A framework for environmental ex-ante impact assessment of livestock value chains

Notenbaert A.[1*], Lannerstad M.[2], Herrero M.[3], Fraval S.[2], Ran Y.[5], Paul B.[1], Mugatha S.[2], Barron J.[4], Morris J.[4]

A.Notenbaert@cgiar.org, M.Lannerstad@cgiar.org, Mario.Herrero@cgiar.org, B.Paul@cgiar.org, S.Fraval@cgiar.org, Ylva.Ran@sei-international.org, S.Mugatha@cgiar.org, Jennie.Barron@sei-international.org

1. CIAT (International Center for Tropical Agriculture), PO Box 823-00621, Nairobi, Kenya
2. ILRI (International Livestock Research Institute), PO Box 30709-00100, Nairobi, Kenya
3. CSIRO
4. SEI (Stockholm Environment Institute), University of York, Heslington, York YO10 5DD UK)
5. SEI (Stockholm Environment Institute), PO Box 242 18, 104 51 Stockholm Sweden

Abstract

Livestock and fish industries are a significant source of livelihoods and income globally. They are organised in complex market chains that employ at least 1.3 billion people globally and directly support the livelihoods of 600 million poor smallholder farmers in the developing world. Livestock and fish production, processing and marketing as well as the waste produced along the value chain also cause important environmental impacts. They include atmospheric and water pollution, global warming, soil degradation, water use and pollution and biodiversity loss. Efforts to maximize yields of milk and meat, and to 'intensify' livestock and fish production, need to be balanced with long-term sustainability and overall efficiency. We must figure out how to produce, process and market livestock and fish in ways that work for individuals, communities and the planet alike.

It is thus important to assess environmental impacts before embarking on large-scale development projects geared towards livestock production and aquaculture intensification and value chain transformation. Here we present a generic conceptual framework for environmental ex-ante impact assessment of livestock and fish value chains. It is taking into account all value chain components, different spatial and temporal scales and environmental impacts across different dimensions. The framework guides users through a step-wise procedure for assessing how interventions are likely to change the production system and value chain. Through providing rapid results and flagging the main environmental issues, it can support evidence-based discussions of alternative development pathways.

Key words

Sustainability, impact assessment, development, eco-efficiency

Introduction

Livestock and fish, as part of global ecological and food production systems, are key commodities for human well-being. Their importance in the provisioning of food, incomes, employment, nutrients and risk insurance to mankind is widely recognized (Herrero et al., 2010; Hall et al., 2011). Livestock and aquaculture systems, especially in developing countries, are changing rapidly in response to a variety of drivers. Globally, human population is expected to increase from around 7.2 billion today to more than 9 billion by 2050 (UN, 2012). Rapid urbanisation and increases in income are expected to continue in developing countries, and as a consequence the global demand for livestock and fish products will continue to increase significantly in the coming decades. Livestock and fish production as well as processing, transport, marketing and waste, however, , can be the cause of important environmental impacts, such as greenhouse gas emissions contributing to global warming, soil degradation, water appropriation and pollution and biodiversity loss.

Most life cycle assessment studies that consider the whole value chain estimate that in developing countries on-farm activities are the greatest contributor to environmental impact (Fraval, 2014). The production of livestock and fish indeed depends on a variety of natural resources, such as animal and plant genetic resources, energy, water, air, land and its nutrients. Feed is grown on huge tracks of land thereby using water and extracting soil nutrients and thus impacting on soil fertility. Steinfeld et al. (2008) approximate that livestock utilise 3.4 billion hectares for grazing and 0.5 million hectares of cropland for the production of feeds (33% of arable land). This land use is closely linked to water cycles. Recent research (Heinke et al., in prep.) suggests that globally, the production of feed for the livestock sector appropriates 5,315 km^3/year of evapotranspiration (ET) (9% of global ET). The authors found that feed production from croplands uses 37% of water allocated for crop production globally, and the biomass consumed by livestock from grazing lands appropriates 32% of the total ET from grazing lands.

In terms of nutrients, livestock manure –considered a serious problem in the developed world– is a critical resource for agriculture in large parts of Africa, where soils are inherently poor (Rufino et al. 2006). Liu et al. (2010) estimated that manure contributes between 12-24% of the nitrogen input in nitrogen cycles on cropland in the developing world. Although animal manure can be a very effective soil amendment, in systems where the land supports livestock production, its availability at the farm level is often very limited. Bouwman et al. (2009) conclude that it was the introduction of synthetic fertilizers that allowed the explosive increase in livestock production. However, it has also been shown that heavy application of pesticides and fertilizers 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). Livestock production and aquaculture also impact biodiversity in several other significant ways. For example, land use with continuous cultivation of feed crops, e.g. soy monocultures, simplifies agricultural systems resulting in major biodiversity loss. Many livestock systems have, however, evolved over long periods and have a high level of biodiversity and impacts are consequently not always negative. Also, recent intensification has increased the productivity of livestock and fish 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). Apart from using, competing for and impacting on the quality of water, soil and biodiversity, livestock are also an important contributor to global greenhouse gas emissions.

Estimates range from 8.5% to 18% of global anthropogenic GHG (O'Mara 2011). According to Steinfeld et al. (2008), methane from enteric fermentation, nitrous oxide from manure management and carbon dioxide from land use, contribute 25, 31 and 36% to the emissions of the livestock sector respectively. Further along the value-chain (VC), key resources used for meat, milk and fish processing include water, raw materials and energy. Processing often produces blood by-products and waste streams, while the facilities are also prone to disease spread. Food waste doesn't only have a direct impact through e.g. emissions from landfills but plays an especially important indirect role. When food is wasted, the energy and resources that go into producing that food are also wasted and greenhouse gas emissions were needlessly produced. FAO (2013) estimate that roughly one third of the food produced in the world gets lost or wasted.

Considering that the demand for meat, milk and fish is increasing, and these are only two of many sectors that will need to grow to satisfy human demands, more competition for natural resource can be expected, and existing and new trade-offs between food security, incomes and environmental sustainability are likely to occur. A revised agenda for managing sustainable growth of the livestock and fish sectors requires development of mechanisms for assessing the environmental impacts of interventions and investments in the sector, and identification of trade-offs between resource appropriation and ecosystem functioning. Consultations with environmental experts and local stakeholders from East Africa confirmed a clear demand for a tool that can flag potential environmental impacts of proposed interventions, often conceived for improving incomes and food security. This paper therefore presents a new framework for ex-ante assessments of environmental impacts of development interventions in livestock and fish value chains. It is developed based on reviews of existing frameworks and expert consultations and is able to address environmental impacts along the whole value chain. The framework is meant to support decision making and help prioritising development action of governments, donors, NGOs and farmer organisations. It is therefore envisioned to be implemented through a user-friendly tool allowing relatively rapid ex-ante estimation of multi-dimensional environmental impacts.

The Comprehensive Livestock and fish Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development framework (CLEANED)

The framework's building blocks

The CLEANED framework is an indicator framework that takes the full value chain into account. It estimates biomass, water and nutrient flows and assesses four dimensions of environmental impacts across different spatial and temporal scales.

1. Value Chain concept

Although the majority of the environmental impacts of livestock and fish value chains can be observed pre-farmgate, natural resource and energy use during the production of inputs, processing or transport can be significant, thus assessment methods benefit from assessment and proper identification along the complete value chain. The main VC modules included in the framework are (i) the natural resource base, where feed is produced or retrieved, (ii) production of livestock or fish, (iii) processing, (iv) marketing, and (v) consumption. In addition, "waste management" is given special attention as a component that stretches along the entire value chain. These modules can be flexibly combined into a full value chain as appropriate in the local context. Although the flows, stocks and processes at the earlier stages of the value chain are treated with greater detail, the framework also considers user-input about flows and losses at later stages. An estimate of total food losses will be used to reduce natural resource efficiencies and thereby influence the size of the environmental impacts.

2. Stocks and flows across scales

The processes that are considered in the CLEANED framework include (i) nutrient flows, specifically N and P, (ii) the use of land resources, (iii) water and biomass use, and (iv) waste. Different processes, stocks and interactions play out at different scales. Scales are therein defined as logical groupings of land areas referring to the size of the unit over which processes operate or at which a problem is analysed. Examples include the field scale with e.g. the processes of infiltration and drainage. While water and nutrients also flow through the landscape, crop-livestock interactions and differences in manure and fertiliser application are mostly determined at the farm scale. Land use changes are mostly implemented at the farm scale, while indirect land-use changes often play out at the regional scale. The greenhouse effect on climate on the other hand is a global issue. The spatial scales explicit in the framework include farm, landscape and regional/global.

3. Environmental impacts and pathways at different time scales

Any intervention along the value chain can change the biomass, water and nutrient stocks and flows and by doing so cause environmental impacts. Some of the impacts are caused directly by the action and occur at the short temporal and small spatial scales. Some impacts, however, are indirect, are likely to occur in the future or as (unintended) externalities. The framework therefore takes the direct and indirect as well as immediate and long-term impacts into account.

4. Key indicators

The main environmental impact categories the framework aims to assess are: water use and quality, soil health, biodiversity and climate change. Table 1 lists the specific indicators to be estimated under each category. The trade-offs between these impact categories is an important consideration in the overall environmental assessment. Different existing methods can be utilised to quantify the indicators in terms of total use as well as efficiencies - per area and/or per livestock produce. Specific impacts and impact indicators are linked to one or several spatial scales and to specific temporal scales. The projected impacts will be compared against baselines and limiting constraints.

Table 1: Main impact categories, associated indicators and scales

Impact category	**Subcategory**	**Indicator**	**Rapid quantification ideas**	**Spatial scale**	**Temporal scale***
Water	Water quantity	Soil moisture used for biomass production (m^3 per time step of analysis)	Cropwat , Kc-value estimation	Farm, landscape	short term: 1 yr
	Water quantity	Streamflow and aquifers (m^3 per time step of analysis)	Water balance partitioning	Landscape, regional /global	short to medium term: 1-10 yrs

	Water quality	Organic pollution in stream	Manure management and application	Landscape	short term: 1 yr
	Water quality	Inorganic pollution in stream	Risk scoring of fertilizer and pesticide application rates and locations	Landscape	short term
Soil	Soil erosion	Sediment loss (kg/ha/timestep)	RUSLE	Farm, landscape	short to medium term: 1-10 yrs
	Soil organic matter	Soil organic matter	IPCC – Tier 1	Farm	medium to long term: 10-50 yrs
	Soil fertility	N, P content in the soil	Nutrient budget (NUTMON)	Farm	short to medium term: 1-10 yrs
Biodiversity	Crop and pasture diversity	Diversity index	Species distribution modelling	Farm, landscape	short to medium term: 1-10 yrs
	Animal genetic resources	Diversity index	Species distribution modelling	Regional	medium to long term: 10-50 yrs
	Landscape multifunctionality	Number of landuses	LU/LC	Landscape	medium to long term: 10-50 yrs
Climate change	Emissions	CH4 emission	IPCC guidelines, GLEAM, RUMIANT, LCA	Regional/global	long term: 50/100 yrs
		N2O emission		Regional/global	long term: 50/100 yrs
		CO2		Regional/global	long term: 50/100 yrs

** when we feel the effect/impact (from column 1)*

Operationalizing the framework

The framework guides users through a step-wise procedure. In a first step the baselines are set. A second step entails the actual ex-ante impact assessment so that the potential impacts can be compared against the baselines (fig 1).

1. Setting the baseline

Smallholder farming systems and livestock and fish value chains are highly heterogeneous, diverse and dynamic. These differences influence both the applicability and the potential impacts of interventions. This first baseline step therefore involves stratifying the region of interest in different strata or simulation units, assumed to respond homogeneously to the proposed changes, and describing each regarding (i) land use and management practises; (ii) stocks and flows at different spatial scales, (iii) the livestock or fish value chain in which it is embedded, and (iv) vulnerable and limiting resources. Different data sources feed into this step, such as existing databases, participatory mapping exercises, household surveys and expert opinion.

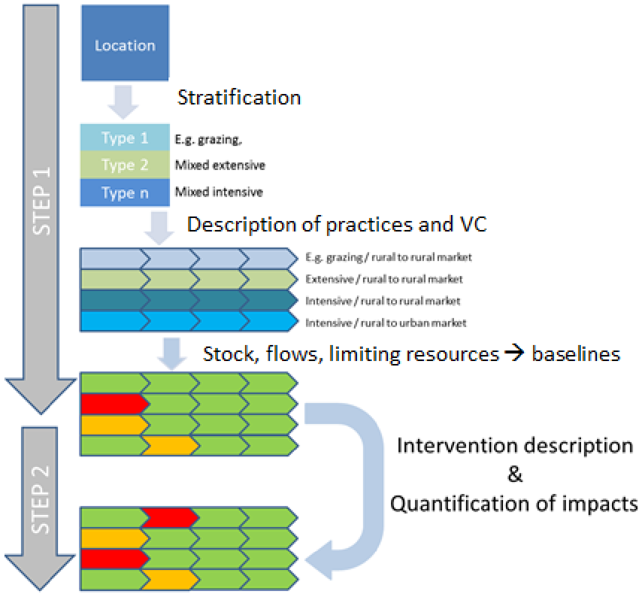

Figure 1: Operationalization of the CLEANED framework

<u>2. Ex-ante impact assessment</u>

When assessing the potential impacts of interventions, scenarios of alternative intervention strategies need to be constructed and compared in reference to a baseline. The sub-steps are:

(i) The description of the envisioned intervention(s): a myriad of interventions are possible. Examples include changing the cropping pattern and management, feeding practices, animal or herd management, milk treatment, transport or processing. A fairly detailed description of the envisioned interventions will need to be provided. The level of detail thereby needs to be in line with the envisioned assessment methods. Changes in relevant input variables will have to be specified or expected impacts qualified. The description of the intervention also needs to clarify suitability to or applicability in different environmental contexts and VCs;

(ii) The assessment of local impacts: the calculation of quantitative indicator values can be done through the use of models or simple equations. These impact values will be combined with waste and re-use estimates to come up with overall impacts. A qualitative assessment, based on qualitative scores of input variables, is possible through the translation of these scores into quantitative input variables for quantitative output calculations. These can in turn be translated into a qualitative impact score based on the potential ranges estimated from existing data, literature review or expert opinion;

(iii) Out-scaling: the stratification of the study area under step 1 aims at capturing the heterogeneity found in the region of interest. The assumption made for out-scaling is that agricultural strategies are likely to have the same relevance for areas falling in the same stratum and that the impacts can be widely applied across the landscape, region or country. Regional impacts are then calculated based on estimated levels of adoption of the promoted technology and a particular distribution of strata/simulation units. For some technologies and impact dimensions, specific models exist that estimate impacts at a larger scale, taking for example landscape or international trade interactions into account. In such case, and if time and resources allow, a more complex out-scaling exercise can be carried out, through the definition of spatially-explicit "scenarios" and feeding these into the larger-scale models;

(iv) Flagging the potential risks: in a last step the projected impacts need to be compared with a critical value or assessed against identified constraints and limiting resources. The aim is to be able to flag important context-specific issues and provide a visualization of the overall environmental impact of the intervention and trade-offs between environmental dimensions at different time scales.

Discussion, conclusion and implications

Food security, poverty and nutrition are high on the global development agenda. Improving yields and farmer incomes are often seen as priorities and development actions are thus designed with these specific aims in mind. However, many proposed farming practices might damage the environment and generate greenhouse gases (GHG). In addition, there is increased competition for land, water, energy, and other inputs into food production. This framework is therefore designed to ensure that actions designed to improve incomes and food security in livestock and aquaculture value chains have a minimum environmental footprint while at the same time lifting people out of poverty. It is focusing on environmental impacts and is meant to complement other more commonly applied assessments such as cost/benefit analyses and feasibility studies. We envisage that the framework would be used in a range of ways. With up-to-date information and knowledge on production systems, it should help users to identify the likely impacts of the implementation of specific technologies. Second, the framework can be used as rapid screening and discussion tool, to screen sets of interventions in farming systems at the early stages of their development. For this, many of the data are likely to be qualitative in nature. A third practice would be to use the framework to quickly evaluate the impacts of a wide range of interventions, to identify sub-sets of promising specific interventions for evaluating using more detailed quantitative information, to estimate aggregated impacts in certain regions, or to link them to global and regional change models.

The target audience for the framework are decision makers at different levels such as donors, government agencies and NGOs. It aims to provide them with a rapid ex-ante assessment highlighting potential positive and negative environmental impacts at multiple spatial and temporal scales and the trade-offs between them. Specific uses include evaluation of project proposals by donors and providing input in investment decisions of local implementers, both in the private and public sphere. An important question remains how to ensure its actual integration in the decision-making processes of these target audiences at different levels and a variety of local contexts.

Acknowledgement

The development of the framework was made possible through the financial support of the Bill and Melinda Gates Foundation and both technical and financial support of the CGIAR Research Program on Livestock and Fish. We would also like to thank all participants in the local and international consultation meetings for their generous intellectual input.

References

Bouwman, A. F., A. H. W. Beusen, *and* G. Billen. 2009. Human alteration of the global nitrogen and phosphorus soil balances for the period 1970–2050, Global Biogeochem. Cycles, **23**, GB0A04

FAO. 2013. Food Wastage Footprint, Impacts on natural resources. http://www.fao.org/docrep/018/i3347e/i3347e.pdf

Fraval S. 2014. Review of live-cycle assessments for livestock, fisheries and aquaculture: perspectives for application to environmental impact assessment in developing countries. Consultancy report to ILRI.

Giller K., Tittonell P., Rufino M., van Wijk M., Zingore S., Mapfumo P., Adjei-Nsiah S., Herrero M., Chikowo R., Corbeels M., Rowe E., Baijukya F., Mwijage A., Smith J., Yeboah E., van der Burg W., Sanogo O., Misiko M., de Ridder N., Karanja S., Kaizzi C., K'ungu J., Mwale M., Nwaga D., Pacini C., Vanlauwe B., 2011. Communicating complexity: integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agric. Syst. 104, 191–203.

Hall, S.J., A. Delaporte, M. J. Phillips, M. Beveridge and M. O'Keefe. 2011. Blue Frontiers: Managing the Environmental Costs of Aquaculture. The WorldFish Center, Penang, Malaysia.

Heinke J., Lannerstad M., Herrero M., Peden D., Notenbaert A. (in preparation). Livestock and water linkages dynamics. .

Herrero M., Thornton P., Notenbaert A., Wood S., Msangi S., Freeman H., Bossio D., Dixon J., Peters M., van de Steeg J., Lynam J., Parthasarathy Rao P., Macmillan S., Gerard B., McDermott J, Seré C., Rosegrant M. 2010. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science 327, 822-825.

Koop, K., D. Booth, A. Broadbent, J. Brodie, D. Bucher, D. Capone, J. Coll, W.Dennison, M. Erdmann, P. Harrison, O. Hoegh-Guldberg, P. Hutchings, G.B. Jones,A.W.D. Larkum, J. O'Neil,A. Steven, E. Tentori, S.Ward, J.Williamson and D. Yellowlees, 2001: ENCORE: The effect of nutrient enrichment on coral reefs: synthesis of results and conclusions. Mar. Pollut. Bull., 42, 91-120.

Liu J., You L., Amini M., Obersteiner M., Herrero M., Zehnder A., Yang H. 2010. A high resolution assessment of nitrogen flows in cropland. PNAS 107, 835–840.

O'Mara, F.P. (2011). The significance of livestock as a contributor to global greenhouse gas emissions today and in the near future. Animal Feed Science and Technology, 166-167, 7-15.

Rufino M., Rowe E., Delve R., Giller K. 2006. Nitrogen cycling efficiencies through resource-poor African crop livestock systems. Agriculture, Ecosystems & Environment 112, 261–282.

UN, 2012, World Population Prospects: the 2012 Revision - http://esa.un.org/wpp/

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C., 2006. Livestock's Long Shadow: Environmental Issues and Options. FAO, Rome, Italy.

Sutton M., Oenema O., Erisman J.W., Leip A., van Grinsven H., Winiwarter W.. (eds). 2011. The European Nitrogen Assessment. Cambridge Univ. Press; available at http://go.nature.com/5n9lsq.