Livestock dynamics and economic resilience: A comprehensive modelling framework

INITIATIVE ON Sustainable Animal Productivity

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The organizers of the symposium include: -

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Session rationale

Livestock assumes a crucial role in household and national economies, contributing up to 40 per cent of agricultural GDP in some cases (World Bank, 2009). Livestock's contribution varies from supplying food and manure to offering essential draft power for crop cultivation. In developing countries, smallholder farmers often use livestock as a tangible store of wealth, thereby enhancing their economic resilience. However, animal disease, poor management practices, and fragmented markets usually constrain production. As the world's population continues to rise, animal-sourced food consumption has shown the potential to deliver nutritional benefits to vulnerable demographic groups, especially in low- and middle-income countries.

The complexities of livestock production necessitate unique considerations (relative to crop commodities) when modelling herd dynamics and their interactions with economic and environmental systems. Those considerations span from reproductive behaviours and lifecycle stages to disease dynamics, feed management, climate variability, and economic viability. In the past decades, various approaches have gained prominence in characterizing livestock systems and trying to incorporate these associated challenges. Those models typically assess how on-farm management affects production growth and producer revenues. Livestock prices may be viewed as static or determined by external factors. Another category comprises multimarket partial (Bahta et al., 2021) and general equilibrium models (RIAPA), which incorporate livestock value chains, respectively, as a distinct sector or interdependently with other segments of the entire economy. Each of these employed approaches allows for scenario specifications and implementations, facilitating cost-effective policy interventions.

This session will address some of the recent innovations made in livestock sector modeling and highlight how they can better evaluate the threats confronting livestock populations, market access, livelihoods, and economic growth. The session will draw from and synthesize research from seven studies conducted across various countries using a range of complementary modeling approaches. The studies highlight obstacles in livestock production, ranging from vulnerabilities to animal diseases to climate-induced shocks such as droughts and fluctuations in feed availability. These models aim to improve the policy planning process, helping policymakers identify relevant investment options and animal health interventions (vaccination, quarantine, surveillance), enabling policies and giving guidance to stakeholders in the various livestock chains on appropriate management and marketing that raise resilience.

An innovation of the session will be the use of a tradeshow format to disseminate modeling and research findings (Kaner, 2014). Each of the presenting groups will be distributed across four stations dedicated to a specific thematic livestock modeling approach. These include (1) an integrated herd/epidemiology model with a country-level multimarket partial equilibrium model; (2) applications of the global multimarket partial equilibrium model IMPACT to livestock sector dynamics; (3) a linked animal systems and economywide model; (4) and the use of system dynamics modeling to integrate production, economic, epidemiology, and environmental components. Each station will feature one or more studies presented as posters and a laptop computer set up with user-friendly interfaces of the different models to allow participants to use and interrogate each model actively. The session will begin with a brief 30-minute segment where each group will give a 5-minute oral overview of their model's structure, approaches, and scenarios. PowerPoint slides are not required; the posters will be projected during these presentations. Following this, participants will have 60 minutes to rotate between stations every 15 minutes, actively engaging in constructing hypothetical scenarios facilitated by the presentation team to test model outcomes and identify potential interventions. While the scenario-building may align with the research's primary objective, both presenters and the audience will have the flexibility to discuss prospective new research applications collaboratively, establish new objectives and build new scenarios.

Station 1: Country-level multimarket partial equilibrium modes

Poster 1. Foot-and-mouth disease incidence on cattle-driven food production and consumption in Rwanda

This study uses a simulated herd dynamics model of the Rwandan cattle population and its interaction with consumer demand to project potential shifts in equilibrium supply, demand, and prices resulting from demographic scenarios and disease shocks from the foot-and-mouth disease that reduce animal productivity and increase animal morbidity and mortality. Unlike previous approaches, the model highlights feedback between cattle dynamics (as influenced by price signals and decisions to sell, hold, or breed animals), disease dynamics how producer management behaviours accentuate or mitigate disease spread, and changes in consumer demand. Simulations include foot-and-mouth disease climate-related shocks, as well as scenarios featuring different population and income levels to assess their potential impacts on the aggregate demand for cattle products and resulting equilibrium prices.

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Poster 2. Exploring the socioeconomic impact of female sexed artificial insemination on farmers in Tanzania: A Sector Modeling Approach

This research article examines the effect of female-sexed artificial insemination (AI) on the socio-economic landscape of farmers, with a particular focus on income derived from livestock and associated by-products. The study employs a synergistic approach, utilizing two dynamic models to analyze the multifaceted effects comprehensively. The Dynmod model (Lesnoff, 2008) captures the sophisticated dynamics of herd management over time, allowing for a nuanced understanding of the evolving composition of cattle populations. Complementing this, the partial equilibrium model, alternatively referred to as the multimarket model or sector model, analyses the economic dynamics involved. This dual-model methodology enables a holistic assessment of the long-term implications of adopting female-sexed artificial insemination practices into livestock management. By exploring not only the immediate economic outcomes but also the broader socioeconomic implications, this research contributes valuable insights for farmers, policymakers, and stakeholders interested in promoting sustainable and economically viable practices within the agricultural sector.

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Station 2: Multi-country (Global) multimarket partial equilibrium models

Poster 3. The future of poultry and maize markets in southern Africa under climate change

As demand increases for livestock-derived food products, calls have increased for enhanced regional trade between countries with well-developed livestock markets and supply chains, and others. Assessments are, however, needed to quantify the roles of such livestock markets and trade. This includes the context of competition between the demand for crops such as food and feed. This study contributes to the discussion with its use of a modeling framework that links the global model IMPACT (Robinson et al., 2015) with a spatial equilibrium, regional multi-market model (Bahta et al., 2021) to analyze the potential interactions of poultry and maize (food and feed) markets in the context of a rapidly growing demand for poultry products in Malawi, Mozambique, South Africa, and Zambia. The study's abstraction of a regional approach to livestock and feed sector interactions in the selected region highlights the role of markets in addressing cross-boundary challenges related to food demand expansion and resource management. The study's findings imply that countries could benefit from addressing growing demands for livestock-derived foods using a harmonized approach. Further, regional livestock markets offer cushioning effects to the impacts of climate change in at least one of the countries.

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Station 3: Linked animal systems and economywide models

Poster 4. Modeling crop-livestock interactions in semi-subsistence economies under weather shocks

Mixed crop-livestock systems dominate farming, particularly in sub-Saharan Africa, and are predominant contributors to livelihoods. These systems are the primary recipients of the effects of climate change, and interaction between them makes the impacts considerable and irreversible. However, the speed of recovery from a climate shock varies between these systems, although the dynamics of recovery and the impact of their close interaction on the recovery dynamics are not yet well-researched. In addition, there are various ways in which these systems may adapt to climate change and be climate resilient, including measures targeting the crop sector or the livestock sector. Crop sector interventions could promote drought-resistant varieties and adapt modern farming practices. The livestock sector could adapt through selective breeding and herd size management practices. Using the version of the Linked Economy and Animal Systems (LEAS) model 1 that incorporates environmental and climate change factors into its forage supply function and that reflects animal traction as a capital factor in the crop sector, this study evaluates (i) crop-livestock interactions in a typical developing economy, taking the case of Ethiopia as example, in the context of weather shocks and (ii) the importance of various crop and livestock adaptation strategies in terms of their impacts on sustaining farm incomes, food security, and welfare. The model is calibrated for the five agroecological zones in Ethiopia.

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Station 4: System dynamics approaches

Poster 5. Assessment of vaccination impact in PPR-Control programme implemented southern states in India: A System Dynamics Model Approach

In India, Peste des petits ruminants (PPR) poses a significant threat to sheep and goat populations, prompting mass vaccination initiatives in states like Andhra Pradesh and Karnataka. Despite a notable decline in outbreaks post-vaccination, sporadic occurrences persist due to the constant movement of animals across states for grazing and trade. This study employs a System model to assess PPR's impact, considering both local and external factors. Mass vaccination in Karnataka and Andhra Pradesh has substantially reduced outbreaks, resulting in decreased PPR-related mortality and morbidity. The surveyed states exhibit a PPR incidence of <4%, attributing this to vaccination efforts. Economic losses, including mortality costs and treatment expenses, range from USD 35.1-108.1 in Andhra Pradesh and USD 40.5-189.2 in Karnataka. The projected losses for 2021-22 stand at USD 26.30 million and USD 22.86 million in Andhra Pradesh and Karnataka, respectively. The result highlights the benefits of high vaccination coverage in increasing flock size and offtakes and reducing infected and death cases. Coordinated inter-state vaccination efforts emerge as crucial for minimizing outbreaks.

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Poster 6. Modelling the carbon and economic dynamics in livestock systems in Tanzania

Livestock production in Tanzania predominantly adheres to traditional methods, especially for ruminants, aligning with domestic demand rooted in traditional value chains. Opportunities for value chain upgrading emerge, particularly in leather production, along with the potential for expanded productivity in milk and ruminant meat. However, considering the high climate impact of these activities, understanding carbon dynamics and emissions is imperative. This study assesses productivity and value-added potential in various livestock value chains based on existing research. Furthermore, we propose integrating a concept for modeling carbon dynamics into an economic value-chain model collaboratively with researchers and experts. This initial step aims to develop a model allowing scenario creation and facilitating "what-if" analyses for potential value chain transformation scenarios.

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Poster 7. Unveiling the dynamics of poultry farm interventions on antimicrobial use in Senegal: A System Dynamics Approach

We employ a System Dynamics approach to model the consequences of poultry farm-level practices related to animal disease prevention and response, focusing on antimicrobial use and productivity. The model targets smallholder farms typical in Senegal and encompasses the dynamics of layer and broiler systems, the acquisition of day-old chicks, vaccination cycles (or lack thereof), the sale of grown chicken and eggs, as well as an accounting of farm profits and costs dependent on production levels and flock size. The model incorporates disease spread, interventions in response to disease, and the dynamics between these elements. Various interventions are tested, including different vaccination regimes and responses to disease outbreaks (limited antimicrobial treatment,

widespread antimicrobial treatment, hygiene intervention without antimicrobial treatment, and no response). The model's results quantitatively assess antimicrobial use under these scenarios and measure their effects on poultry mortality and farm productivity, providing valuable insights for on-farm decision-making and policy guidance.

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