ENVIRONMENTAL AND SOCIAL EFFECTS OF LIVESTOCK SYSTEMS: POULTRY, BEEF AND DAIRY

Subtheme: Knowledge & Information.

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Abstract

Livestock production has positive and negative impacts and externalities that have an effect on the socio-economic systems as well as the ecosystem, from both the global and national perspective. This study assessed the scale, range and degree of both positive and negative impacts of livestock production systems on ecosystems, human health and livelihoods (outputs). We have characterised a set of livestock production systems for poultry, beef and dairy which we indicate as 'snapshots', for which the economic, social and environmental values and impacts were quantified and monetized. This kind of analysis can act as the foundation for decision-making within a specific geographical scope.

The positive and negative socio-economic impacts in livestock production depends on local circumstances. We found substantial diversity in the regions we studied in terms of productivity, impact on climate, water quality and biodiversity, but also in the potential for improvement; big is not always beautiful; intensification is not always better. The growth of the livestock sector presents many risks for natural capital, but there is much that can be done to tackle these risks. It is possible to produce animal products for the world population without losing this form of wealth, if the right path is followed.

***Key words**: eco-agri-food systems, livestock production, ecosystems, human systems, ecosystem services, externalities*

1. Introduction

Due to an increasing human population that on average becomes richer and increasingly lives in urban centre, the global demand for animal products will grow further in the next decades. The main drivers that will increase demand for animal products in the future are income, population growth and urbanization. Global population growth – which is expected to increase from about 6.9 billion people to 8.5 and 10 billion between 2010 and 2050 – will further increase demand (estimates range from an increase of 46% to 99%). Additionally, the demand for animal products between 2000 and 2050 is expected to increase with about 19% to 37% per capita as a result of higher incomes (Animalchange, 2012). Consumption and production are expected to grow particularly in Africa, India, Indonesia and Latin America (Animalchange, 2012). These are also regions with vulnerable and valuable ecosystems and biodiversity (e.g. compare with Myers et al., 2000 or Newbold et al., 2015). At the same time, it is well known that the livestock sector is a major contributor to the global ecological footprint.

Livestock production has positive and negative impacts and externalities that impact socio-economic systems as well as the ecosystem, from both the global and national perspectives. TEEB (The Economics of Ecosystems and Biodiversity) for Agriculture & Food (TEEB AG) developed a framework to assess these impacts (Hussain and Miller, 2014). Our research objectives are to evaluate the scale, range and degree of both positive and negative impacts of selected livestock production systems on ecosystems, human health and protein production.

2. Conceptual framework

Livestock systems affect human wellbeing in many different ways. Livestock systems provide animal protein as healthy food for the world, but at the same time, livestock production has an impact on the ecosystem and on biodiversity. We adapted the TEEB-AG framework to provide insights into the relationships between different livestock production systems, human systems, ecosystems and biodiversity in different countries. In order to do this, we map, visualise and quantify the use of natural capital inputs, and assess the negative and positive externalities of these livestock production systems.

Figure 1 shows the relation between the scope of this study and the TEEB framework. The TEEB framework provides the sub-systems (human, livestock, ecosystem and atmosphere) and how they are linked together. We make use of this framework to assess selected livestock production systems. Data were gathered locally as much local as possible for the impact assessment.

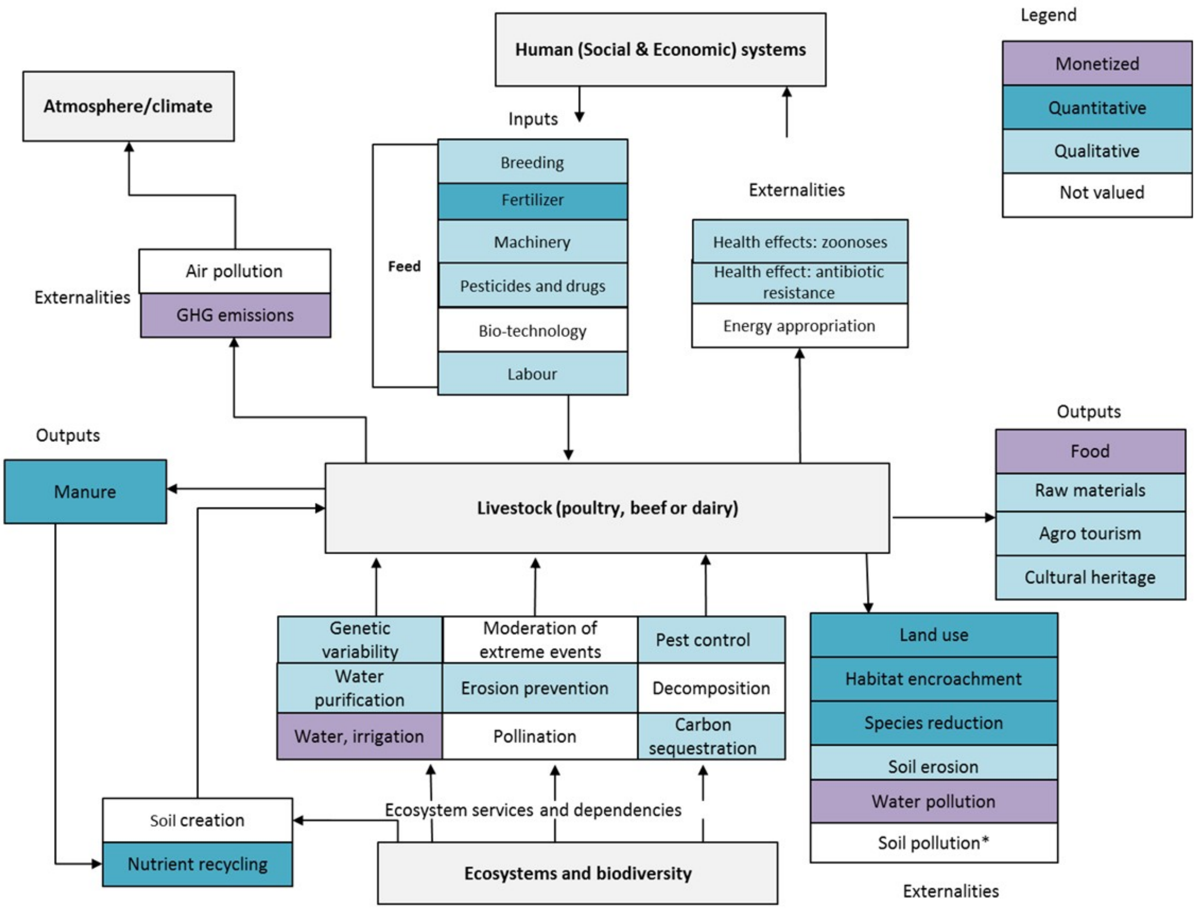

Figure 1: Scope of the assessment (adapted from Hussain and Miller, 2014)

3. Snapshots of livestock production systems

To get grip on the different impacts of livestock production, we characterise eco-agri- food systems; specific livestock production systems in a specific country or region. We developed snapshots for these systems, based on a set of farm characteristics (yield, farm inputs etc.) and evaluate these systems. A snapshots is a combination of a livestock production system and a country or region. We have selected a set of 'typical' livestock production systems with different levels of intensity. Ten snapshots have been selected for the analysis (see **Error! Reference source not found.**).

Species	Extensive <--> Intensive		
Poultry	1. Tanzania	2. Indonesia	3. Netherlands
	(backyard)	commercial family farm	industrial broilers
Grassland-based beef	4. Tanzania (pastoralist)	5. India (pastoralist)	6. Brazil (grassland based with 3 months in feedlots for fattening)
Dairy, mixed systems	7. Tanzania (extensive),	8. India	9. The Netherlands 10. Indonesia

Figure **Error! No text of specified style in document.**: Selected snapshots for TEEB-AF animal production systems

Poultry systems selected are backyard systems that produce eggs and meat, and (semi) specialized broiler systems which only produce chicken meat in a commercial or industrial way (MacLeod et al., 2013; Robinson et al., 2011).

Four production systems have been selected for dairy production (see Table 1). Three snapshots are small-scale farmers in Tanzania, India and Indonesia. These farmers have five cows but operate in different countries and contexts. The Indonesian example is considered to be the most intensive one, due to its relatively high input of synthetic fertilizers and concentrates. The fourth snapshot is a Dutch dairy farm, as an example of intensive dairy farming being still land and family based but using a lot of inputs such as fertilizers, chemicals, concentrates, artificial insemination, financial capital, machinery and medicine.

Three snapshots have been selected for beef systems. Two of these snapshots are pastoralist systems in Tanzania and India. Both systems are very extensive in the sense that almost no additional inputs (less than 1 kg N/ ha) besides animals, ‘pasture’ and labour are used (See Table 1). The Brazilian beef system is the most intensive system with grazing cows and calves. The beef animals are fattened in feedlots about three months before they are slaughtered.

Table 1: Characteristics of the livestock systems selected

Country	Type; feed systems	Animal heads per farm	Hectares	N-input feed (kg N/ha)	N-input fertilizer (kg N/ha)	Total input (kg N/ha)
Tanzania	Poultry;	100	n.a.	n.a.	n.a.	n.a.
Indonesia	Poultry	5,000	n.a.	n.a.	n.a.	n.a.
Netherlands	Broilers	90,000	n.a.	n.a.	n.a.	n.a.
Indonesia	Dairy; Mixed feed	5	2	47	64	111
India	Dairy; Mixed feed	5	2	137	100	237
Tanzania	Dairy; Mixed feed	5	2	157	4	161
Netherlands	Dairy; Mixed feed	85	40	108	150	258
Tanzania	Pastoral; grass fed	300	1000	0.2	0	0.2
India	Pastoral; grass fed	100	300	0.1	0	0.1
Brasil	Beef; mixed	300	300	10	0	10

To characterise the snapshots, indicators and data are used from the FAO Global Livestock Environmental Assessment Model GLEAM (Gerber et al., 2013). This model provides data about many different characteristics per snapshot such as herd parameters, feed per animal, food conversion rate, kg CO2 per kg carcass, milk or egg, nutrient inputs and surpluses.

4. Measuring the economic, social and environmental impacts

Given the typology of the systems, an analysis of impacts and dependencies between the livestock system and the ecosystem and the human system was carried out. Some of the impacts and dependencies can only be expressed in qualitative terms, whereas others may be quantified and/ or valued. Some impacts could be important, but due to limited availability of information, not included in the assessment.

The valuation method builds upon the framework provided by UNEP's Inclusive Wealth Reports (UNEP-IHDP and UNEP, 2014, 2012). The value of a natural capital asset is determined by its contribution to inclusive wealth, representing the present and future benefits of an asset to people.

Negative externalities are valued as natural capital costs because they damage ecosystems services (i.e. clean water supply, or climate regulation) and reduce the benefits they provide to humans. In addition to negative externalities, natural capital dependencies can also be valued. The dependency of a good on a natural capital asset is the contribution of that asset to the economic value of the good.

The degree of valuation per impact is summarised in Table 2. The monetary valuation analysis of negative externalities presents the natural capital costs of greenhouse gases (GHG) emissions and water pollution. Land footprints of livestock production are then quantified, with a quantitative assessment of the impact on biodiversity. Lastly, results are presented concerning the degree of dependency of animal husbandry on ecosystems for the provision of blue water.

Table 2: The degree of valuation (not valued, qualitative, quantitative and monetized) per type of relation between livestock systems/ ecosystems and social systems (as characterized in the TEEB-AG framework)

Relation from/to	Not valued	Qualitative	Quantitative	Monetized
Livestock system/ outputs		1. Raw materials 2. Agro tourism		1. Food
Livestock system/ social system	1. Food security	1. Health effects food 2. Zoonoses 3. Antibiotic resistance 4. Cultural heritage		
Social system/ livestock system	1. biotechnology	1. Breeding 2. Machinery 3. Pesticides and drugs 4. Labour	1. Fertilizer as part of nutrient balance	
Ecosystem/livestock	1. Moderation of extreme events 2. Pollination	1. Genetic variability 2. Water purification 3. Erosion prevention 4. Pest control 5. Carbon sequestration		1. Water irrigation
Livestock/ ecosystem	1. Soil creation	1. Soil erosion 2. Health externalities	1. Nitrogen and phosphor leaching 2. Nutrient recycling 3. Land use 4. Species reduction	1. Water pollution 2. Greenhouse gas emissions

5. Results

In this section, the results of an overall integrated assessment of livestock production systems is presented per group of snapshots (poultry, beef and dairy), and some snapshots are compared where such a comparison is viable and relevant.

Combined milk and beef production

The output of the three smallholder snapshots with five cows is 7,500 kg of milk per year for Tanzania and 7,000 kg in Indonesia, but only 5,000 kg per year in India because of poor feed quality (large fraction of crop residues) and periodical feed shortages. The Dutch farm produces about 700,000 kg of milk which is almost completely sold to the milk processing industry. In Tanzania much of the milk is for home consumption or sold locally on the informal market, whereas in parts of India the supply chain is better developed (See Table 3).

Besides milk all four systems produce meat from culled cows, male calves, and heifers not used for replacing cows. The amount varies per farm from 550 kg of meat in India to 15,800 kg in the Netherlands, where all the meat is sold to slaughterhouses.

Beef production

The beef snapshots are very different in terms of productivity (output in kilograms of protein) and efficiency (inputs per kilogram of protein). Pastoral systems produce less kilograms of protein per unit of land or input and are more labour intensive compared to medium and large-scale beef production systems.

Both pastoral systems and extensive, large-scale beef systems make an important contribution to food security, at the local level and beyond, and to the livelihoods of many poor small-scale farmers all over the world. Market orientation and the commercial trade of beef production increases along with the scale and production level of the system. The productivity level of the pastoral systems is so low that these systems are not able to feed large urban populations.

Beef produced in dairy systems

The production of beef as a ‘side’ product of intensive dairy farming with a high animal replacement rate is an alternative comparable to poultry in terms of the low impact on natural capital. This system, explored in its Dutch variation, appears to have water pollution and GHG emissions comparable to poultry, due to the system’s high efficiency.

Poultry systems compared

Backyard chicken rearing is found to have an environmental profile similar to that of more developed poultry systems, in terms of GHG emissions and water pollution, while it provides animal proteins at a lower cost in terms of land occupation and blue water use. But only low volumes can be produced in backyard systems as it strongly relies on the use of food and kitchen waste and scavenging.

Pastoralist systems produce more than food

Pastoralist systems generally have lower natural capital efficiency than other cattle systems, and land requirements are especially high. However, as opposed to feed-based or pasture-based systems, pastoralism can reap benefits from semi-natural ecosystems without seriously negatively affecting biodiversity and natural capital. This is highlighted in a scenario analysis carried out within the same overall research project on pastoralism in Tanzania that looks at the changing benefits of ecosystem services for the local population in the transition from pastoralism to sedentary farming (Baltussen et al., 2016).

GHG & water pollution

GHG externalities for dairy systems in the selected snapshots vary from 5.4 USD/kg protein for the Dutch situation to 18.2 USD/kg protein for the Indian situation. The analysis also shows that greenhouse gases released as part of animal husbandry processes are primarily associated with 1) enteric fermentation in dairy systems with ruminants, 2) organic and synthetic fertilizer use and, to a lesser extent, 3) fossil fuels related to transport. The GHG emissions per animal are lower in the smallholder systems, but expressed per kg of milk GHG emissions in the smallholder systems are higher compared to the specialised highly productive dairy systems. Costs of GHG-externalities per unit of protein for dairy farms are high compared to broiler production but low compared to pure beef production systems.

Table 3 Overview of quantified impacts of four dairy systems three (mainly) beef systems

Impact	Tanzanian smallholde	Indian smallholder	Indonesian smallholder	Dutch family	Tanzania Pastoralist	Indian Pastoralis	Brazilian Beef
Output (kg of milk)	7,500	5,000	7,000	700,000	1,125	21,250	-
Output (kg of meat)	640	550	815	15,800	12,676	3,665	28,000
Costs of GHG externalities (USD/kg protein)	12.80	18.20	13.60	5.40	34.5	41.32	36.47
Value of blue water dependency (USD/kg protein)	0.00	0.00	0.01	0.00	0.19	0.32	0.00
Land use (m^2/ kg protein	1,231	275	59	23	10,913	5,574	1,131
Biodiversity weighted land use (MSA.ha/ kg protein)							
-pastures	0.0048	0.0002	0.0011	0.0001	0.1062	0.0551	0.0108
-crop land	0.0075	0.0004	0.0017	0.0001	0.0029	0.0007	0.0005
Total	0.0123	0.0006	0.0028	0.0002	0.1091	0.0557	0.0113
Nitrogen leaching (kg N per ha)	59	63	20	119	8	9	23

Land use

Land occupation of the dairy and pastoral systems varies from 23 m2 per kg of protein in the Dutch system to 1231 m2 per kg of protein in Tanzania. This difference is caused by differences in crop productivity and by differences in animal productivities (kg protein per cow). Land occupation per se should not be considered a negative externality. For instance there is considerable evidence that forcing pastoralists from communally-managed rangelands is detrimental not only to their livelihoods but also to ecosystem functioning (and also to cultural heritage) (FAO, 2009; World Bank, 2009). Chicken meat production requires the smallest amount of land per unit of animal protein produced because of its favourable feed conversion rate and absence of grazing. Mixed crop-livestock farming also occupies relatively smaller amounts of land, especially where productivity is high or reliance on grazing and imported feed is low. However, land occupancy can be better understood if viewed alongside the impacts on biodiversity and local communities that each production system has within its specific region.

Biodiversity impacts and dependencies of livestock production

Livestock has both a direct and indirect impact on biodiversity. The direct impact through trampling and grazing and defecation appears to be smaller than the indirect impact through land-use change (deforestation) and intensification and through its contribution to climate change resulting from emissions of methane and other greenhouse gases. This reduces species abundance in most ecosystems considered.

Dairy systems in Tanzania, Indonesia and India with mixed feed systems have a limited direct impact on biodiversity and ecosystems. Per unit of land used, these impacts are very small. MSA losses per ha for feed production were found to be lowest for the Tanzania mixed system. However, the total amount of land and inputs needed per kg protein produced were also highest in the Tanzania system. As a result the combined direct and indirect impact expressed as MSA per hectare per kg of protein in the four systems ranges from 0.0002 in the Netherlands to 0.0123 in Tanzania.

Intensification of livestock production is an important trend resulting from the increasing demand for animal protein. Intensification involves a further concentration of resources (financial, labour and nutrient inputs) to produce more livestock on the same unit of land. As a result, intensification can influence livestock’s impact on biodiversity and natural capital in different ways. Locally, the impact of more intensive production will increase; at the same time demand for feed will increase, leading to a higher distant impact. If, however, this increase in intensity is accompanied by better production efficiency, i.e. more kilograms of protein (or meat, milk or eggs) per unit of input, then the overall biodiversity impacts per unit of protein product may decrease. Intensification is not a solution under all circumstances.

Poultry and biodiversity

In poultry, and more intensive industrial-scale livestock production systems, the relation between land use and its biodiversity impact is more obscure. Although these systems are sometimes called 'land-less' production systems, this is a misleading term. These systems still rely on (distant) cropland for production of the concentrated feed they import, spatially disconnecting the livestock and an important part of its biodiversity impact.

Animal and human health

In general, intensification of livestock production can go hand in hand with an increase in the use of antibiotics. However, there are mitigation strategies that enable a mix of intensive production and low input of antibiotics. Zoonoses exists in all regions and animal production systems. The impact of food-borne diseases and non-alimentary zoonoses (like Q-fever in the Netherlands) is more or less unknown.

6. **Conclusions**

The message is clear: the growth of the livestock sector presents many risks for natural capital, but there is much that can be done to tackle these risks. It is possible to produce animal products for the world population without losing this form of wealth, if the right path is followed. First, natural capital has to be fully measured, as its visibility is a requirement for its conservation. Second, a single livestock production system alone cannot supply animal products to the whole world. The entire range of livestock systems would need to contribute for that to happen. Therefore, the right improvements need to be identified and pursued for each context and production scale, using a suitable, location-specific approach. The links between livestock, ecosystems and society needs to be valued and understood at the regional level. Finally, livestock systems are key components of agro-ecosystems and under specific management practices can enhance the provision of ecosystem services. Therefore, mechanisms have to be developed to internalize external costs and encourage good agricultural practices, without affecting food security for the poor. Internalization will help market forces to steer the food sector down a more sustainable path, where natural capital wealth is leveraged to create wealth for the current as well as future generations.

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