and security of the various population groups.

Given the planet's finite natural resources, and the additional demands on the environment from a growing and wealthier world population, it is imperative for the livestock sector to move rapidly towards far-reaching change. Four lines of action are suggested:

First, the strive for efficiency gains in resource use for livestock production must continue, on the basis of much-required price corrections for inputs, and replacing current suboptimal production with advanced production methods – at every step from feed production, through livestock production and processing, to distribution and marketing. Policy-makers are called upon to steer and facilitate this process.

Second, there is a need to accept that the intensification of livestock production is an inevitable characteristic of the structural change process that is ongoing for most of the sector. The key challenge is to make this process environmentally acceptable by facilitating the right location so as to enable waste recycling on cropland, and applying the right technology, especially in feeding and waste management. Locating industrial livestock units in suitable rural environments and not in congested peri-urban or otherwise favoured settings allows for the availability of land area and recycling of nutrients. When making changes to the structure of livestock market chains in order to mitigate adverse environmental effects, it will at the same time be important to consider social impacts.

Third, extensive land-based production will continue to exist. However, decision-makers will need to adjust grassland-based production so as to include the provision of environmental services as a major purpose, and probably as the most important one in vulnerable areas. Policy makers need to provide a framework for the delivery landscape maintenance, biodiversity protection, clean water and eventually carbon sequestration from extensive grazing systems, in addition to production of conventional livestock commodities.

Last, but certainly not least, for the suggested changes to occur, there is an urgent need to go beyond existing policy frameworks at the local, national and international level. A strong political will and urgency, established together with potential actors and beneficiaries, are required to initiate action and investment in creative ways to avert the environmental risks of continuing "business as usual."

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