Participatory system dynamics modelling for dairy value chain development in Nicaragua

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Abstract

The use of system dynamics (SD) tools can add valuable insights when identifying and evaluating priorities for pro-poor value chain upgrading. However, to better understand the complex systems in agricultural value chains and to develop useful models, a participatory modelling process is important. This paper highlights the group model building (GMB) process of the dairy value chain in Matiguás, Nicaragua, one of a few examples of participatory model building in developing countries. The results confirm several benefits with participatory SD modelling including team learning, a greater understanding of the value of modelling, and a tool for decision-making and priority setting.

Introduction

Smallholder farmers are an important component of international food and nutrition security, but face numerous challenges when trying to improve their livelihoods. While there is limited participation of smallholder farmers in increasingly professionalized and complex agricultural value chains, opportunities exist for smallholders to access markets, which can contribute to a range of positive, pro-poor impacts. One of the virtues of focusing on the value chain, instead of a specific sector or commodity, is the ability to characterize more broadly the system in which smallholder farmers can take part, and to identify the role that contextual factors such as governance play in determining market access (Rich et al. 2011).

A number of value chain frameworks have been developed by NGOs and donor consortiums (e.g. Making Markets Work Better for the Poor, World Vision, SNV) to guide practitioners on the analysis and development of pro-poor value chains. These toolkits have been mainstreamed to engage stakeholders to work in a systems setting as a means of developing common goals, and the promotion and development of new, pro-poor market opportunities. However, an important challenge and limitation of value chain analysis (VCA) and value chain toolkits is that they are highly qualitative and descriptive in their orientation. In particular, it is difficult to project *ex-ante* what impact or outcome different interventions might have within these complex systems (Rich et al. 2011). As the introduction of new interventions will cause changes in both marketing and contextual features of the value chain, various feedback mechanisms may be activated that could undermine or reduce, as well as improve, the effectiveness of a specific intervention over time. As such, it is important to identify analytical frameworks that can provide a richer understanding of the impacts that policies could have on the value chain and its participants. Equally important in development settings is to find the means to operationalize the process of impact assessment in

environments where data is poor or unavailable, and to ensure a process of stakeholder engagement throughout.

System dynamics methods are one means to address these gaps in value chain analysis. A system dynamics (or SD) model maps the flows, processes, decision rules, and relationships between actors that operate within a complex system (Sterman 2000). It is highly interdisciplinary and can be used as a tool to test and analyze interventions and policies. Recent research on value chains has revealed the utility of this approach in agricultural and livestock systems in *ex-ante* testing of the dynamic impacts of feedbacks from different policy and technical interventions within the chain (Rich et al. 2011, Naziri, Rich, and Bennett 2015).

A particular advantage of SD models is that they can be conceived and developed through participatory processes with stakeholders in the field. In particular, many analysts use what is known as group model building, or GMB, to develop their models jointly through participation and direct collaboration (Vennix 1996). Several methods for developing models with stakeholders exist (e.g. see Voinov and Bousquet 2010 for an overview of different methods). However, in the context of developing SD models, GMB is particularly appropriate, as the participatory process is specifically oriented towards the explicit use of the language and concepts of system dynamics in the development of models with stakeholders. In addition, GMB is especially relevant when there are diverse types of stakeholders involved, when many different intervention options exist, and when it is difficult for stakeholders to understand individually the possible consequences of a collective decision made within a complex system (Vennix 1996, Andersen, Richardson, and Vennix 1997).

Despite the potential applicability of GMB in a developing country and in a value chain context, little research has utilized this approach (an exception is McRoberts et al. 2013). The purpose of this paper is, therefore, to demonstrate and assess how a GMB process can be applied in building models that contribute to pro-poor value chain development. We provide a detailed example of the participatory SD model building process applied in the analysis of the dairy value chain in Matiguás, Nicaragua. The dairy sector is large and important in Nicaragua, and Matiguás is one of the areas where most of the country's milk is produced. The area is smallholder-focused, with several cooperatives and private milk collectors that supply the dairy industry in the capital Managua. Given the shifts towards more commercial and export-oriented markets, it is a priority of the government to understand the scope and impacts of policy options available to promote the continued inclusion of small- and medium-scale producers (MAGFOR 2013, Polvorosa 2013). The research objectives of the project include (i) an identification and understanding of the dynamic processes in the dairy value chain in Matiguás, Nicaragua and (ii) a collective discussion of relevant interventions, policies, and decision-making processes based on these processes, and their possible implications on smallholder competitiveness.

In this paper, we first provide some background to system dynamics with particular focus on group model building. We follow this with an introduction to the study area of Matiguás, Nicaragua. We then give a detailed account of the research methodology, offering insights into the implementation of a participatory value chain modelling process. We conclude with perspectives, lessons learned, and challenges of using this approach in developing pro-poor value chains.

Participatory system dynamics modelling

Value chains and system dynamics

A value chain denotes the various processes and actors involved in the development, transformation, marketing, and final retail of a good or service (Kaplinsky and Morris 2001). In conventional value chain analysis and development, practitioners analyze the structure of the system through a process of participatory actor mapping with stakeholders. This provides insights on flows of goods and services, how different actors interact with one another and identifies the contextual factors (termed governance). Governance examines how different decisions are made and implemented, how activities are coordinated, and how decision-makers are held accountable. The lead stakeholder(s) in the value chain often have the power to control the terms of participation and influence the involvement of other actors (Gereffi, Humphrey, and Sturgeon 2005). This analysis is used to inform the development of upgrading strategies to add value for the actors. Upgrading strategies can involve the development of new products, improving processes, changing ones position in the chain, or moving into a new chain all together (Kaplinsky and Morris 2001, Bair 2009). It is particularly important to pay special attention to vulnerable groups such as smallholder farmers when upgrading value chains in developing countries, so that the interventions do not have the opposite effect of the desired development outcome (Bolwig et al. 2010) .

As noted, the process of value chain analysis is largely qualitative and descriptive, making it difficult to evaluate the benefits and costs associated with different intervention options. Rich et al. (2011) proposed the use of SD tools as a means of complementing value chain analysis. System dynamics is a computer-aided, interdisciplinary approach to policy analysis and design (Sterman 2000). What SD models provide to value chain analysis is a quantitative overlay to conduct scenario analysis. A standard value chain mapping exercise produces only

static snapshots of the system processes. System dynamics software enables studying the behavior of these processes over time.

SD models are built on the concepts of stocks, flows, and feedback loops. Stocks denote the accumulation of any good or service at a particular period of time. In a livestock system, the number of animals on a farm or the volume of milk processed are considered as stock variables. Flows define the rate of change into and out of a stock and represent the decisions that are made to change stock values. Sales of cattle by a farm (units: head of cattle sold per week) would be an example of an outflow, while purchases of raw milk (units: liters of milk purchased per week) by a milk processor would be an example of an inflow. Different technical parameters regulate the speed by which inflows or outflows change the level of a stock. Within a system, feedback loops exist when decisions change one component of a model and initiate changes in the conditions and information of another component that influence the broader system (Sterman 2000). Figure 1 provides an illustration of how stocks, flows, and feedbacks are represented in SD modeling.

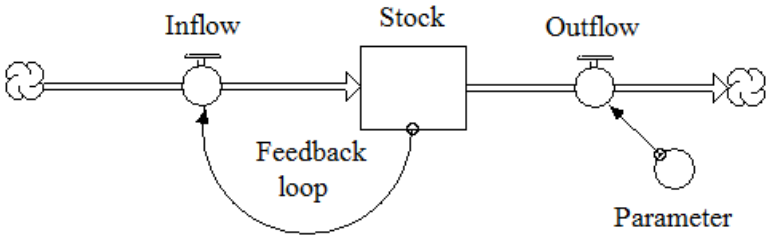

Figure 1: Illustration of stock, flows and feedback Source: Modified from Sterman (2000)

Group model building

Group model building, or GMB, is a participatory method that includes various relevant stakeholders in constructing a SD model. GMB combines bottom-up and top-down perspectives on systems problems, especially those found in value chains, thus increasing the

credibility of proposed solutions. The GMB process offers an opportunity to take part in, understand, and influence decision-making in the value chain for all stakeholders (Vennix 1996). It can also uncover different attitudes and understandings among the value chain stakeholders during the process, a valuable outcome of participatory research (Gaventa and Cornwall 2008). GMB is also a good tool of building consensus and commitment to the final chosen strategy since all stakeholders are involved in constructing the model, testing suggested interventions and policies, and making choices. By their nature, GMB sessions are interactive and iterative. Furthermore, it can help to achieve stakeholder buy-in and commitment to selected policies and value chain interventions and assure sustainability after project end (Hovmand 2014, Andersen, Richardson, and Vennix 1997, Cornwall and Jewkes 1995). It is also particularly useful in environments where data is scarce.

Critiques of participatory research remark that true participation is often not achieved, limited by either temporal constraints associated with the research process or an inability to achieve sufficient heterogeneity in participants. Others criticize that unintended negative consequences of the process often is not considered. Participatory research further puts pressure on ensuring equal participation of farmers and other stakeholders, which necessitate focus on issues such as power, knowledge, interests, and freedom of speech. Equal ownership to results is also important (Cornwall and Jewkes 1995).

A GMB process starts with problem identification and definition, whereby the system is conceptualized through identifying different elements in the system and their relationships. The outputs of a GMB session can either be a qualitative model of the system that can help in joint learning about the system itself or the development of quantitative models that can be used to run scenarios of different interventions. This is subsequently used to formulate

dynamic hypotheses about the causes of various problems. The quantitative modelling involves parameterizing proposed relationships, followed by validation, testing and analysis to develop policy recommendations. The final step is to assess the process and the process outcomes (Vennix 1996, Sterman 2000).

Within the value chain, a GMB process ideally includes key stakeholders, such as producers, processors, traders, and retailers. Most importantly, GMB sessions need to include those who have local knowledge and are affected by and can implement changes (Gaventa and Cornwall 2008). It should also include those that work with the value chain, often called the enabling environment, since they have more power and resources to initiate and support interventions. These are stakeholders that offer services and support to the key stakeholders in the value chain, such as credit- and research institutions, NGOs, and government agencies. Ensuring inclusion of women is important to highlight the direct and indirect roles women play in value chains (Rubin and Manfre 2014).

The selection of participants in a GMB project is therefore important. It can be a small group of around five to seven people or a large group of more than ten or twelve (Vennix 1996). In value chains with many stakeholders, a larger group might be necessary. Including one too many is often better than one too few since those excluded from the process may easily resist the resulting conclusion from the GMB process (Vennix 1996, Voinov and Bousquet 2010). Creating an environment for active participation by all is critical (Gaventa and Cornwall 2008).

Other considerations with a GMB session include establishing the roles and responsibilities of the facilitation team, and procedures used to facilitate discussion. A facilitation team

typically consists of the lead facilitator, a recorder that takes detail notes in each session, a modeler, a process coach paying specific attention to the group process- and dynamics, and a gatekeeper that is the liaison between the facilitation team and the participants. One person could take on several roles, but a minimum of two people is advised, and more if working with a large group (Vennix 1996). Likewise, the GMB process can start from scratch with the GMB participants, or can start with a preliminary model. This depends on the number of participants and facilitators, the time available, the location, cultural setting, and financial resources (Vennix 1996). Scripts are often used to guide each session where the process, procedures, and the time set aside for each step is agreed upon to ensure progress in the modelling process (Luna-Reyes et al. 2006, Andersen and Richardson 1997).

Despite the many highlighted benefits, McRoberts et al. (2013) provide one of very few examples of participatory model building of a value chain. They constructed a SD model focusing on small-scale dairy development in Mexico and tested the possibilities of collective action to produce goat cheese by focusing on key biological and economic factors. They concluded that a systems-based participatory approach can help test potential development and agribusiness interventions.

Study area

Nicaragua is an agricultural country with livestock being the most important component, contributing to 13% of the national GDP, and 45% of the national value of agricultural production in 2013 (MAGFOR 2013). The size of the dairy sector has increased over the last decade and is one of the government's priority areas. National milk production has increased over the past five years and is estimated to be two million liters per day, where only 25% is

absorbed by formal processing plants and 75% by the informal sector (MAGFOR 2013, Holman 2014).

The research analyzed the Nicaraguan dairy sector at the meso level and selected the dairy value chain within the Matiguás municipality in the Matagalpa region, 160 km away from the capital Managua. Matiguás municipality has a population of nearly 50,000, where over 80% are livestock keeping households. Matiguás is part of the "Via láctea", the "Milky Way", which consists of four municipalities that produce 20-30% of Nicaragua's milk (INIDE-MAGFOR 2013). Dual-purpose cattle is the most common, with a high number of small- and medium-scale producers (80%), which is the target group of this research. In Nicaragua, small-scale producers typically farm less than 14 ha of land, own between 2 and 20 cows, and produce on average 20 liters of milk per day. Medium-scale producers farm 14 to 100 ha and produce around 50 liters/day. In total, about 100,000 liters are produced per day in Matiguás. Most of the milk (60-65%) is collected through one of the five cooperatives and supplied to the large milk processors in Managua, as illustrated in figure 2. About 35% of the milk is collected by private collectors and supplied to the industry or to semi-industrial processors who primarily export to El Salvador. There are also numerous small local processors in Matiguás, which are part of the large informal dairy sector in Nicaragua (Polvorosa 2013, Alcaldía Municipal de Matiguás 2011). These three sub-chains make up the dairy sector in Matiguás. This paper focuses on the cooperative driven chain that reaches national and international markets through contracts with commercial dairies. Studies show that the small- and medium-scale milk producers who are part of the cooperative chain receive higher and more stable prices throughout the year, compared with other producers who sell to alternative chains (Polvorosa 2013).

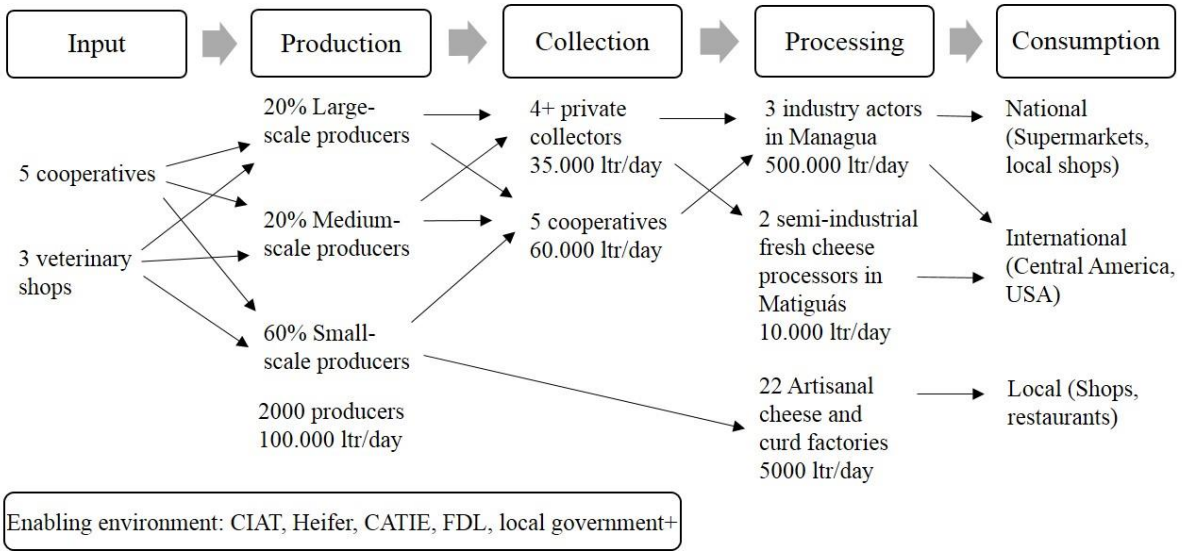

Figure 2: The Matiguás dairy value chain. Source: Modified and updated from Polvorosa 2013, Flores et al. 2011, Velásquez and Manzanarez 2014.

About seventy percent of small- and medium-scale milk producers are organized in one of the five dairy cooperatives in Matiguás (Polvorosa 2013). The cooperatives provide them with access to the formal market through the collection centers and other support services such as credit, input, and veterinary services. One of the five cooperatives is the largest dairy cooperative in Nicaragua with over 900 members. Despite the influence of cooperatives, the three industrial processors lead the chain, tightly coordinating transactions through strict food safety regulations, milk prices, and demand for milk. Consolidation in the industry has reduced the number of main players from five to three large-scale dairy processors over the last few years. As a result, the negotiation power of the cooperatives is reduced.

Milk demand is regulated through a quota system based on quantities of milk supplied across seasons. Producers are encouraged to increase production during the dry season with low production to stabilize milk supply. Milk prices are also higher during this season and offer an opportunity to increase their income. Milk is additionally classified within an A, B, C quality-system with different prices. The collection centers put the industry regulations into

practice by controlling milk quality and quantity, and receive no support from the lead firms, which control the conditions (Polvorosa 2013).

Farmers need to produce an average of 40 liters of milk per day to cover their costs of production and supply, as well as to become a member of a cooperative. Investments in more intensive and productive dairy farming practices are necessary to achieve this for some small-scale producers. Proximity to a collection route and basic infrastructure such as roads, water, and electricity are also important to access the high value dairy value chain. The smaller and less resourceful farmers face the highest restrictions to supply to collection centers, and can result in exclusion from the higher value dairy value chain. The alternative is to supply the semi-industrial collectors with fewer quality and quantity requirements, but with highly fluctuating prices, or the traditional cheese makers with limited requirements and low prices (Polvorosa 2013).

The enabling environment consists of various organizations and research institutions who provide support to cooperatives and producers to remain competitive in the increasingly commercial dairy industry in Nicaragua. Several credit institutions such as FDL, a leading microfinance institution, provides credit to farmers to meet the higher requirements when participating in the formal dairy chain. The different analyses of the dairy sector in Matiguás and the "Via láctea" by enabling environment such as the International Center for Tropical Agriculture (CIAT), Heifer International, the research and development institute Nitlapan, and the Tropical Agricultural Research and Higher Education Center (CATIE) highlight the potential of increasing the amount of milk produced, improving milk quality, and enhancing coordination among the involved actors (Polvorosa 2013, Flores et al. 2011, Velásquez and Manzanarez 2014).

The current increase in milk production is primarily due to an increase in the number of animals and the use of more land for livestock purposes. However, land availability is close to reaching its limits, thus requiring strategies for achieving milk production increases and stability. Stabilizing the volume of milk throughout the entire year and improving animal productivity are two of the biggest challenges, especially since there is little room and expensive to continue land expansion for livestock purposes. In addition, milk collection centers face underutilization of their capacities, especially during the dry season from January to mid-May (Alcaldía Municipal de Matiguás 2011). Despite several studies and plans, none have presented any justified projections of potential impacts if any or all of the identified interventions were to be implemented. This suggests a need for methodologies that can better evaluate returns to alternative intervention strategies with a specific focus on the inclusion of small- and medium-scale dairy farmers.

Methodology

Four GMB sessions were held between March and June 2015, with a follow-up exercise conducted in mid-April 2016. Key informant interviews with stakeholders were also held during this time. The sessions included project facilitators, a reference group, and the group model building participants. The facilitation team consisted of one project leader and lead modeler, one expert modeler, three group facilitators, one recorder, and one gatekeeper, which participated at different times. The reference group comprised of researchers from CIAT based in Managua, Nicaragua and Cali, Colombia that contributed with technical and local knowledge to the model and modelling process. Table 1 highlights the research design and timeline, including the number of participants and the goals of each stage of the GMB process.

Table 1: Project timeline with an overview of specific GMB activities, participants, and goals Source: Developed by the authors

Date	**Activity**	**Participants**	**Goal**
25 - 27.03.15	Scoping trip	1 Researcher 1 Research assistant 2 field facilitators 1 Gatekeeper	1. Familiarize with the study area and the various actors 2. Interview different actors in the dairy value chain in Matiguás
08.04.15	Project presentation for municipal government and key institutions	2 Presenters 1 Research assistant 1 Gatekeeper 8 participants	1. Achieve final acceptance and go ahead from gatekeeper and municipal government 2. Participant selection
13.04.15	Reference group discussion 1	2 Presenters 1 Recorder 6 participants	1. Achieve basic knowledge of SD and GMB in reference group 2. Practice run for GMB1
15.04.15	GMB 1	4 Facilitators/ Recorder 14 participants	1. Introduce the research to the GMB participants 2. Agree on the value chain goal 3. Identify and prioritize problems, and discuss their causes and consequences 4. Make reference mode(s)
28.04.15	GMB 2	3 Facilitators/ Recorder 12 participants	1. Introduce the concept and language of system dynamics modeling 2. Start building the model
06.05.15	Reference group discussion 2	2 Facilitators/ Recorder 3 participants	1. Discuss draft model and way forward
19.05.15	GMB 3	4 Facilitators/ Recorder 14 participants	1. Validate and add to the model 2. Add numbers to the model
16.05.15	Reference group discussion 3	2 Facilitators/ Recorder 6 participants	1. Discuss draft model and way forward
16.06.15	GMB 4	3 Facilitators/ Recorder 9 participants	1. Add more numbers to the model 2. Assess the GMB process so far
18.04.16	Reference group discussion 4	2 Facilitators/ Recorder 3 Participants	1. Validate SD model 2. Present and discuss preliminary findings 3. Prepare last GMB
20.04.16	GMB 5	4 Facilitators/ Recorder 14 participants	1. Validate SD model 2. Present and discuss preliminary findings 3. How to access and use the model 4. Assess the GMB process and value of SD model
23-24.04.16	Reference group discussion 5	1 facilitator 2 participants	1. Discuss and verify edited and added structures and data

The GMB participants represented each node of the value chain and those working in the enabling environment, including small- and medium-scale farmers (4 participants),

cooperatives (3), local processor (1), local government (3), and institutions (7) working on value chain interventions, such as Heifer International, CIAT, CATIE and Nitlapan. The target number of representatives from various stakeholder groups was set to fifteen, a relatively large group for GMB sessions, to include all actors in the dairy value chain. The specific participants were selected in cooperation with the gatekeeper who was a local project coordinator working in the Matiguás dairy value chain. Only 14% of the GMB participants were women, reflecting the male dominance of the livestock sector in Nicaragua (Flores et al. 2011). The male dominance complicates the selection of women, especially from institutions working with the dairy value chain in Matiguás. Our selection of participants focused on including representatives from all nodes of the value chain, including the enabling environment, and despite trying did not achieve the ideal gender balance. The number of participants in each GMB session varied, as well as the participants themselves, due to busy schedules and varying interest – a common challenge in participatory research (Cornwall and Jewkes 1995). On average, thirteen participants attended each time and each group of stakeholders was represented in every session.

Four GMB sessions were planned from the beginning to interact with participants over time, as well as to give them time to absorb the information and new ways of thinking. They were held approximately every other week and had a duration of around three hours each. An overall plan was made for the different sessions, with detailed scripts developed before each session focusing on goals, activities, and timing, although with flexibility for *ad hoc* changes. After each session, detailed summaries focusing on the process, the data collected and the decisions made were written to ensure recoverability. Each session was also evaluated among the facilitators and changes were made accordingly in the next session, following an iterative research design. A follow-up trip to Nicaragua in April 2016 focused on presenting,

validating, and discussing the model and preliminary results with the GMB participants and reference group. An assessment of the entire process was also conducted with the participants of the last session, GMB5, through plenary discussion and a short individual questionnaire. Twelve of the fourteen participants in the last GMB session answered the questionnaire.

In addition to the GMB sessions, semi-structured individual interviews were conducted with the leadership of the cooperative, a private dairy industry actor in Managua, The Nicaraguan Chamber of the Dairy Sector (Canislac), and different local credit institutions before and during the GMB process. These interviews provided background and in-depth knowledge about the various actors and processes and discussed specific aspects to be covered in the SD model.

Participatory model building of the Matiguás dairy value chain

Group model building (GMB) process

The roadmap of the GMB process is illustrated in figure 3, and highlights the progress made during each step of the process. The scoping trip and the initial meeting with the local government and key institutions provided the necessary background information and introduction to the field site to start implementing the model building process with the reference group and selected GMB participants.

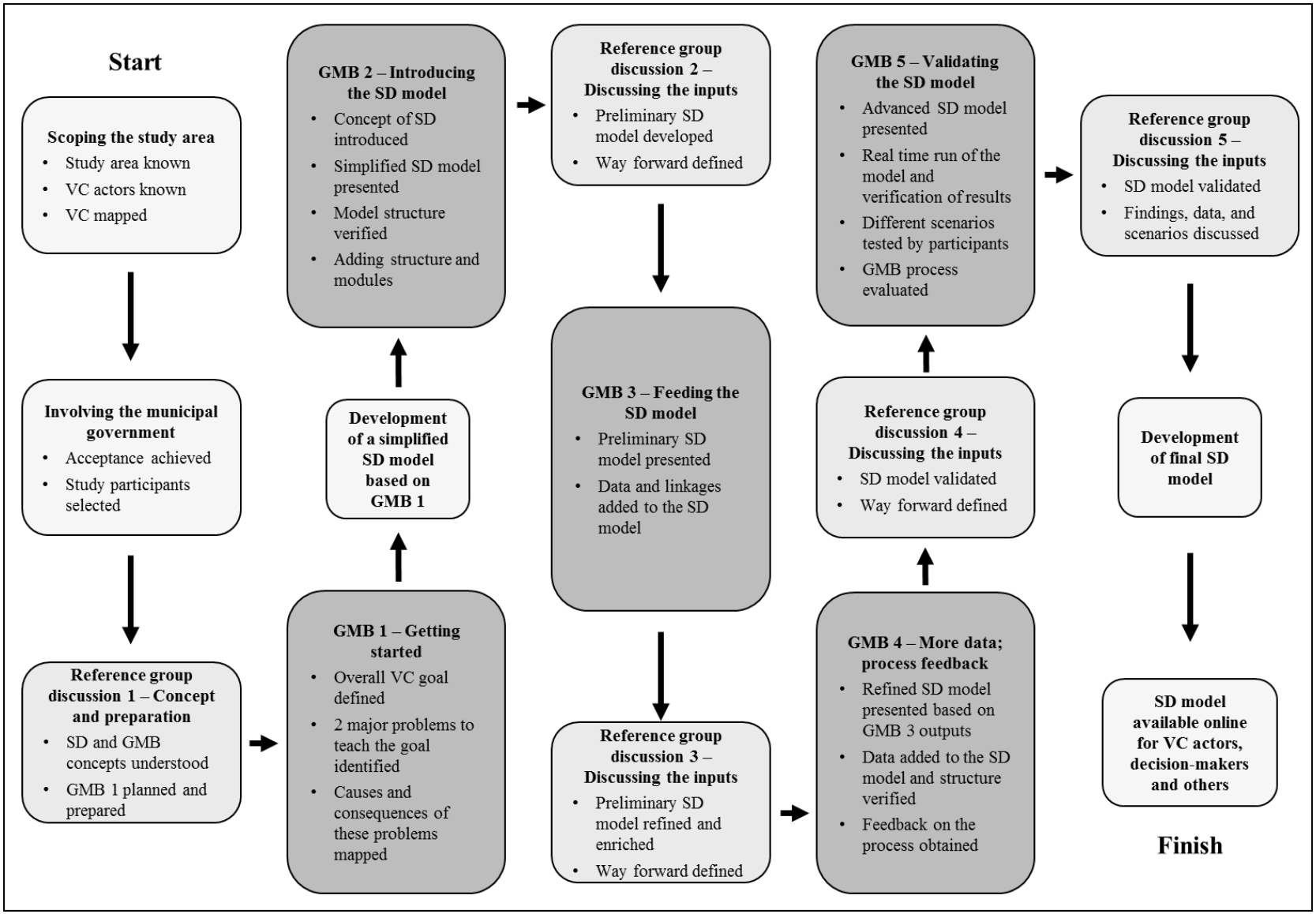

Figure 3: Overview of the progress in the GMB process. Source: Developed by the authors

The first GMB session established goals and problem variables. Plenary discussions with participants defined the goal for the Matiguás dairy value chain as: “Contribute to the national goal of increasing milk production in terms of quality and quantity, and achieve a higher income for the actors that are involved in the chain”. Agreement on a common value chain goal set the stage for focusing on the entire chain and its dynamics, and not on individual nodes. Next, fifteen problems associated with reaching the goal were identified in an individual card-writing exercise followed by a round robin sharing and discussion session. Each participant voted on the top three problems. The highest ranked problem was deficient animal feeding systems, followed by a lack of incentives to improve milk quality. The group discussed and agreed to proceed with these two problems, which encompassed several of the other problems identified. Causes and consequences for the two main problems were identified and discussed in small groups. This was followed by discussion and mapping of these causes and consequences. An example is that poor pasture and forage management and limited feed availability during the dry months are causes of deficient feed availability, leading to low cow productivity, low milk production, and low profitability among producers. The SD model therefore focused on these identified issues. The discussions and exercises gave participants an understanding into the complex nature of the Matiguás dairy value chain. The group also defined reference modes that illustrate the historical and future behavior of milk production, with and without possible interventions. Figure 4 denotes the outcomes associated with GMB1.

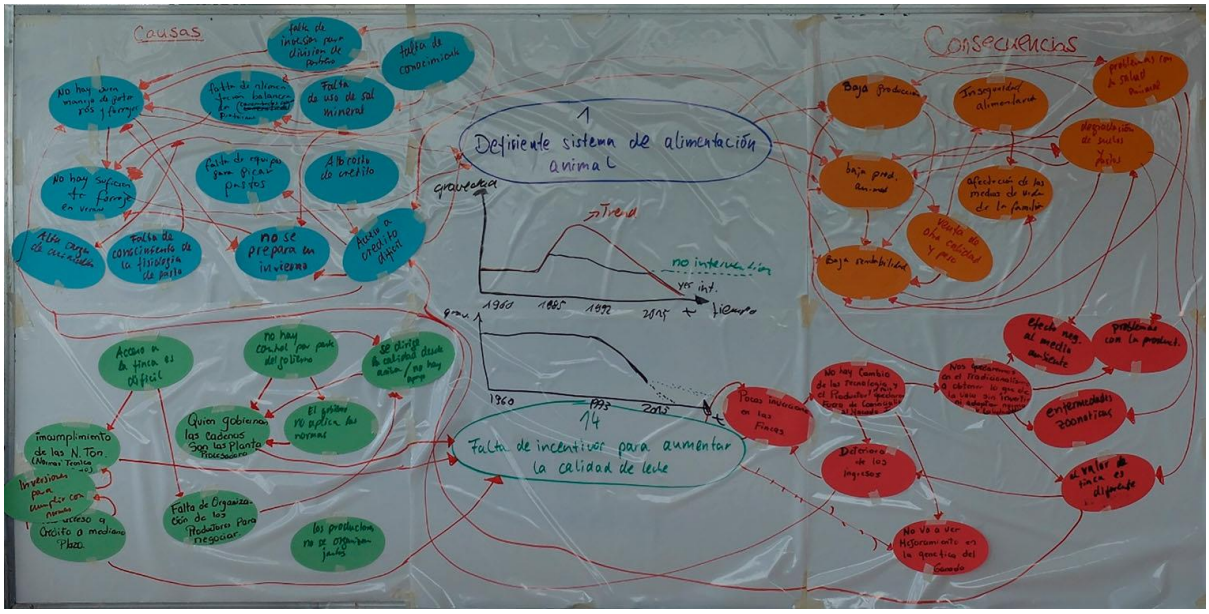

Figure 4: Outcomes generated from GMB1 Photo: CIAT staff

In the second GMB session, the concepts and language of system dynamics was introduced. A simple cow production model was introduced and explained step by step using the storytelling function in the software modelling program, iThink. (1) Storytelling provides a platform for annotating and animating specific parts of a model to ease in model explanation. Next, we ran a few model simulations to illustrate how changes and results can be presented in an SD model.

This introduction facilitated the presentation of a simple SD model structure focusing on cow and milk production that was used as a starting point for the Matiguás SD model. We had planned to verify and add to the structure in plenary, but due to unequal participation in the beginning, we split into small groups. Three groups were formed based on the focus from the previous GMB session: cow production, milk quality, and feeds. At the end of the day, the groups presented and discussed their group work in plenary, as seen in figure 5 and figure 6. These presentations revealed that each group's work overlapped due to the interrelated issues

in the value chain. GMB2 resulted in adding feeds as a separate module to the model alongside its feedbacks with milk and cow production.

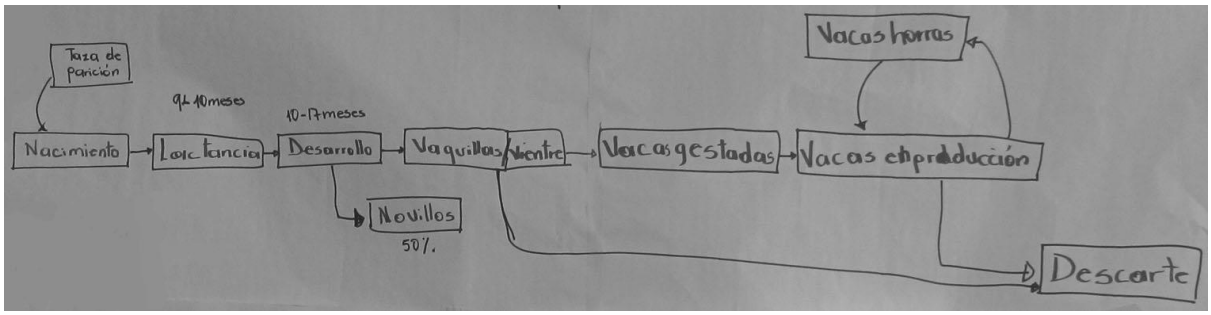

Figure 5: Herd module from group work illustrating the development of dairy cows from birth. Photo: Authors' archives

Figure 6: Presentation of the group work in plenary for discussion and consensus. Photo: Authors' archives

Based on GMB2, the model structure was further developed by the lead modeler and the reference group. For example, the identified modules from the group work were re-

formulated to follow the SD language of stocks, flows, and auxiliary variables. Additionally, a financial module was added to gather the financial data and highlights feedbacks with the other three modules. At this stage, the model remained qualitative.

GMB3 and GMB4 focused primarily on model parameterization and data collection to enable the simulation of scenarios. The structures and the relationships between the modules were also further developed. In GMB3, the current version of the model was printed on large sheets of paper to be used in group work. The group members were assigned beforehand to ensure that each group contained producers and that those with specific knowledge were put in the most relevant group. Each group added data on post-it notes and changed and added structures and linkages between the modules, as seen in figure 7.

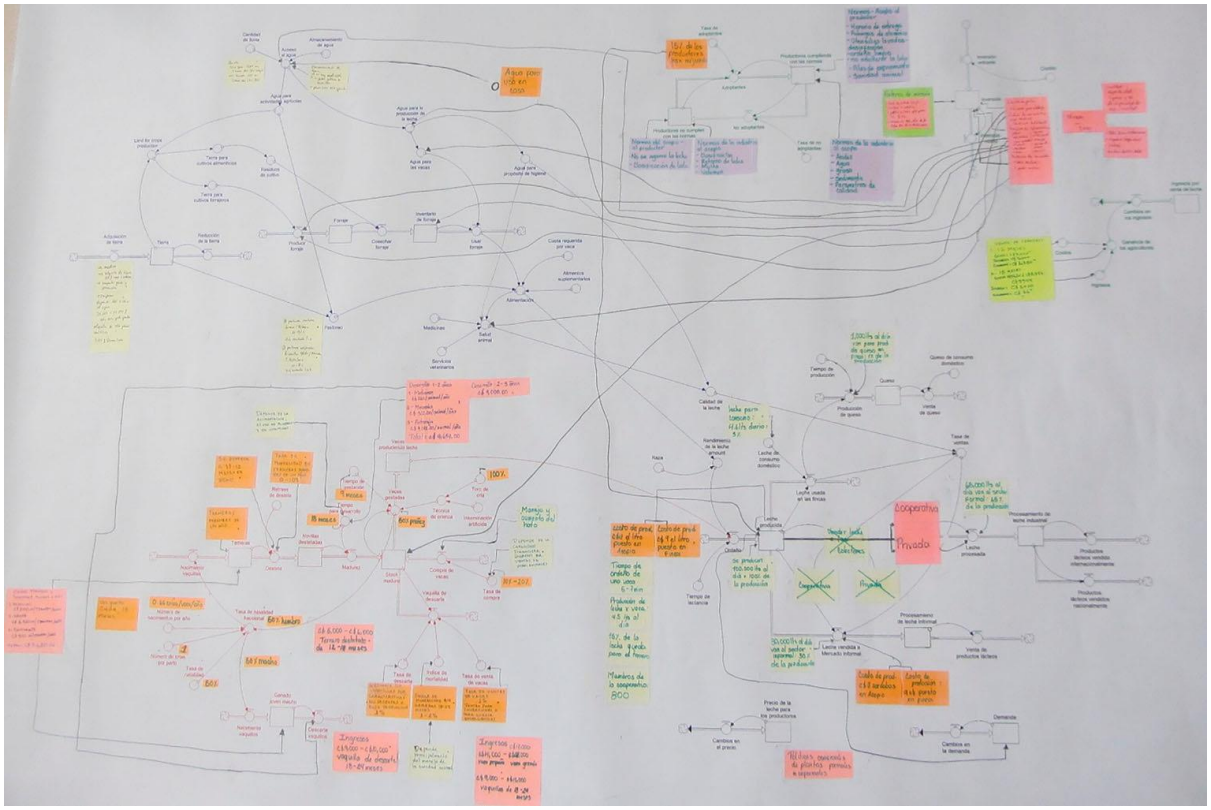

Figure 7: Printed model used in GMB3 showing the four modules with added linkages, structure, and data from group work discussions. Photo: Authors' archives

Data collected in the milk module included: (a) the total amount of milk produced by small- and medium-scale producers, (b) the quantity of milk sold to different channels such as home consumption, formal- and informal sectors, and (c) milk prices. The herd module required information on technical parameters e.g., the amount of time needed for calves to mature, the quantity of milk produced each day by a dairy cow, and the costs of cow production. The feed module focused on data associated with feed use, land use by pasture type, and feed production costs. All data focused only on small- and medium-scale producers. The data used was based on consensus among group members. The diversity and experience of session participants allowed us to efficiently collect the necessary primary data. Additional data on the number of cows and the total amount of land in Matiguás were taken from the national census as a starting point (INIDE-MAGFOR 2013). GMB4 followed GMB3 by verifying the current structure and gathering additional data in groups. Feedback on the process was also conducted in GMB4, which was initially planned to be the last session.

After GMB4, the team conducted several interviews with key stakeholders of the value chain. The lead modeler and facilitator continued to work on the model based on the large amount of data from the last two GMB sessions, and continued discussions with key members from the reference group on major model decisions. The modeling focus narrowed to assess the top identified problem, deficient feeding systems.

The last GMB session, GMB5, was organized in April 2016 with reference group meetings before and after the group session. GMB5 served to present, discuss, and validate the model and preliminary results which data and time limitations prevented during GMB4. The updated model was presented using the storytelling function in iThink. The model and baseline results were run and discussed in real time based on the baseline data collected in the

previous GMB sessions. We then ran scenarios where we changed land allocation and cow productivity. There was active discussion of the structure and results in plenary, which was followed up in two groups focusing on the different modules: herd, milk, feeds, and finance. These discussions centered on feeding systems, specifically on the use of improved pastures and concentrates, and water availability. The individual groups, different facilitators, and some participants also tested different model scenarios during the session. GMB5 added valuable information to complete the model and ensure its usefulness. The reference group continued the discussion from GMB5. They focused specifically on data and scenarios in the feeds section, which is their expertise and a topic that can be difficult for the GMB participants to provide details.

GMB process reflections

Considerable effort was put into planning and implementing each GMB session. Specific emphasis was placed on ensuring equal participation of all participants despite differences in their position in the value chain, power structures, and available knowledge. For example, two participants who could not read or write very well were given support when participants were instructed to write something down. Printed models were also always presented orally so that all could follow the more detailed discussion. Producers ended up sitting together in the back in the beginning of GMB1 and did not contribute much in the first plenary discussions. Due to the iterative research design, the GMB implementation plans changed during the process to focus more on smaller group work than plenary discussions, and this resulted in higher producer participation.

There were also strong personalities with expertise knowledge and high confidence. This put pressure on the facilitators with respect to enabling all to participate. They sometimes had to facilitate more firmly who could talk when and for how long. Only one participant, a

producer, reported that he did not feel free to express his mind. However, all participants reported that they would participate in a process like this again if they were given an opportunity.

In terms of data collection, the GMB process provided invaluable information that would otherwise have been difficult or time-consuming to obtain. National census data and project data is available, but participants commented that this data was outdated. It also did not cover all aspects included in the model. A particular challenge in value chains is to find weekly or monthly data. Annual data is too aggregated to be of use in the simulation. On the other hand, much of the information obtained in the sessions was too detailed and specific to model. Additionally, participants were not always consistent in providing information. It is therefore important to have a clear boundary for what is being modelled and not, and at what aggregated level the model is being applied.

Different native languages between the main modeler and facilitator and the participants presented challenges, but the modeler was proficient in conversational Spanish and had several facilitators supporting her, as well as a person dedicated to note-taking. Access to a recorder was crucial in capturing the details of each GMB session, the progress made, and to document the entire process to assure recoverability. System dynamics also comes with its own technical terms and way of thinking. This was introduced in GMB2, partly using the storytelling function in iThink which worked well. Despite this, the SD language was perceived as difficult to understand by the producers. We found that setting aside enough time for the GMB participants to understand system dynamics, involving modelers with experience in interactive processes, and having a team of modelers and facilitators to share

the different facilitation tasks was important to ensure participation and understanding among all, and to progress in co-creating a useful model.

GMB process results

The GMB process resulted in a conceptual model, shown in figure 8, which focuses on the essential dynamic processes of the Matiguás dairy value chain. It is a qualitative model and provides an overview of the main modules in the model (herd, milk, feeds, and finance) and how they are interrelated (see Lie and Rich 2016 for further details). This provides a good foundation for understanding and discussing the model.

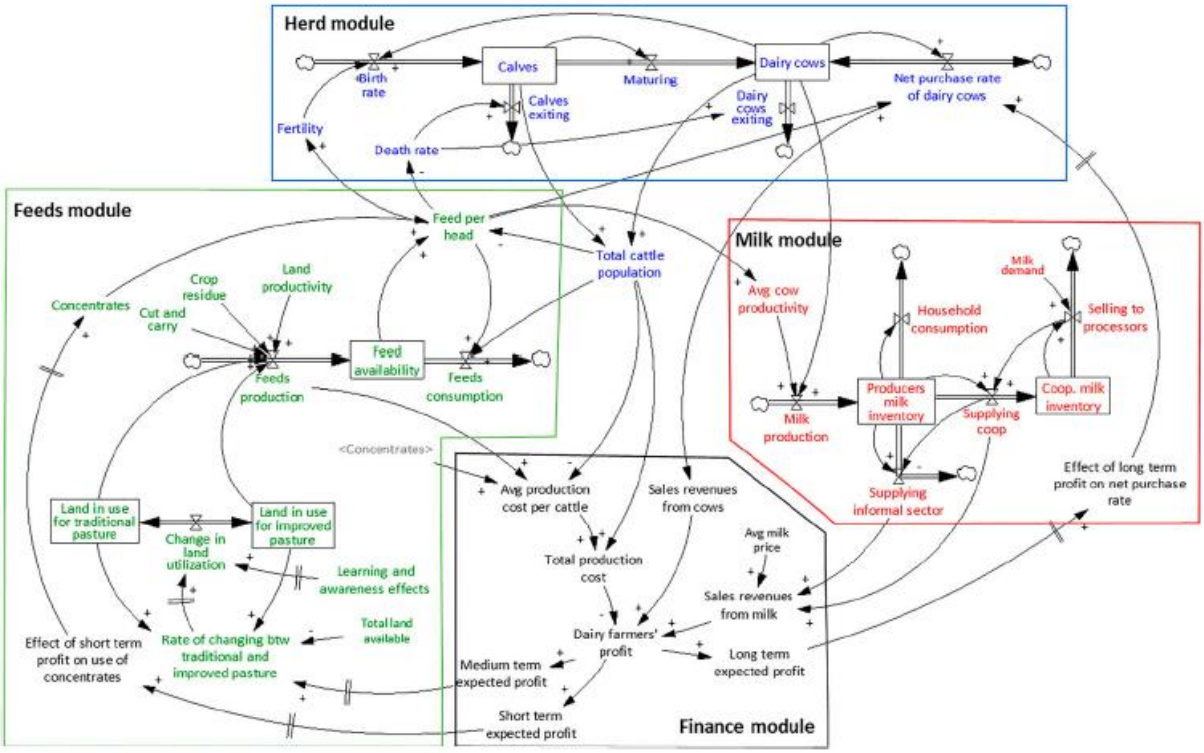

Figure 7: Conceptual system dynamics model of the Matiguás dairy value chain. Source: Modified from Lie and Rich (2016)

The primary output of the GMB process was the quantitative SD model. The model enables simulation of various scenarios over a ten-year period for the purpose of improving the small-

and medium-sized farmers' feeding systems and increasing their income. An example of a typical scenario could be assessing the changes that occur in milk production and farmer profit if more land were to be allocated to improved pasture land. Scenario testing and sensitivity analysis of model results provide valuable information to policymakers and others working with dairy value chain development in Matiguás.

All participants in the GMB process and other interested persons can access the quantitative model online through isee Exchange. (2) The model structure is presented step by step in English and Spanish using the storytelling function. Anyone can also run and compare various scenarios by changing key data in the model interface and see results in comparative graphs. This enables all users to actively interact with the model together or separately to support decision-making in value chain development.

The GMB process itself led to positive outcomes such as team learning, which is an important aspect of participatory research. The stakeholders participating in the process have strengthened their social capital by building closer ties with other actors from different nodes of the value chain. There is now a greater understanding and mutual appreciation of the roles played by different actors, the challenges they face in the value chain, and the importance of looking at the chain as an entity rather than through an individual perspective. One realization was that producers have limited understanding of the new quality-based pricing system and how the quality is determined. By improving interactions among stakeholders, our process potentially puts into motion a collective platform for them to place pressure on the industry to improve the dissemination of information about the pricing system. Small- and medium-scale producers, as well as the collection center and cooperative management, now also feel increasingly heard and know that their voice can matter in decision-making associated with

interventions in the value chain. The interaction between the researchers and different stakeholders working in and with the value chain identified large data gaps. Closer interactions and discussions of problems, causes, consequences and potential solutions, plus having interactive tools to support them all in decision-making, benefits the value chain development process.

During the final session, GMB5, the participants wrote down what they had learned in an individual questionnaire. Seventy-five percent reported that the process had helped them "much" or "very much" to better understand the complex and dynamic processes in the Matiguás dairy value chain. Ninety-two percent stated that the process helped "much" or "very much" in identifying good interventions to improve the value chain, and 92% also indicated that they think this process will impact their future work. Despite the complexities of the SD model, 92% the participants reported "well" or "very well" that they understood the model, the results, and how it can be used. Several new stakeholders were introduced by the participants themselves since they found it interesting and thought their co-workers would as well. This indicates that participants were content with the process and are committed to using the SD model to support decision-making in value chain development.

Conclusion

The presentation of the participatory model building process of the Matiguás dairy value chain and its results illustrates its utility in value chain analysis. The participatory process enabled various value chain stakeholders to develop a deeper understanding of the complex and dynamic structure of the value chain, and how they perceive it differently. It offers a good alternative to the common top-down approach of collaboration among value chain stakeholders.

Co-creating the SD model enabled the participants to understand how the system dynamics model functions and can be used, but importantly to trust the model and its projections. The participatory model building process offered a good alternative to surveys for acquiring quantitative data in a non-extractive manner. Had the model been built on survey data, it would have been quickly outdated or not able to grasp the complexities, local practices, and decision-making logic of the dairy value chain actors.

The participants now have an online quantitative modeling platform that combines biological, agricultural, financial, and market aspects. It can be used to run scenarios on interventions in the short-, medium-, and long-run, providing valuable information for decision-making in value chain development. It is also possible to further develop the model to permit testing of other interventions, such as improved breeds.

The Matiguás experience illustrates that participatory SD modelling is time- and resource consuming. It is nonetheless critical for confidence building in and acceptance of the model among policymakers and others working with value chain development. It also illustrates the importance of carefully planning an iterative research design with specific emphasis on participant selection and procedures to ensure equal participation. Based on the experience in Nicaragua, participatory model building of value chains can be a powerful tool to support policymakers and other actors working with pro-poor value chain development in developing countries.

Notes

1 Available here: http://www.iseesystems.com/softwares/STELLA-iThink.aspx

2 Available here: https://sims.iseesystems.com/helene-lie/dairy-value-chain-development-in-nicaragua

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