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Changing demand for animal source foods and their effects on the provision of ecosystem services

Dolapo Enahoro, Marta Kozicka, Catherine Pfeifer, Sarah Jones, Nhuong Tran, Chin Yee Chan, Timothy B Sulser, Elisabetta Gotor and Karl M Rich

Highlights

- A novel linking of models assesses localized effects of global socioeconomic change on environmental and ecosystem services.
- Model application to Tanzania shows increased food supplies leading to reduced hunger and malnutrition in 2030.
- Trade-offs emerge between meeting the demand for animal source foods and maintaining ecosystem services provision.
- Interventions based on increased crop productivity or more biodiverse systems, like agroforestry, show promise for mitigating losses to key ecosystem services.

Objective

Higher incomes in developing countries are associated with dietary shifts away from traditional staples towards highly processed foods and foods with higher nutritive value, such as animal source foods (Popkin 2004; Delgado et al. 2001). These shifts, in combination with population growth, urbanization and related factors, will have an important bearing on the evolution and capacities of production and environmental systems. In the case of animal source foods, it will be critical to improve understanding of the nature of the emerging demand, as well as its effects on capacities of production systems to continue supporting production in the long-term (ILRI 2019).

The Meeting Future Demand for Animal-based Foods project, a multi-centre initiative co-funded by the CGIAR research programs on Policies, Institutions and Markets (PIM); Livestock; Fish; and Bioversity International recently studied these related themes. The purpose of the project was to explore current and future meat and fish consumption patterns, assess implications for sustainable development goals (SDGs) related to human nutrition and management of environmental and ecosystem services and derive policy implications for livestock and fish sector development in a case study country.

Key questions

The following research questions were explored in the context of Tanzania:

i. What are the main drivers of increased animal source food demand?

ii. What are the impacts of changing demand for animal source foods on agricultural production systems and associated provision of key ecosystem services such as water supply, soil retention and carbon storage?

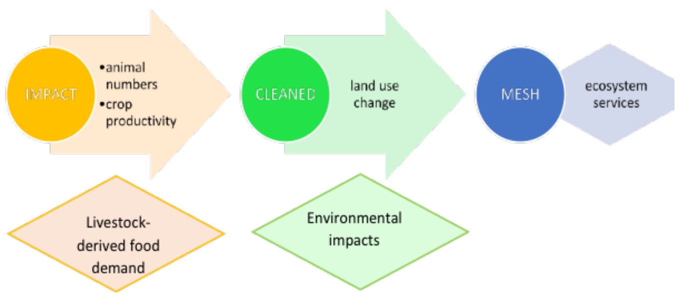
iii. To what extent can increasing diversity in agricultural production systems mitigate losses to ecosystem services?

Tanzania is at an early stage in its dietary and land management transitions for immediate policy change to be relevant for steering towards desired long-term outcomes. Quantitative analyses and a series of stakeholder consultations were aligned to existing platforms for livestock sector analyses, planning and development in Tanzania. However, the study was designed to draw lessons that are also useful to other low- and middle-income countries (LMICs).

Methods

We developed an integrated modelling framework to explore drivers of changing livestock and fish demand, and feedbacks between livestock demand, land use and the environment . Our approach used a censored Quadratic Almost Ideal Demand system analysis (QUAIDS) to quantify growth in the demand for both livestock and fish-derived food products (Bronnmann et al. 2016). Environmental impacts and ecosystem services provision associated with future demand of livestock-derived food (LDF) products—including meat, milk and eggs, and excluding fish—were then simulated using an integrated modeling framework (Figure 1) consisting of economic, environmental and ecosystems services simulation and modelling techniques. To define future macroeconomic scenarios relevant to livestock sector transitions in LMICs, our analytical framework relied on scenarios of global economic change previously quantified for the Intergovernmental Panel on Climate Change (IPCC) (Riahi et al. 2017). The IPCC scenarios to 2030 have been modeled using IMPACT, a multimarket economic model that can project global demand for animal source foods given assumptions about growth in human populations and incomes, among others (Robinson et al. 2015).

Figure 1: Illustration of integrated quantitative modelling using IMPACT, CLEANED-R and MESH



Ex ante environmental impact assessments were then simulated in CLEANED-R, an environmental simulation tool that can compute livestock-driven changes in land use (Pfeifer et al. 2016). Finally, assessments on changes in the provision of water, soil erosion control, water pollutant filtering (nitrogen and phosphorus) and carbon storage and sequestration ecosystem services were done using MESH—an integrative modelling tool that quantifies the change in ecosystem service supply with land use change (Johnson et al. 2019).

We selected a set of global scenarios for 2030 that provide a plausible range of macroconditions under which livestock sector policymakers in Tanzania will need to operate. These scenarios intersect three socioeconomic pathways representing sustainable, unequal and middle of the road (or baseline) futures of economic development (Riahi et al. 2017), with a climate change/greenhouse gas concentration trajectory called the Representative Concentration Pathway 6.0 (RCP 6.0). The scenarios were quantitatively simulated using the IMPACT model. In the next modelling step, for each macro-level specification, we imposed a range of different options for meeting the resulting food demand by defining land use, crop productivity and degree of agrobiodiversity. The results of the six most compelling scenarios for agricultural expansion were modeled based on a 2030 climate scenario using MESH and compared against a baseline situation in 2015. Under each expansion scenario, we considered the effect of increasing agrobiodiversity on the new agricultural land by comparing mono-cropped annual crops (e.g. maize) to agroforestry/silvopasture (e.g. forage or maize grown for fodder cropped with fruit or other trees) systems.

Results

The econometric analysis revealed increasing consumption in fish and meat products by households in Tanzania, with higher consumption changes in urban households than elsewhere. Incomes and education levels were identified as key determinants of household fish and meat consumption decisions.

From the analysis using integrated foresight assessment tools, all macro scenarios simulated showed large increases in animal source food consumption by 2030 . Total feed demand was estimated to increase more than 75% for all three scenarios of economic change. However, the total amount of cereal that will need to be produced for food or livestock feeds, and land needed for cereal production, decreases marginally following assumptions of substantive increases in cereal productivity. Future ecosystem service supplies decreased under all scenarios of agricultural expansion, except for small increases in water provision at the country level. The severity of these negative consequences depended on the economic model's projections of the share of imports in total (beef) supply. The greatest losses to ecosystem services were with respect to water quality. Reduced phosphorus and nitrogen retention by vegetation were associated with lower water quality in areas downstream of the agricultural expansion. Carbon storage and soil erosion control losses were less than 5% across all scenarios. Prioritizing agroforestry over monocropping had no effect on water provision and a slight positive effect on carbon storage by 2030, yet noticeably reduced losses to nitrogen and phosphorous retention services and thus helped maintain water quality.

Overall, total food availability increased under the optimistic economic growth scenario, leading to decline in the rate of hunger and undernourishment in the population in 2030, impacting on SDG 2 (end hunger). Changes in food consumption, including in patterns of livestock-derived food intakes and import volumes, contributed to these outcomes and defined other changes in livestock production and related impacts. Losses in ecosystem services from agricultural expansion, without considering gains in food production, are expected to result in negative impacts by 2030 on SDG 3 (health), SDG 6 (clean water), SDG 11 (sustainable cities), SDG 13 (climate) and SDG 15 (terrestrial life). Losses in these ecosystem services would also result in relatively small negative impacts on SDG 2, SDG 7 (energy), SDG 8 (industry) and SDG 14 (marine life); with a small positive impact on SDG 1 (poverty). Negative impacts on SDG 2 would be partially offset by the benefits of increased food production, which would also result in additional positive impacts on SDG 1.

Discussion

Our initial results showed that current arable land in Tanzania is enough to produce the fodder needed for livestock production in 2030 as projected by the models. However, without the assumed crop productivity gains and in view of higher demand for cereals in the future, there could be competing claims on arable land, likely leading to land conversion. These dynamics could be further accentuated under climate change. Alternatively, depending on which cereals or animal source foods are more profitable to produce locally, increased importation of one or the other could take place. Increasing the import of cereals will allow local farmers, the majority of whom are currently smallholders, to produce animal source foods that are often more profitable. On the other hand, importing livestock food products will allow for a reduced environmental footprint of livestock production in Tanzania. Both cases raise the need for regulatory mechanisms that support the sustainable management of food production more globally. Negative effects on SDGs are shown to be partially mitigated by incorporation of agrobiodiversity into production systems, which is a policy intervention to consider. These outcomes indicate potential tradeoffs from anticipated transitions in the livestock sectors of LIMCs that need to be better analyzed and managed.

Ways forward

Stakeholder engagements building on the results from this study further identified questions for which policymakers at the national level require analytical support within the livestock-environment-land use nexus, and directions of possible change. These issues revolve around conflicts in pastoral zones that are increasing with land degradation and seasonal variability in feed and fodder production, loss or degradation of rangeland, land use planning and its enforcement, seasonal variability in feed and livestock production and non-optimal use of local feed resources in the different production systems. Adjusting the models and scenarios to better address these questions will be useful for both livestock research and policy in Tanzania.

As a direct follow up to the project, a series of policy experiments could be tested to assess the extent to which increased provision of ecosystem services affect potential food supply gaps, as well as incentives and regulations needed to address any negative externalities. Rangeland management options should be appropriately included in future analyses for informing livestock-environmental policy, alongside assessments of animal health, livestock genetics and related technical interventions. More robust analyses are also needed on the role that market-based risk management instruments, such as forward contracts and livestock insurance, could play in supporting expanded production. The insights and further research questions that emerge from the study are interesting from both academic and policy perspectives and should have relevant connotation for many developing countries.

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Authors

Dolapo Enahoro, Catherine Pfeifer and Karl M Rich all work for the International Livestock Research Institute.

Marta Kozicka, Sarah Jones and Elisabetta Gotor work for Bioversity International.

Nhuong Tran and Chin Yee Chan work for WorldFish.

Timothy B Sulser works for the International Food Policy Research Institute.

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Contact

Dolapo Enahoro
ILRI, Kenya
D.Enahoro@cgiar.org
ilri.org

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Box 30709, Nairobi 00100 Kenya
Phone +254 20 422 3000
Fax +254 20 422 3001
Email ilri-kenya@cgiar.org

ilri.org
better lives through livestock

ILRI is a CGIAR research centre

Box 5689, Addis Ababa, Ethiopia
Phone +251 11 617 2000
Fax +251 11 667 6923
Email ilri-ethiopia@cgiar.org

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