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Responsible environmental choices for a sustainable "Livestock Revolution"

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Introduction

Livestock production is one of the most important and fastest growing agricultural subsectors in the world. It provides livelihoods for over 1 billion people, generating 40% of global agricultural GDP, and is a major contributor to food and nutrition security (World Bank 2009). It also requires large amounts of resources, especially land areas - using one-third of our globe for feed crops and pastures. In this background paper, we present some of the major trends, driving forces, challenges and opportunities characterizing the present rapidly expanding, demand-driven growth some call the "Livestock Revolution." We focus on the environmental resource constraints to sector development that this continued expansion can experience.

The environmental effects of livestock production are diverse in scale and nature depending on the type of affected ecosystem and the production methods chosen. Ecosystems provide humans with many ecosystem goods and services (e.g. food, feed, and fuel production, erosion control, pollination, potential for recreation, etc.) (MA 2005). Agricultural ecosystems, of which livestock are often an integral part, are multifunctional and can generate a whole bundle of ecosystems services simultaneously. Depending on the production methods chosen, the relative abundance of different services can change. For example, grazing areas in Sweden generate not only animal feed, but also sustain other ecosystem services such as culturally desirable open landscapes and biodiverse meadows (Eriksson et al 2002, Pykälä 2000).

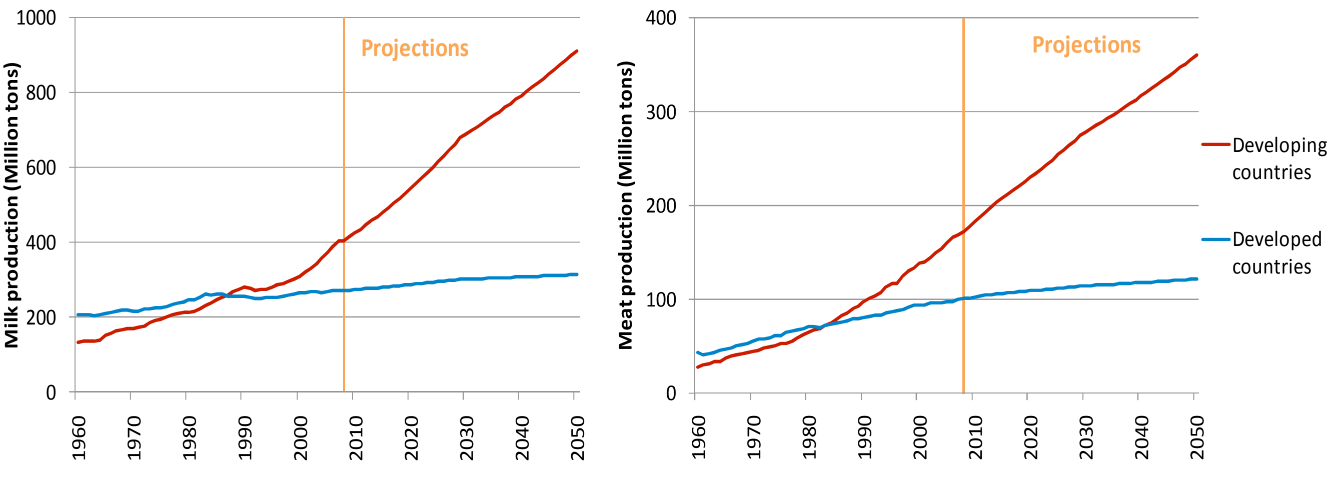
Since we assume livestock production will continue to expand significantly, we explore five of the various ways that ecosystem services may be disturbed by livestock production choices effecting: land, water, greenhouse gas emissions, biodiversity and nutrients. This is to encourage discussion of knowledge-based tradeoffs and choices that will need to be made in of search for opportunities to make livestock production sustainable.

Rapidly increasing production and trade

The impressive growth and transformation of the livestock sector can mainly be attributed to **technological developments**, e.g. fertilizers, antibiotics, mechanization and genetic breeding to improve the feed-to-meat conversion, and **increased use of resources**, e.g. more crops for feed, expansion of grazing areas, intensified fertilizer use and more water and energy.

In the last 50 years, global meat production has almost quadrupled and milk production has doubled (Figures 1 and 2). By 2050, this production is expected to increase by more than 70% and have a total output of almost 1,200 million tons of milk and close to 500 million tons of meat. Developing countries already lead both global meat and milk production and, by 2050, are expected to generate three-quarters of global meat output and two-thirds of global milk output. Bovine meat dominated production until the end of the 1970s when pig production surpassed it (Figure 3). However, by 2020, poultry is projected to lead, supplying 44% of total meat production.

Livestock production systems are commonly divided into three different types: grazing, mixed and intensive. Basically, livestock consume grass and/or crops for feed and different systems have different resource requirements (Figures 4 and 5). Grazing requires large amounts of pastures, mixed production has a diversity of resource requirements, i.e. can be dominated by crops, fodder or pastures, and intensive production requires the largest amount of cropland.



Figures 1 and 2: Past and projected global milk and meat production from 1960-2050 (FAOSTAT 2011, Alexandratos 2006, 2009).

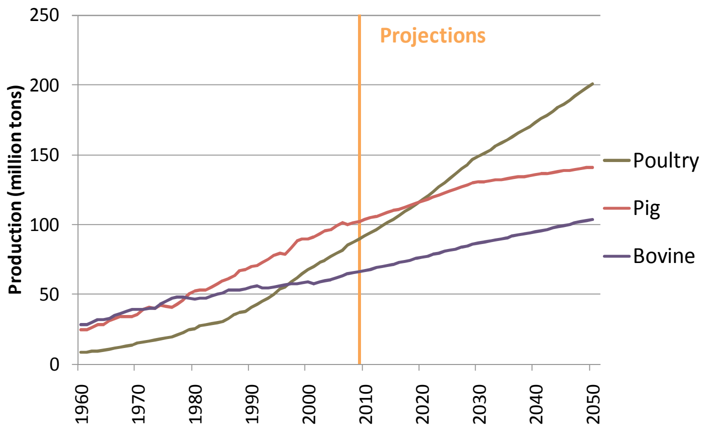


Figure 3: Past and projected trends of global production of different livestock products from 1960 - 2050 (FAOSTAT 2011, Alexandratos 2006, 2009).

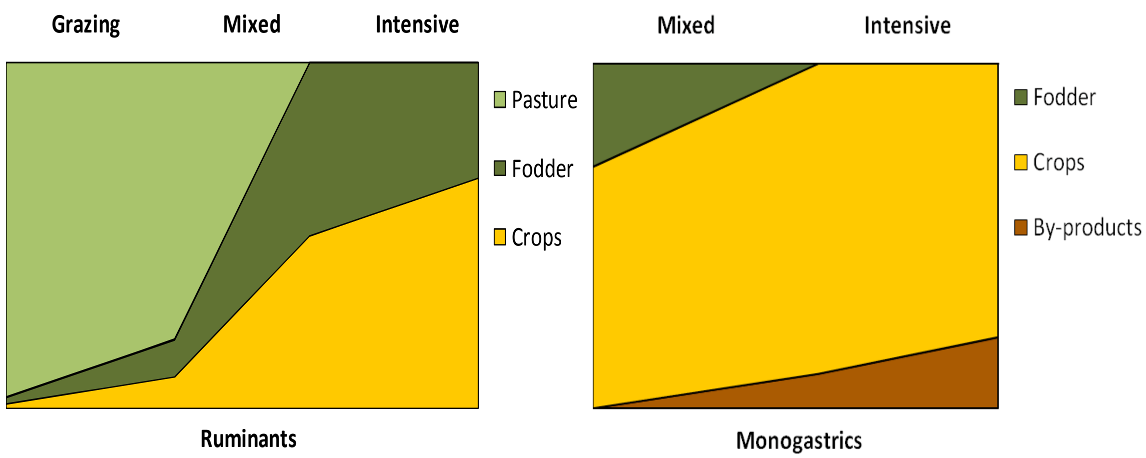
Globally, livestock production is moving towards more intensive and mixed systems, primarily to feed pigs and poultry. Monogastrics account for 80% of global concentrate feed consumption (Galloway et al 2010). In 2002, intensive systems provided almost half of global meat production and almost as much as 70% of poultry and 60% of pork production. Ruminant production is intensifying as grazing systems become mixed production, but in 2002, less than 5% were intensive systems

The enormous increased trade of livestock products the past 50 years clearly visualizes the ongoing rapid globalization of the livestock sector. In comparison with global production of meat and milk between 1961 and 2007, which quadrupled respectively doubled, the global trade of meat increased by a staggering 900% and milk by more than 500%. Brazil is the significantly largest exporter and contributes 18% of global meat exports, with 22% of bovine, 13% of pig and 28% of poultry meat exports. Second largest is USA with 14 % of total meat exports, and 7, 10 and 28% of bovine, pig and poultry meat respectively (FAOSTAT 2011).

Trade of milk products is dominated by Europe where the main exporters Germany, France and Netherlands, contributing 12, 10 and 9% of total exports respectively, also belong to the top ten global importers. However, the most important dairy products exporting nation is New Zeeland with 14% of global exports. In contrast to Europe New Zeeland just barely qualifies to be among the top 100 imports (FAOSTAT 2011).

The last 50 years (1960-2007) total Swedish meat production has increased from 360,000 to 520,000 tons per year. Similar to global trends annual poultry production has increased ten times to 115,000 ton, and pork production has increased by about 25% to 265,000 tons whereas bovine meat production has been fluctuating around 140,000 tons per year during the entire period. Bovine meat production in Sweden is closely related to milk production livestock system. More than 65% of Swedish beef production can be assigned to the milk sector. However, the dairy sector is today in decline and in 2007 the number of cows in Sweden had decreased by 50% percent compared to 1960. Although the production per cow has more than doubled, total milk production (excluding butter) has decreased by more than 20% and is today about 3 million tons per year. The import of animal livestock products to

Sweden is increasing and the net import per year of beef is 100,000 tons, of pork 60,000 tons, of poultry 30,000 tons and of milk 275,000 tons (Swedish board of agriculture 2007, 2010). Sweden mainly imports livestock products from other European countries where the largest exporters are Germany, Ireland, Netherlands and Denmark. Import from non-European countries is primarily from Brazil and Uruguay (Swedish Board of Agriculture 2011).



Figures 4 and 5: Bio-resources for livestock production systems of ruminants (e.g. cattle, sheep) (Figure 4) and monogastrics (e.g. pigs, chickens) (Figure 5) where by-products also includes food leftovers, fish, meat & bone meal (adapted from Deutsch et al 2010)

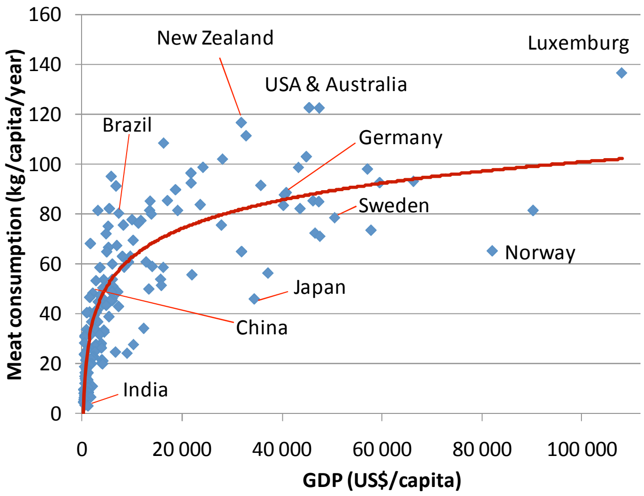


Figure 6: Per capita GDP of meat consumption by country in 2007 (FAOSTAT 2011, UNSTAT 2011).

Consumption-driven Livestock Revolution

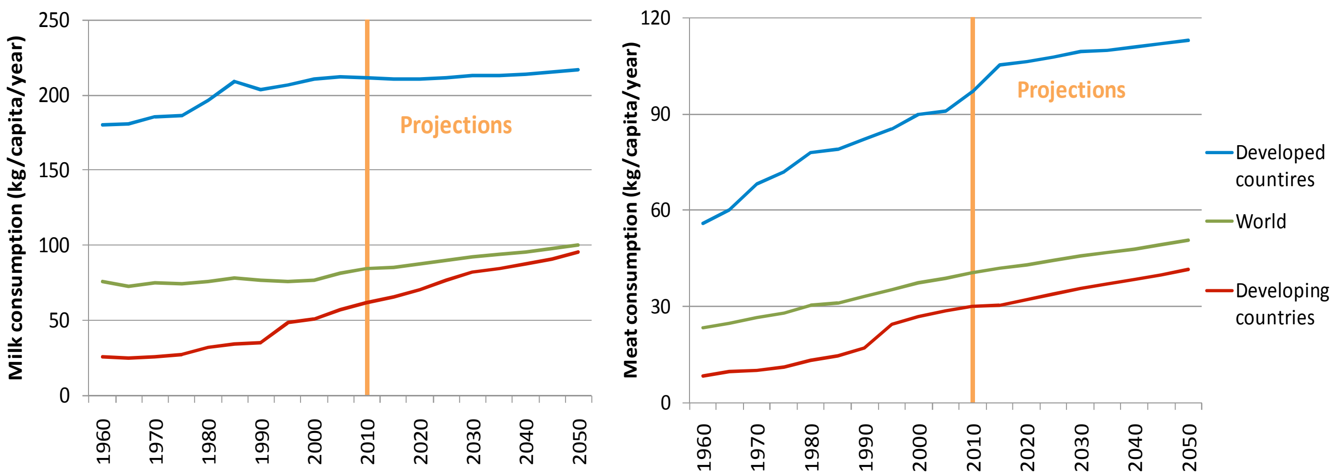
The current growth in animal products' production has mainly been driven by increased demand. Overall, increases in consumption are based in three factors: population growth, rising affluence and urbanization. An increase in population creates an obvious increase in demand. There is also a clear linkage between increasing per capita income and meat consumption (Figure 6). The graph flattens out above a GDP per capita of US$ 30,000 and indicates saturation of demand at higher income levels. Urbanization is tied to global convergence of diet preferences across the world, including more foods of animal origin as well as, more pre-processed food, more added sugar and fat, and often more alcohol (Steinfeld et al 2006).

Changing food habits have two main components. The first is an increase in calorie consumption per person. Average food supply per person and day has increased steadily in most countries since the 1960s. From 1961-2007, global average food consumption increased by 27%, from 2,200 to 2,800 $kcal^{-1}$ $pers^{-1}$ day^{-1} (FAOSTAT 2011).

The second component concerns the increased consumption of animal products. In the last 50 years, global average animal product supply per person has increased by more than 42% to about 17% of the daily calorie consumption (FAOSTAT 2011). While about 30% of the average food supply of calories in the US and the EU consists of animal products, the corresponding ratio is about 20% in China, Mexico and Brazil, and less than 10% in India, Bangladesh, Indonesia and Nigeria.

Developing countries are expected to continue their rapid increase in total consumption of livestock products and by 2050 they will consume twice as much meat and four times the amount of milk of developed countries. However, the daily per capita consumption is still expected to be more than double in the developed compared to developing countries (Figures 7 and 8). It is also interesting to notice that the world average is close to the average in the developing countries, this is explained by the fact that almost 90% of the global population will live in these countries by 2050 (UN 2010).

Meat consumption in Sweden has increased from 51 to 83 kg per capita and year over the past 50 years. Poultry consumption stands for the largest rise with a ten-fold increase to 16 kg cap^{-1} yr^{-1}, while the consumption increase of bovine and pork meat has been less than 50%, from 19 to 25 and 25 to 36 kg cap^{-1} yr^{-1} respectively. Moreover, consumption of poultry products remains to increase, and is the explanation behind the small rise in overall livestock product consumption in Sweden the past decade. The demand for bovine and pig meat has stagnated and remains relatively stable (Swedish Board of Agriculture 2011).



Figures 7 and 8: Past and projected per capita food consumption patterns of milk (Figure 7) and meat (Figure 8) in developing and developed countries (Alexandratos 2006, 2009, UN 2010, FAOSTAT 2011).

Main impacts on ecosystem services

As stated before, there are many environmental impacts associated directly and indirectly with livestock production. Assuming that livestock production will continue to expand, we address five key areas where the impacts of livestock on ecosystem services are large and in many cases negative in relation to the production of other ecosystem services besides animal feed.

Land use and land cover change

Land cover change, e.g. when forests are converted to pastures or crops, has been the most important driver of ecosystem degradation over the past 50 years (MA 2005). Humans have already altered more than half of the Earth's surface (Ellis et al 2010) and croplands and pastures occupy about 40 percent of all lands (Foley et al 2005) in relation to 14 % in 1850 (Figure 9). With about 33% of all croplands used for feed crops (Steinfeld et al 2006) the livestock sector in total occupies more than 30% of global terrestrial biomes.

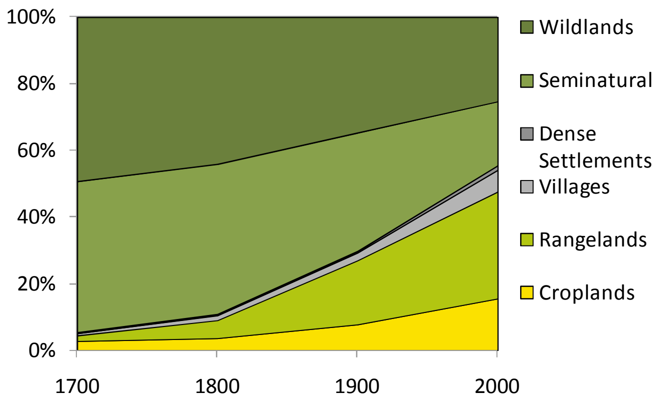


Figure 9: Global change in land-use areas from 1700-2000. Wildlands represent wild wood, treeless and barren lands. Semi-natural lands are residential areas, populated and remote woodlands and inhabited treeless and barren lands (Ellis et al 2010).

It is estimated that the production of cereals for feed will rise from 645 Mton per year in 2000 to 1,010 Mton per year by 2050 (Figure 10) and unless the productivity of feed grain cultivation increases more than expected, an increase in **croplands** will be needed (de Haan et al 2010). Cereals, together with soybeans, constitute more than 80 % of the diet of poultry (Wirsenius 2000) and the demand for this key protein source in animal feeds has increased eight-fold since the 1960s (Figure 11).

Soy is exported on a global scale with more than 95 % cultivated in only eight countries (de Haan et al 2010). Expansion of soybean croplands can result in land cover changes for both exporters (e.g. deforestation or pasture conversion in the tropics) and import countries (e.g. reforestation of meadows in Europe), reducing the multitude of ecosystem services provided for producers and consumers (Deutsch & Folke 2006).

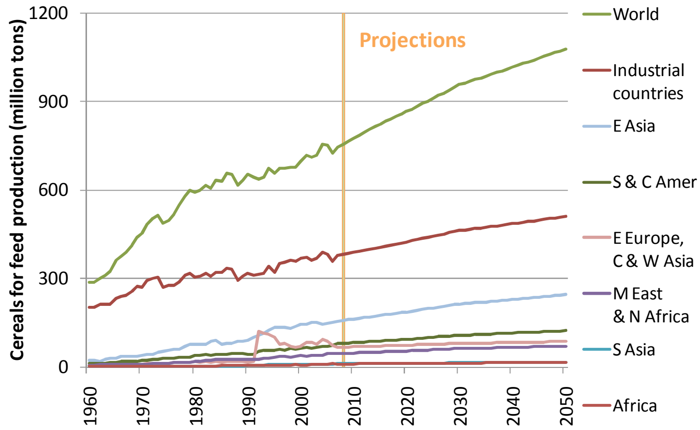


Figure 10: Global and regional past and predicted future trends of quantities of cereals used for animal feed (FAOSTAT 2011, Alexandratos 2006, 2009).

Pasture areas have increased six-fold the last two centuries (Figure 9) and calculations indicate that land-use change associated with the livestock sector contributes 6 % of global GHG emissions, mainly due to deforestation (Steinfeld et al 2006). However, in the last two decades the extent of grazing lands has stayed more or less stable.

The only major pasture expansion is taking place in the Amazon forest area (de Haan et al 2010) where 60-75% of newly deforested areas are used as pasture (Cederberg et al 2011). In other regions of the world the availability of rangelands is decreasing due to arable land encroachment (i.e. demand for more feed and food crops), land degradation, urbanization and reforestation. Moreover, rangelands tend to be overgrazed in many locations (e.g. western Asia, North Africa, Australia and South and Central America), often an initial cause of desertification but also resulting in uncertainty of fodder availability and reduction of biodiversity (Toutain et al 2010). Hence, the scope for further increasing herd numbers in these systems remains limited.

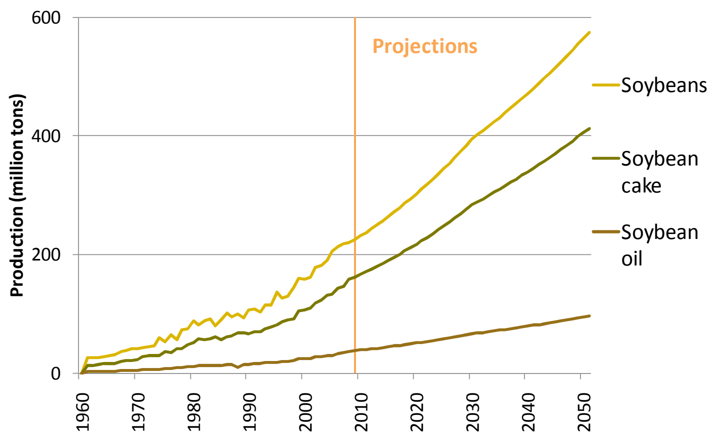


Figure 11: Global trends and projections in demand for soybeans and soybean cake and oil from 1960 to 2050 (FAOSTAT 2011, Alexandratos 2006, 2009).

A comparison of global trends in land-use areas for livestock production and total production of meat and milk between 1961-2001 highlights the enormously impressive productivity increases that have taken place. While meat and milk production increased by 250% and 170%, respectively, pastures and arable lands for feed crops only increased by only 10% and 30%, respectively. This productivity increase, characterizing the on-going Livestock Revolution and its predecessor the Green Revolution, has radically reduced the need for land expansion coupled to meeting global demand for livestock feed products, and thus also reduced additional pressures on limited land resources (Steinfeld et al 2006).

Livestock industry development in Sweden follows the global trend of increasing and intensified production. For example, the fraction of agricultural areas appropriated for grazing and fodder decreased from 43% to 37% (Deutsch & Folke, 2005). When considering total land areas used for Swedish food consumption (between 1990 and 2008) about 35% were actually cultivated abroad (Deutsch & Folke 2005, Johansson 2005). For example, Swedish soybean imports increased from 108 to 320 thousand tons 1961-2007, and during the same period soybean cake used for feed increased from 100,000 to 250,000 tons (FAOSTAT 2011). This example confirms the general global trends of more globalized food production and intensification of livestock practices with monocultures producing specified crops at specific sites that are exported globally.

Livestock water use

Water is used in livestock in four general ways, for: 1) animals' drinking water, 2) servicing animals and facilities, 3) processing livestock products and, 4) producing animal feed. The first three uses are relatively small in size (less than 1% of total annual freshwater withdrawals). Undoubtedly the largest amount of water used in livestock production is the amount used for feed production (Deutsch et al 2010).

Depending on climate, e.g. arid or temperate, crops choice, and agricultural management performance, the amount of water required for feed cultivation varies greatly. In arid Egypt or Israel as much as 3,000-5,000 kg (3-5 m^3) of water is required per kilogram grain, while in the temperate Netherlands or Canada only 1,000-2,000 kg is needed.

Due to the energy required for animal growth, type of animal chosen, livestock production system and management practices there are large conversion losses from feed to livestock products. Thus, the water used to produce one kilo of livestock products is 5-20 times higher than the water needed to produce one kilo of crops (Hoekstra & Chapagain 2003).

Since water is the basis for functioning ecosystems, understanding how feed production affects water flows can help discern environmental impacts of livestock production and understand management choices in terms of water. To understand water-related environmental effects it is important to distinguish between the different water flows in the hydrological cycle. Water originates from rainfall, which at the land surface is partitioned either into: runoff which eventually reaches rivers, lakes or reservoirs; or soil moisture allowing crops and pastures to grow and returning as evapotranspiration to the atmosphere, or infiltrates through the soil and generates groundwater.

Feed production affects the hydrological cycle in three ways. (1) Through **water withdrawals** for irrigation which can deplete groundwater resources and reduce river flows and impact associated ecosystem services and water uses downstream. (2) Through **land cover changes**, e.g. with increasing runoff formation when rain forest is converted to crop or grazing lands. Reductions or increases in water flows affect the environmental conditions for all ecosystems connected to the livestock system. (3) Through **changes in land use management**, for example, increasing grazing pressure can affect water use by compacting soils and increasing runoff (Deutsch et al 2010).

Total global annual evapotranspiration from croplands amount to as much as 7,000 km^3. Out of this 80% comes from rainfed soil moisture and only 20% from irrigation (Molden 2007, Rockström et al 2007). Livestock already uses half of the water from grasslands and croplands (Steinfeld et al 2006, Zimmer & Renault 2003). With increased food demands and more animal foods both the volume and the share are predicted to increase dramatically in the future. Since 1950 water withdrawals from rivers and aquifers have increased twice the rate of population growth, now leaving many rivers desiccated in both the developed and developing world. Already 1.2 billion people live in river basins with physical water scarcity and another 1.6 billion in basins where water scarcity prevails due to economic constraints to improve water management (Figure 12) (Molden 2007) and water is in particular limiting for development in semi-arid areas with high population (Falkenmark & Rockström 2004).

As mentioned earlier, livestock production is expected to continue to increase globally. Production of cereals used for animal feed, requiring large amounts of water annually, is expected to be 60% higher by 2050 than in 2007. Hence, a growing livestock production will contribute to increased competition and future withdrawals of already scarce water resources. This development raises the concern of how to allow feeding of a growing world population and dietary preferences of such when water resources are depleted all over the world.

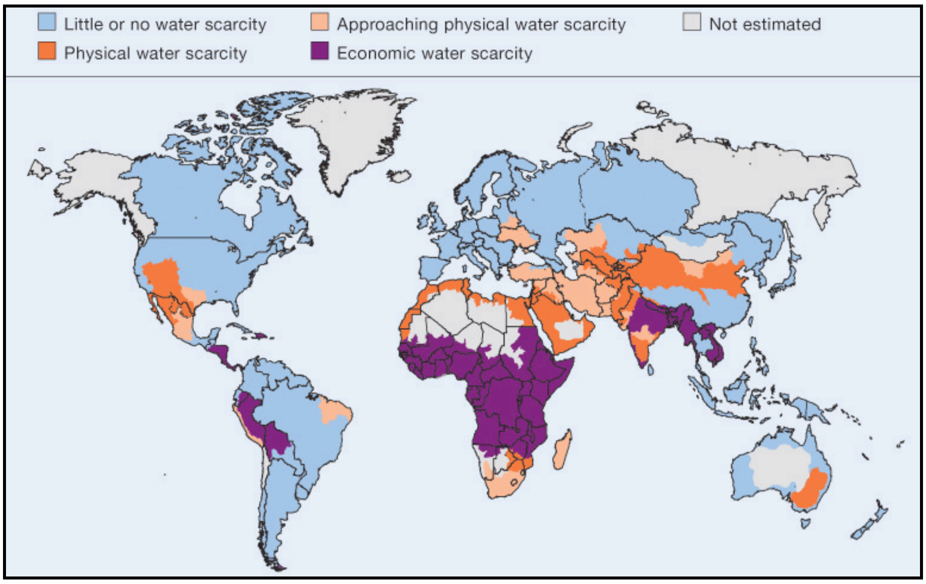


Figure 12: Global water scarcity (Molden 2007)

Greenhouse gas emissions linkages

That human emissions of greenhouse gases (GHG) contribute to global warming is a well-known issue supported by scientific evidence (IPCC 2007). Total GHG emissions from livestock production are argued to be as much as 18% of global emissions (Steinfeld et al 2006).

Livestock production contributes to GHG emissions in several ways (Figure 13). The largest contribution is emissions associated with **land use and land cover change** (LUCC), which can result from, e.g. carbon being released when areas are deforested to create croplands for feed or rangelands for livestock (Cederberg 2011). The second largest source is a result of **animal enteric fermentation**, i.e. when the digestion process of ruminants produces methane (CH_4), a very powerful GHG (Sonesson et al 2010).

The third most important livestock activities generating emissions is nitrogen emissions related to **use and management of manure** (Sonesson et al 2010). Emissions from **feed production** are primarily fossil fuel use for production of fertilizers (Steinfeld et al 2006). GHG emissions from **processing and transportation of livestock products** still remain relatively insignificant, but is increasing due to the globalization of the production.

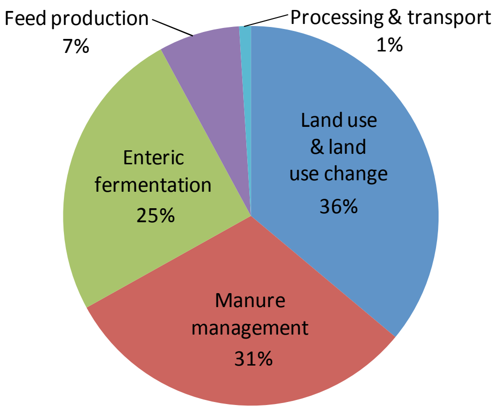


Figure 13: Green house gas emissions from livestock production divided between production-associated processes (emissions from feed production are fossil fuel use for production of fertilizers) (Steinfeld et al 2006).

Ruminants have significantly higher emissions of GHGs than monogastric animals due to enteric fermentation of feed and slower relative growth and regeneration (Sonesson et al 2010). Generally, higher use of feed crops contribute more GHG emissions from the production of such feed stuffs, however, the amount of methane emitted from ruminants eating crops decreases since concentrate feeds result in higher growth rates (Cederberg et al 2007).

In Sweden, ruminants contribute 75 % of total GHG emissions from livestock production, with pork and poultry 19% and 6%, respectively (Cederberg et al 2009). However, land use and land cover change are not included in these estimates which results in an underestimation of emissions (Cederberg et al 2011). Second in magnitude after emissions from enteric fermentation and manure, emissions from production and transport of imported meat and feed stuffs are most important, since at least 40% of the beef consumed in Sweden is imported, primarily from Brazil and Ireland. Production in Brazil generates higher GHG emissions as production is more extensive, animal growth rates slower and animals live longer (Steinfeld et al 2006, Casey & Holden 2005).

By contributing to global warming livestock plays a significant role in effecting ecosystem services at global scales by changes such as modified precipitation patterns, warmer climates, carbon storage in soils, changes in extreme events and other predicted feedback changes of global warming with results from local to global scales (Richardson et al 2011).

Livestock and biodiversity

Biodiversity is essential for functioning ecosystems and refers to the variability among living organisms including diversity at every level from genetic to species, populations, and even ecosystems (Convention on Biological Diversity 2011). The concept indicates the levels of complexity and organization in ecological systems that in various ways determine the essential system functioning like productivity and responses to disturbances (Hooper et al 2005). Maintaining this natural capital, with a portfolio of species, provides insurance that the system will be able to cope with disturbances and shocks, such as fires or pest outbreaks, and still continue to provide desired ecosystem services, e.g. feed crops, and if damaged, rebuild and regain productivity. The capacity is particularly important today as we enter into an era characterized by uncertainties related to the environment, such as the effects of climate change.

Livestock production impacts biodiversity in several significant ways. Land use with continuous cultivation of feed crops, e.g. soy monocultures, simplifies agricultural systems resulting in major biodiversity loss. Land cover changes such as the ongoing conversion of the Amazon rainforest to grazing lands or crop lands for livestock, fundamentally degrades local biodiversity. Further, heavy application of pesticides and fertilizers also results in losses of plant and animal species (Reid et al 2010) as well as secondary cascading effects on a larger scale e.g. destruction of coral reefs (Koop et al 2001).

It is important to remember that human development, especially during the last 300 years, has transformed almost all ice-free land surfaces into “anthromes” (anthropogenic biomes – human shaped systems) and only 22% of areas remain as genuine wild lands(Figure 9) (Ellis et al 2010). A land use change is thus often a change from one human altered ecosystem to another. Many livestock systems have evolved over long periods and many of these agricultural ecosystems have a high biodiversity. In Sweden, heavily managed landscapes as a result of livestock production today and thus have an ecological as well as cultural value (SOU 2003). Impacts on biodiversity are consequently not only negative. Livestock production can be used as a tool for maintaining and increasing biodiversity, and grazing lands can be used to protect wildlife both in the African savannas and European meadows. Also, recent intensification has increased the productivity of livestock production. Thus, fewer land resources are required per kg of produced product resulting in a decoupling of the linear relationship between production increases and environmental degradation (Reid et al 2010).

However, unfortunately there still remains a huge knowledge gap on the link between biodiversity and the generation of multiple ecosystem services in relation to livestock production systems. There is a need to highlight and promote positive benefits, as well as to prevent and balance the significant and alarming impacts from livestock production on biodiversity.

Nutrient flows of nitrogen and phosphorous

Nitrogen (N) and phosphorous (P) are two key nutrients used for fertilization of crops and cultured pasture lands. Unless there is a substantial increase in fertilizer efficiency, the already large N and P flows in agriculture are expected to increase threefold by 2050 (Tilman et al 2002).

Nitrogen is naturally assimilated to the biosphere from nitrogen gas in the atmosphere through nitrogen fixing plants, like legumes. However, today about half of the nitrogen used in global crop production is synthetically fixated through the Haber-Bosch process and applied as chemical fertilizers. Synthesis of nitrogen fertilizers has increased from 10 million tons in 1960 to 80 million tons in 1980 (Figure 14) and as a result humans have now doubled natural rate of nitrogen entering the land-based nitrogen cycle (Galloway et al 2010).

The two main sources of phosphorous entering agriculture are fertilizers from mined phosphate rock and natural phosphor uptake from pastures. Mining of phosphate rock has increased threefold since 1960 (Figure 14). Agricultural phosphorous flows converge in the livestock sector, resulting in manure containing more phosphorous than total inorganic fertilizer use (Steinfeld et al 2010).

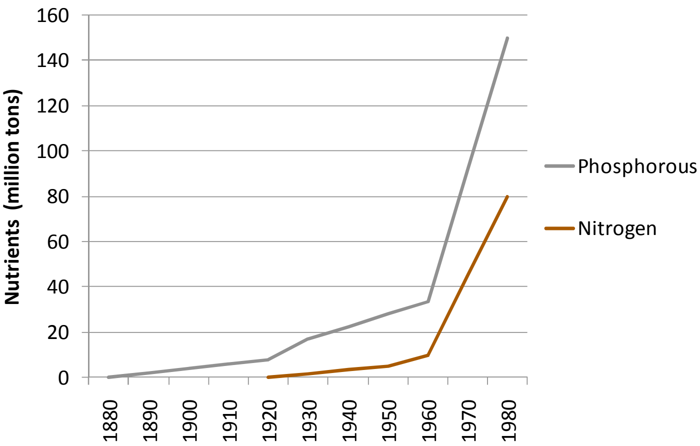


Figure 14: History of global mining of phosphate rock and synthesis of nitrogen fertilizer (adapted from Nixon 1995)

Losses of nitrogen and phosphorous from crop and livestock production are considerable and mainly a result of low uptake on croplands or inappropriate manure management. Phosphorous not taken up by plants is temporarily accumulated in cultivated soils and erosion is the main driver for releases of phosphorous, eventually deposited in water bodies or other sinks. (Cordell et al 2010). In contrast, nitrogen not taken up from the soil or detained in manure storage systems moves quickly to the atmosphere or water bodies in gaseous or soluble ion forms. In principle, all nitrogen, returns to the atmosphere as nitrogen gas due to denitrification (Galloway et al 2010).

More than 80% of the P and N used globally in agriculture is not taken up by vegetation and, in fact, leaks out and effects other terrestrial, aquatic and atmospheric systems (Cordell et al 2010, Galloway et al 2010). Eutrophication of inland and coastal waters is a problem of global significance, e.g. toxic algal blooms leading to build-up of toxic compounds and anoxic bottom waters. Air pollution by nitrogen compounds contributes to nutrient depositions and climate change (Galloway et al 2010). It is also important to remember that although the Haber-Bosch process can provide an unlimited source of nitrogen, the process requires large amounts of energy and thus is both costly and if fossil fuel based indirectly contributes to climate change. Phosphorous is a non-renewable resource and the recent discussion around "peak phosphorous" highlights the necessity to protect this essential and finite nutrient also for future generations.

Use of nitrogen and phosphorous is globalised. Large-scale international trade in fertilizers, feed and animal products result in a nutrient exchanges across continents contributing to concentration in some areas and deficits in others. Industrial animal productions systems are the most important global actors and also large contributors of nutrient leakages as they concentrate nutrient flows locally. Considering the increasing intensification of livestock production it is important to improve nutrient management and close the broken nutrient cycle between crop cultivation, livestock production and human food consumption. This can be enabled by e.g. changing the existing view of manure as a waste to considering it a valuable nutrient source (Menzi et al 2010).

Conclusions

Through global trade, human activities now affect changes from local farms to agricultural landscapes to the global Earth System. This implies that societies and economies today rely on ecosystem services that have been shaped and are impacted by feedbacks from both past and present human choices. One such human activity that links multiple scales and is propelling global change is the rapidly expanding, demand-driven growth in animal foods called the "Livestock Revolution."

One important message we hope to convey is that local management alone is no longer possible. The increasingly global magnitude and range of the livestock industry means that the scale and reach of analysis for decision-making also has to be expanded. In Sweden, the future of livestock production rests on the industry's ability to ensure quality control along the entire global production and supply chain.

We also hope we have conveyed the interrelated and complex interactions with ecosystem services related to the livestock sector. Broadening the management approach of productivity from a focus on a single ecosystem service, such as animal feed, to one that assesses the combined productivity of a system with a multitude of services will result in higher total system productivity. For example, pasture systems can provide animal feed, carbon sequestration, and water and biodiversity protection. We have focused on land, water, greenhouse gas emissions, biodiversity and nutrients. These are only five of a multitude of ecosystem services involved, but certainly enough to encourage discussion of knowledge-based tradeoffs and choices that will need to be made in of search for opportunities to make the Livestock Revolution sustainable.

Lastly, it can be argued that the per capita consumption of animal foods in industrialized countries is too high and can be reduced. However, consumption in developing countries, where 90% of the population will be living in 2050, is still at a very low level. So, there is still a need to increase the per capita protein intake of this part of the world and thus global production will increase in the future. Given the planet's finite resource base, increased production of resource intensive animal products poses major challenges. A sustainable intensification minimizing environmental impacts and grasping opportunities for win-win options will be necessary.

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