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Representation and dynamic implications of mental models of food systems

A case study of dynamic decision making of small-scale farmers in Zambia

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Abstract

Undernourishment is a persistent problem in sub Saharan Africa. Climate change is expected to make achieving food security even more difficult in nations such as Zambia, where agriculture is dominated by small-scale farming and rain-fed maize production. In order to evaluate current and proposed policies to enhance food security, it is important to understand the dynamic decision making processes of small-scale farmers, a major stakeholder group and the main target group of government policies in the Zambian food system. This paper analyzes qualitative text data from in-depth interviews with small-scale farmers and represents them in the form of a causal loop diagram, which serves as a visual representation of the group mental model of this stakeholder group. This causal loop diagram is then simplified and analyzed. The resulting discussion examines the implications of farmers' current dynamic decision making and its effectiveness in light of changing framework conditions. The paper concludes with a discussion of how the group mental model can be used to design policies that integrate farmers' knowledge with the knowledge required to address current and emerging food system challenges.

1. **Introduction**

Undernourishment is a persistent problem in Zambia, particularly for the rural population (FAO 2014; Neubert et al. 2011). Data from 1990 to 2014 indicates that the dietary energy supply for Zambia's population is not adequate, even if food is distributed equally (FAO 2014). Climate change, which manifests itself, among other ways, in the delayed onset of the rainy season, is anticipated to make the achievement of food security in Zambia even more challenging, as agriculture is dominated by small-scale farming and rain-fed maize production (Neubert et al. 2011).

Policies with the goal of poverty reduction such as fertilizer subsidies are targeting the agricultural productivity of small-scale farmers (Neubert et al. 2011; Chapoto 2014). Examples of studies that evaluate Zambia's agricultural policies include a paper by the German Development Institute (Neubert et al. 2011) and ongoing papers by Indaba Agricultural Policy and Research Institute (IAPRI).

Several quantitative and model-based studies of small-scale farm households have been conducted. A System Dynamics model at the farm level in Zambia emphasizes biophysical and economic factors (Grabowski 2012). Small-scale farm households in Zambia are being surveyed for quantitative data by government and research institutions (Food Security Research Project 2015). System Dynamics models at the farm level have been generated for food systems in other African nations (Bontkes & van Keulen 2003; Stephens et al. 2012). At the same time, the decision making processes of small-scale farmers are not well researched (Saldarriaga et al. 2014).

Decision making and behaviour of small-scale farmers has been addressed in some studies. Kalinda et al. (2000), in a study of resources and household decision making among small-scale farmers in Zambia, analyze quantitative data from interviews with households and categorize farms while providing some qualitative descriptions of decisions and social structures. Chilonda and Van Huylenbroeck (2001) provide a conceptual framework for the analysis of factors influencing decision making of small-scale farmers in animal health management. Their framework includes an agricultural household model and a separate qualitative choice model, and they stress that more empirical research is needed to improve understanding of decision-making and behaviour of small-scale farmers in order to guide policy decisions (Chilonda & Van Huylenbroeck 2001).

As part of a project that uses simulation models and associated learning tools to contribute to the achievement of food security in Zambia, a study of the dynamic decision making of small-scale farmers was initiated by conducting and analyzing interviews with farm households (Saldarriaga et al. 2014). The objective of this paper is to build on the study of dynamic decision making by applying an explicit System Dynamics frame to the interviews.

While focus groups and interviews with small-scale farmers are listed as data sources for other model-based studies to address food security in light of climate change in Zambia (Crawford & Olson 2012), no previous studies use the systematic and inductive qualitative data analysis method outlined in this paper to generate a mental model of the food system in Zambia (Kim & Andersen 2012). The mental model takes the form of a rich causal map that links factors influencing small-scale farmers' decisions to other causal structures in the map.

Understanding the dynamic decision making of small-scale farmers is important for the evaluation and design of policies to enhance food security, as small-scale farmers represent a key group of decision-makers in the food system (Neubert et al. 2011; Saldarriaga et al. 2014). The generation and analysis of the mental model or causal map presented in this paper is intended to address the following research questions: How do small-scale farmers view the food system? What are some of the drivers of decisions made by small-scale farmers? What are the dynamic implications of the mental model of the small-scale farmers? What are some factors to consider when designing policies targeting small-scale farmers? What are the benefits and drawbacks of the approach of representing the mental model of the farmers?

The paper begins with further explanation of food security and agriculture in Zambia, as well as a discussion of the framework for the study. Then the method to translate interview data into a causal map is outlined. The resulting causal map is presented in stages and analyzed with a discussion of its major themes and dynamic implications. The results of additional interview data collected in Zambia are discussed as part of a validation process. Current and proposed policies to enhance food security are evaluated in the context of the causal map. The paper proceeds with a discussion of how the group mental model can be used to design policies that integrate farmers' knowledge with the knowledge required to address food system challenges. Finally, further research into the quantitative modelling of farmers' decision rules is proposed to build confidence in the quantitative testing of policies.

2. Background and Theory

2.1 Indicators of Food Security in Zambia

One of the indicators of food availability, a dimension of food security, is Average Dietary Supply Adequacy, which expresses the supply of dietary energy in the nation as a percentage of the average dietary energy requirement (FAO, IFAD & WFP 2013; FAO 2014). Since the 1990s, Zambia's dietary energy supply adequacy has been consistently below 100%, meaning the supply is not enough to meet the dietary energy requirement of the population (FAO 2014). Food availability is the focus of this study, and the causal map in this paper addresses food production by farmers.

Food insecurity in Zambia is not only a problem of supply, but also a problem of access (FAO 2014). Undernourishment has been prevalent in over 30% of the population since the 1990s, actually growing to over 50% around 2010 (FAO 2014). The causal map produced in this paper contains causal links that show different pathways used by households to access food.

2.2 Small-scale Farming and Maize Dominance in Agriculture

Maize is the staple food and dominant crop in Zambia (Sitko et al. 2011; Ministry of Agriculture and Livestock 2013). Small-scale farmers cultivate between 0.1 and 5 hectares of land, while emergent farmers cultivate between 5 and 10 hectares of land, and together these represent approximately 98% of farmers in Zambia (Neubert et al. 2011).

Neubert et al. (2011) focus their study of agricultural development in Zambia on small-scale and emergent farmers because they represent the majority of farms and produce the majority of staple food for the country. They also represent the most vulnerable group of people in Zambia (Neubert et al. 2011). Rural poverty is 83% versus 73% for the total population (Neubert et al. 2011).

2.3 Food Systems and Scale

The framework outlined by Ericksen (2008) serves as a guide for the concept of a food system in this paper. In Ericksen's framework (2008), food system activities (ranging from production to consumption) are linked with environmental and socioeconomic drivers and food system outcomes (including food security), and feedback exists between activities, drivers and outcomes.

Ericksen's discussion of cross-scale interactions in the food system is of interest to this study (2008). Cross-scale interactions drive this research, as it is a goal to better understand the effect of national level policies on household decision making and behaviour, which aggregates to national level data.

2.4 Previous Research on Local Decision Making and Behaviour

In 2013, Saldarriaga et al. (2014) interviewed 19 small-scale farmers in four different regions in Zambia. The farmers were asked questions about the last farming season and the upcoming farming season, including questions about: farming activities, crops grown, income sources, foods consumed, household food security and rainfall signs (Saldarriaga et al. 2014). The interviews also covered long term rainfall predictions and household coping strategies (Saldarriaga et al. 2014).

Small-scale farmers represent a key stakeholder group in the Zambian food system. With agriculture as their livelihood, they possess a sophisticated knowledge of their environment (Saldarriaga et al. 2014). Their daily decisions affect food production, processing, distribution and consumption, activities in Ericksen's (2008) food system framework that influence food system outcomes.

Saldarriaga et al. (2014) find in their study that the farmers understand the dynamic complexity of the food system, but at the same time they are restricted by income available from purchasing all food that is required to achieve the food system outcomes in Ericksen's framework (2008).

2.5 Causal Mapping in Food Systems

Causal maps or causal loop diagrams are tools used in the System Dynamics field to communicate and analyze the structure and dynamics of systems. "System dynamics integrates both positivistic and interpretive paradigms in social science […]. It recognizes the existence of objective reality, but it also recognizes that actions intended to change the reality are generated by actors, each of whom owns subjective perception of the reality (often referred to as "mental models")" (Kim & Andersen 2012, p. 315; Lane 2001). A definition of a mental model of a dynamic system used in System Dynamics literature is: a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure is analogous to the perceived structure of the system (Doyle & Ford 1999).

The causal mapping approach in this paper reflects the integration of positivistic and interpretive paradigms, in that causal structures are first generated from statements in interviews with farmers, and then categorized and linked by the modeller to form a group mental model of the food system based on assumptions about how these variables or structures are related (when the categories or relationships are not explicit in the interviews). The process of representing mental models in the form of a causal map also requires interpretation of data by the modeller (Kim & Andersen 2012).

3. Method

The approach used in this paper to generate the small-scale farmers' group mental model of the food system is based on a method described by Kim and Andersen (2012) as a systematic way to code qualitative text data to generate causal maps for system dynamics modelling. This chapter describes the main characteristics and steps of this method and explains how it is applied to the analysis of dynamic decision making by small-scale farmers in Zambia.

3.1 Method Characteristics

3.1.1 Grounded Theory and Traceability

Kim and Andersen's (2012) method is influenced by grounded theory, which is an inductive, rigorous and flexible method used to build theory from raw qualitative data. Grounded theory involves interpreting qualitative data through coding, the process in which labels are attached to segments of data to depict what each segment is about (Charmaz 2006). The coder's mental model will influence the product of this analysis in any stage that requires interpretation (Kim & Andersen 2012). Kim and Andersen explain that the influence can be minimized by making the method systematic, meaning that the process is defined in advance of the analysis and then followed and documented step by step (2012).

Kim and Andersen's (2012) method requires specific documentation of the coding process in order to link qualitative data to the causal structures in the model generated from interpretation of the data, with the objective of building confidence in the causal map. As one of the objectives of this paper is to inform policy design and evaluation, it is important to have confidence in the model generated. Kim and Andersen's (2012) documentation steps have been modified for the method used in this paper while the objective remains the same.

3.1.2 Open Coding

Kim and Andersen use the traditional grounded theory process of open coding in a formal way to define the problem, set the system boundary, and identify key variables (2012). In this paper, open coding is performed, but the system boundary, key variables and problem definition are in a large part controlled by the semi-structured interview format of the data analyzed.

Hybrid System Dynamics and Grounded Theory Coding

Kim and Andersen (2012) describe a second phase of open coding, in which data are micro-analyzed to identify causal structures revealed in the data. The unit of analysis is an argument made about the system's structure or a system behaviour that is believed to be true by the speaker (Kim & Andersen 2012). In this paper, a method is written based on Kim and Andersen's (2012) description, with some modifications, to cover this phase of open coding, which generates variables and relationships between them (see Appendix A).

In the qualitative text data analyzed in this paper, the variable names and relationships that result from the analysis are often deeply buried in the text, meaning they would not likely be coded during a surface level analysis. However, because of this hybrid System Dynamics and Grounded Theory coding method, where interviewee's statements are translated into variables that increase or decrease numerically when influenced by other variables that increase or decrease numerically, these causal structures are uncovered. Grounded theorists have mixed opinions about imposing such a frame on the data, as it has the potential to produce theories that are not actually grounded in the text (Charmaz 2006). Regardless, it is a valuable exercise to perform this type of coding, as the results can be validated by the farmers with further data collection (Kim & Andersen 2012).

3.1.3 Axial Coding

Kim and Andersen (2012) use the grounded theory concept of axial coding to merge variables and relationships, as the coding process in the previous stage of analysis breaks the data down into a large number of variables and relationships. Kim and Andersen (2012) create separate "word and arrow diagrams" from the codes and start grouping codes before merging the generalized "word and arrow diagrams" in a causal map. Kim and Andersen (2012) merge their variables based on generalizations and idiosyncratic language usage, sometimes adding implicit and intermediate variables to enable the merging of structures.

In this paper, the codes generated during open coding are mapped in Vensim, one by one, with documentation of the source, at the original level of detail before axial coding occurs. Duplicate variables and relationships are not created in Vensim, but the documentation section of the variables note that the causal structure is found in the data more than once. This approach is chosen because of the high level of detail and richness of the data used for causal mapping. In a desire to stay as close as possible to the data, the codes are preserved in detail until it is certain that the codes can be generalized.

The main technique used in axial coding of the detailed causal map is to examine variables that could be grouped into one category to see if they are contained in similar causal structures. If they are, the structures can be merged together with notes in the documentation section of the merged causal structure and notes in a text file to document the process.

Some variables (usually those that do not influence other causal structures) are deleted in the abstraction process, and the documentation section of each deleted variable is examined to ensure that it is not a variable identified by the majority of the interviewees. If it is, then the variable is too important to remove. Again, the abstraction process, including variable deletion, is documented.

Other important techniques used in the simplification process include examining variables to see if they are representing the same concept with slightly different names, or if they are the inverse of each other. In both cases, the variables can be merged with care to preserve the original intent of the coding, including causal relationships with other variables. In some cases, variables do not represent the same concept but are (by interpretation of the coder) linked in a logical way, either by use language or obvious physical relationships. In these cases, arrows are drawn in red in Vensim to demonstrate that the coder is the one linking the variables. Finally, there are cases where a causal link needs to travel through intermediate variables in order to be merged with other causal structures, requiring a high level of interpretation and documentation by the coder.

3.2 Data and Case Study

Kim and Andersen's (2012) method is designed to analyze purposive text data, which: (1) arise from an honest discussion involving key stakeholders or decision-makers in the system and (2) capture a discussion focussed on the system and the problem under study. The modeller requires assurance that the mental models of the decision-makers or stakeholders are revealed in the discussion (Kim & Andersen 2012). The modeller also needs assurance that people with expert knowledge of the system are providing relevant material for the causal map. Purposive text data is not limited to group discussions, and can include individual interviews with stakeholders (Kim & Andersen 2012).

The qualitative text data source used to produce the group mental model or causal map in this paper is the transcription of in-depth interviews with small-scale farmers conducted by Saldarriaga et al. (2014) (described in Section 2.4). This data source fits the definition of purposive text data very well. As previously explained, the farmers are key decision-makers in the food system. The nature of the questions asked by the interviewers force the interview discussion to be focused on the problem at hand, food security (Saldarriaga et al. 2014). Interviewees were asked to discuss past and future activities and to explain "why", so the discussion was causally and dynamically rich. Finally, it is unlikely that the discussion in the interviews was dishonest. One of the interviewers has intimate knowledge of small-scale farming and local languages in Zambia, and some data that appears in the interviews could be observed visually at the farms (Saldarriaga et al. 2014).

Other sources of qualitative text data are used for validation processes for this paper. Data is provided by group model building sessions and follow up interviews with farmers who participated in the sessions (Hager et al. 2015). The grounded theory concept of theoretical sampling is used to design group interview questions to complement the in-depth interview data analyzed by open and axial coding (Charmaz 2006; Appendix B). Group interview questions are also designed to perform a boundary test for the group mental model (Appendix B). The qualitative data sources used in validation processes similarly satisfy the requirements of purposive text data.

All interviews and group sessions were conducted partially in the local languages and partially in English. The local language portions were translated to provide full transcriptions in English (Saldarriaga et al. 2014; Hager et al. 2015).

3.3 Application of Method to Case Study

3.3.1 Method Outline

Table 1 contains a summary of the application of the method described in this Chapter to the case study of dynamic decision making of farmers in Zambia. A detailed description of the steps followed during open and axial coding is found in Appendix A. A detailed description of interview questions designed is found in Appendix B.

Table 1 - **Summary of processes, inputs and outputs of the method used in this paper**

Process Description	**Input**	**Output**
Traditional open coding for grounded theory	In-depth individual interviews with farmers (Saldarriaga et al. 2014)	Grounded theory codes; Assessment of problem definition, system boundary, key variables
Hybrid grounded theory and System Dynamics open coding	In-depth individual interviews with farmers (Saldarriaga et al. 2014)	In Excel: Causal structures (variables and causal relationships) at high level of detail; Coded variables with data and behaviour; Potential categories of variables;
Mapping of detailed codes in Vensim with documentation	In Excel: Causal structures at high level of detail; Potential categories of variables;	In Vensim: Raw detailed causal loop diagram; Venn diagram of potential variable categories
Identification of theoretical gaps	Raw detailed causal loop diagram	Areas of the raw detailed causal loop diagram that are red, blue or "empty"

Design of further interview questions	Areas of the raw detailed causal loop diagram that are red, blue or "empty"	Further interview questions (for theoretical sampling and validation)
Data collection in Zambia	Highly simplified version of causal loop diagram presented to farmers for group model building (Hager et al. 2015); Further interview questions;	Transcribed follow up interviews with group model building participants (Hager et al. 2015); Transcribed group interview results; Confidence in axial coding;
Axial coding	Raw detailed causal loop diagram; Venn diagram of potential variable categories	Intermediate causal loop diagram; Documentation of axial coding process;
Simplification of causal loop diagram	Intermediate causal loop diagram	Simplified causal loop diagram highlighting feedback loops and major variables
Surface level hybrid grounded theory and System Dynamics open coding	Transcribed follow up interviews with group model building participants (Hager et al. 2015); Transcribed group interview results;	Diagrams of causal structures identified in text; Validation of causal loop diagrams (raw, intermediate and simplified) representing farmers' group mental model;

3.3.2.1 Validation: Group Model Building Exercise

In February 2015, group model building sessions with small-scale farmers were designed and conducted by Hager et al. (2015) based on key variables and relationships identified in a preliminary causal loop diagram produced for this paper. Farmers were presented with visual representations of aggregated variables such as "water", "land", "food produced" and "livestock", and they discussed factors affecting different variables with explanations about how they are related to other variables in the diagram (Hager et al. 2015).

Follow up interviews were conducted with a subset of individuals who participated in the group model building sessions (Hager et al. 2015). Interviewees were asked to identify variables, relationships and policy options from the group sessions among other questions (Hager et al. 2015). Causal relationships and policy options identified based on a surface analysis of the follow up interview text validate a subset of causal structures in the simplified mental model of the farmers and provide information about policies suggested by the farmers.

3.3.2.2 Validation: Boundary Test

In order to build confidence that all major variables in the farmers' mental model of the food system are included in the causal loop diagram, a group of farmers was asked in February 2015 to generate a list of positive and negative contributors to food security and to describe how each factor contributes (Appendix B). The analysis of the results (presented in Appendix C) serves as a boundary test in the validation process of the group mental model.

3.3.2.3 Theoretical Sampling and Validation: Group Interviews

Interviews with two groups of small-scale farmers (not previously interviewed) were designed and conducted by Kopainsky, Nyanga and Spicer in February 2015 to supplement the qualitative text data from Saldarriaga et al.'s (2014) interviews. Appendix B contains a complete description of the interview questions, while results of the interviews are presented in Appendix C.

Farmers were asked for a list of their income sources in Saldarriaga et al.'s (2014) interviews, and they frequently mentioned having goals to purchase items, often for the household and for farming. In order to find out more about what kind of expenditures affect income available, a group of farmers was asked to generate a list of their expenditures throughout the year. Farmers were also prompted to discuss the savings process. Additionally, two groups of farmers were asked questions about decision making regarding land and input allocation.

4. Results and Discussion

4.1 Raw Detailed Causal Loop Diagram

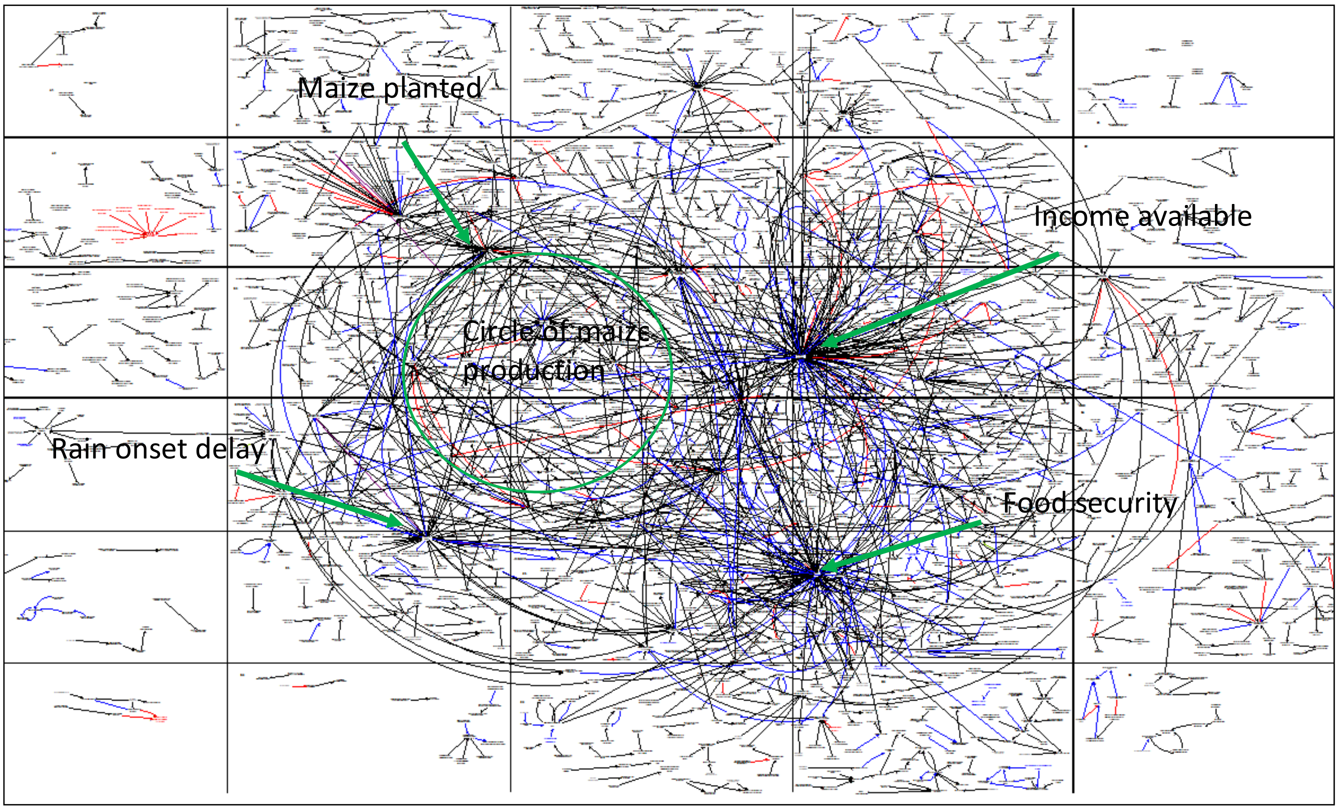

Figure 1 - Raw detailed causal loop diagram produced by open coding of in-depth interviews

In Figure 1, raw open codes from qualitative analysis of the farmer interviews, consisting of variables and causal relationships between them, are represented in Vensim. This diagram contains 1,956 variables, some of which are very similar to other variables but have not yet been merged by axial coding. The majority of variables are at the household level because farmers are asked about their own activities in the in-depth interviews, but several farmers mention regional agricultural and economic activities and outcomes as factors influencing household decision making and outcomes. Problems on the national and international scale are alluded to in several instances.

Many variables in the diagram represent concrete and measurable concepts, such as “livestock”, “maize planted”, and “area under ripping”. The diagram also contains many soft variables. Examples include “strength of tradition”, “fear of wasted inputs”, “preference for groundnuts” and “desire to plant maize”. The existence of a variable in a diagram does not mean that the farmer would describe the concept with the same name. For example “willingness to slaughter livestock” is not a phrase that appears in the interviews, but in order to translate into a System Dynamics framework, the farmers’ descriptions of their decision making must be micro-analyzed and broken into pieces that positively or negatively influence other pieces. Nor does the existence of a variable imply that a farmer knows the measurement of a variable precisely.

Colour coding of arrows and variable names corresponds to how explicitly the causal relationships are represented in the farmer interviews. Black is for explicit variables and relationships, blue is for implicit variables and relationships, and red is for assumptions made by the coder. The arrows are almost always assigned a + or - sign to indicate whether an increase (or decrease) in one variable causes an increase (or decrease) in the other variable [+, causal positive relationship], or whether an increase (or decrease) in one variable causes a decrease (or increase) in the other variable [-, causal negative relationship]. Many blue or implicit arrows exist because the language used by the interviewee implies that this relationship is known to the interviewee even though the relationship is not described explicitly. For example, the phrase "we buy meat when we have money" provides an explicit causal relationship between "income available" and "meat purchased", but it does not provide an explicit causal relationship between "meat purchased" and "income available", while the use of the word "buy" implies that the money is used with the purchase, which decreases "income available". The diagram represents all relationships between variables and does not differentiate between causal and correlational relationships identified or implied by the farmers. The existence of a relationship between variables does not imply that precise calculations are made by the farmer of one variable's influence on the other at any specific time. Farmers may only use specific portions of the mental model when making a given decision at a given time.

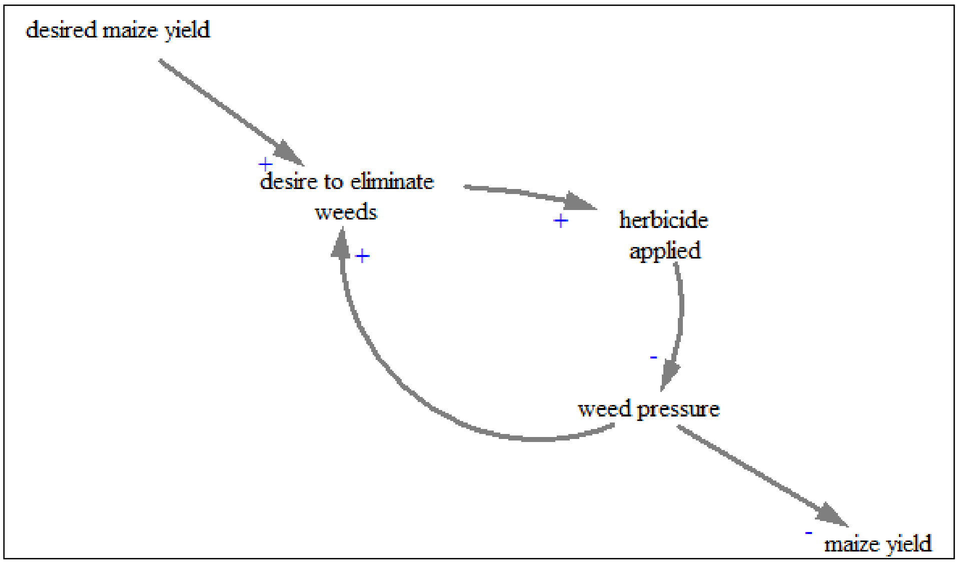

Figure 2 - Example of a goal-gap structure created from causal arguments in the in-depth interviews

Partial or full goal-gap structures emerge when farmers describe the reasons why they do certain activities. For example, with respect to the relationship between weeds, herbicide and maize yield, a goal-gap structure emerges from the interview text and is simplified in Figure 2 for communication purposes. The interviewees provide a reason for why herbicide is applied to maize (which is to increase maize yield by eliminating weeds). The effect of the herbicide application is also represented with a causal explanation from one of the interviews.

4.2 Intermediate Causal Loop Diagram

In the intermediate causal loop diagram in Figure 3, axial coding of the raw detailed causal loop diagram (from Figure 1) has occurred, and many variables and relationships have been merged together. All causal structures involving variables belonging to a category are merged together to create a general causal structure for the category, and the links between one category and other parts of the system become more evident when the variables are grouped together.

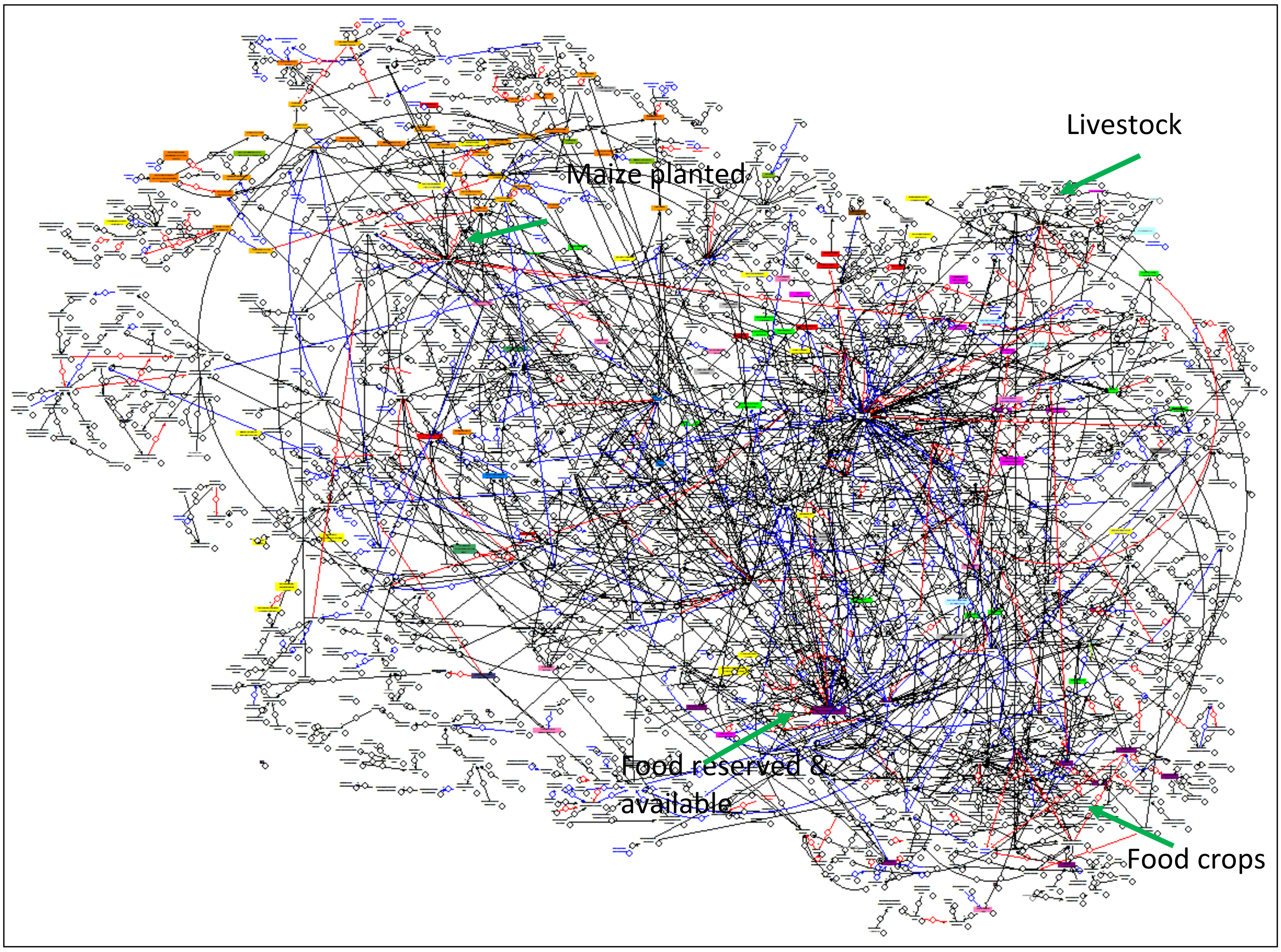

Figure 3 - Intermediate causal loop diagram produced by axial coding of raw detailed CLD

Major Categories of Variables include:
Livestock: chicken, goats, cattle/cows, puppies, doves, pigs
Food Crops: grown for consumption and possible sale, including sweet potatoes, cowpeas, soya beans, okra, beans, sunflower, sugar cane (not including maize and garden vegetables)
Garden Vegetables: cabbage, rape, tomato, onions
Fruits: bananas, water melons, mangoes
Cash Crops: crops grown for sale, not consumption, including tobacco and cotton
Inputs: herbicides, fertilizer, lime, pesticide, but not seed in this analysis
Farm Equipment: plow, spare parts, tractor, ripper, cultivator, hoe, ox-cart
Off-farm Labour Products: includes river sand ferrying, block making, grass cutting, firewood selling
Re-selling Business: includes group business, wife's reselling stand, vegetables resold
Wild Food: includes wild okra, wild roots, wild spinach

While the intermediate diagram in Figure 3 is still too complicated to read, input and output trees can be created by Vensim to examine the causes and uses of each variable in the system. To assist with axial coding and identification of categories and themes, colour coding is used.

The axial coding process results in a reduction in the number of variables in the causal map and identification of themes in the data. Themes identified in this analysis include:

(A) Scarcity

Several variables and structures coded in the analysis indicate that small-scale farmers are operating from a position of scarcity. The desire to do advance purchase of inputs is mentioned as a result of fear of running out of money later. Keeping money in the bank is viewed as a way to reduce your savings. Strategies to sell assets (including maize reserve and livestock) for cash are in place, and food insecure farmers offer their labour to receive food in kind or cash. Those who are more food secure have strategies in place to reserve extra maize to give to extended family and visitors who are food insecure. Required household purchases and school fees use household resources. The implications are that the income available variable is never very high.

Access to loans, inputs, equipment and irrigation are mentioned as major challenges for farmers. At the same time, failure to repay loans has reduced individual access to loans, and the interest paid on loans reduces a farmers' willingness to enter a loan agreement.

One interviewee mentions the ability of one seed variety to yield without fertilizer applied and other interviewees mention the fertilizer requirements of a seed as a reason not to use it, which further builds the case for scarcity.

(B) Waste and Risk Aversion

Several variables convey the idea that farmers will become unwilling to plant when rain onset delay is evident, for fear of wasting their resources on weather conditions that will not yield. Influences on the effectiveness of inputs (including the need to replant seed) are described in different interviews, implying that farmers take wasting their inputs on bad conditions seriously. Herbicide is mentioned in one interview as a financially risky item, and in many interviews its effectiveness and danger are evaluated.

A large number of codes and complex causal structures influence the planting date of crops and seed variety selected, especially for maize. Farmers spend time waiting for the rains to start and evaluate the probability that it will rain soon based on signs, historical dates and forecasts. Rain onset delay causes a great deal of worrying about the planting date, for fear that crops will not be able to mature if the rainy season is too short. Choosing the appropriate variety of seed becomes very important. Early maturity seed is treated as a way to increase food security, but other interviewees mention that late maturity seed has a higher yield. Farmers exchange late for early maturity seed when rain onset delay is evident. Farmers have access to their local seed variety no matter what their financial position, and since they prefer the food from the local variety seed, they tend to plant at least a small portion of local maize.

Another area where farmers avoid risk is in choosing crops to grow for sale. For cash crops and maize, the farmers list the perceived number of buyers for a crop as a reason to grow the crop. Cotton price and groundnut price fluctuations are mentioned as disturbances of plans. One farmer even describes an obvious shift in loans and market structure from cotton to maize, leading him to stop growing cotton.

(C) Strength of Tradition

Traditional values, including the village structure with the headman in charge, have a strong influence on the system. Strength of tradition is explicitly listed as a reason to increase family size by adopting orphans from extended family (thus reducing the number of street kids). Tradition also dictates that you give food to those who are food insecure (especially extended family) and give bags of maize for funerals and occasions.

Extended family traditionally can help with farming activities such as manure application. Strength of tradition also leads to resistance to change farming methods. One interviewee explicitly states that he was resistant to change because he believed in following the traditional ways. This same interviewee also mentions that a new farming method increases yield.

The traditional village structure dictates how land is used within the village. One interviewee provides a rich description of the allocation of land by the headman to farmers, based on his desire to increase his prestige by increasing production in his village. One farmer states that he does not garden because he has not been granted permission by the headman.

(D) Knowledge and Learning (education level, training, new methods)

Knowledge and learning is a major theme in the interviews. Knowledge appears in many places in the diagram, and frequently where it comes to influences on adoption of certain farming methods. Knowledge of preservation methods for food and how to prepare certain foods for consumption influences how much of that food is prepared or grown for consumption.

A desire for knowledge drives farmers to attending training sessions, and knowledge of coping strategies influences the adoption of coping strategies. Considerable amount of household resources are dedicated to paying school fees so that children can attend school. Education level is linked to employment and income, as well as ability to provide resources or knowledge for coping strategies and success of development activities.

(E) Hearing, Experience, Observation and Satisfaction

Frequently when it comes to knowledge of the benefits of a method or seed variety, the interviewee mentions the desire to try the method and observe the benefits firsthand (when the benefits come second hand from radio, training sessions or neighbours).

When the farmer has tried something, he or she can experience satisfaction with the benefits. In addition, satisfaction with current activities drives a willingness to try a new method. If the farmer is satisfied with current results, he or she has no reason to change methods or try something new.

4.3 Simplified Causal Loop Diagram

The intermediate causal loop diagram in Figure 3 is further simplified by examining the structure for feedback loops and major variables or themes to produce the causal loop diagram in Figure 4. The purpose of presenting the simplified diagram in Figure 4 is to illuminate key causal loops to facilitate an analysis of the dynamic implications of the mental model of the food system. What is represented in Figure 4 is embedded in a rich context represented by the more detailed causal loop diagrams. A large number of connections between variables have been eliminated in Figure 4.

While the interviewees may not think of the system in loops or variable names as they are represented in this diagram, evidence can be found in the interviews for each causal relationship presented in Figure 4. The raw codes, assumed to originate from the mental model of the farmers at a given time, can be analyzed, categorized and represented in many different ways by the coder to produce different simplified causal maps, which is consistent with grounded theory (Charmaz 2006).

Colour Scheme for Links in Figure 4 and Figure 5

Green: links involved in three categories of income generating coping strategies (livestock sales, investment in business, and piecework) which are driven by the need to purchase food
Red: links involved in investment in farming and "farming as a business"

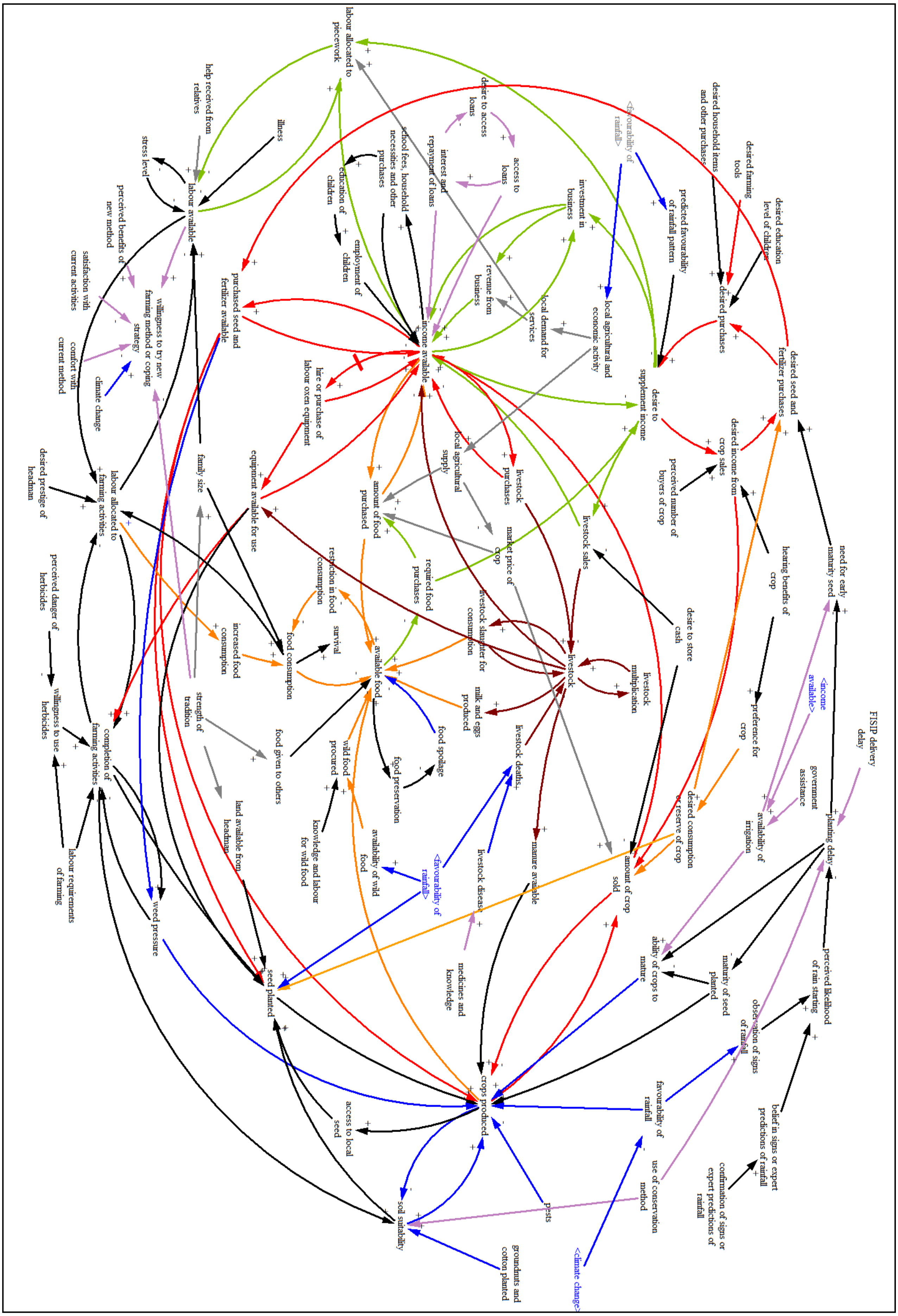

Figure 4 - Simplified causal loop diagram highlighting loops and influencing variables in the intermediate CLD

Blue: links from natural factors (such as rainfall, soil, pests, spoilage, weeds)
Brown: links involving livestock
Orange: links involving food and food consumption
Purple: links involving current or proposed policies (government support for inputs (FISP), irrigation, new farming methods)
Grey: regional and community links
Black: all other links

Critical Variables in Figure 4:
"Income available" is a central variable. It influences everything from "crops produced" to "available food" to education to adoption of income generating strategies. It is similarly influenced by "crops produced", "available food", education and adoption of income generating strategies.

"Livestock" is also a central variable. "Livestock" contributes to "available food" and "crops produced", and it is also available to sell as an income generating strategy. When income is available, livestock is purchased as an investment strategy. Oxen, a type of livestock, influence the "equipment available for use" variable, which influences "crops produced".

"Crops produced" is another central variable because it influences "income available" and "food available" and is influenced by many natural factors and human decision-making factors.

"Favourability of rainfall" is an exogenous variable in this diagram, but it influences many aspects of the mental model. "Availability of irrigation" relieves some of the influence this variable has on the system.

Key Loops in Figure 4:
One of the more prominent loops is the "inputs / crop production loop" ("income available" → "purchased seed and fertilizer available" → "crops produced" → "income available"). A similar loop is the "capital / crop production loop" ("income available" → "equipment available for use" → "completion of farming activities" → "crop produced" → "income available").

The three income generating strategies in green ("investment in business", "piecework", and "livestock sales") represent loops that could produce unanticipated consequences. Depending on how "labour allocated to piecework" affects "completion of farming activities", the "piecework" loop could have net negative consequences for "income available". Depending on local economic activity, the "investment in business" loop could have net negative consequences for "income available". And depending on the effect of lower "livestock" on "available food" and "manure available" for crop production, "livestock sales" could also have a net negative effect on "income available".

The "desire to supplement income → desired seed and fertilizer purchases → income → desire to supplement income" loop can actually erode income if there is no return on investment in the form of crops produced due to natural or human factors.

Figure 5 is the result of removing some variables from Figure 4 and reorganizing the remaining loops in a clockwise direction. Below is a listing of some of the interesting reinforcing (R) and balancing (B) loops in Figure 4 and Figure 5. Other loops consist of combinations of these labelled loops.

R1: inputs purchased lead to increased crop production, crop sales and income
R2: livestock births increase the number of livestock (multiplication)
R3: investment in business gives revenue which then allows for investment in business, as long as revenue exceeds expenses (B8)
R4: crops produced provide seed (recycled) that can be planted to produce more crops
R5: purchased equipment or capital can be hired out to others for income
R6: purchased livestock provides income from hiring or sale of animal products
R7-8: purchased equipment and livestock lead to increased area cultivated, which increases crop production and sales; similarly, purchased equipment and livestock lead to increased labour productivity and seed planted, which increases crop production and sales; equipment and livestock increase labour productivity and reduce weed pressure, increasing crop production and sales
R9: payment of school fees to educate children gives them employment income which they can send to their parents
R10: livestock provide manure which increases crop production and sales, which allows for purchase of more livestock and stimulates other reinforcing loops involving crop production
R11: available food is preserved to reduce spoilage so that the food stock lasts longer
R12: hard work in the fields requires food to continue
B1: when food stocks are lower, and the harvest is not here yet, families restrict their food consumption to allow the food stock to reach the next harvest
B2: after a long period of crop production on an area of land, farmers notice the soil becomes less productive (maize and weeds grow less), which reduces crop production
B3: people spend their time clearing fields, cultivating the fields, planting, applying inputs, weeding, harvesting, etc., and when they are busy in the fields, there is no time available for other activities (fatigue, stress, not enough hours in the day)
B4: when one does not have or expect to have enough income, one offers their labour to other farmers as piecework in exchange for cash or food (in kind food payments are not a direct link here)
B5: as weeds grow, weeding activity is not complete, which prompts the allocation of labour to weeding, which reduces weed pressure
B6: as people pay interest on the loans they receive, they become less willing to take a loan out
B7: a need for cash prompts the sale of livestock which increases income
B11: when food is short, food is purchased to restore the amount of food available
B14: when the soil is perceived to be no longer suitable, seed is no longer planted there
B15: when labour is allocated to piecework, it reduces the amount of labour available for other activities (which can affect their own farming depending on the time that farming labour is required)
B16: application of purchased fertilizer increases weed pressure which reduces crop yield and crop sales, reducing income

4.4 Results of Theoretical Sampling and Validation Processes

For a full discussion of the results of the theoretical sampling and validation processes, please refer to Appendix C.

4.5 Assessment of Appropriateness of a Group Mental Model for Individual Farmers

The in-depth interviews collected by Saldarriaga et al. (2014) are classified by gender, income level and region, among other factors. Based on analysis of the in-depth interviews in this paper, a hypothesis is generated that the largest differences between the behaviour of individual farmers

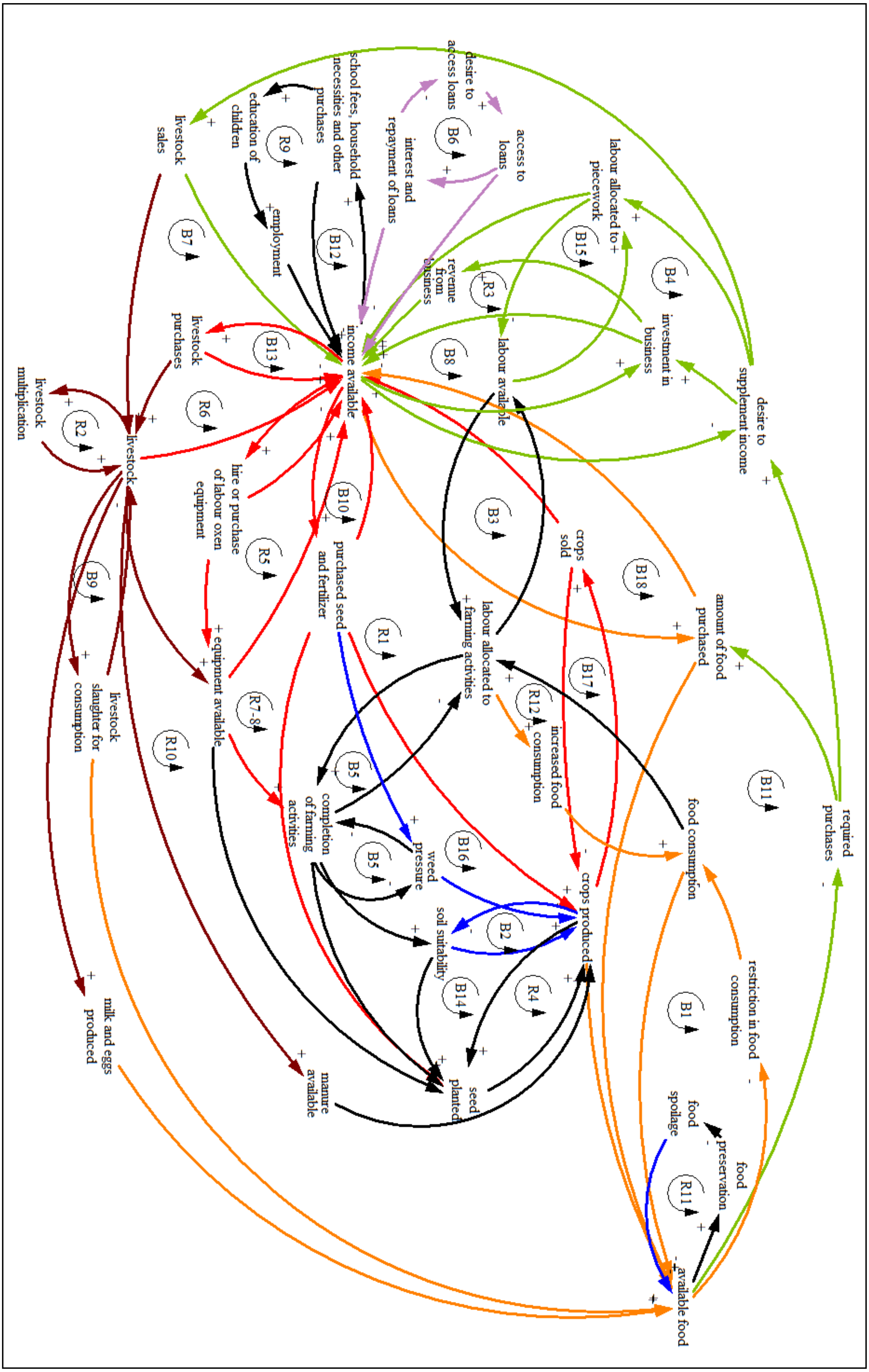

Figure 5 - A simplified version of Figure 4 to highlight and label loops for discussion

lies not between regions or genders but income level. One causal map represents the group mental model of the food system, but different farmers may use different substructures in the causal map. Low income farmer interviews appear to generate fewer causal structures, as their asset profiles and options are limited. Some interviewees have trouble generating ideas for coping strategies when the idea of having no water is proposed, as they have no money with which to make plans. Informal unscheduled interviews with Zambian farmers in 2015 spanning the income categories provide support for this hypothesis.

4.6 Dynamic Implications of the Mental Model

The causal loop diagram in Figure 4 representing the group mental model of small-scale farmers in Zambia consists of many stock concepts with relationships to each other, as well as some external limitations and physical factors. There is a large number of reinforcing loops that are tempered by balancing loops. For example, livestock multiplies, but the stock is reduced by sales, disease and consumption. There are several reinforcing loops that travel through the variable crop production, but these loops are limited by factors such as soil, rain, labour, land, inputs and equipment.

The most interaction occurs between the food, income, livestock and crop production variables. When there is a shortage in one area, farmers try to adjust in other areas. For example, if there is a shortage in food and there is not enough income to purchase food, the farmer can do piecework to obtain food, which may have the future consequence of reduced crop yield and food available. In cases of cash shortage, livestock can also be sold. Livestock is an important contributor to the system, so a reduction in this asset will likely result in reduction of income, crop production and food in the future. If the farmer is anticipating purchases in the future, he or she can purchase or set aside livestock or food to sell at a later time, or participate in business to earn a profit to buy the desired items.

The expected behaviour from a reduction in one stock is a cascade of reduction among other stocks, following the path of downward reinforcement. The expected behaviour for a major increase in one stock is that it creates a cascade of increases among other stocks, following the path of upward reinforcement. The exception would be in case of an unexpected reduction in one of the stocks.

Although there are a large number of connections between different variables in the diagram, it appears that most of the dynamics in the system come from the reinforcing crop production and assets loops, with factors that reduce the variables in the reinforcing loop such that the behaviour of the variable crop production never increases past a certain level. The loops in the diagram, often as a result of unpredictable drivers from outside the loops, act at different times. Some balancing loops operate on a longer time scale, where the effects are not noticed right away, but after many years, for example soil quality. Available capital, labour and land appear to be limiting factors, with rainfall as a major factor in productivity of the food system. Assets are eroded by natural factors such as pests and disease, while labour requirements of farming under the traditional methods in this system are very high.

Poverty traps are mentioned in agricultural literature (Stephens et al. 2012), and the results of this paper demonstrate that the farmers understand the links in the reinforcing loops that are analogous to poverty traps. The lack of access to resources is mentioned in several interviews as a challenge for small-scale farmers. Cultural preferences and balancing loops such as the debt repayment loop and soil quality loop likely affect the ability to enter the positively reinforcing productivity loop.

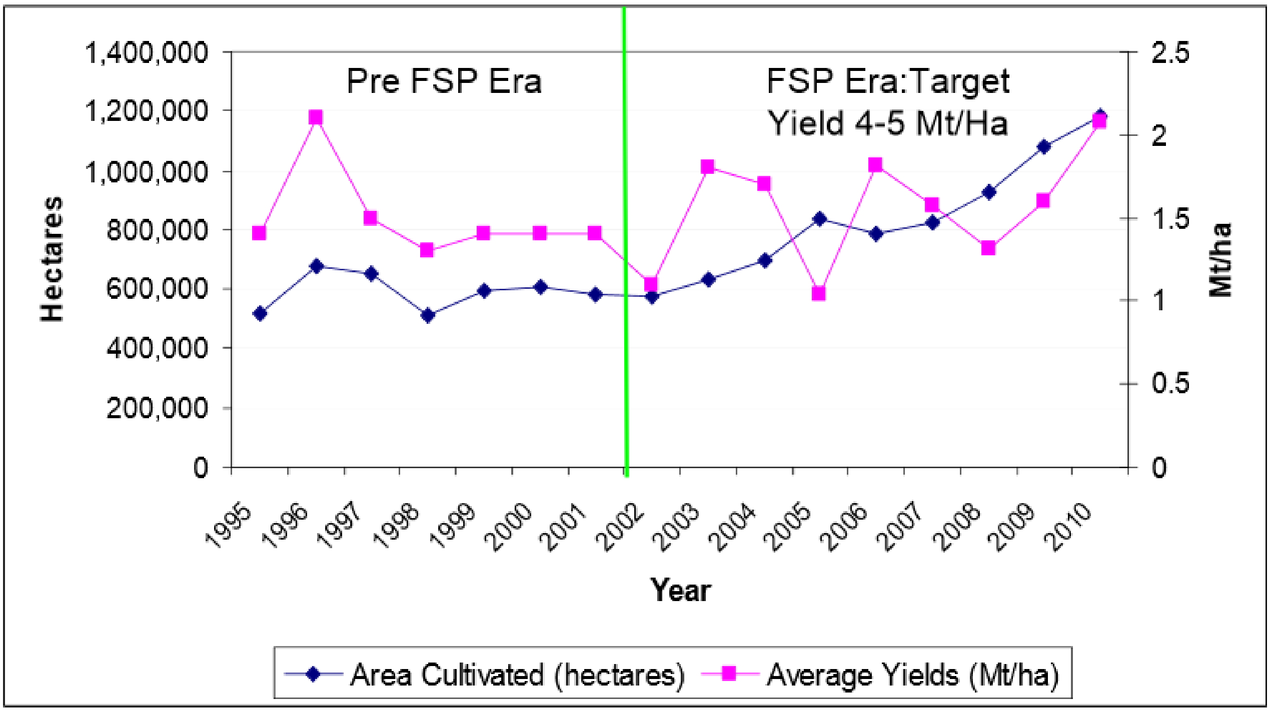

Figure 6 - Maize production in Zambia from 1995 to 2010, area cultivated and average yields (Chapoto 2010)

Figure 6 shows that although the area under maize cultivation has increased between 1995 and 2010, agricultural productivity for maize has hovered around the same level, with and without input subsidies (Chapoto 2010). Bumper crops often result from favourable rainy seasons (Chapoto 2010), which helps to explain the large swings in agricultural productivity. Figure 6 illustrates the difficulty in stimulating the reinforcing loop of crop production in Zambia. Balancing loops and limiting factors that reduce the strength of the reinforcing loop must be acting to limit growth in agricultural productivity, and the mental model of the farmers produced in this paper provides some insight into why this is occurring.

5. Policy and Implementation

5.1 Current Agricultural Policies Targeting Small-scale Farmers

According to Neubert et al. (2011), agricultural policies in Zambia have failed with respect to addressing the needs of small-scale farmers and improving their outcomes. A National Agricultural Policy has a stated goal of growth in the agricultural sector, and it focuses on small-scale farmers but falls short in the area of implementation (Neubert et al. 2011).

The government programs mentioned by the small-scale farmers are the Farmer Input Support Program (FISP) and the Food Reserve Agency (FRA). The FRA buys maize and was originally intended as a buyer of last resort for small-scale farmers (Neubert et al. 2011). Some farmers list the guaranteed market provided by the FRA as a reason to plant maize (Appendix C). While FISP is designed to increase agricultural production by subsidizing inputs, it is mentioned as a source of frustration by the farmers because of delivery delay of inputs (Hager et al. 2015; Figure 4). IAPRI has released policy recommendations to amend FISP because it only benefits high income small-scale farmers, is expensive to run and has failed to increase yields (Chapoto 2014).

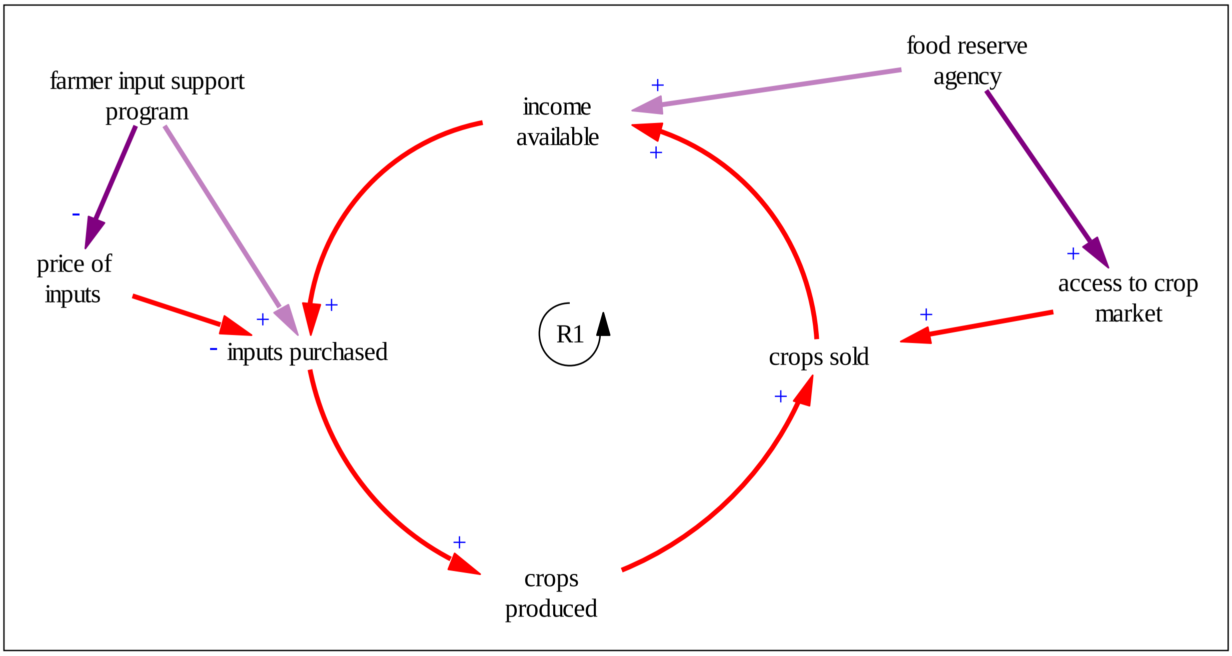

Figure 7 - Assumed target loop of agricultural policies (FRA and FISP) in Zambia

Based on the causal loop diagram in Figure 7, the policy interventions made by the government in Zambia to increase food production and availability have targeted the system in direct and effective ways. The model in Figure 7 is embedded in a much more complex model. The policies face practical implementation challenges such as delays (light purple arrows represent delivery of the inputs and cash, described by farmers in both in-depth and group interviews) and unintended consequences in other parts of the system that ultimately affect income available and crops produced (dark purple arrows represent the intended effect of policy on variables that may influence system behaviour in unintended ways). Finally, income available and crops produced are affected by other parts of the system not visible in this diagram. Stakeholders understand the relationships in the reinforcing loop R1, but they are not able to control, or sometimes not aware of, all effects that the system has on the variables in the loop.

As indicated in the discussion of the themes emerging from the intermediate causal loop diagram, the small-scale farmers' food system in Zambia is characterized by scarcity and risk aversion. An input subsidy intervenes in one stage of the reinforcing loop R1 in Figure 7, but the loop cannot act to reinforce an upward trend in crop production if other structures in the system cause a reduction in other variables in the loop. For example, if cash is chronically scarce, then the amount of inputs available to a small-scale farmer every season is similarly limited, and fear of wasting these inputs may cause a delay in application (to be sure the rainy season has started and everything is predicted to be favourable in the growing season). The delay in application may result in a lower than anticipated effect on yield. Late delivery of inputs would have a similar effect. Farmers waiting for inputs to arrive may have to come up with alternative strategies for the farming season. Even with delays, the provision of inputs for maize and guaranteed access to the maize market (in addition to perception of maize as the staple food and currency in the food system) appears to have perpetuated maize dominance in the food system which may reduce the practice of crop rotation and have adverse effects on soil suitability. Crop production is influenced by many other variables in the food system, including land, soil suitability, labour and weather, and these factors can easily limit agricultural yield even when inputs are applied.

The critique that the input subsidy only benefits the well-off farmers (Chapoto 2014) is consistent with an analysis of the dynamics of the system. The strength of the reinforcing loop is increased with more cash and inputs available, while the farmers in the lowest income category can hardly afford to “enter” the reinforcing loop (R1).

5.2 The Importance of Context to System Dynamics and Policy Interventions

While the goal of System Dynamics modelling is sometimes to produce the simplest model that reproduces the dynamics, one of the goals of this study is to make visible the context in which model structure and dynamics are embedded. Simplified diagrams are valuable communication tools, and simulation of behaviour provides valuable insights. However, there may be hidden variables in the system that do not change over the simulation period, but do have an effect on the system once a policy intervention is introduced. The preferences, goals and cultural traditions of decision-makers in the system can be represented as causal structures that change overall system structure and thus have the potential to affect system behaviour.

The intermediate causal loop diagram representing the group mental model of the small-scale farmers (Figure 3) provides a great deal of contextual information. It can be used as an illustration of the complexity of the food system and the number of factors and causal pathways that influence decisions and outcomes.

Based on the analysis of the intermediate causal loop diagram, several factors appear to be important to consider when designing and implementing policies, including: strength of tradition, risk aversion, satisfaction with current results, cash scarcity, livestock (critical factor; savings in form of livestock can be wasted by disease), soil suitability, easing labour requirements of farming, timing, knowledge, and encouragement of diversification (lowering risk, allowing crop rotation). In addition, policy design should take into account the most limiting factor in the desired outcome in the food system. Dependence on the policy intervention, or ineffectiveness of the policy intervention, may result if the most limiting factors are not addressed. Two major limiting factors in the food system are water and cash.

Several interviewees report irrigation as a solution to many difficulties farmers face. One interviewee says that access to irrigation allows one to be a proper farmer. Irrigation allows for crops to be harvested throughout the year and reduces the risk involved in growing crops that take longer to mature than the rainy season allows. Irrigation would reduce the amount of panic at the onset of rains to plant in time. It would reduce the need and risk involved in planting before the rains start. Since rainfall and rain onset delay are such critical variables for all sectors of the food system (crops produced, livestock, regional income, regional labour demand, regional food supply, food price, etc.), it appears that irrigation is a high leverage point for the system. Irrigation unfortunately requires capital, labour and expertise, and to distribute the infrastructure nation-wide may be a challenge for the government. If individuals are providing their own irrigation systems, then they face similar challenges in cash, labour and expertise.

Causal structures in the group mental model provide information about the effectiveness of policies to provide access to credit (to relieve short-term pressure on cash in order to stimulate a reinforcing loop). Failure to repay loans in the past has reduced government provision of loans, and farmers express aversion to debt. Credit is described as exploitative. The interest paid on loans explicitly lowers willingness to enter a loan agreement in the future in the group mental model. One interviewee clearly states that capital is required to access loans, which are desired to access capital such as equipment. A policy to increase access to credit is not likely to succeed, based on this

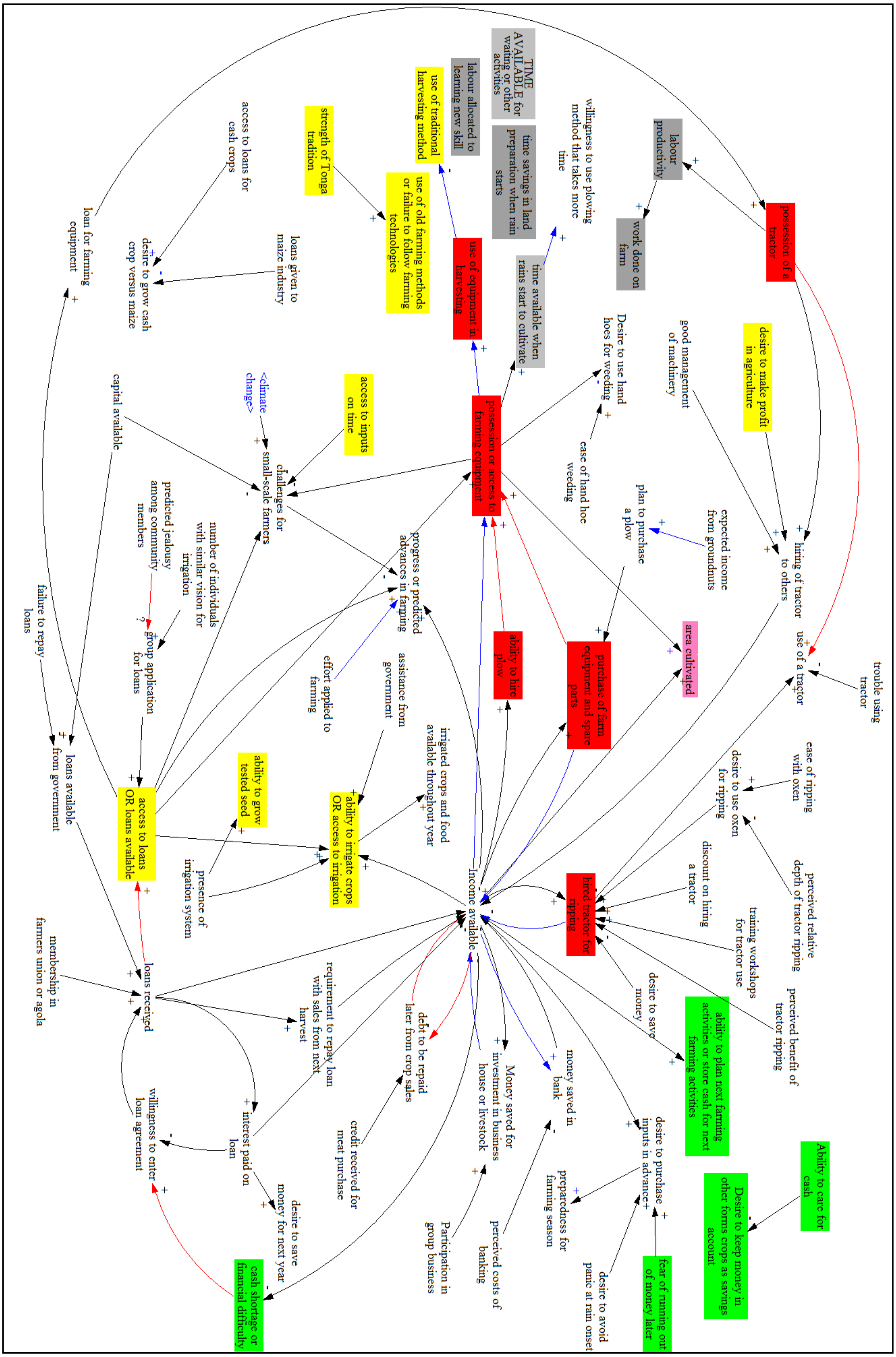

Figure 8 - Simplified diagram produced from the intermediate causal loop diagram in Figure 3 with causal structures related to loans, irrigation, cash and equipment.

analysis, without changing farmer perceptions and implementation strategies.

While context is evidently important, the intermediate causal loop diagram representing the mental model of small-scale farmers is too complex to be readable. Fortunately, the intermediate diagram provides a starting point to produce more simplified diagrams highlighting important loops, sectors, pathways or leverage points. For example, loops were extracted and presented in Figure 4 for analysis of the dynamic implications of the mental model, while themes emerging from the variables were discussed to provide context for the loops and expected behaviour.

Figure 8 has been extracted from the intermediate causal loop diagram in Figure 3 to provide support for the policy discussion regarding credit and irrigation. Figure 8 also presents causal structures and variables from the coding analysis that support themes identified in Section 4.2 and structures in the simplified causal loop diagram in Figure 4. In the next section, the livestock sector will be presented and discussed as a case study of how the intermediate causal loop diagram can be used for policy discussion.

5.2.1 Livestock Sector: How the Causal Map Can Be Used for Policy Discussion

An example of the richness of data provided by the interviews regarding dynamic decision making in the food system is provided by the livestock sector, which includes chicken, cattle, pigs and goats.

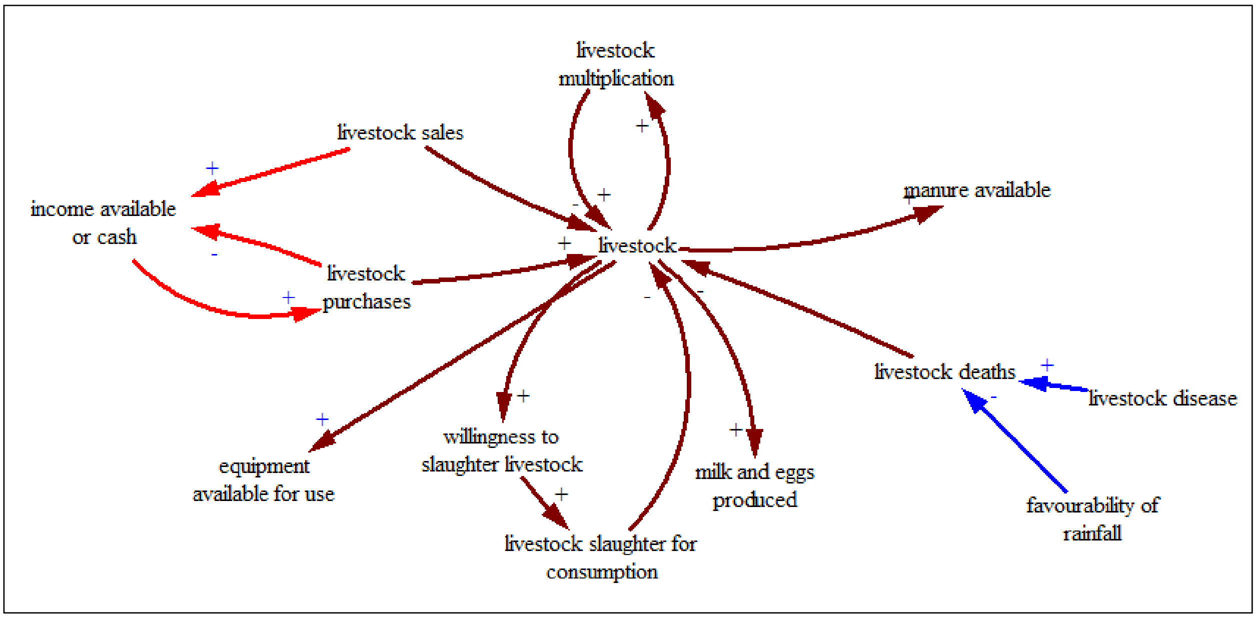

Figure 9 - Livestock sector extracted from the simplified causal loop diagram in Figure 4

When the livestock sector is extracted (and presented in Figure 9) from the simplified causal loop diagram in Figure 4 that is designed to illustrate the dynamics of livestock and the effect of livestock on other important sectors, it appears to be a straightforward policy recommendation to provide medicines to reduce livestock disease. However, upon closer examination of the livestock sector extracted (and presented in Figure 10) from the intermediate causal loop diagram in Figure 3, there are policy implementation challenges to consider. Knowledge of when and how to apply the medicines is required by the farmers. A larger stock of animals requires more labour, capital and medicine. A farmer mentions explicitly that he trims his pig stock when it becomes too large because of maintenance costs. Another mentions that rearing a large number of chickens requires

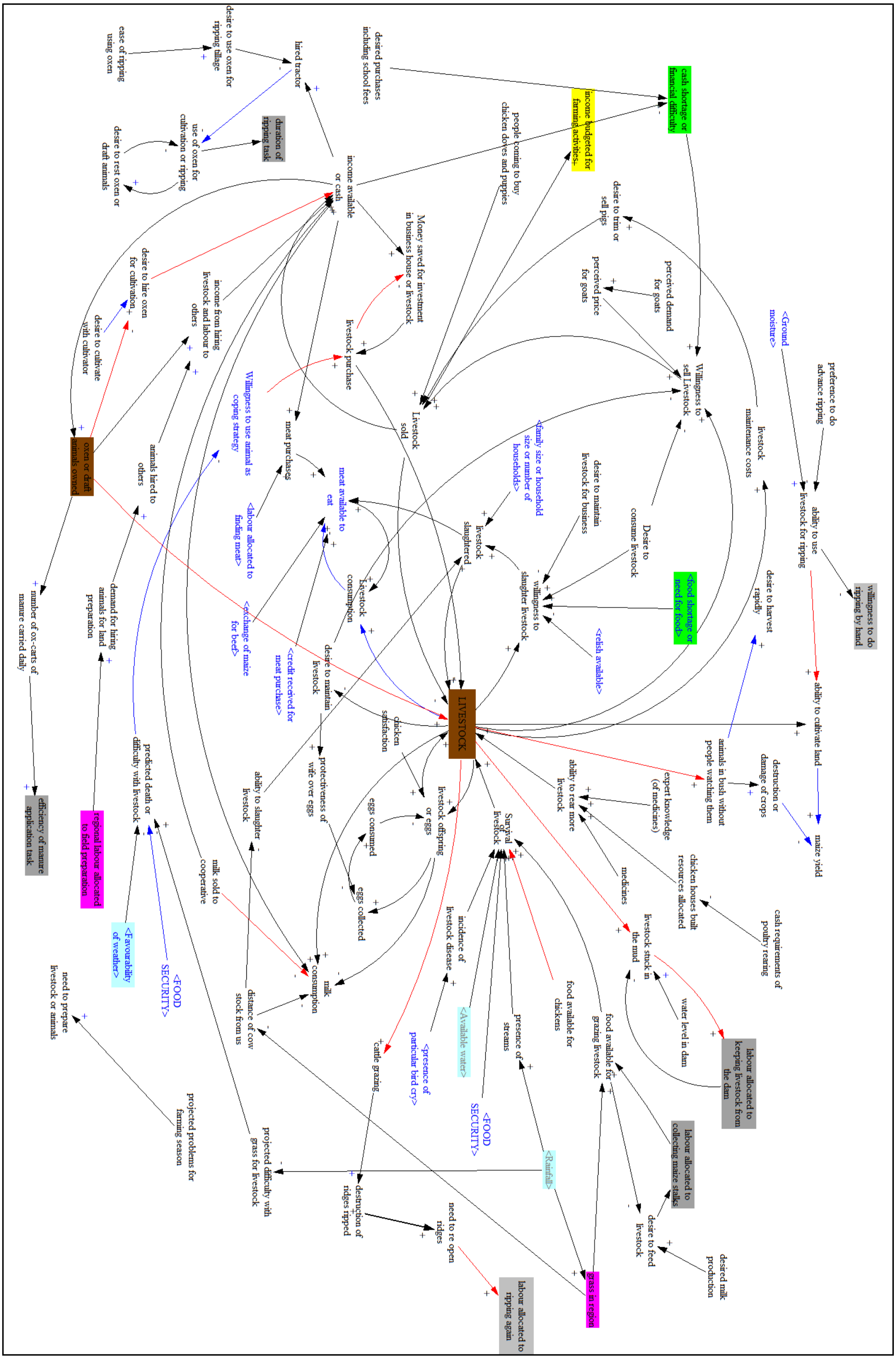

Figure 10 - Livestock sector extracted from the intermediate causal loop diagram in Figure 3

investment in houses for chickens. One of the group interviewees in Zambia indicates that more livestock require more medicine (Appendix C). Additionally, livestock need water and food, and when these are in short supply, medicine will not assist in livestock survival. An interesting point mentioned by more than one interviewee is that when grass is scarce, the livestock graze far away, which reduces the availability of milk and meat for consumption. Finally, in order for livestock to be converted to cash, there must be a demand and regional income available to purchase livestock.

Figure 10 provides an excellent example of the type of causal structures that the causal mapping method used in paper can generate. The livestock sector is a particularly useful one to examine because it is linked with many different sectors of the food system, including cash, labour, farm productivity, food, regional environment and regional economy. The causal map visually establishes causal pathways to enable the user to trace the effects of changing one variable and reminds the user of the potential unintended consequences of influencing livestock if no action is taken to account for changes in other variables in the system. While some of the links in Figure 10 remain at a high level of detail, the map can be generalized and simplified for the purpose it needs to serve.

The results of this paper support the claim that there is not a simple cause and effect relationship between policy intervention and outcome (Finegood et al. 2010). The policy intervention interacts with a number of different variables through a number of different pathways and loops that act at different times, resulting in an outcome that may or may not match the desired or expected outcome. Context, which is represented in this study by a detailed mental model of the food system, is important to take into account in policy analysis and discussion (Finegood et al. 2010). Failure of past policy interventions indicates that there is a need to understand soft variables that act in the system, such as tradition, fear and knowledge. While these variables are difficult to measure, the System Dynamics field recognizes their importance, going as far as to say that it is preferable to represent such variables than to omit them from a model because the only value known to be wrong for the effect of the variable on the system is zero (Forrester 1969).

6. Conclusion

The study of dynamic decision making of small-scale farmers in Zambia is crucial to understanding the food system and evaluating policy options to improve food system outcomes. This paper builds on a previous study of dynamic decision making by adapting and applying an inductive and systematic method to generate a group mental model from qualitative text data to in-depth interviews with small-scale farmers in Zambia (Kim & Andersen 2012; Saldarriaga et al. 2014).

The resulting mental model is in the form of a complex causal map. The map can be simplified to highlight relevant sectors or to highlight important loops and links between sectors for an analysis of dynamic implications. Confirming Saldarriaga et al.'s (2014) results, the map shows that small-scale farmers perceive the dynamic complexity of the food system, including reinforcing processes. The map also creates a visible link from influences on decision making, including soft factors such as tradition, knowledge, food preference, scarcity, risk aversion and stress, and economic factors such as price and relative profitability, to other causal structures in the map.

The map sheds some light on why it is difficult to stimulate reinforcing processes in the food system. Access to credit is problematic or perceived negatively. Water and livestock are identified as critical to food security. Irrigation would remove the threat to food security posed by a change in rainfall pattern. Policies to reduce livestock disease would help to maintain positively reinforcing processes, but the causal map should be examined for unintended consequences and dynamic implications of such a policy intervention.

The method used to generate the causal map is extremely labour intensive, but its inductive and systematic nature increases the probability that its causal structures originate from the mental models of the farmers and not the modeller. Detailed descriptions of food system outcomes and activities in the in-depth interviews generate an immense number of explicit and implicit causal structures. The detailed coding performed in this paper permits interesting themes and soft variables to emerge from the data to provide additional hypotheses about decision making. Conceptual generalization loses data that could be important determinants of system behaviour, while a map with a large number of variables and relationships is difficult to analyze.

A general policy recommendation is to use the mental model of small-scale farmers to evaluate policies to enhance food security in Zambia. The map can be presented and analyzed in different stages of simplification depending on the stakeholders involved and purpose of the exercise. The qualitative model produced in this paper is an important first step in producing a quantitative model at the farm level, which could be used for quantitative testing of policies. Further research into the quantitative modelling of farmers' decision making is proposed.

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Appendix

Appendix A: Detailed Guide to Coding Method

Traditional Grounded Theory Coding
(0) Before analyzing in detail, the interviews are read at least once by the coder.

Hybrid System Dynamics and Grounded Theory Open Coding
(1) Each paragraph in each interview has a CIN (conversation identification number) in the form of FX-YYY where X is the number assigned to the interviewee, and YYY is the paragraph in the interview. An interview paragraph is defined as all of the text assigned to one speaker before the next speaker begins speaking.

F05-330	**MALE INTERVIEWER**: Alright, we have now seen what you were doing, but now we want to hear why you did those activities, because as you can see we started with the results then we went to activities; so we want to hear the reasons why you did those activities, for instance here you told us that from this point you just do piece work; digging holes and helping out in packing of charcoal, why did you do this?
F05-331	**MALE INTERVIEWEE**: Okay, we did this because we fail to access what our friends have, so we go to them in order to get help.
F05-332	**MALE INTERVIEWER**: Okay, now you said fail to access things; do you entail in terms of farming or business?
F05-333	**FEMALE INTERVIEWEE:** We fail to progress even when we do farming activities, because we lack help in order to access those things.
F05-334	**MALE INTERVIEWER**: Do you have the tools for farming?
F05-335	**FEMALE INTERVIEWEE**: Such as?
F05-336	**MALE INTERVIWER**: Tools such as Hoes?
F05-337	**FEMALE INTERVIEWEE**: Hoes (mase), at least we have.
F05-338	**MALE INTERVIEWER**: Okay. What of the tools such as animals?
F05-339	**MALE INTERVIEWEE:** We do not have the animals, and we also do not have money to buy seeds and other in-puts like our fellow friends have; hence we fail to yield.
F05-340	**MALE INTERVIEWER**: Okay, so this makes you fail to yield! Then here, the other activity was clearing (kugukaula) and burning those big trees, why did you do this?
F05-341	**MALE INTERVIEWEE**: This we did, so that the fields are clear; such that if we do piece work and get money, then we could hire people with animals to plough the fields, but it so happened that we failed, so we ended up making holes with our hands.
F05-342	**MALE INTERVIEWER**: Alright, I see. Now, was this field a new one for you to burn the trees?
F05-343	**FEMALE INTERVIEWEE**: Yes.
F05-344	**MALE INTERVIEWER**: Okay, the other action you performed from here; you entered piece work for digging, why?
F05-345	**FEMALE INTERVIEWEE**: We performed these pieces of work in order to earn a living; so that we are helped in one way or another.
F05-346	**MALE INTERVIEWER**: Now, look at this; you are doing piece work on one hand and on the other hand you are weeding your fields, so you have combined two activities; therefore what makes you do this?
F05-347	**FEMALE INTERVIEWEE:** What makes us do this; is lacking within the household.
F05-348	**MALE INTERVIEWER**: Oh, so it is lacking within the house hold; then how do you manage, combining the two actions?

Figure 11 **-** *Sample portion of an interview that has been assigned Conversation Indication Numbers (CINs)*

(2) Each interview is analyzed from start to finish, filling Coding Charts explained in (3) with the results of the qualitative data analysis.

(3) Each coding chart contains the following information:
- Chart ID: each chart contains codes with a common context
- CIN: all CINs from which codes in the chart are generated (can be a range)
- Context: usually what types of questions the interviewee is responding to when he/she provides text that generates codes
- Notes: Any reasoning, extra details or special ideas to note when examining the codes in the coding chart
- Codes: causal structures or standalone variables (associated with data or behaviour) identified in the text
    - Each code has a:

        - Source: the exact CIN(s) identifying the source of the text for the code
        - Cause Variable: if a relationship is identified between two variables, the name of the cause variable occupies this space (otherwise insert "N/A")
        - Effect Variable: the name of the effect variable or the data variable (in cases where there is no cause variable) occupies this space
        - Relationship: if there is a causal relationship between the two variables, then this space is either Causal Positive or Causal Negative.
            - Other relationships include: "Type of" (identifying a category for a variable), "Equivalent" (identifying relationship) and "N/A" for standalone variables
        - Temporal: if there is any time of year or season during which this variable behaviour or relationship applies, then it is entered here (for example, if cabbage is purchased only in rainy season, then "rainy season" would occupy the Temporal space)
        - Var behaviour for Cause var: if any behaviour of the cause variable has been identified, then it is entered here
        - Var behaviour for Effect var: if any behaviour of the effect or data variable has been identified, then it is entered here
    - Special characteristics of codes by background colour:
        - Grey: for straightforward causal codes and reference modes or data identified
        - Green: for identifying or categorical relationships between variables ("Type of", "Equivalent")
        - Blue: for codes identified as ***implicit*** in the data
            - interviewee does not explicitly state the relationship between two variables, but it can be assumed to be present based on the explanation provided by interviewee
            - or, in some cases, the relationship is omitted from the interviewee's explanation because of how obvious the relationship is
        - Red: for codes that arise from major assumptions by the coder
            - the interviewee's explanation was unclear and incomplete
            - or, a major leap in logic had to be taken by the coder to fill a gap

Chart#	27	CIN	F05-183 to F05-362					
INTERVIEWEE		CONTEXT	Answering questions about farming activities					
	Source	F05-313; F05-315; F05-317	F05-315; F05-317	F05-321	F05-323	F05-323	F05-325; F05-327	F05-329
Causal structure	Cause var	Readiness of maize for h	Readiness of maize for har	Farming activity	Maize yield	N/A	Farming activity	Piecework
	Effect var	Drying maize	Eating maize	Harvesting (maize)	Duration of harvest	Maize yield	Piecework	make holes
	Relationship	Causal Positive;	Causal Positive;	Type of	Causal Positive;	N/A	Type of	Type of
	Temporal	N/A	N/A	May	N/A	May 2012	all year round	N/A
Var behaviour	Cause var	now ready for harvest	after it was ready for harve	N/A	maybe just 3 bags	N/A	do not stop	N/A
	Effect var	so we started drying	we started eating the food	N/A	one week finished	not much, 3 bags	continuous process	N/A
Notes:								

Chart#	28	CIN	F05-183 to F05-362					
INTERVIEWEE		CONTEXT	Answering questions about farming activities					
	Source	F05-329	F05-331	F05-333	F05-333	F05-331; F05-345	F05-337	F05-339
Causal structure	Cause var	Piecework	Desired access to goods	Access to goods	Help	Piecework	Tools owned	N/A
	Effect var	pack charcoal	Piecework	Progress in farming	Access to goods	Help	Hoes	Animals owned
	Relationship	Type of	Causal Positive	Causal Positive;	Causal Positive;	Causal Positive;	Type of;	N/A
	Temporal	N/A	N/A	N/A	N/A	N/A	Dec 2013	N/A
Var behaviour	Cause var	N/A	fail to access	lack...access	lack help	go to friends	N/A	N/A
	Effect var	for those who want	did this because	fail to progress	in order to access tho	to get help	N/A	none
Notes:								

Chart#	29	CIN	F05-183 to F05-362					
INTERVIEWEE		CONTEXT	Answering questions about farming activities					
	Source	F05-339	F05-339	F05-339	F05-339	F05-339	F05-339 Assumption?	F05-341
Causal structure	Cause var	Income	Income	N/A	Purchased seeds	Farming Inputs	Animals owned	Desired field area clear
	Effect var	Purchased seeds	Farming Inputs	Income	Yield	Yield	Yield	Clearing
	Relationship	Causal Positive;	Causal Positive;	N/A	Causal Positive;	Causal Positive;	Causal Positive;	Causal Positive;
	Temporal	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Var behaviour	Cause var	do not have money	do not have money	N/A	do not have seeds	do not have inputs	do not have animals	N/A
	Effect var	to buy seeds	to buy inputs	not enough money to bu	fail to yield	fail to yield	fail to yield	N/A
Notes:	For effect of owned animals on yield, it is not clear whether animals are included in the list of drivers of yield because the and is ambiguous.							

Figure 12 - Sample coding charts from open coding of in-depth interviews

(3) Once the coding charts are completed, the codes are mapped in Vensim

- Starting with one coding chart, variables in the codes with causal relationships to other variables added to a diagram in Vensim
- Arrows with polarity that correspond to the Causal Positive (+) and Causal Negative (-) relationships identified in the codes are drawn between them
- Arrows are coloured to match the background colour of the code in the coding charts (Black=Grey, Blue (implicit), Red (assumption))
- The CIN sources for the codes are entered into the documentation section of both the cause and effect variables the code, along with any relevant notes
    - It is helpful to include an overview of the code with the CIN for easier tracking later, for example: “F09-100 crops sold → income”
- When the same causal relationship (A →+ or - B) is identified by two different codes in the coding charts, then a second set of variables is not created. Instead, the documentation section of A and B is expanded to include the documentation of sources for all subsequent coding that identifies the relationship.
- "Type of" coded variables are added to a separate Vensim diagram with the CIN sources and the category name in the documentation section (for example, “F18-033 Farming activity”)
    - In the diagram, the variables are grouped in boxes with titles for the category name (for example, "Purchased Foods" and "Income sources"). The Vensim file resembles a Venn diagram.
- Data or reference mode codes (standalone variables with behaviour) are not entered into Vensim but instead are coloured in orange in the Excel file to indicate they may be useful later for simulation model building
- As the coder proceeds through the coding charts, links and variables added to the diagram (or documentation sections are modified to include confirmation of the relationship by other CINs).

- If there is a conflicting or contradictory statement about the causal relationship between two variables, the polarity of the arrow between them will be changed to a question mark, or two different arrows (with different polarity) between the variables will be created, with explanations in the documentation of the cause and effect variables.
- Note that arrows can change colour during the coding process if codes being added to the diagram have been assigned a more explicit relationship time
    - Arrows that were red (assumed) can be changed to blue or black if another code has identified the relationship between two variables as implicit or explicit
    - Arrows that were blue (implicit) can be changed to black if another code has identified the relationship between two variables as explicit
- When all coding charts are entered into Vensim, blue and red (and empty) areas of the resulting causal map are potential gaps to fill by further interviewing (theoretical sampling)

Axial Coding: Overview of Steps

- Variables and causal structures that appear to be unattached to the major causal structure in the centre of the diagram are examined to see if they can be merged with other similar causal structures or if they link logically with other variables
- Seemingly obvious logical connections between variables are identified by linking the variables with red arrows (polarity added using coder judgment)
- Variables are examined one by one to see if they are very similar or precisely the inverse of other variables in the diagram. The variables are merged, preserving the original intent of the relationship between variables. Documentation section of the merged variables contains all relevant documentation from the variables that are eliminated.
    - For example, "weed height", "grass in field" and "weed growth" are "weed pressure" are all very similar and logically related variables that can be merged or linked with red arrows depending on the judgement of the coder
    - Merging is documented with notes in a text file
- As codes are examined, major variables and categories are defined and described in a text document.
    - Similar causal structures with variable names that belong to the parent category are merged together (for example, causal structures involving chickens, pigs, goats and cattle are merged together)

Appendix B: Questions for Theoretical Sampling and Validation

Interview text in Appendix B has been adapted to reflect the actual questions asked during the interviews and to eliminate introductions and conclusions. Questions were designed by Kopainsky, B., Nyanga, P.H. and Spicer, J. in February 2015.

SMALLHOLDER FARMER GROUP INTERVIEW A: February 20, 2015

Food Security Drivers, Budgeting and Resource Allocation

Purpose of the interviews: In order to improve our simulation models and causal loop diagrams, we want to learn more about the smallholder farmers' mental models of the food security system and their decision making processes. In particular, we are interested in finding out:

- the drivers of food security according to the smallholder farmers (positive and negative)
- their annual expenditures and spending priorities, as well as the savings process
- their decision rules about land and input allocation, including perception of soil fertility

Sample: 1 group of 6 participants who have not been previously exposed to the group model building process, preferably a mix of men and women, high and low income from village listings

1. **Drivers of Food Security**

- Defining food security as food availability, the farmers will be asked as a group for:
  - a list of the causes of food insecurity (-), and a list of the causes of food security (+)
- For each factor listed, the farmers will be asked
  - <u>Why</u>/<u>how</u> it contributes to food security (*The factor will be checked from the table on the following page with a (/) for all factors mentioned by the group without probing and a (+) or (-) depending on the relationship to food security)*
- Then the group will be probed for the factors not mentioned from the table, to see if they agree that it contributes to food security, and <u>how</u> (*Those factors will be checked with a (p+) or (p-) in the probed column)*

LIST OF DRIVERS or FACTORS	Factor mentioned probed (p+/p-)	Food security ((-)	Notes: how, why, when, clarification
Planning			
Inputs			
Climate or weather change			
Drought or Flood			
Population growth			
Soil fertility			
Knowledge			
Access to equipment			
Cash available			

Livestock			
Crop diversification			
Crop rotation			
Labour availability			
Delivery delay of inputs			
Price of maize			
Pests or disease			
Proper budgeting			
Distance from market			
Being exploited by buyers			
School fees			
Illness or death			
Funerals, weddings, ceremo occasions			
Debt / credit			
Reliance on maize			
Conservation farming			
Piecework			
Theft			
Irrigation			
Reliance on local seed			
Recycling hybrid seed			
Using hybrid seed			
Herbicides			
Manure			
Fertilizer			
Livestock breeding			
Hard work			
Land area under cultivation			
Gardening			
Doing business			
Saving cash			
Weed pressure			
Liming			
Nitrogen fixing trees			
Gender issues			

3. Budgeting Cash

- ask for a list of annual expenditures
- ask if the trend from the past has been increasing or decreasing spending, and what the expectation is for future expenditures
- ask about the saving process
  - how much do they save every year? for how long do they save it?
  - what is it saved for? how is it saved (bank, mattress, livestock)?
  - what happens to savings? are goals met?

- **Assessing spending priorities: Ipsative scaling exercise (PILOT ONLY)**
    - *To be entered in a worksheet (below) individually for each farmer that participates*
    - *The exercise will be carried out on a whiteboard, using fake kwacha notes and areas to place the notes (images will accompany the category name)*

A) Given an income in June of <u>500 kwacha</u>, how would you budget and spend the money in the following 12 months? Take into account your current situation and explain why you allocated the money as you did. Assume no other income sources.

B) Do the same for an income of <u>2000 kwacha</u>

BUDGET ITEM	Picture to identify catego	Amount budgeted from 500 kwacha	Amount budgeted from 2000 kwacha
Inputs (Fertilizer, Seed, Herbicide, Pesticide)	Fertilizer on trucks		
Food (including grinding ma	Family eating food		
Household (fuel, soap, cloth repairs, roofing..)	Family and house, soap, clothes, fuel		
Livestock (purchase, medici care)	Cattle		
Farm tools/equipment (buying, repair)	Ripper and hoe		
Education	Children in school		
Medical	Doctor		
Water and ceremonial contributions	Water pump and people dancing		
Hiring labour, oxen, land	Workers in field with kwacha bill		
Remittances given	Kwacha bill, arrow and ha		
Luxury	Beer, earrings		

4. Land and Input Allocation

- Decision rules for area under cultivation
    - How do you decide how much area to cultivate?
    - What factors included in decision? When?
    - What are the number estimates for these factors?
- Decision rules for <u>maize</u> area under cultivation
    - How do you decide how much area to allocate to maize?
    - What factors included in decision? When?
    - What are the number estimates for these factors?
- Decision rules for input allocation (seed, fertilizer, herbicide, etc.)
    - How do you decide how much input to buy?
    - How do you decide which fields to apply it on?
    - Why do you choose these inputs?
    - How do you assign quantities of inputs to each field?

- Probe for historical trend in area under cultivation
- Probe for equipment owned, labour availability (historical trend)
- probe for soil fertility as a factor in land and input allocation and then follow up with questions
    - What is the current level of soil fertility on your land? High, medium, low
    - How was the level of soil fertility in the past 20 years? Did it change over time? How can you tell? Why did it change?
    - How do you expect the soil fertility level to be in the future? Why? How will you know?

SMALLHOLDER FARMER GROUP INTERVIEW B: February 22, 2015

Budgeting and Resource Allocation
Purpose of the interviews: In order to improve our simulation models and causal loop diagrams, we want to learn more about the smallholder farmers' mental models and decision making processes. In particular, we are interested in finding out:

- their spending priorities
- their decision rules about land and input allocation, including perception of soil fertility

Sample: 1 group of 6 participants who have not been previously exposed to the CBSD process; A mix of men and women, high and low income from village listings

1. **Land and Input Allocation**

- Probe for historical trend in area under cultivation
- Decision rules for total land area under cultivation
    - AS A GROUP: How do you decide how much area to cultivate?
        - What factors included in decision? DRAW DIAGRAM
    - CASE BY CASE: Which factors do you use, and what are the numerical estimates?
- Decision rules for <u>maize</u> area under cultivation
    - AS A GROUP: How do you decide how much area to allocate to maize?
        - What factors included in decision? DRAW DIAGRAM
    - CASE BY CASE: What factors do you use, and what are the number estimates for these factors?
- Decision rules for input allocation (seed, fertilizer, herbicide, etc.)
    - AS A GROUP: What are the factors influencing the amount of inputs accessed (bought/given)?
        - Seed, Fertilizer, Manure, Herbicide
    - CASE BY CASE: How do you decide on which fields and how much to apply? (Given that you may not have enough to apply to all of your land?)
        - 3 types of seed, Fertilizer, Manure, Herbicide
- AS A GROUP: probe for soil fertility as a factor in land and input allocation and then follow up with questions
    - How was the level of soil fertility from 2001 to 2015?
        - Did it change over time? How can you tell? Why did it change?
    - How do you expect the soil fertility level to be in the future? Why?

Assessing spending priorities: Ipsative scaling exercise PILOT ONLY

- *To be entered in a worksheet (below) individually for a few farmers in the group*
- *The exercise will be carried out on a whiteboard, using fake kwacha notes and areas to place the notes (images will accompany the category name)*

C) Given an income in June of 1000 kwacha, how would you spend the money in the following 12 months?

a. Take into account your current situation and explain why you allocated the money as you did. Assume no other income sources.

D) Do the same for an income of 5000 kwacha

BUDGET CATEGORY	Picture for category	Amount budgeted from 1000 M and F	Amount budgeted fr 5000 M and F
Inputs (Fertilizer, Seed, Herbicide, Pesticide)	Fertilizer on trucks		
Food (including grinding maiz	Family eating food		
Household (fuel, soap, clothing, repairs, roofing, etc	Family and house, soap, clothes, fuel		
Livestock (purchase, medicine, care)	Cattle		
Farm tools/ equipment (buying, repair)	Ripper and hoe		
Education	Children in school		
Medical	Doctor		
Water and ceremonial contributions	Water pump and peopl dancing		
Hiring labour, oxen, land	Workers in field with kwacha bill		
Remittances given	Kwacha bill, arrow and		
Luxury	Beer, earrings		

Appendix C: Results and Discussion of Theoretical Sampling and Validation Processes

Group Model Building Exercise

As outlined in Section 3.3.2.1, a group model building exercise designed by Hager et al. (2015) provided an opportunity to validate the simplified mental model of the farmers generated in this paper. The farmers explained that the exercise was valuable because it involved concepts that represented their lives (Hager et al. 2015). The relationships and loops identified by the farmers build confidence in the analysis performed this paper (Hager et al. 2015).

Individual follow up interviews with farmers who participated in the group model building session provided further opportunity to validate the hypothesized mental model of the farmers (Hager et al. 2015). The individuals easily identified variables and loops, elaborated on their importance and provided policy options to maintain the important variables such as “cash”, “food available” and “livestock”. Whether or not the farmers exhibited loop thinking before or after the group model building exercise is not a topic to be addressed in paper, as farmers only have to identify (implicitly or explicitly) a relationship between two variables for the structure to be included in the mental model. The follow up interviews also provide text data that builds confidence in the themes generated in the analysis of the in-depth interviews (Section 4.2).

As livestock is identified as a critical factor by most farmers in the follow-up interviews, options to increase or maintain livestock are mentioned. Disease prevention for livestock, including knowledge and medicines, is a popular policy suggestion. One farmer even adds that an increase in livestock leads to an increase in the need for disease prevention, which is an observation to note for policy design. Selling livestock for cash is mentioned repeatedly as the last line of defense when facing shortages.

Boundary Test

The list of positive and negative contributors to food security generated from the group interview designed to serve as a boundary test for the group mental model (Section 3.3.2.2) is as follows: advanced purchase of inputs, access to seed and fertilizer, business (both positive and negative), planning, inputs from FISP, early planting, fertilizer, crop diversification, knowledge, drought, flood, seed, lack of farming tools, careless use of money, piecework. When probed for additional factors, the farmers agreed that the following contribute to food security: crop rotation, labour, delivery delay of inputs, delivery delay of cash from maize sales to the government, maize price versus fertilizer price, disease, distance of the market, debt or credit (exploitative, having to sell assets to pay the credit), conservation agriculture, control of weeds, school fees, gardening, grinding mill fees, land area, cattle. Good rain was listed as the most important factor, and livestock is treated as equivalent to cash in their discussion.

None of the factors listed are outside of the boundary of the causal map representing the mental model of the farmers. The farmers mentioned similar factors and internal activities that lead to food security or food insecurity to those mentioned in the in-depth interviews. The results of the boundary test build confidence in the current representation of the mental model of the farmers. Causal relationships and policy options identified based on a surface analysis of the group interview results are represented in Figure 13. Yellow and orange variables and links highlight interesting links and validation of themes in this paper.

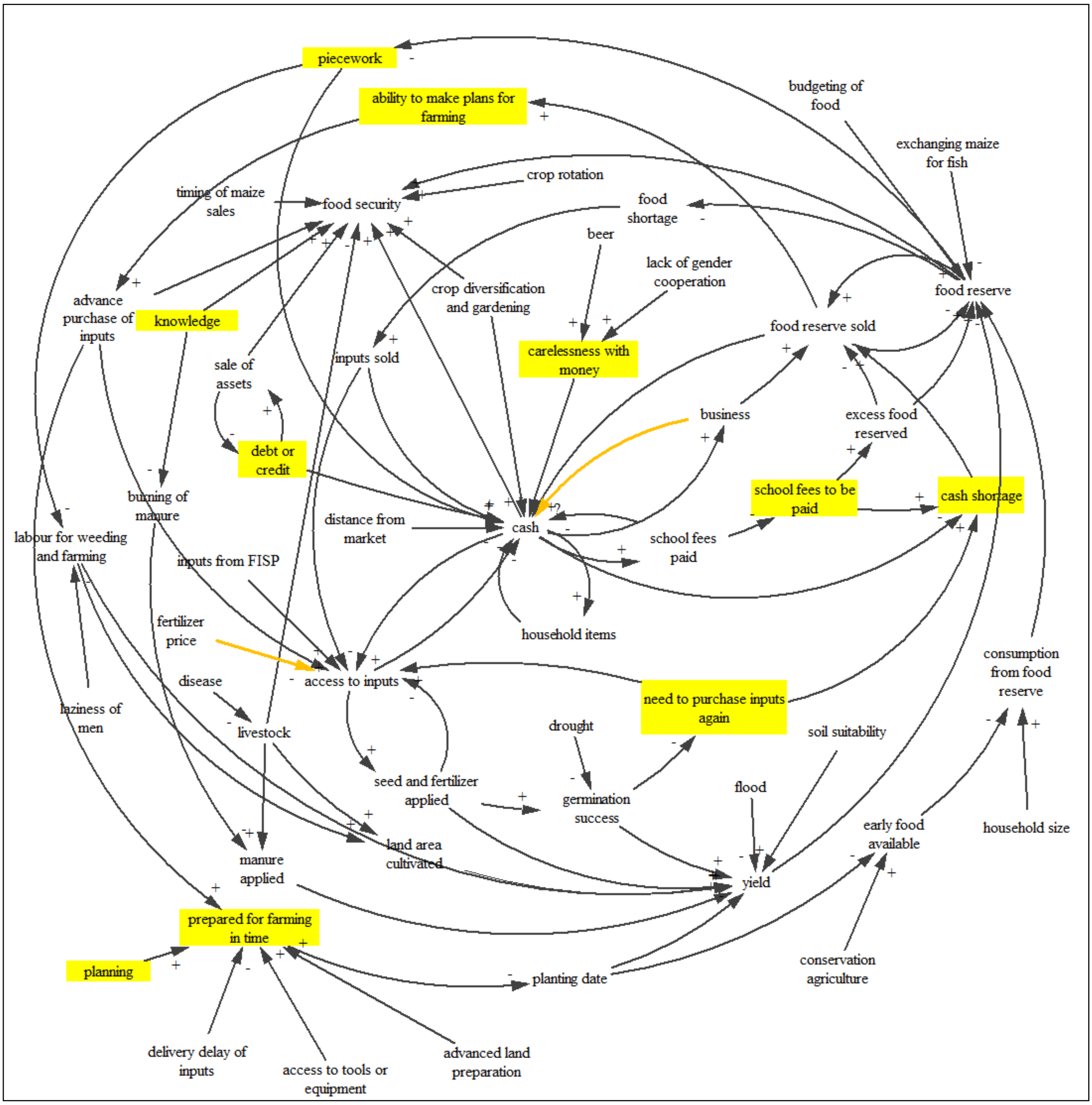

Figure 13 – Causal loop diagram generated by analysis of discussion of drivers of food security in a group interview

All causal structures in Figure 13 already exist in Figure 1 and Figure 3 (even if represented slightly differently), except for two: the effect of fertilizer price on access to inputs, and the willingness to sell inputs to obtain cash for food in times of food shortage. It is clear that the farmers understand the reinforcing loops in producing more from their crops, as well as the reinforcing piecework loop (where labour dedicated to someone else's farm takes away from one's own farm production and contributes to hunger the following year).

It is interesting to note from their discussion that timing of labour dedicated to piecework negates the negative effect of reduced labour for one's farming activities. An interesting discussion surrounded the effect of business on farming. Some described business as bringing in cash for inputs, while others said the cash for business could be lost. This discussion represents the risk in investing in business, which may or may not generate a profit.

The farmers' discussion surrounding the drivers of food security adds some depth of information to the variables in the causal map and supports some of the themes that emerged in Section 4.2. Risk and waste aversion are evident in the description of what drought can do to purchased inputs (farmers do not have the money to purchase the inputs again, leading to sale of the food reserve). The sale of purchased inputs is even mentioned as a method to combat hunger. Labour, livestock and equipment are mentioned as constraints for cultivated land and food production. Finally, school fees and the ability to care for money are major contributors to the cash stock.

Theoretical Sampling and Validation

***Expenditures and Savings*:**

As outlined in Section 3.3.2.3, a group of farmers is asked for a list of annual expenditures, which helps to illustrate what kinds of demands are placed on the cash stock that contributes to the reinforcing crop production loops in the food system. The list of expenditures generated in a group interview is as follows: Inputs, School fees, Livestock, Business, Medicine, Grinding mill fees, Clothes, Plow or Implements (purchase and hire), Hiring labour, Food, Donations to community (for example, for clinic service), Funerals and marriage, Traditional ceremony, Phone or talk time, Kitchenware or tools, Bicycle

When prompted to discuss savings methods, the farmers indicated that few people keep their money in the bank because of lack of knowledge. When dealing with a large sum of money, inputs are purchased first and then livestock. The remainder is kept in the house or is loaned with interest to friends. Normally cash is not kept for very long before being invested in programs. Cash is subject to destruction by pests as well as thieves. One farmer mentions that banks can actually give you interest, which conflicts with causal structures in the group mental model (in Figures 4 and 6) that indicate that banks reduce your savings. Some money is saved for illness and household purchases. Strongly related to savings is livestock, which are described as not increasing (except in diversity) because of diseases. Selling of livestock is described as a last resort.

When provided with the opportunity to spend a set amount of fake cash among several pre-determined categories of expenditures, individuals in two groups of farmers consistently prioritized spending on inputs, while other categories that consistently received a significant allocation of cash include food, household, livestock, farm tools, school fees, hiring labour and oxen. Given a large enough sum of cash, the farmers started to purchase larger livestock and equipment. At this stage the data can only analyzed qualitatively, an analysis that can be supported by farmers' reasoning as to why they allocated this amount of cash (Appendix B).

Land and Resource Allocation:

As outlined in Section 3.3.2.3, farmers are asked for a list of factors influencing the area under cultivation for their households, as well as the area allocated to maize production. The causal arguments are represented visually in Figure 14. The consensus of one of the groups interviewed is that the area under cultivation is increasing, even if agricultural output from these fields varies.

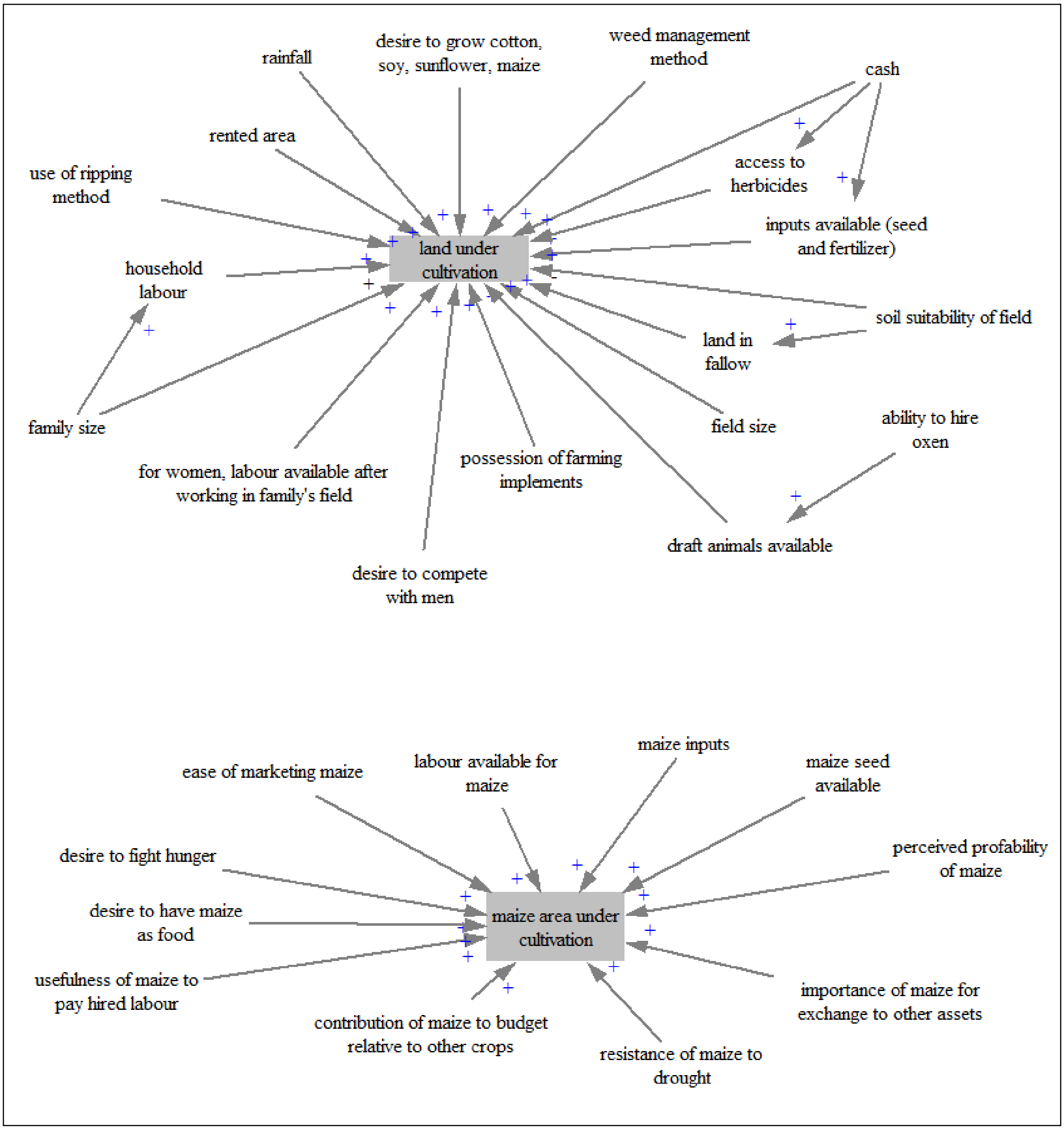

Figure 14 - Factors influencing total area under cultivation and area allocated to maize (from group interviews)

One group of farmers is also asked to generate a list of factors influencing the allocation of different inputs, including seed, fertilizer and manure. The causal arguments are represented visually in Figure 15 and Figure 16. Farmers describe a set of complex decision rules regarding fertilizer and hybrid seed application on fields of differing soil qualities. Risk management and aversion to wasting purchased inputs plays a role in determining where the purchased inputs are applied.

When discussing how inputs are allocated among the fields, the farmers identify the reinforcing loop of good harvest to inputs purchased to good harvest. Farmers describe the practice of applying inputs on fields where the germination percentage is high, which fits with the theme of risk and waste aversion.

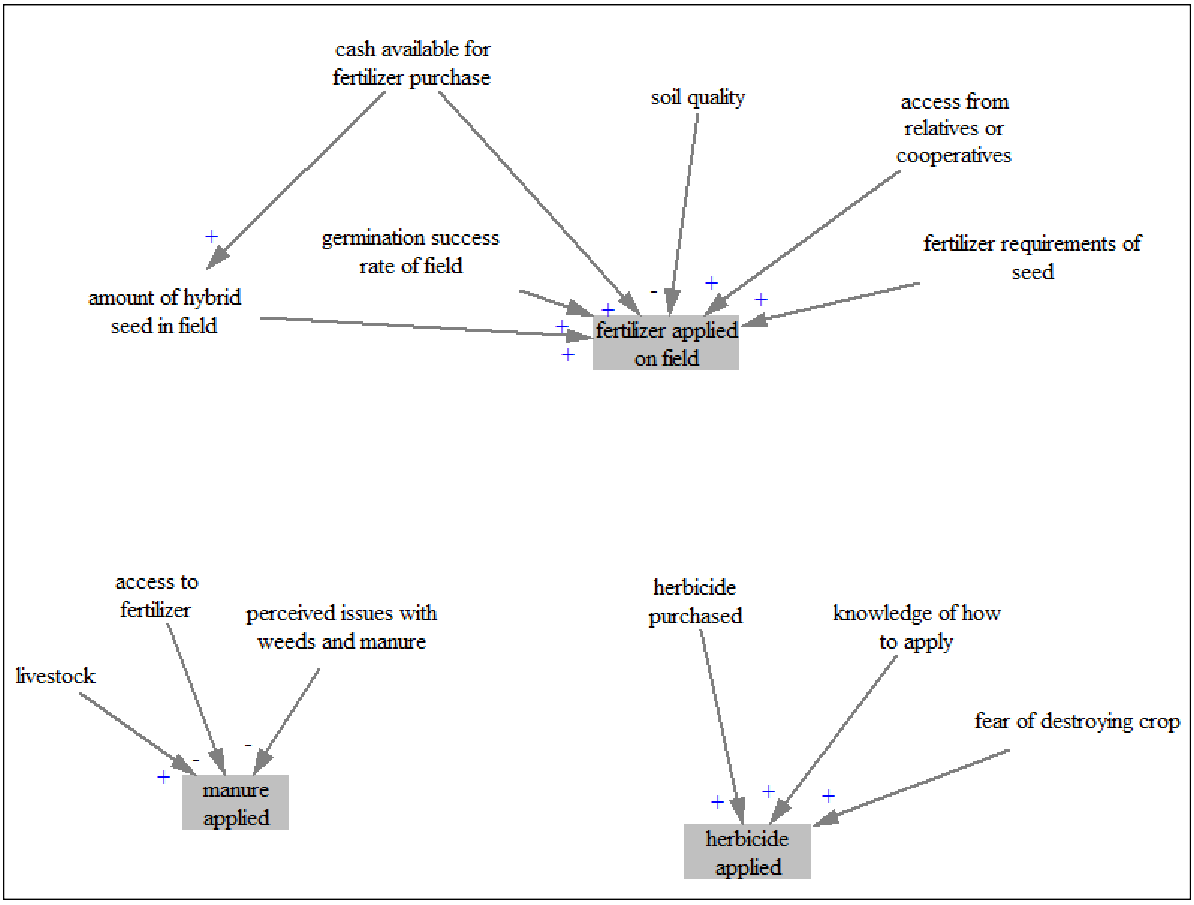

Figure 15 - Factors influencing fertilizer, manure and herbicide application (from group interviews)

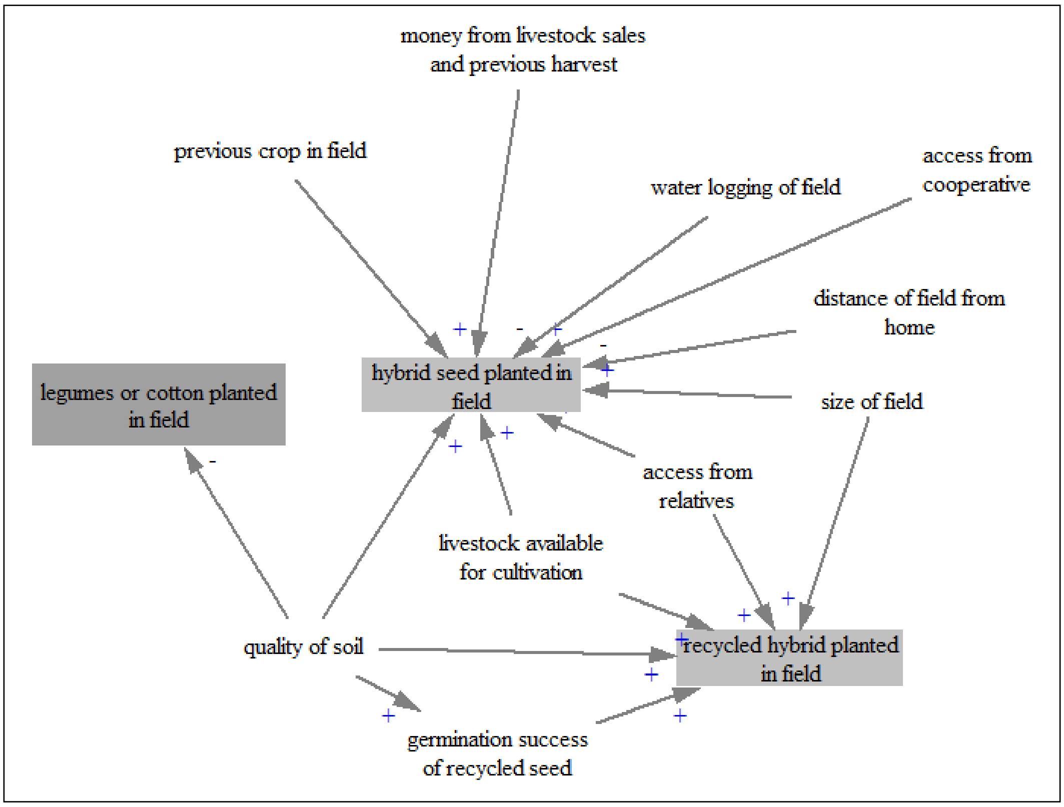

Figure 16 - Factors influencing hybrid, recycled hybrid, cotton and legume allocation to fields (from group interviews)