A system dynamics approach to chain/network analysis in the primary industry sector

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Motivation

- Significant research has been conducted on agricultural/agribusiness value chains in the past 15-20 years

- And while we have lots of analyses, new definitions, and created a lot of confusion over terminology (supply chain vs value chain vs netchains vs value networks e.g.), we haven't moved much methodologically.

- Current value chain methods are:
  - Largely qualitative
  - Largely descriptive
 - Reaching their limits in terms of analytical power

Motivation

- A big gap: limited use of *quantitative* techniques to look at dynamics of value chains, their actors, and interventions that affect the system (priorities, impacts, etc.).

  - *The $20 million question…*

- But are current analytical methods good enough in a value chain context – are we missing anything? Can we identify other, more appropriate methods?

Current methods

- We can identify a number of quantitative methods that can be used in a policy analysis/impact assessment setting:
  - Cost-benefit/partial budget models (used in a few value chain studies e.g. Tchale & Keyser 2010)
  - Partial equilibrium models (single-sector, multi-sector)
  - General equilibrium models (including social accounting matrices and input-output models)

- How applicable are these in a value chain, particular given the complex interactions that exist between actors from production through consumption?
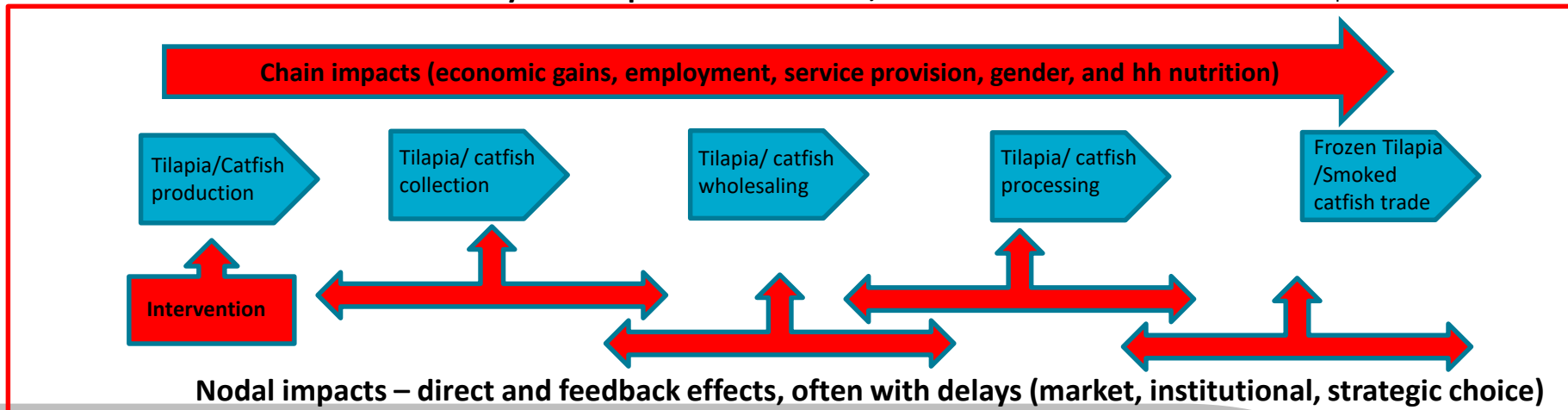
Partial equilibrium models vs value chains
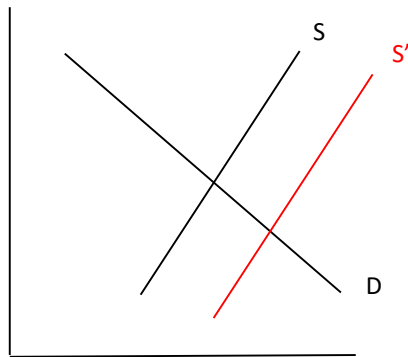
Fish production

???
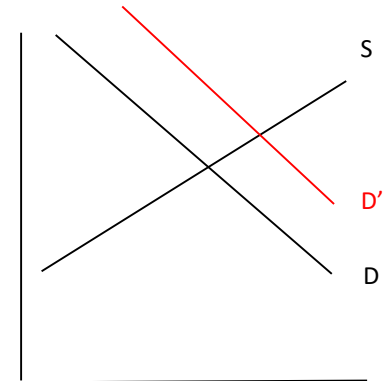
Fresh and Frozen Tilapia /Fresh and Smoked catfish production

System impacts – contextual, environmental

Chain impacts (economic gains, employment, service provision, gender, and hh nutrition)

| Tilapia/Catfish production | Tilapia/ catfish collection | Tilapia/ catfish wholesaling | Tilapia/ catfish processing | Frozen Tilapia /Smoked catfish trade |

Intervention

Nodal impacts – direct and feedback effects, often with delays (market, institutional, strategic choice)

Source: Dizyee, K., Baker, D., Rich, K. M., Fleming, E., & Burrow, H. (2016). *Applying system dynamics to value chain analysis*(No. 235242). Australian Agricultural and Resource Economics Society.

Research method: what is system dynamics?

- **What is Systems Dynamics?**
  A modelling approach that examines the dynamic interactions and feedback effects among different components (and sub-components) of a system, using integral calculus and differential equations represented through a graphical representation
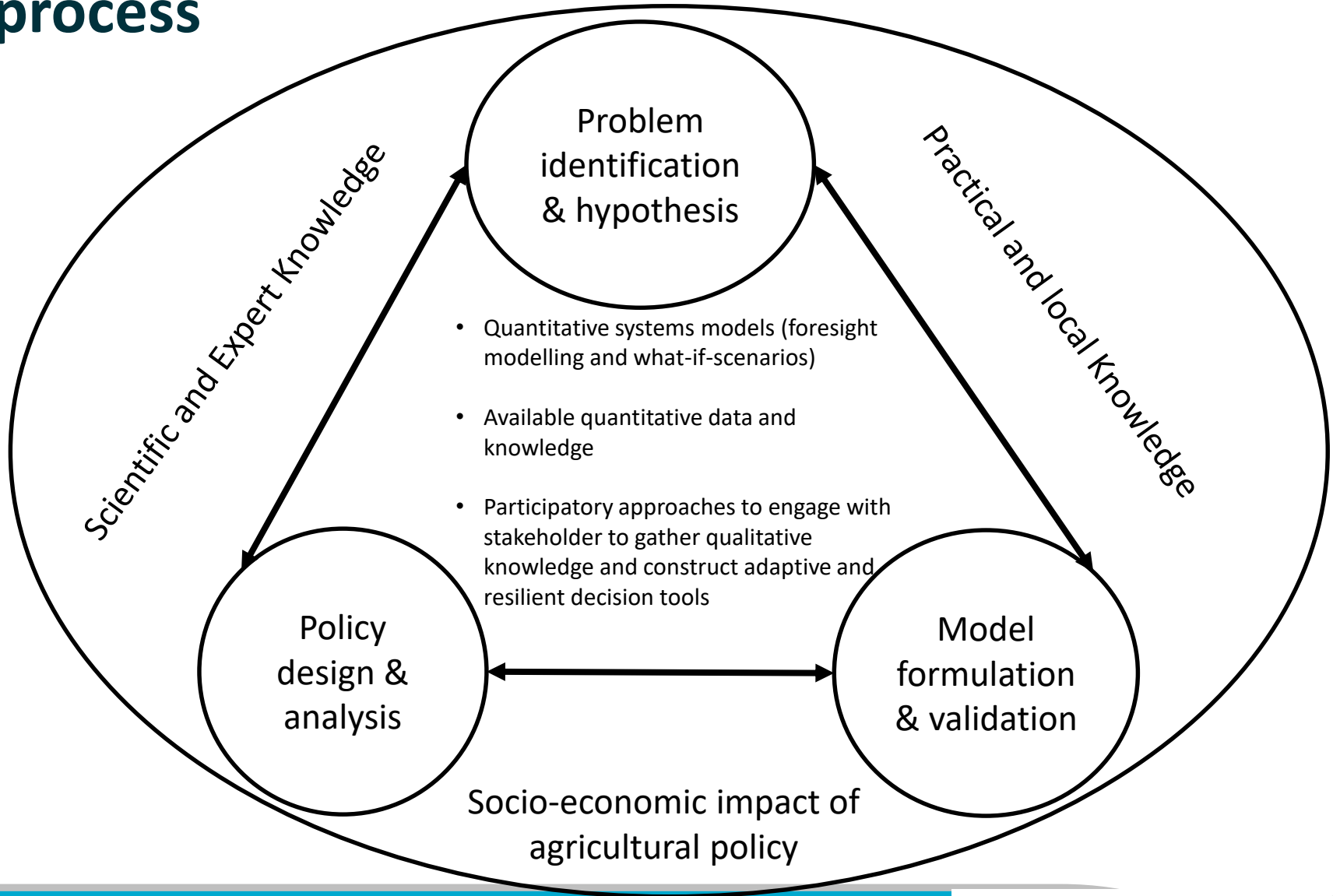
- **How does it work?**
  Analyses a problem from a whole chain perspective (producers, intermediaries, consumers) to facilitate understanding of trade-offs (winners/losers – based on VC actor profit) under different intervention scenarios (new/improved production/technologies) and market diversification (new trade channels)
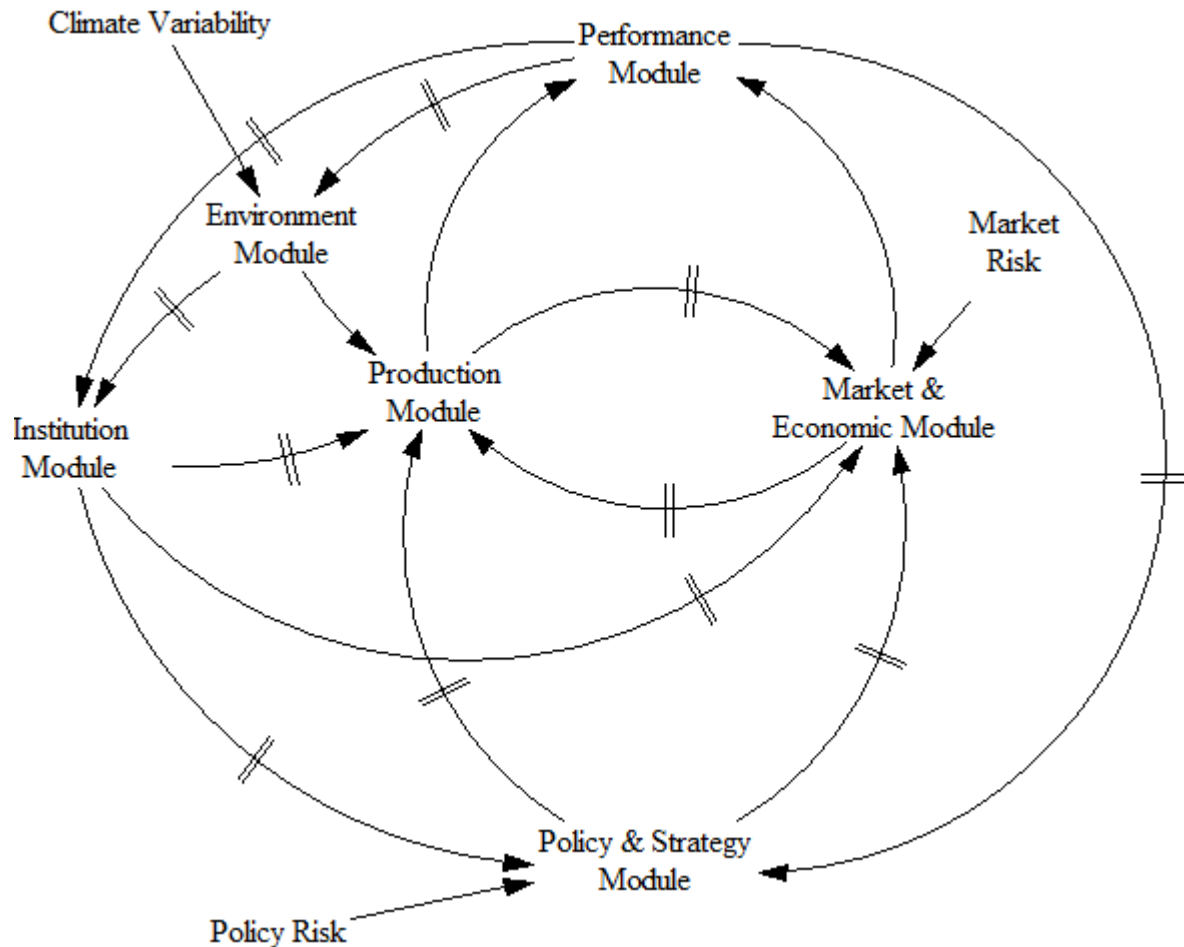
- **What opportunities exist through integration?**
  Value creation from by-products through technology (leather: hides, bones, manure); environmental footprint through inclusion of GHG emissions and resource use along the chain (economic, consumer, ecological values); broader understanding of value beyond VC actor profit (jobs creation, multiplier effect)

Research method: research design & modelling process

Problem identification & hypothesis

Policy design & analysis

Model formulation & validation

Scientific and Expert Knowledge

Practical and local Knowledge

Socio-economic impact of agricultural policy

- Quantitative systems models (foresight modelling and what-if-scenarios)

- Available quantitative data and knowledge

- Participatory approaches to engage with stakeholder to gather qualitative knowledge and construct adaptive and resilient decision tools

Conceptual framework: Feedback loops

Source: Dizyee, Kanar, Derek Baker, and Karl M. Rich. "A quantitative value chain analysis of policy options for the beef sector in Botswana." *Agricultural Systems* 156 (2017): 13-24.

8

Botswana: beef value chain

Performance Module

- Chain actors profit (cumulative & over time)
- Whole chain profit

Environment Module

- Pasture
- Disease
- Management
- Seasonality

Production Module

- Continuous production and trading
- Extensive production system

Market & Economic Module

- BMC monopsony
- Transboundary diseases
- Market disruption

Institution Module

- Market power
- Disease management

Policy Module

- Better disease control
- Partial ease of BMC monopsony
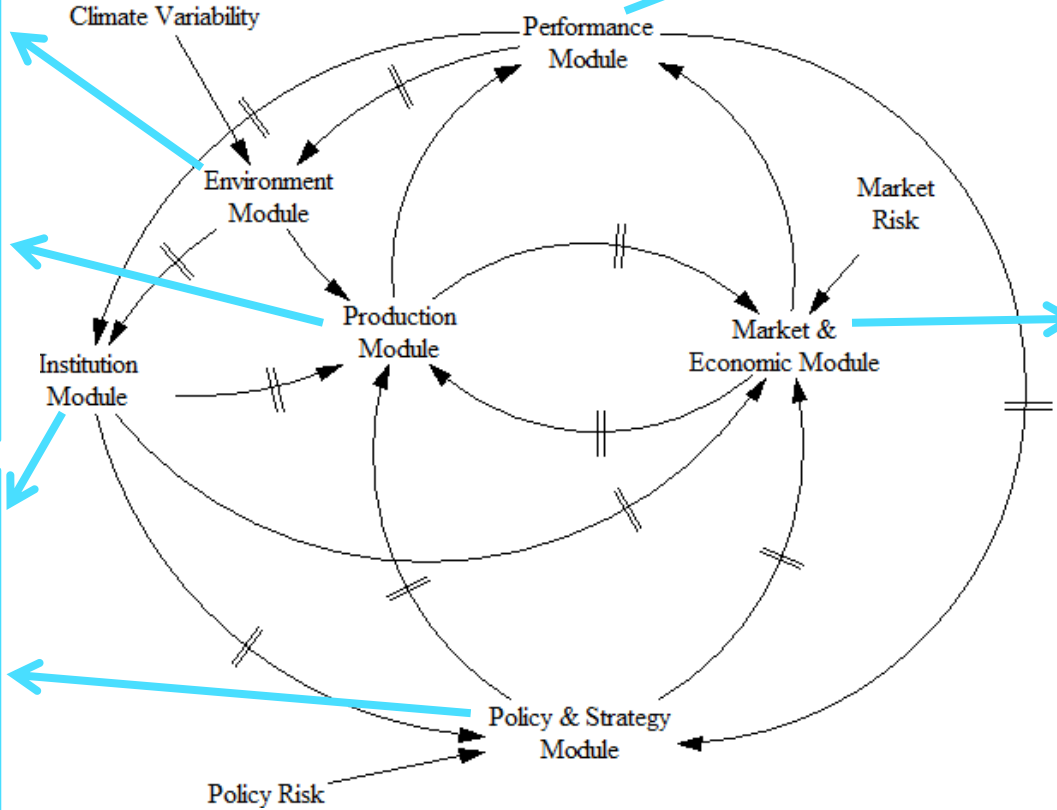
Beef value chain in Botswana (Profit performance)

Value chain actor financial performance relative to baseline scenario (Source: simulation results)

Runs	Producers	BMC	Feedlots	Traditional Butchers	Modern Butchers and Retailers	Whole Chain Performance[1]
Run 2 Vs. 1	84%	-379%	-28%	1%	-5%	17%
Run 3 Vs. 1	26%	101%	9%	0.5%	4%	19%
Run 4 Vs. 1	141%	-399%	-26%	1%	-3%	43%
Run 4 Vs.3	NA	NA	NA	NA	NA	20%

[1] % sign means per cent change relative to baseline (e.g., 17% in the first row means Run 2 is 17% more profitable than run 1).

Run 1: Business as usual; Run 2: Market liberalization; Run 3: Business as usual + FMD freedom; Run 4: Market liberalization + FMD freedom.

Source: Dizyee, Kanar, Derek Baker, and Karl M. Rich. "A quantitative value chain analysis of policy options for the beef sector in Botswana." *Agricultural Systems* 156 (2017): 13-24.

Summary: What does SD provide us in value chain analysis?

- Analysis at a finer resolution (from sector to level of chain actors)

- Ability to endogenize the role that governance and institutions play in value chains

- System context – incorporating the role of environmental and biophysical factors directly in the model

- A bridge to qualitative value chain analysis: SD can serve as an additional overlay to existing value chain maps and description

Thank you

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Supplementary slides

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Upgrading the smallholder dairy value chain: a system dynamics ex-ante impact assessment in Tanzania's Kilosa district

Research Article

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Abstract

This paper examines ex-ante impacts of two policy interventions that improve productivity of local-breed cows through artificial insemination (AI) and producers' access to distant markets through a dairy market hub. The majority of cattle in Kilosa district in Tanzania are local low productivity breeds kept by smallholders and agro-pastoralists. Milk production is seasonal, which constrains producers' access to distant urban markets, constrains producers' incomes and restricts profitability in dairy processing. We developed and evaluated an integrated system dynamics (SD) simulation model that captures many relevant feedbacks between the biological dynamics of dairy cattle production, the economics of milk market access, and the impacts of rainfall as an environmental factor. Our analysis indicated that in the short (1 year) and medium (5-year) term, policy interventions have a negative effect on producers' income due to high AI costs. However, in the long term (5+ years), producers' income from dairy cattle activities markedly increases (by, on average, 7% per year). The results show the potential for upgrading the smallholder dairy value chain in Kilosa, but achievement of this result may require financial support to producers in the initial stages (first 5 years) of the interventions, particularly to offset AI costs, as well as additional consideration of post-farm value chain costs. Furthermore, institutional aspects of dairy market hub have substantial effects on trade-offs amongst performance measures (e.g. higher profit vs. milk consumption at producer's household) with gain in cumulative profit coming at the expense of a proportional and substantial reduction in home milk consumption.

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A quantitative value chain analysis of policy options for the beef sector in Botswana

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ARTICLE INFO

ABSTRACT

The liberalization of beef exports in Botswana is hotly debated among policy makers and relevant value chain actors. While some policy makers argue that such a move might increase prices for producers and make beef unaffordable for consumers, others suggest an open market would reduce the profitability of the beef sector in Botswana. At the same time, these impacts will be mediated by the presence of animal disease and the availability of sufficient feed and water. In this paper, we constructed an integrated system dynamics (SD) model that captures the feedbacks between the biological dynamics of cattle production, the economics of animal and meat marketing and trade, and the impacts that environmental pressures such as rainfall and animal disease have on the system. We used this model to run a series of scenarios associated with market liberalization and animal health shocks to quantify their impacts throughout the value chain, taking into account the feedbacks between biology, markets, and environment on the value chain itself. This approach allows for a holistic evaluation of policy options on different chain actors and whole chain performance, and provides a knowledge base for prioritizing interventions. Model results suggested that although disease control policies benefit all value chain actors, gains from market liberalization come at the expense of substantial losses to Botswana Meat Commission (BMC) and its contracted feedlots. They also suggest that combining market liberalization policy reforms with better animal disease controls greatly improved the financial performance of all value chain actors.

African swine fever control and market integration in Ugandan peri-urban smallholder pig value chains: An ex-ante impact assessment of interventions and their interaction

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ABSTRACT

Pig production in peri-urban smallholder value chains in Uganda is severely constrained by impact of disease, particularly African swine fever (ASF), and the economic consequences of an inefficient pig value chain. Interventions in the form of biosecurity to control ASF disease outbreaks and pig business hub models to better link smallholder farmers to pig markets have the potential to address the constraints. However, there is a dearth of evidence of the effects of the interventions on performance and distribution of outcomes along the pig value chain. An ex-ante impact assessment utilising System Dynamics model was used to assess the impact of the interventions in peri-urban pig value chains in Masaka district. The results showed that although implementation of biosecurity interventions results in reduction of ASF outbreaks, it also leads to a 6.3% reduction in farmer profit margins per year but more than 7% increase in other value chain actors' margins. The pig business hub intervention alone results in positive margins for all value chain actors but minimal reduction in ASF outbreaks. When biosecurity and the pig business hub interventions are implemented together, the interaction effects of the interventions result in positive outcomes for both the control of ASF and improvement in farmers' margins. Farmers may therefore be unwilling to adopt biosecurity practices if implemented alone to control ASF outbreaks unless there is a corresponding financial incentive to compensate for the high costs. This has implications for policy or developing institutions to facilitate cost sharing arrangement among chain actors and/or third party subsidy to provide incentives for producers to adopt biosecurity measures.

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A SYSTEM DYNAMICS APPROACH TO SEA LICE CONTROL IN NORWAY

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☐ *Various methodologies have been used to model the epidemiology and economics of aquatic diseases, including input-output models, benefit-cost analysis, linear programming, compartment models based on differential equations, and spatial models. Despite the virtues of each of these models, there is a need to develop a more integrated approach to the epidemiology and economics of disease that better represents and captures existing feedback mechanisms that can influence the success of disease control interventions and their cost-effectiveness. In this paper, we motivate the use of system dynamics (SD) modeling in the context of sea lice control in Norwegian farmed salmon. Separate models of sea lice and salmon growth were designed and integrated to capture the feedbacks between them. Different simulation scenarios highlight the benefits of the approach. Model results indicated that changing the timing and type of treatment vis-à-vis current practices can markedly reduce sea lice infection pressures; such simulated practices are also more cost effective. Our approach further highlights how delays and feedbacks present in these systems influence the success of any disease control protocol, and demonstrates the utility that SD models can play in aquatic health.*

Keywords aquatic diseases, cost-effectiveness, lice control strategies, sea lice, system dynamics

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■ *Research Paper*

Primary Industry Chains and Networks: Analysis for Public and Private Interests

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Modern primary industry makes obsolete the conventional analysis of private and social performance. This is due to the dominance of chain failure as opposed to the more familiar market failure. This paper makes the case that value addition dominates aspirations for primary industries, and vertical coordination and shifts in commercial power balances feature in the sharing of benefits within value chains. Moreover, complexity in chain relationships and some particular features of primary industry bring challenges to forward planning and concerted effort. Value addition in New Zealand's forestry and wood products' industry presents several such challenges, and these are examined with a qualitative system dynamics model. Potential policy responses that eliminate chain failure are discussed in association with the Australian beef industry research model. The paper advocates joint industry-university-government action in terms of research and skills development. Copyright © 2016 John Wiley & Sons, Ltd.

Keywords value chain analysis; systems dynamics; primary industry

Assessing the sustainable development and intensification potential of beef cattle production in Sumbawa, Indonesia, using a system dynamics approach

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Abstract

The intensification of beef cattle production in dryland areas of East Indonesia has the
potential to substantially raise the incomes of smallholder farmers that dominate the sector.
In this study we assess the potential for intensifying beef production on Sumbawa Island, by
introducing a household feedlot production system (2–20 animals) based on the *Leucaena
leucocephala* (leucanea) tree legume as an improved source of feed. We used a system
dynamics approach to model the entire value chain, accounting for herd dynamics, demand
dynamics and seasonality. Our findings complement the growing body of biophysical evi-
dence about the potential success of this intervention, by simulating improvements in the
annual profitability for beef farmers in the project area of up to 415% by 2023. Increases in
farm profit were shown to depend near equally on the higher productivity of the leucaena
feeding system and an associated price premium, demonstrating the importance of support-
ing improved agricultural production with better marketing practices. The intervention was
also shown to generate positive or neutral benefits for the main post-farm value chain
actors. Importantly, it also reduced the GHG emission intensity of outputs from the beef
herd by 16% by 2020. We explored number of scale-out pathways, including a relatively
moderate pace of autonomous adoption for our main analysis, resulting in the accumulation
of 3,444 hectares of leucaena 20-years after the initial project phase, which could sustain
the fattening of 37,124 male cattle per year. More ambitious rates of scale-out were found to
be possible without exceeding the animal and land resources of the island.
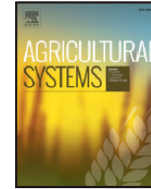
Participatory systems approaches for urban and peri-urban agriculture planning: The role of system dynamics and spatial group model building

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ARTICLE INFO

ABSTRACT

Urban agriculture has become an important research theme in recent years. Over the past decade, a number of different, diverse value chains have been established in the urban areas of developed and developing countries alike, with increasing convergence in their motivations related to food security and livelihoods development, particularly for poor and disadvantaged segments of society. However, for urban agriculture to be sustainable as a livelihoods and resilience strategy will require decision-support tools that allow planners and participants alike to jointly develop strategies and assess potential leverage points within urban food value chains. In this paper, we argue that system dynamics (SD) models combined with participatory approaches have important roles in bridging this gap, though these will need to be adapted to the spatial influences that exist in urban settings. We first review elements of urban agriculture and some of the policy challenges faced in this growing phenomenon. We follow this by motivating the role of SD models in the context of urban agriculture and note their potential utility in overlaying quantitative models of urban food value chains alongside their land-use characteristics, highlighting the dynamic feedbacks between intensive processes within changing urban food systems and extensive processes associated with land-use and planning. From this background, we introduce the concept of spatial group model building (SGMB), which adapts standard group model building concepts to account for both the spatial context of urban agriculture and enables a spatially sensitive, participatory approach to qualitative and quantitative model building. We provide a qualitative proof-of-concept of SGMB principles and techniques in the context of describing the setting and dynamic issues facing organic urban agriculture value chains in Christchurch, New Zealand. Our approach fills an important space between participatory GIS practices and the development of complex spatial system dynamics models, infusing systems thinking principles to participatory processes, while showing a way to enhance the future development of quantitative spatial system dynamics models more generally.

Quantitative value chain approaches for animal health and food safety

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ABSTRACT

Economic impact assessments are increasingly important in the context of animal health and food safety, although much of the existing literature does not address the broader systems context in which disease transmission takes place. In this paper, we discuss the role of system dynamics modeling in addressing the value chain impacts associated with animal health and food safety issues. System dynamics methods hold promise as a means of capturing the complex feedbacks that exist between the biology, economics, and behavioral aspects of food safety and animal health systems. We provide a proof-of-concept of this approach in the context of food safety and animal health in the smallholder pig sector of Viet Nam. Results highlight the important tradeoffs that exist between policy objectives and the costs required to achieve them.

Commercializing Smallholder Value Chains for Goats in Mozambique: A System Dynamics Approach

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