

ABSTRACT

WOOTEN, ELIZABETH KAYE. Modeling the Decisions of Malian Farmers as Climate Change Decreases Their Food Security. (Under the direction of Dr. Louie Rivers III.)

Food security in West Africa has become increasingly unstable in recent years. This instability threatens the capacities and developmental abilities of individuals, households, communities, and states. In Mali, a largely agrarian country, the risk of food insecurity is severe. One reason for this, which will be the focus of our project, is climate change. As the drier climate from the north shifts southward rainfall is becoming increasingly variable, and unpredictable. This is leading to yield decreases that are further increasing food insecurity in Mali. These decreases are having far reaching impacts that are altering how people live. This project has sought to better understand what these impacts are using mental model methodology. This method has allowed us to model how farmers are thinking about, and reacting to, their changing climate and the impacts it is having on how they live. Our models were developed by first conducting 41 open-ended interviews with farmers in the administrative circle of Koutiala, located in southern Mali. Questions asked during these interviews were determined by the participants age and sex so that they reflected the division of labor seen within this culture (Elder Males, Elder Women, Young Males, and Young Women). Interviews were then analyzed using qualitative coding which allowed for important concepts within the interviews to be tagged, and recurring themes to be identified. From here we determined seven “hubs” which were concepts or behaviors that were frequently mentioned by participants. These were then used to create the final models which were made for each of our four participant groups and their relationship to each hub for a total of 28 models. Once these were created we could identify the decisions that participants

were making as they adapted. The most prominent one being the choice by many younger people to migrate away from their rural villages to find better opportunities in urban centers. When this happens, there is a labor shortage that further harms agriculture as these farmers have little mechanized equipment. There is also a recurring problem with the large multigenerational families breaking up into smaller units to adapt to decreasing food security. When people leave, or families break apart, the social networks that these farmers have relied upon for support disappear hurting their ability to adapt. Another pattern of interest was that women found the most success in adapting by forming collectives that allowed them to pool money and power to better advocate for their needs. These findings show the importance of social networks in responding to climactic change, and it is recommended that further work focus on strengthening, or rebuilding, these networks as a method of adaptation.

© Copyright 2018 Elizabeth Kaye Wooten

All Rights Reserved

Modeling the Decisions of Malian Farmers as Climate Change Decreases Their Food
Security

by
Elizabeth Kaye Wooten

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Natural Resources

Raleigh, North Carolina

2018

APPROVED BY:

Dr. Louie Rivers III
Committee Chair

Dr. Jason Delborne

Dr. Barry Goldfarb

DEDICATION

To my family.

BIOGRAPHY

Elizabeth Kaye Wooten was born and raised in rural southeastern Guilford County. Growing up on her parents 17-acre property, Elizabeth spent most of her childhood playing outside and watching the local wildlife that frequented her backyard. This connection to nature eventually turned into a passion for protecting her home state of North Carolina's natural places, and wildlife. In high school, this passion led Elizabeth to become a volunteer at the Valerie H. Schindler Wildlife Rehabilitation Center at the North Carolina Zoo, a role she still holds today. It was here that Elizabeth interacted with members of the public who cared about protecting wildlife, and nature, but didn't have the know how to really make an impact. After completing a degree in Biology at UNC-Chapel Hill in December of 2015, she sought a graduate program where she could better understand how people interact with their environment. This led her to Dr. Louie Rivers, and in January of 2016 she began a Master of Science in Natural Resources. During her time there she completed a research project that modeled the decisions of subsistence farmers in the African nation of Mali as climate change decreased their food security. Elizabeth is currently seeking a career where she can work with people to help them better understand their environment and how they relate to it.

ACKNOWLEDGEMENTS

I would like to first thank my family for always supporting me no matter what. I am also grateful to Dr. Louie Rivers for giving me the opportunity to complete a Master's and, along with my committee members Dr. Jason Delborne and Dr. Barry Goldfarb, for providing me invaluable guidance along the way. In addition, I'd like to thank Dresden McGregor for helping code all my interviews, and Alexa Wood for patiently explaining NVivo to me. A huge thanks goes to Sarah Slover for being someone I can always count on to know my requirements and deadlines better than I do. And finally, a special thank you to my GWSG ladies for keeping me, at least somewhat, sane for the last two years, and for teaching me what true strength and resiliency are.

TABLE OF CONTENTS

LIST OF TABLES	vi
LIST OF FIGURES	vii
CHAPTER 1	1
Introduction	1
<i>Food Security</i>	1
<i>Climate Change in Dryland West Africa</i>	2
<i>Malian Agriculture</i>	2
<i>Malian Culture</i>	3
CHAPTER 2	6
1. Introduction	6
2. Background	7
3. Methodology	10
<i>3.1 Site Selection</i>	10
<i>3.2 Interviews</i>	12
<i>3.3 Analysis</i>	15
<i>3.4 Mental models</i>	17
<i>3.5 Model Development</i>	17
4. Results	24
<i>4.1 Elder Males and adaptive behaviors</i>	24
<i>4.2 Young Males and adaptive behaviors</i>	36
<i>4.3 Elder Women and adaptive behaviors</i>	45
<i>4.4 Young Women and adaptive behaviors</i>	54
5. Discussion	62
6. Conclusion	65
CHAPTER THREE	68
REFERENCES	71

LIST OF TABLES

Table 1	Overview of all figures included in the article.....	23
---------	--	----

LIST OF FIGURES

Figure 1.	Partial map of Africa, with Mali marked by a tag.....	11
Figure 2.	Map of the Sikasso region of Mali, with the Koutiala Cercle highlighted in orange.....	11
Figure 3.	Questions used in our interviews, broken down by age and gender.....	13
Figure 4.	A portion of our coding rubric highlighting the primary node of agriculture, secondary node of crops, and tertiary node of categories of crops.....	15
Figure 5.	A key for following the models presented in this article.....	19
Figure 6.	Food Security and its effects on the behaviors of Elder Women.....	22
Figure 7.	How rain problems caused by climate change are affecting the lives of Elder Males.....	26
Figure 8.	Elder Males' decisions and how they relate to Food Security; they are the only family members who can have a direct effect on food security.....	27
Figure 9.	The effects of non-rain related agricultural difficulties on the decisions of Elder Males.....	29
Figure 10.	The effects of farm labor shortages on Elder Males' behavior and decisions.....	30
Figure 11.	Elder Males' relationship to Alternative Income strategies. The more complex diagrams formed for Elder Males represent their greater power over decision-making.....	32
Figure 12.	Elder Males can face intergenerational conflict that stems from others' decisions as well as their own.....	34

Figure 13. Migration and how it affects the decisions that are made by Elder Males.....35

Figure 14. How agricultural difficulties can affect Young Men’s lives, and impact the decisions they make about their agriculture.....37

Figure 15. Young Men can make decisions that impact food security, however most of the important decisions are ones they make in consultation with the Elder Males who have final say on the matter.....38

Figure 16. Rain problems have significant effects on Young Men and their decisions related to agriculture. This is also the only hub that the farmers have no means to influence as it is caused by global warming.....39

Figure 17. Young Men can choose to migrate, as well as be affected by migration through labor shortages.....40

Figure 18. Many Young Men may choose to find alternative income strategies to support themselves and their families.....42

Figure 19. Young Men can create conflict by their decision to leave agriculture, but they also can face it when their own children choose to live different lifestyles...43

Figure 20. Young Men can create a labor shortage by leaving the farm, as well as be affected by it when they have less people to help them work the fields.....44

Figure 21. Alternative income strategies can positively impact the lives of Elder Women by allowing them to buy more food or garden items that will generate income.....46

Figure 22. Rain problems can affect Elder Women’s gardens, which can in turn impact their food security.....47

Figure 23.	Agricultural difficulties affect all family members, but women have chosen to address some of them using agricultural collectives.....	48
Figure 24.	Elder Women do not have a close relationship to migration, only feeling the effects it can have on the whole family. This is because they are unable to migrate due to greater commitments on the farm and within their families than younger members.....	49
Figure 25.	Elder women face conflict with younger generations when the latter leave farming to find better paying jobs, often un urban areas.....	51
Figure 26.	Elder Women don't create the labor shortage, but are impacted by its effects on agriculture and their gardening.....	52
Figure 27.	Young Women and their relationship to food security, through the decisions they make.....	54
Figure 28.	Young Women and how their decision to migrate affects them and their family.....	55
Figure 29.	How young women can contribute to a family's labor shortage.....	56
Figure 30.	Young Women's decisions to seek alternative incomes can have both positive and negative effects.....	57
Figure 31.	This model shows how young women's decisions lead to conflict with older generations.....	59
Figure 32.	How rain problems are affecting the decisions made by the Young Women.....	60
Figure 33.	How Young Women's behaviors can negatively impact family agriculture...	61

CHAPTER 1

Introduction

Food Security

According to the World Food Summit food security exists “when all people, at all times, have physical, and economic, access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (De Heaen et al. 2011). The lack of food security threatens the capacities and developmental abilities of individuals, households, communities, and states (Hussein 2002). On the continent of Africa, food security is highly precarious with 75% of countries classified as extreme or high risk for food insecurity (Verisk Maplecroft 2015). A significant risk factor is the pressure exerted by an expanding global population that is projected to reach nine billion by 2050 (Godfray et al. 2010). Other threats include a breakdown in social capital due to conflict, HIV/AIDS, political instability, and poverty (Misselhorn 2005). Competition over scarce water resources also increases the risk for rural areas, and international competition for grains elevates food prices beyond what small scale farmers can afford (Hanjra and Qureshi 2010; Brown and Funk 2008). In Mali, a country with many small-scale farmers, these factors are making life harder, and increasing the food insecurity risk of said farmers. Decreases in yields further exacerbate the risk to food security, reducing the amount of food farmers can produce for their families. Furthermore, this process forces farmers who already spend up to 70% of their limited income on food to buy more (Bocoum et. al 2014; Misselhorn 2005; Verisk Maplecroft 2013; Mayne 2006). Climate change is thought to be the reason behind the yield decreases Malian farmers are seeing, and this study will look at its effects on their lives via food security (Brown 2008).

Climate Change in Dryland West Africa

Climate change in West Africa poses a serious risk to the largely agrarian based economy (Butt et al. 2005). This is especially the case in Mali. The drier Sahelian climate found in the northern part of the country has been observed to be expanding into the less arid Sudanian region (Wittig et al. 2007; Sylla et al. 2016). These climatic shifts have brought more rainfall variability, warmer temperatures, higher winds, and increasingly unpredictable wet/dry seasons (Traore et al. 2013). In a region where agriculture is 93% rain-fed, variability in rainfall, and the onset of the wet season, are critical factors (Sultan et al. 2013). If farmers aren't sure of the start of the rainy season they don't know when to plant, and they could plant too early risking their crops drying out (Tschakert 2007; Traore et al. 2013). Once planted, the increasing unpredictability of the rainfall can lead to too little, or too much, rain, decreasing crop yields (Tschakert 2007). If their yields decrease, food prices will increase (Butt et al 2005). This significantly threatens farmers' food security, considering that they are subsistence producers that will have to buy more food if their yields are too low (Brown, Hintermann, and Higgins 2009). This creates a positive feedback loop of insecurity as they will have less to sell, but will need to buy more for food, even as prices increase due to limited supply. A cycle like this will be hard for the farmers to break.

Malian Agriculture

Malian agriculture mainly consists of subsistence farms, run by large extended families headed by the eldest male (Brown, Hintermann, and Higgins 2009; Wooten 2003). There is a large central field that is worked collectively, and the harvest is distributed amongst the whole family. The main field is typically worked by men to cultivate cereal

crops such as sorghum, millet, maize and rice. There are smaller fields controlled by women who grow the “condiment crops” such as vegetables and ground nuts that will be used as additives to food. In addition, there are smaller individual fields or gardens that family members can cultivate for their own use, or profit (Becker 1990; Wooten 2003). Cotton was a large cash crop until prices began to fall and the government owned Compagnie Malienne pour le Développement du Textile failed (Benjaminsen, Aune, and Sidibé 2010; Dougnon et al. 2010; Falconnier et al. 2015). After government controlled price increases and privatization of the CMDT, cotton prices have begun to recover. But as their market recovers, Mali is facing increased competition from other cotton exporting countries (Coulibaly et al. 2015). Cereal yields in recent years have not kept pace with population growth, but have been shown to improve via natural resource management as well as sustainable intensification¹ (Tappan and McGahuey 2007; Laris, Foltz, and Voorhees 2015). Even with these improvements food security remains precarious. These mostly poor subsistence farmer families will have to adapt in order to survive in the increasingly harsh climate. Ultimately this has the potential to lead to changes in the lives and traditions of the farmers as well as Mali as a whole.

Malian Culture

The lives of these farmers largely revolve around their agricultural operations with most of their time spent toward farm labor. They live in family groups consisting of multiple

¹ For further information on sustainable intensification of agriculture see: Tilman, David, Christian Balzer, Jason Hill, and Belinda L. Befort. "Global food demand and the sustainable intensification of agriculture." *Proceedings of the National Academy of Sciences* 108, no. 50 (2011): 20260-20264.

Harvard

generations, headed by the eldest male (Solivetti 1994). The country is 92% Muslim with many citizens practicing polygamy (Sommerfelt, Hatløy, and Jesnes 2015; Madhavan 2002). This is advantageous for farming as it allows for more children to be born, and provides more labor on the farm (Solivetti 1994). Marriages traditionally have been arranged by family elders, and a bridewealth paid to the bride's family (typically in the form of money, labor, and/or animals). The marriage process has historically been a long complex procedure of negotiation formalized by a village ceremony (Hertrich and Lesclingand 2012). Once married a wife's relationship with her co-wives can vary widely from friendship to one of competition and jealousy based on cultural norms (Madhavan 2002). Traditionally, women in Malian culture have widely been considered subordinate to men, and are often not seen as a part of the husband's family (Akeredolu, Asinobi, and Ilesanmi 2007). While 45% of Malian women are in a plural marriage the number of polygamous unions is decreasing. Today it is uncommon to find a man with more than two wives whereas traditionally men have followed the Quranic guidelines of marrying four wives. This shift is due to the increasing costs of supporting so many women and their children (Madhavan 2002; Bledsoe 1990).

Due to the increased cost of supporting multiple wives some polygamous men have created a hierarchy among them. It is based on variables such as their social status and education levels with lower ranking wives receiving little or no support from the husband even if she has children. A number of men are also turning towards informal unions with girlfriends and mistresses especially in Mali's urban areas (Bledsoe 1990). Another change marriage in Mali is seeing is the increasing age at which the first marriage occurs. When

interviewed, village elders blamed this on increasing temporary migration of teenage girls to the cities for work. While this plays a role in the changes, it is part of an overall shift in marriage norms. Part of this alteration includes a shortening of the complex marriage process, as well as changes in what is included in the bridewealth (Hertrich and Lescligand 2012).

Another significant change in Malian culture is religion, and its role in government. While Mali is 92% Muslim, their government is technically a secular state, following the precedent set by the French during colonial rule. However, religiosity in Mali is growing, and Islam is becoming more prevalent in public spaces (Sommerfelt, Hatløy, and Jesnes 2015). In the northern part of the country fundamentalist Islam has grown and led to a call for the return to a “pure” practice of Islam based on the scriptures. Many of those calling for this want a government based on Sharia Law (Thurston 2013). In 2012-2013 Islamists frustrated by governmental neglect led a separatist rebellion that was eventually suppressed. While they made no lasting gains it did bring the discussion of Islam’s place in government to the forefront, and opened a door for possible broad references to Islamic law in future policy and constitutions. This is due to the fact that even though politicians believe in a secular state they are increasingly influenced by religious leaders who act as powerful lobbyists on behalf of Muslim citizens (Sommerfelt, Hatløy, and Jesnes 2015; Thurston 2013).

The information presented in this section was used to create the coding rubric that ultimately guided the research process moving forward. In the next chapter of this thesis the literature review is a condensed version of the information that has been presented here.

CHAPTER 2

Modeling the Decisions of Malian Farmers as Climate Change Decreases Their Food Security

1. Introduction

Food security is defined by the World Food Summit as “existing when all people, at all times, have physical, and economic, access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (De Haen, Klasen, and Qaim; 2011). Food *insecurity* threatens the capacities, and developmental abilities, of individuals, households, communities, and states (Hussein, 2002). In many parts of Africa, food security is a volatile proposition, with 75% of countries classified as extreme, or high risk, for food insecurity (Verisk Maplecroft, 2013). There are several reasons for the high risk, including increasing population pressure, conflict, HIV/AIDS, political instability, poverty, and climate change (Godfrey et. al, 2010; Misselhorn, 2005). Climate change’s main effect on food security is through its altering of traditional rain patterns, which is leading to agricultural yield decreases, a serious concern for areas that are reliant on rain fed agriculture (Sultan et. al, 2013; Butt et. al, 2005). In one such region, dryland West Africa, food security is already precarious, with many nations in this region, including Mali, classified as high risk for food insecurity (Verisk Maplecroft, 2013). In the Sikasso district of southeastern Mali, the research site for this study, subsistence farmers are already feeling the effects of climate change via its impacts on their rain-fed agricultural operations. They have seen yield decreases leading to lower amounts of food, as well as less income, both of which are forcing the need to adapt. Previous research has shown that farmers in remote

areas such as these understand that the climate is changing and are working to adapt to changing conditions (Dunlap, 1998; Mertz et. al, 2000). Our project will model the decisions Malian farmers are making as they undergo these adaptations. This will be done using mental model methodologies to develop influence diagrams that outline their decisions, and how different external factors affect their decision process, as well as how their decisions subsequently affect these factors. These models have been developed using in-depth open-ended qualitative interviews with farmers in the region as a source of data. The interviews were analyzed using qualitative coding techniques guided by a coding rubric. The rubric was informed by information drawn from primary literature on topics including food security, culture, agriculture, and climate change in Mali.

2. Background

In West Africa, and more specifically Mali, it has been found that climate change is already having significant impacts on agriculture (Butt et. al, 2005). The Sahelian climate found in the northern part of the country is expanding southward into the less arid Sudanian region, where the farmers that participated in this project reside (Wittig et. al, 2007; Sylla et. al, 2016). This shift has brought more rainfall variability, warmer temperatures, higher winds, and increasingly unpredictable wet/dry seasons (Traore et. al, 2013). The central impact for farmers in the Sikasso district has been increases in rainfall variability, specifically the pattern and start date of the rainy season is considerably less predictable than in the past. Because of this unpredictability, farmers are facing new problems: such as planting when the rains start only to have them stop, leading to crops drying out; too much

rain falling at once and subsequent flooding of fields; long periods of drought during the rainy season that often leads to crop failure or various combinations of all three causing decreased yields and increased food insecurity (Butt et. al, 2005; Brown, Hintermann, and Higgins, 2005). These effects are amplified due to the regions reliance on rain-fed agriculture (Tschakert, 2007; Traore et. al, 2013; Sultan et. al, 2013).

In this region of southern Mali, the agriculture is largely subsistence farming (Brown, Hintermann, and Higgins, 2009; Wooten, 2003). Most of a family's arable land goes to their large central field that they work together to grow cereals (millet, maize, sorghum, etc.) that are shared amongst the entire family. There are also small fields where women grow the condiment crops (i.e. peanuts, vegetables, groundnuts) that will be used as additives to food. Some individuals maintain gardens that they cultivate for their own use or profit (Becker, 1990; Wooten, 2003). Cereal yields in recent years have not kept pace with population growth, but have been shown to improve through natural resource management as well as sustainable intensification, a process in which there is a "moderate intensification focused on existing croplands of underyielding nations" using technologies from high-yield areas² (Tappan and McGahuey, 2007; Laris, Foltz, and Voorhees, 2015). This could eliminate the need in many areas for clearing increasing amounts of land to meet growing food needs by focusing efforts on making already cleared areas more productive. Cotton was a large cash crop until prices began to fall, and the government run Compagnie Malienne pour le Développement du textile (CMDT) company failed (Benjaminsen, Aune and Sidibé, 2010; Isaïe et. al, 2010; Falconnier et. al, 2015). While cotton is still popular, most farmers, and

² For further information on sustainable intensification of agriculture see: Tilman, David, Balzer, C., Hill, J., and Befort, B.L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences* 108(50). 20260-20264.

almost all who participated in our interviews, carry out some type of cereal based farming as the primary source of food for their family.

These farmers' lives revolve largely around their farms where they live in often-large family groups consisting of multiple generations, headed by the eldest male -whether a father or brother (Solvetti 1994; Mercy, Asinobi and Ilesanmi 2007). The older males in the family unit make most of the decisions regarding farming and food consumption, and the women are considered subordinate to the men (Tone, Hatløy and Jesnes, 2015). The families tend to be large due to polygamous practices stemming from a traditional Muslim faith (Tone, Hatløy, and Jesnes, 2015; Madhavan, 2002). Polygamy can be advantageous for farm families as it provides more labor, and allows for more children to be born (Solvetti, 1994). The couple's family elders traditionally have arranged marriages, and a bride wealth paid to the bride's family (typically in the form of money, labor, and/or animals). Once married, a wife's relationship with her co-wives can vary widely from friendship to one of competition, and jealousy, based on cultural norms (Madhavan, 2002). While 45% of women in Mali are in a plural marriage, the number of polygamous unions is decreasing. Today it is uncommon to find a man with more than two wives, whereas traditionally families have followed the Quranic guideline of four wives. This shift is due in part to the increasing cost of supporting multiple wives and their children (Madhavan, 2002; Bledsoe, 1990).

One factor in the rising costs is the decrease in agricultural outputs. All the families in our research rely on their farming for most, if not all, of their food. With yield decreases due to climate change, it is becoming harder to feed large polygamous families. Therefore, these large multigenerational families are decreasing in size, and splitting into smaller units.

This is an example of how climate change is having impacts beyond weather patterns; it is affecting people and how they live their lives. This research project has looked at how climate change is affecting people by modeling the decisions they are making as it decreases their food security. This was done using mental model methodology to create influence diagrams that will serve as models of our subjects' decision-making processes.

3. Methodology

3.1 Site Selection

The first step in creating these models was to conduct interviews with relevant subjects. These interviews took place in the Koutiala Cercle of Mali, an administrative region within the Sikasso district of southern Mali during May/June of 2015. It has a population of approximately 575,000 people, and covers an area of 3370 mi². This region was selected due to its location within a region known to have precarious food security that is already encountering significant impacts from climate change. It was also chosen due its resident's limited access to the resources needed to effectively address these impacts, allowing insight to be provided on how climate change is impacting vulnerable populations in other parts of the world facing similar conditions.



Figure 1. Partial map of Africa, with Mali marked by a tag.

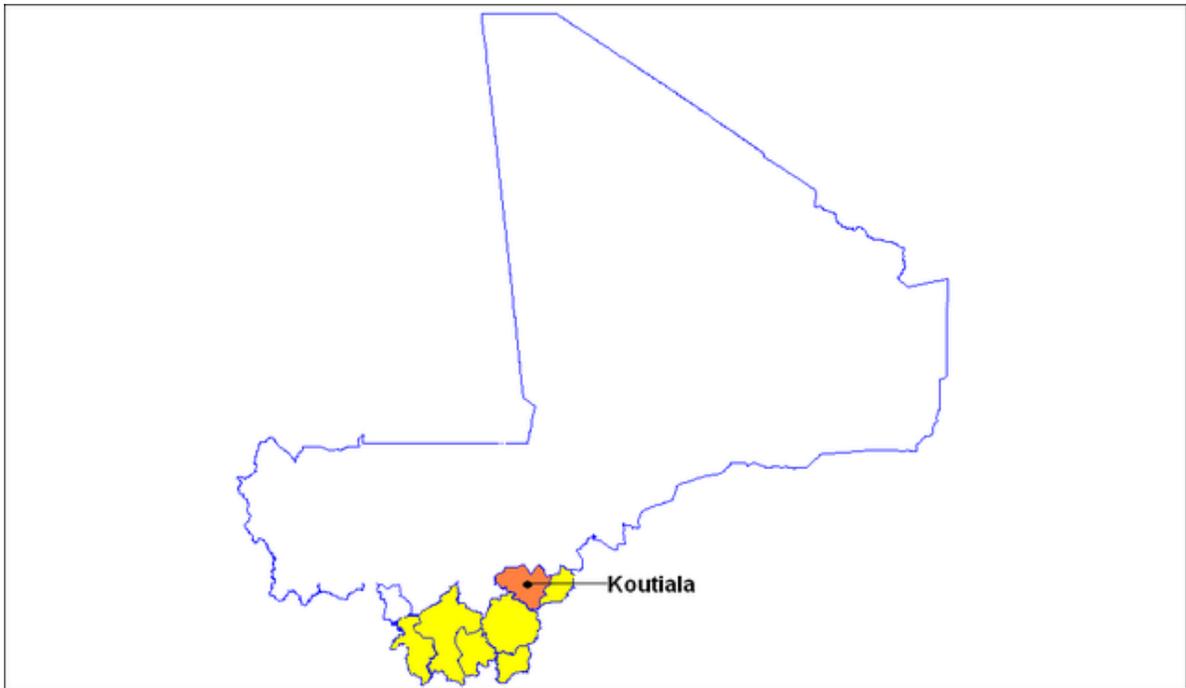


Figure 2. Map of the Sikasso region of Mali, with the Koutiala Cercle highlighted in orange.

3.2 Interviews

The interviews used for this research are focused on the general topic of food security. They were conducted using open-ended questions allowing for subjects to speak widely about food security allowing for a broader scope than a survey or close-ended interview methodology. Interviewees were sorted into four groups -Elder Males, Elder Females, Young Males, and Young Women- with each group having their own set of unique questions (Figure 3). Different questions were asked to each group in reflection of how gender and age shape roles and responsibilities within the family, and on the farm. Questions covered topics that included farming, food, family, and changes within all three spheres of activity. Interviews were conducted in the respondents native Bambara, then translated to French, and finally to English, with each interview transcript ranging from .5 page to 2 pages. In total, 41 individuals were interviewed in seven different villages, all located within 50km of the city of Koutiala to ensure that there would be similarity between subjects geographic and cultural context.

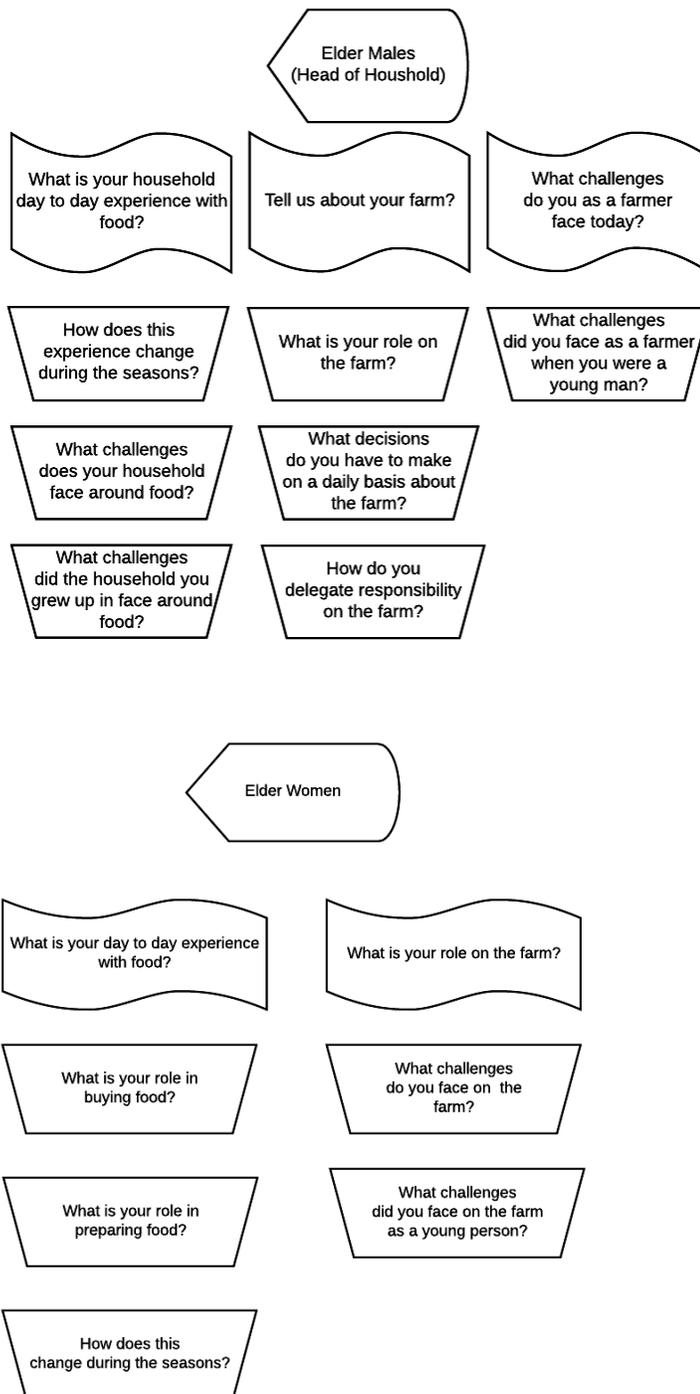


Figure 3. Questions used in our interviews, broken down by age and gender.

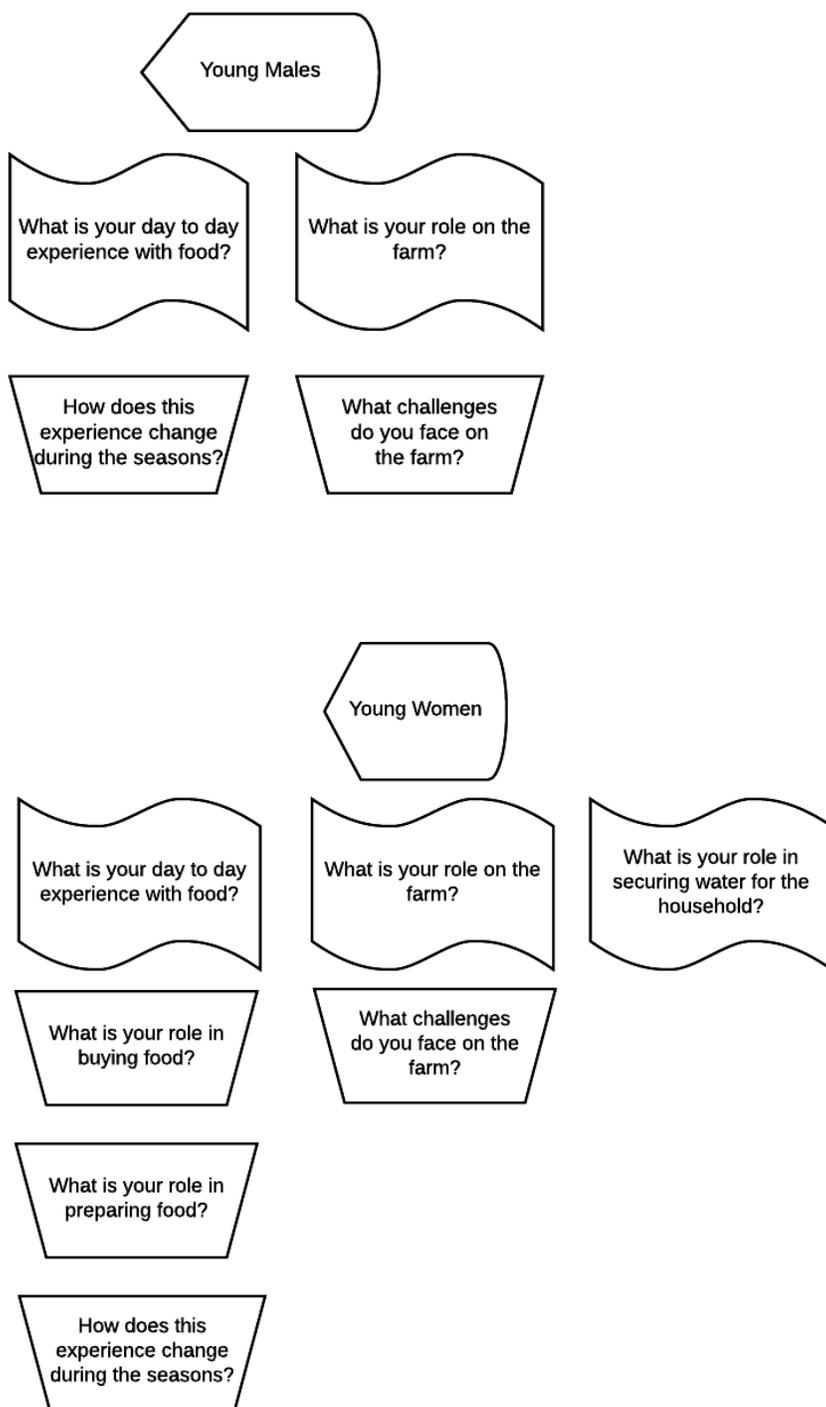


Figure 3 (Continued). Questions used in our interviews, broken down by age and gender.

3.3 Analysis

Interviews were analyzed using the software NVivo, through a process known as qualitative coding that allows a person to sort qualitative data (in our case interviews with farmers) based on a predetermined rubric. We developed our rubric from an extensive literature review on farming, culture, food security, and family life in Mali (see Introduction). This rubric consisted of primary nodes then secondary and tertiary nodes that are subsets of the primary node. An example of this structure would be the primary node of Agriculture which is linked to the secondary node of Crops (a subset of the concept of agriculture) that then connects to tertiary nodes labelled Cotton, Cereals, and Condiments which are the main crops grown by these families (see Figure 4).

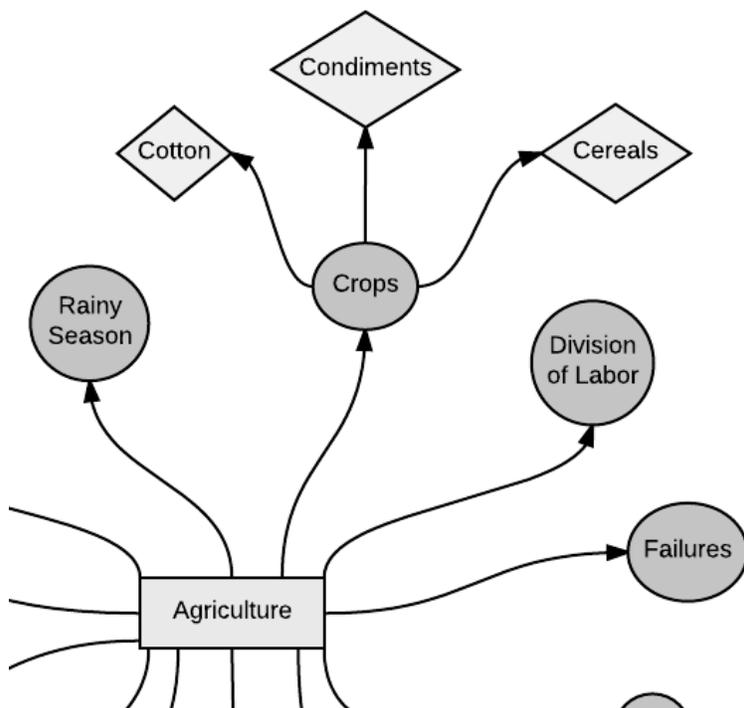


Figure 4. A portion of our coding rubric highlighting the primary node of agriculture, secondary node of crops, and tertiary node of categories of crops.

After the rubric was created and entered into NVivo, all 41 interviews were uploaded in the program. Two separate coders then closely read the interviews and when information arose that displayed a concept covered by a node in the rubric it was tagged using the software. Two coders were used to control for personal bias, and intercoder reliability was calculated to see what level of agreement there was between the two. The higher the agreement, the lower the influence of personal bias there is in the results. Agreement was calculated by first using NVivo to merge the separately coded interviews. Then for each node, in each interview, a percent agreement was calculated based on overlap between the coder A and coder B. For example, in an interview with a Young Man, the percent of the text (based on number characters) coded as agriculture in the same spots by both coders was 6.97% (Known as % A and B). The amount of the interview not coded as agriculture by both coders was 52.17% (known as % Not A and Not B). If a node was not coded, then it's percent agreements were not included. The two percent agreements calculated here were then summed to create a total percent agreement. This was repeated for every node that was coded at least once an interview, for every interview. Finally, all the total percent agreements were averaged for an average percent agreement of 94.7%. This number represent little influence on the results from personal bias of the coders.

After all interviews were analyzed and percent agreement calculated, we went through each node in the rubric to discern how these concepts were playing out in farmers' lives as well as to see if there were any noticeable trends related to them. For example, under the node for alternative income strategies many of the Elder Women discussed growing gardens, and how these gardens supplemented their families' diets either directly or

indirectly by providing income to buy foodstuffs. These patterns were eventually translated into models of behavior and decision-making.

3.4 Mental Models

The mental models presented in this study were created as influence diagrams based on mental model methodology in the program Lucid Chart. Philosopher Charles Sanders Peirce first proposed the idea that our minds make models in 1896 when he stated that a person:

“examines the state of things asserted in the premises, forms a diagram of that state of things, perceives in the parts of the diagram relations not explicitly mentioned in the premises, satisfies itself by mental experiments upon the diagram that these relations would always subsist, or at least would do so in a certain proportion of cases, and concludes their necessary, or probable, truth.”

This idea was then adapted by cognitive scientists to become the concept of mental models. These scientists believe that our mind “constructs mental models as a result of perception, imagination and knowledge, and the comprehension of discourse.” Meaning that mental models represent our minds reaction to a situation: what we know about a situation from previous knowledge, and how we believe we should react to the situation in question. By using this methodology, we could examine how interviewees thought about and responded to different concepts found within the coding rubric.

3.5 Model Development

The models we created using this methodology started out as one large influence diagram that connected all the concepts introduced in the interviews through the coding rubric. This however the complexity of this model obscured any insights that could be drawn from the research, thus, it was separated in smaller, clearer models. In the large diagram, several hubs were identified (alternative income strategies, food security, migration, labor shortages, intergenerational conflict, rain problems, and non-rain related agricultural difficulties) based on the number of connections they had with other concepts in the diagram. From here, we created influence diagram models that showed each subset of the family's (Elder Males, Elder Women, Young Males, and Young Women) behaviors/decisions and how our "hubs" affected them- for a key all models in this article see **Figure 5**.

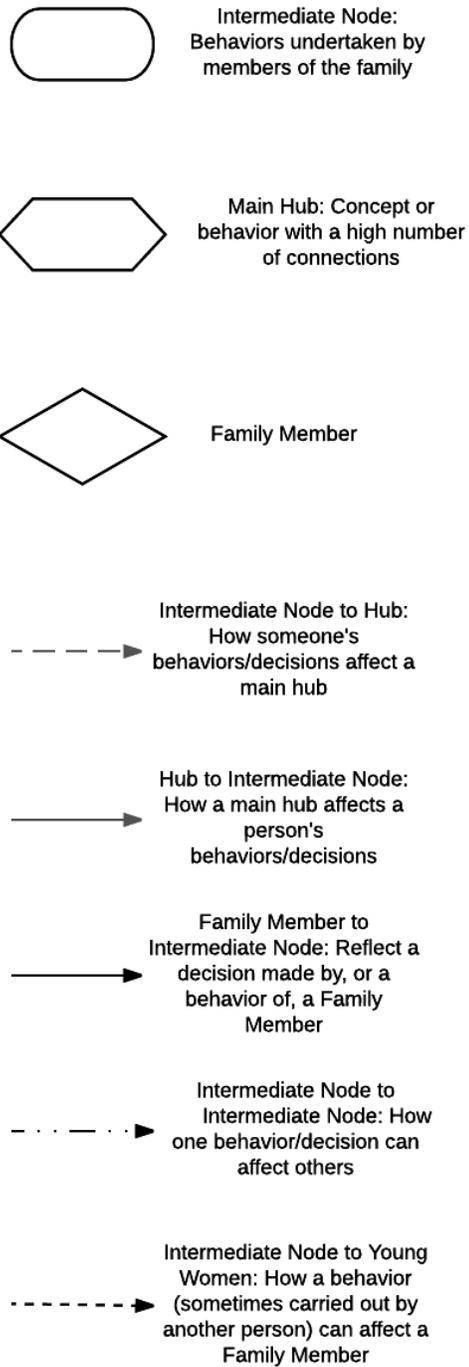


Figure 5. A key for following the models presented in this article

An example of this process is the creation of the model showing how Elder Women's decisions relate to food security, specifically how gardening affects food security (Figure 6). The first step in this creation was to determine what decisions/behaviors Elder Women have direct control over. These were use of wells, prioritizing child nutrition, gardening, food preparation, decreasing food allocations, buying food, and joining agricultural collectives. We discerned these from the interviews by looking at which nodes (or concepts) were repeatedly mentioned in interviews with Elder Women, and what information within these nodes discussed was a task directly controlled by elder women.

One such quote that was used is the following from an elder woman that was coded under the node *food security*: "I do the gardening and when I sell my harvest, I divide the money into two and I contribute one half to the purchase of cereal." While this is not specifically tagged as gardening (as there was no node for gardening), it shows that elder women are planting gardens, and that this has an effect on food security. In addition to this quote, there were multiple interviews where elder women mentioned their gardening efforts, and linked it to either producing more food, or generating income for them to buy more food. Altogether, this led us to conclude that elder women were (1) gardening and (2) it was providing a cash income (3) that was positively influencing their personal and their families' food security. This relationship is represented in Figure ## by the arrow that exits the Elder Women bubble, goes into the *gardening* bubble (reflecting their decision to garden), and then exits this bubble as a dashed line and travels to *food security*. The node for *buying food* also connects to the food security bubble, and has an arrow entering it from *gardening*. This part of the diagram reflects the influence *gardening* has on the ability to *buy food* and how both

can positively affect *food security*. It also shows that as food security decreases the need to buy food increases because subsistence farming is not able to cover the families' dietary needs. The previous quote was also coded for *alternative income strategies* as her gardening, as well as many other elder women's gardening efforts, provides cash for the family to buy additional food, in this case cereals. This part of the coding is represented in the model by the arrows that exit *gardening*, *Elder Women*, and *food security* and connect to *alternative income strategies* node that then *connects to buying food*. A similar process was used to create all remaining models.

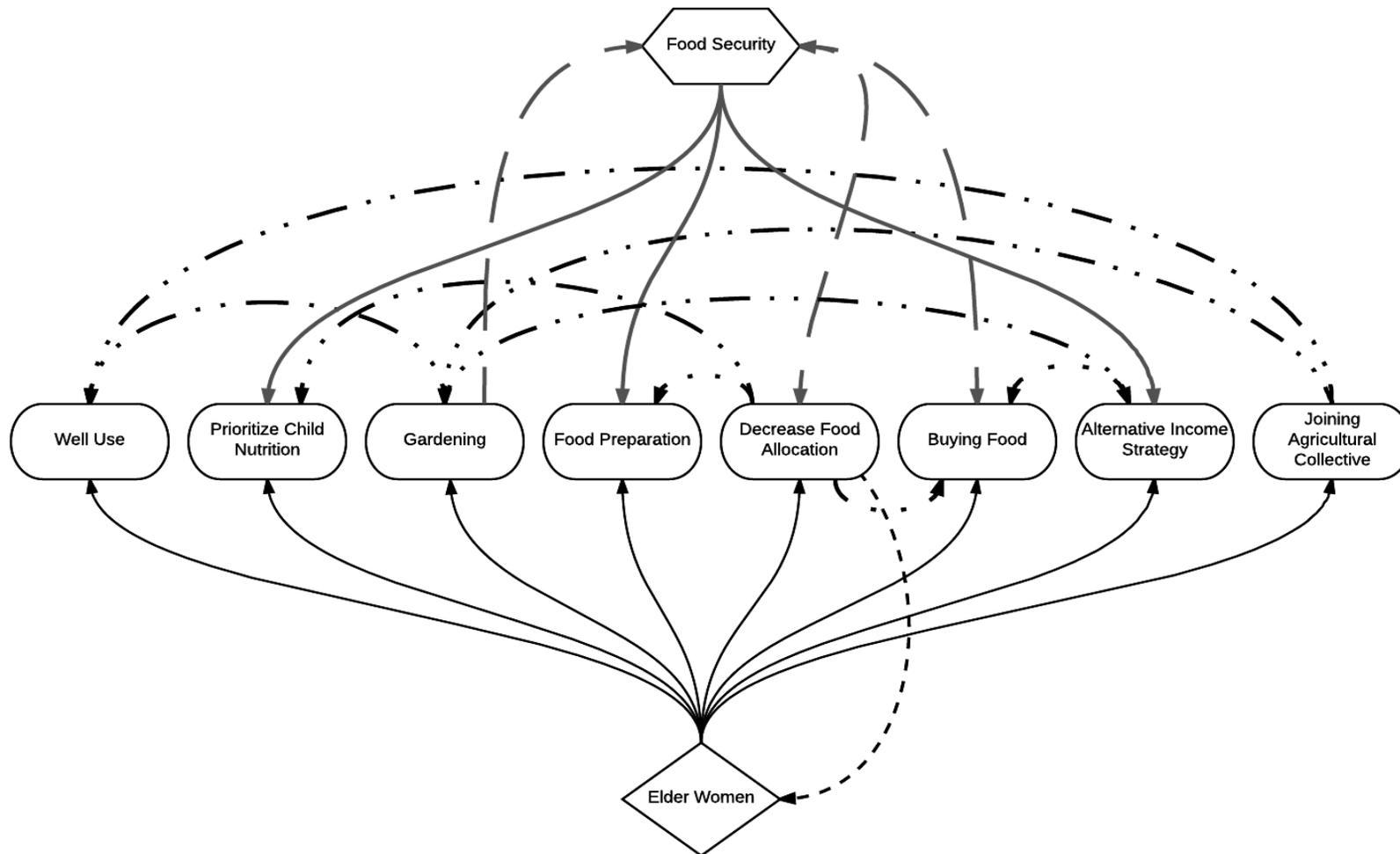


Figure 6. Food Security and its effects on the behaviors of Elder Women.

Article Figures Guide		
Figure No.	Section	Description
1	3.1	Map of Africa with Mali featured
2	3.1	Map of Mali with the Koutiala Cercle and the Sikasso region highlighted
3	3.2	Interview Questions
4	3.3	Example of three levels of nodes
5	3.5/4.3	Key for influence diagram models
6	4.4	Young Women and Food Security
7	4.1	Elder Males and Rain Problems
8	4.1	Elder Males and Food Security
9	4.1	Elder Males and non-Rain related Agricultural Difficulties
10	4.1	Elder Males and Labor Shortages
11	4.1	Elder Males and Alternative Income Strategies
12	4.1	Elder Males and Intergenerational Conflict
13	4.1	Elder Males and Migration
14	4.2	Young Males and non-Rain related Agricultural Difficulties
15	4.2	Young Males and Food Security
16	4.2	Young Males and Rain Problems
17	4.2	Young Males and Migration
18	4.2	Young Males and Alternative Income Strategies
29	4.2	Young Males and Intergenerational Conflict
20	4.2	Young Males and Labor Shortages
21	4.3	Elder Women and Alternative Income Strategies
22	4.3	Elder Women and Rain Problems
23	4.3	Elder Women and non-Rain related Agricultural Difficulties
24	4.3	Elder Women and Migration
25	4.3	Elder Women and Intergenerational Conflict
26	4.3	Elder Women and Labor Shortages
27	4.4	Young Women and Food Security
28	4.4	Young Women and Migration
29	4.4	Young Women and Labor Shortages
30	4.4	Young Women and Alternative Income Strategies
31	4.4	Young Women and Intergenerational Conflict
32	4.4	Young Women and Rain Problems
33	4.4	Young Women and non-Rain related Agricultural Difficulties

Table 1. Guide for figures in article.

4. Results

In the next section, we present the models focused on Elder men and Young Women and their behavior as representatives of the larger family³. The first section focuses on Elder Males who are the main decision makers within the family as they are the heads of the large family unit. This is followed by Young Males who tend to be the sons and grandsons of the Elder Males. The third section focuses on Elder Women who tend to be the wives of the Elder Males, they have power within the family especially over the domestic sphere. The final section focuses on Young Women who are at the opposite end of the decision-making spectrum from Elder Males in terms of scope and influence. They have little to no power over household level decision making, as well as very few resources that they directly control. This makes their ability to adapt to decreasing food security, as well as climate change, limited when compared to other household members, suggesting that they maybe a group uniquely suited for targeted intervention.

4.1 Elder Males and adaptive behavior

Within each model there is first the Elder Male, then their behavior, followed by one of the central hubs. The arrows connecting the different parts of the model show how the Elder Male's behavior affects the main hub either directly or indirectly, as well as how their behaviors affect other behaviors within the model. One of the most important models we constructed was that of Elder Males and "Rain Problems" (Figure 7). Changes in rains are linked to climate change, and are having a significant impact on farmers' rain fed agriculture.

³ For a key to how these models are laid out see Figure 5

These changes are affecting when these men choose to plant (as this is typically determined by the start of the rainy season), what they plant, and how much they plant. The effect of climate change on rain, as mentioned earlier, are leading to yield decreases which is causing an increase in food insecurity in an already vulnerable region of the world. The effects on food security, as seen in our models, are far reaching (Figure 8), as food security is connected to many other nodes within the model, showing how it weighs heavily on the decisions that the heads of household must make.

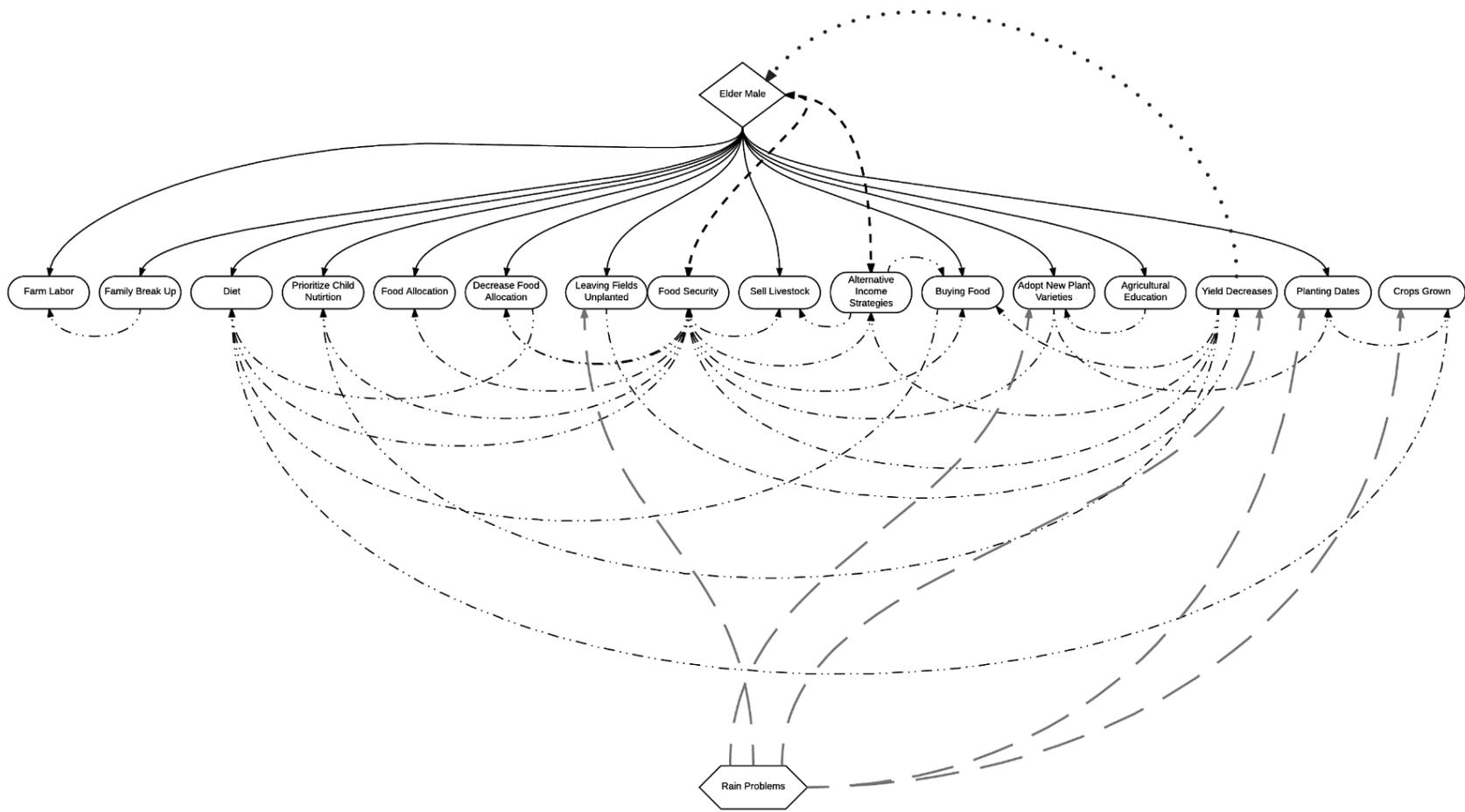


Figure 7. How rain problems caused by climate change are affecting the lives of Elder Males

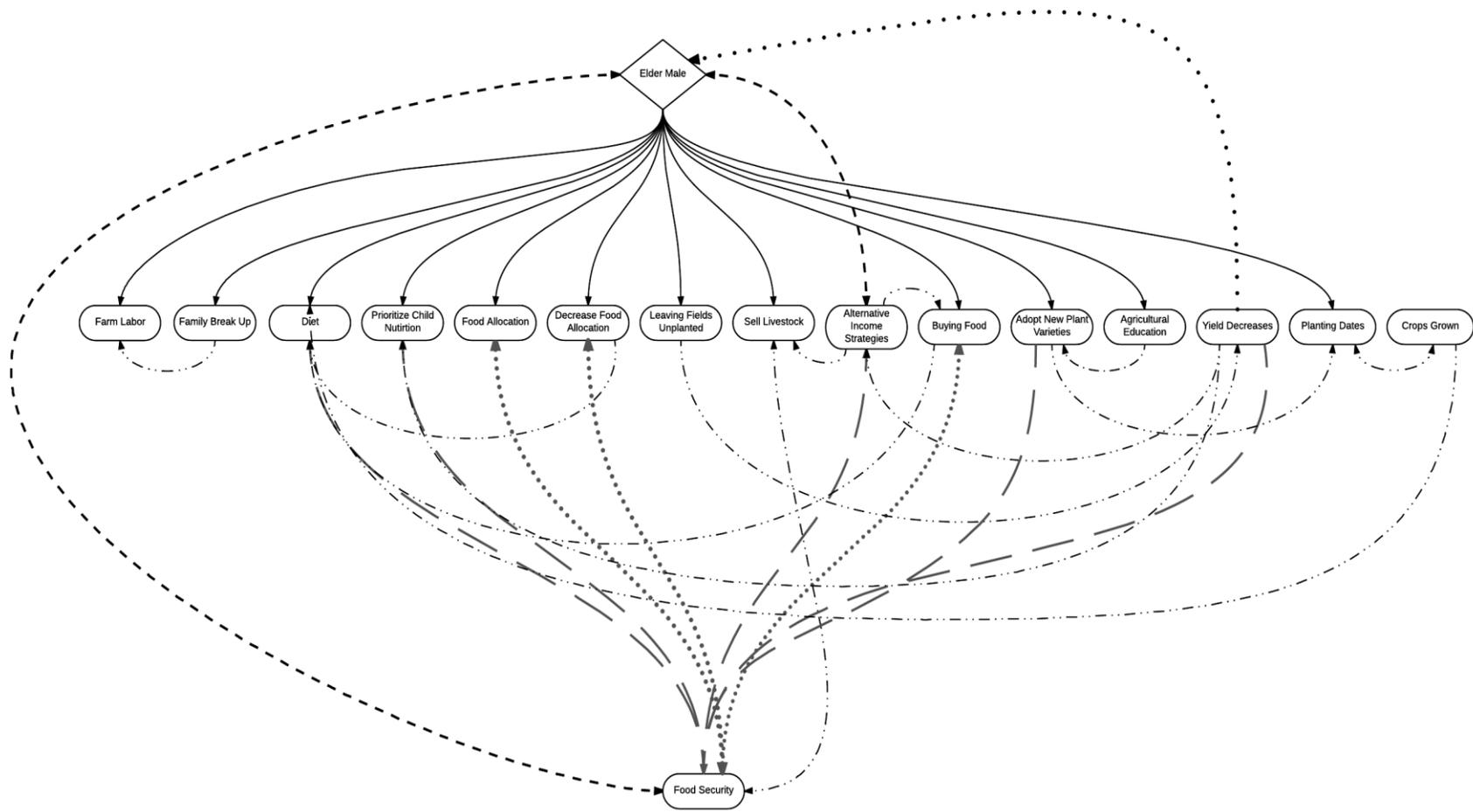


Figure 8. Elder Males' decisions and how they relate to Food Security; they are the only family members who can have a direct effect on food security.

The elder males' mental model on food security is the most complex as they are the family member with the largest amount of control over decisions that directly affect the food security of the entire family. Elder men control decisions over food allocation, what crops are grown and how much is planted, selling livestock, adopting new plant varieties, and even whether the multigenerational family unit will stay together or split up into smaller factions. Some of these decisions are not beneficial to overall food security, but are the results of dire circumstances. For instance, the decision to not plant due to a lack of fertilizer, labor, or other equipment/resources needed for agriculture. They often lack the proper resources for agriculture because they have little cash which is needed to purchase fertilizer, seeds, equipment (Figure 9). Labor deficiencies can arise when young people choose to pursue work outside of agriculture. Many times, this work causes them to move to other cities (see Figure 10). As seen in the model for non-rain related agricultural difficulties, these problems often lead to decreased yields, and by extension decreased food security.

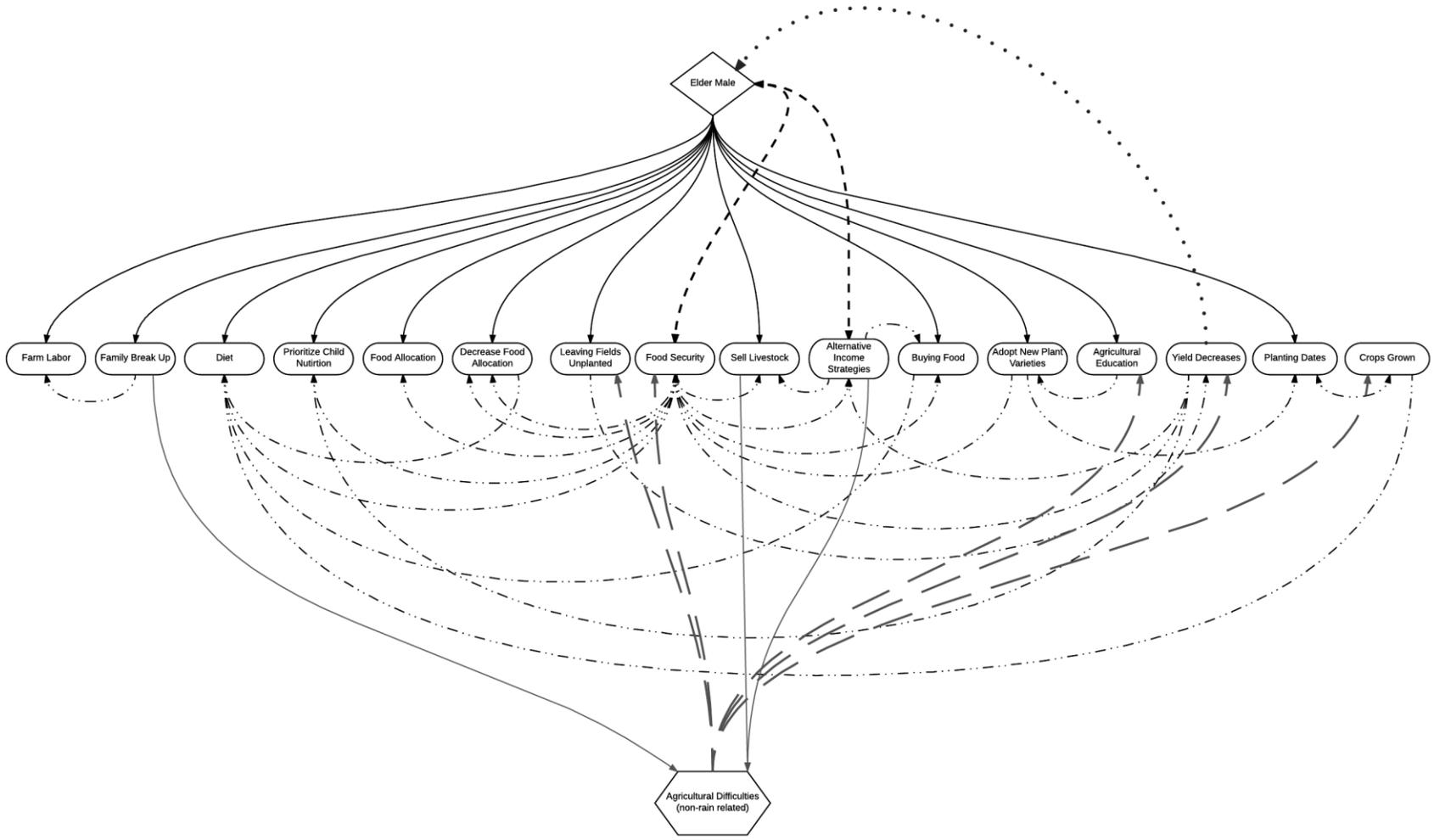


Figure 9. The effects of non-rain related agricultural difficulties on the decisions of Elder Males.

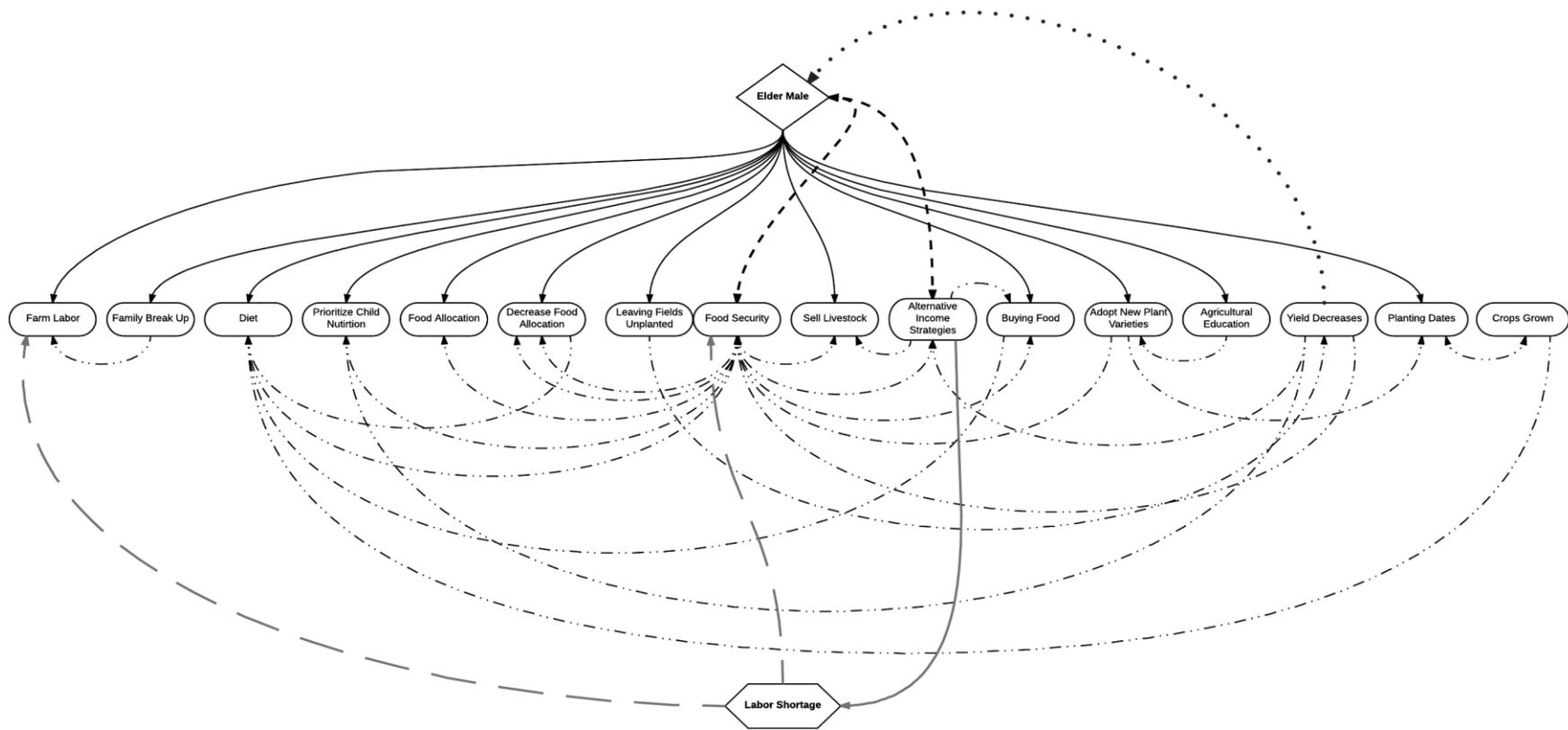


Figure 10. The effects of farm labor shortages on Elder Males' behavior and decisions.

This decrease in food security and the increased necessity for inputs has led to an even greater need for cash to purchase items such as fertilizer, and extra food. This, combined with less (or no) surplus crops to sell off, has led to the elder males searching for alternative incomes. Unlike their younger family members, they cannot move and must find ways to earn additional income within their community; whether this is growing different crops that can make a better profit, or selling off livestock (see Figure 11). And when they can't make enough cash, many of these men are choosing to take out loans to cover their needs, especially when it comes to buying fertilizer. They also use these loans to buy new seeds, some of which are adapted strains. These strains are better able to resist drought and increased temperatures, making them more suitable for the changing climate.

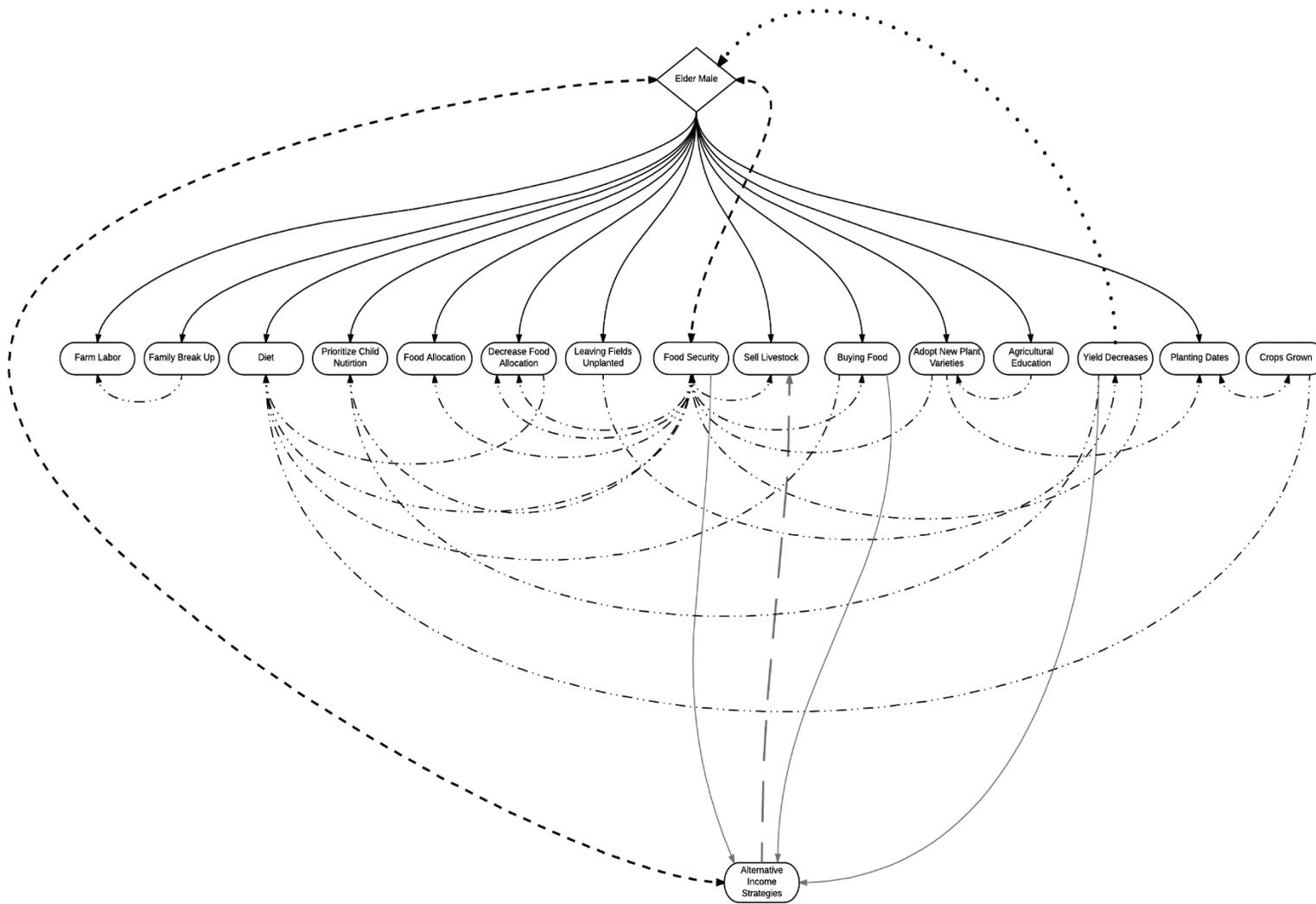


Figure 11. Elder Males' relationship to Alternative Income strategies. The more complex diagrams formed for Elder Males represent their greater power over decision-making.

While additional income provides benefits, such as being able to buy these new varieties of seeds, it can also be a source of conflict (Figure 12). As stated earlier, the elder men (and women) within the family are often at odds with the younger people who migrate. This is because when young people move to urban centers it provides them with job opportunities, but takes away much needed labor from the family farm. This situation is evidenced in the following quote from an Elder Male in the Village of Konsequela. When asked what his greatest difficulties were in farming he responded, “Lack of labor: all young people go to the migration and gold mining” (Figure 13). These farmers rely on their younger family members for labor, as they are able to do more physical work than their older relatives.

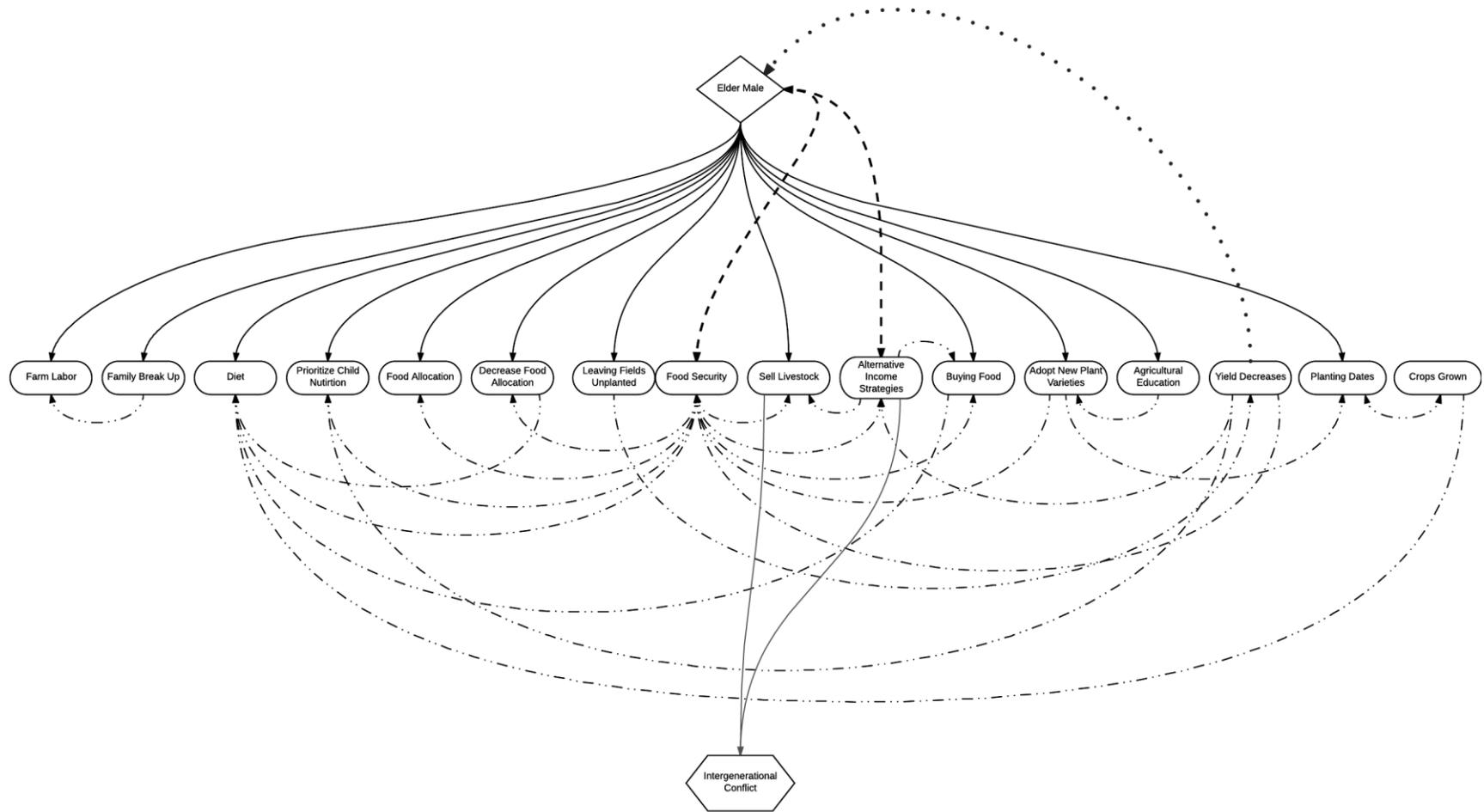


Figure 12. Elder Males can face intergenerational conflict that stems from others' decisions as well as their own.

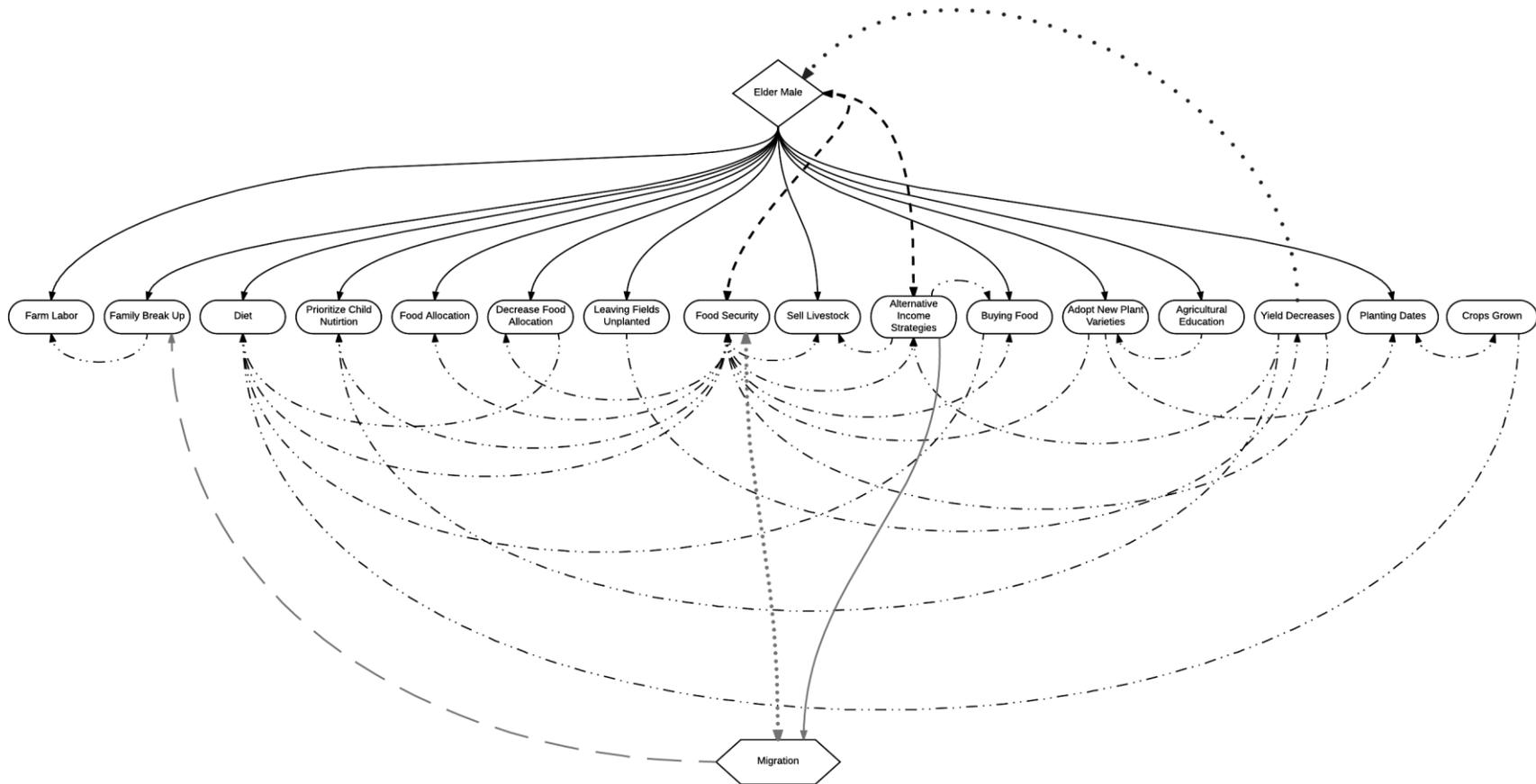


Figure 13. Migration and how it affects the decisions that are made by Elder Males.

In many cases, the need to adapt, and the strain it has brought on them, is leading to families breaking apart. This break up is a recurring behavior within families that has far reaching effects and is brought about by several factors. As seen in the models for young women, their decision to migrate can indirectly contribute to family disintegration, whereas Elder Males can directly effect it by choosing to break up the family as a strategy to address food insecurity. This strategy involves individual families within the larger multigenerational dealing with the food security issues on their own. In addition to breaking up large polygamous family units, men have been decreasing the number of wives they have due to the increasing cost of supporting such large families. These types of decisions are indicators of social behavioral shifts that are occurring, in part, due to climate change and its impacts on food security.

4.2 Young Males and adaptive behavior

Young Males also make important decisions for the family about agriculture and food security, however this is often done in conjunction with the Elder Males who have the final say (See Figures 14 and 15). These are decisions that involve decreasing food allocations, adopting new plant varieties, and leaving fields unplanted. New plant varieties are typically ones that have a different life cycles that are more suited to the delayed rainy season, or are drought tolerant (See Figure 16). Young Males can also operate as assistants to the heads of household, and take over running the corporate fields when the older men are no longer able to work. Some of these men, especially those who are younger, choose to migrate for better opportunities leaving their family behind (See Figure 17).

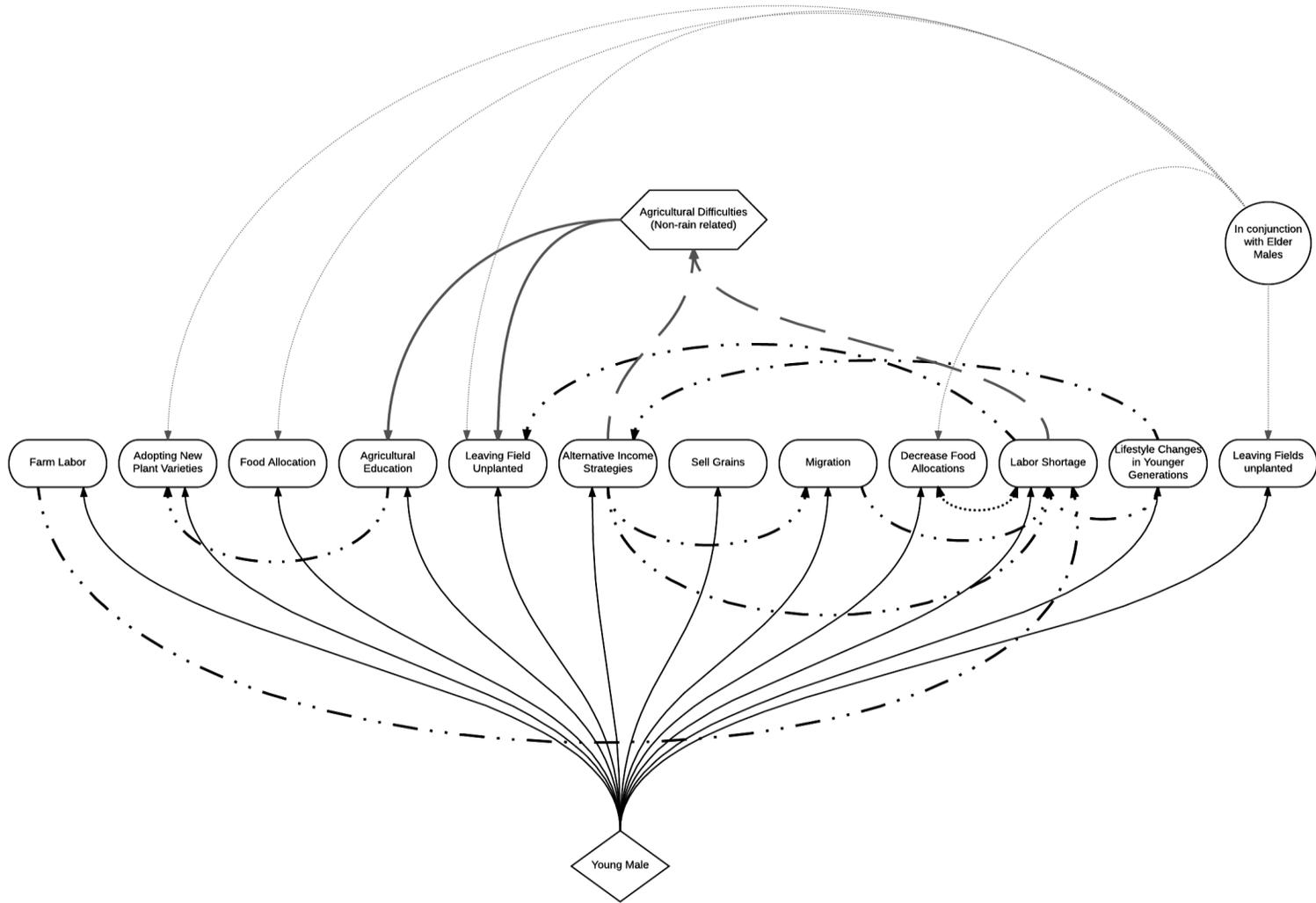


Figure 14. How agricultural difficulties can affect Young Men’s lives, and impact the decisions they make about their agriculture.

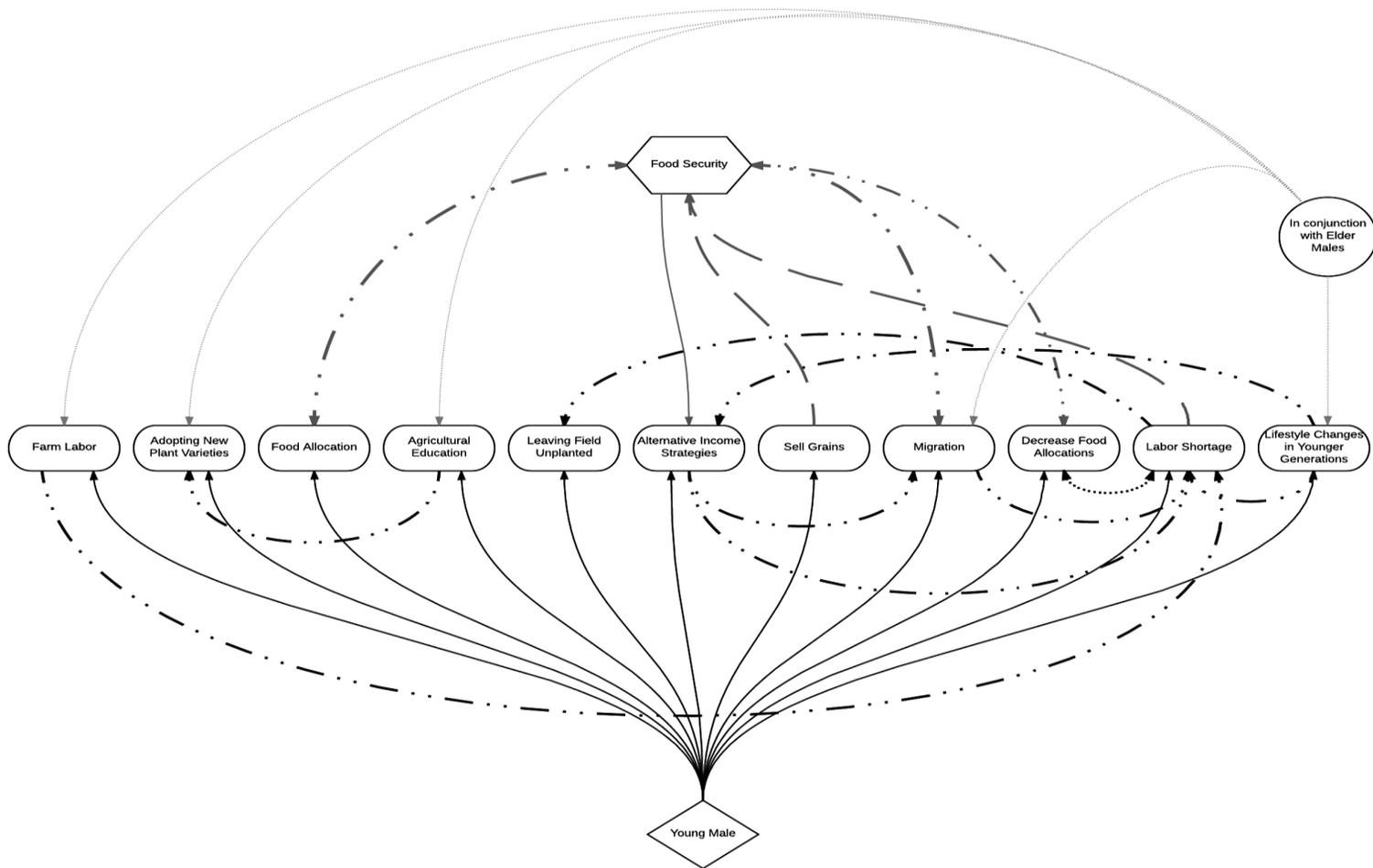


Figure 15. Young Men can make decisions that impact food security, however most of the important decisions are ones they make in consultation with the Elder Males who have final say on the matter.

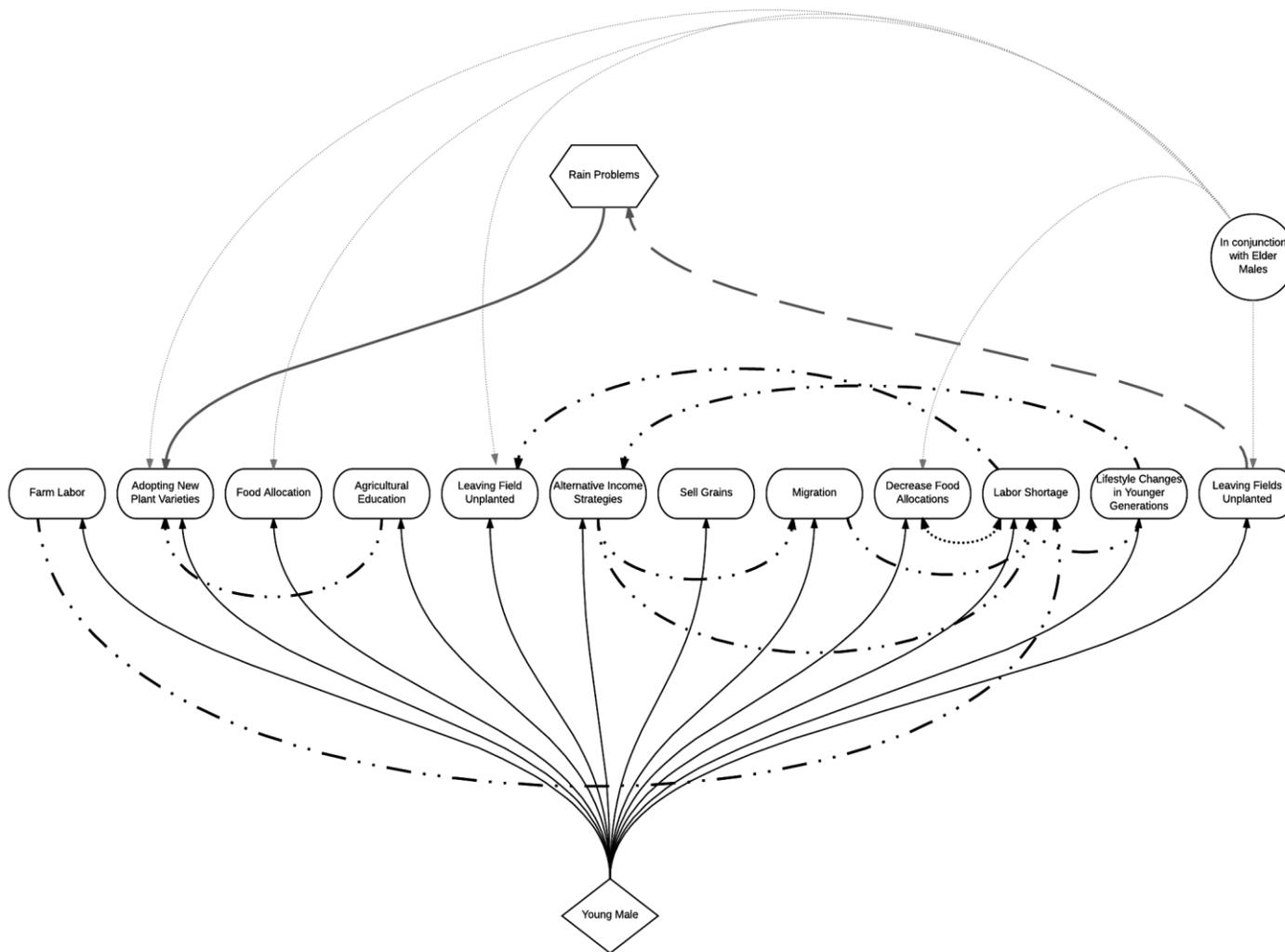


Figure 16. Rain problems have significant effects on Young Men and their decisions related to agriculture. This is also the only hub that the farmers have no means to influence as it is caused by global warming.

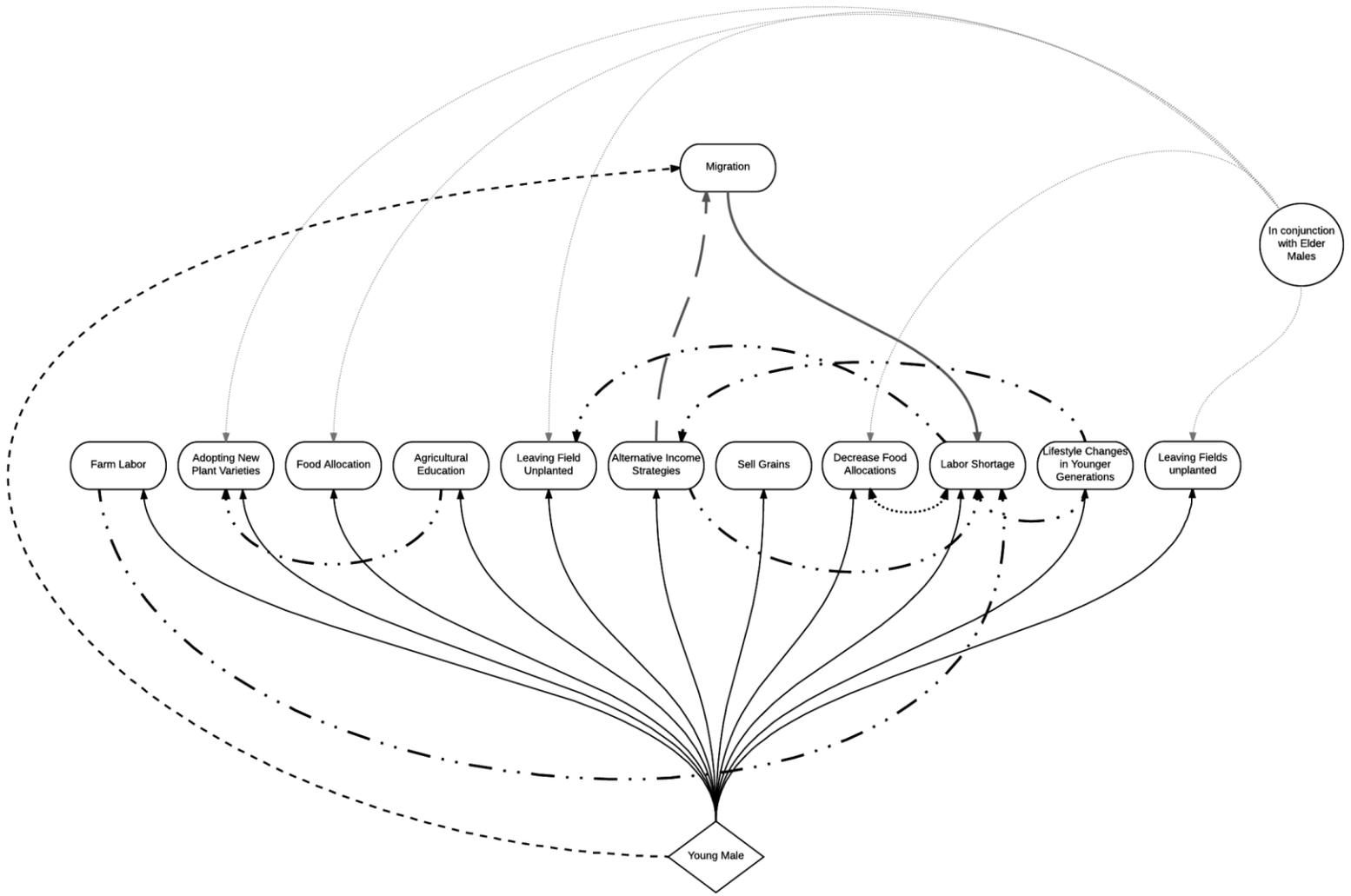


Figure 17. Young Men can choose to migrate, as well as be affected by migration through labor shortages.

These migrations can be permanent or seasonal, but are part of a trend among younger people to move away from agriculture. They are moving to urban areas to find paying jobs in service to wealthier individuals, such as domestic workers, or as market vendors (Figure 18). While these jobs can increase their own food security, it can hurt that of the larger family unit (Figure 19). When they leave, they create a void as their labor can be crucial to the family's farming operations (Figure 20). With less labor, there is less output from the agriculture, and consequently a further decrease in food security. And even if they stay in their village, off farm work can reduce the amount of time they are in the field, still decreasing the family's labor supply. This situation is illustrated by the following quote from a Young Male in the village of Molobala: "young people don't take collective work more seriously, so they rush to go quickly to paid labour and earn for themselves." Meaning that even when young people remain in an agricultural community, and don't migrate to an urban center, they will seek work away from the family farm due to the attraction of a cash income.

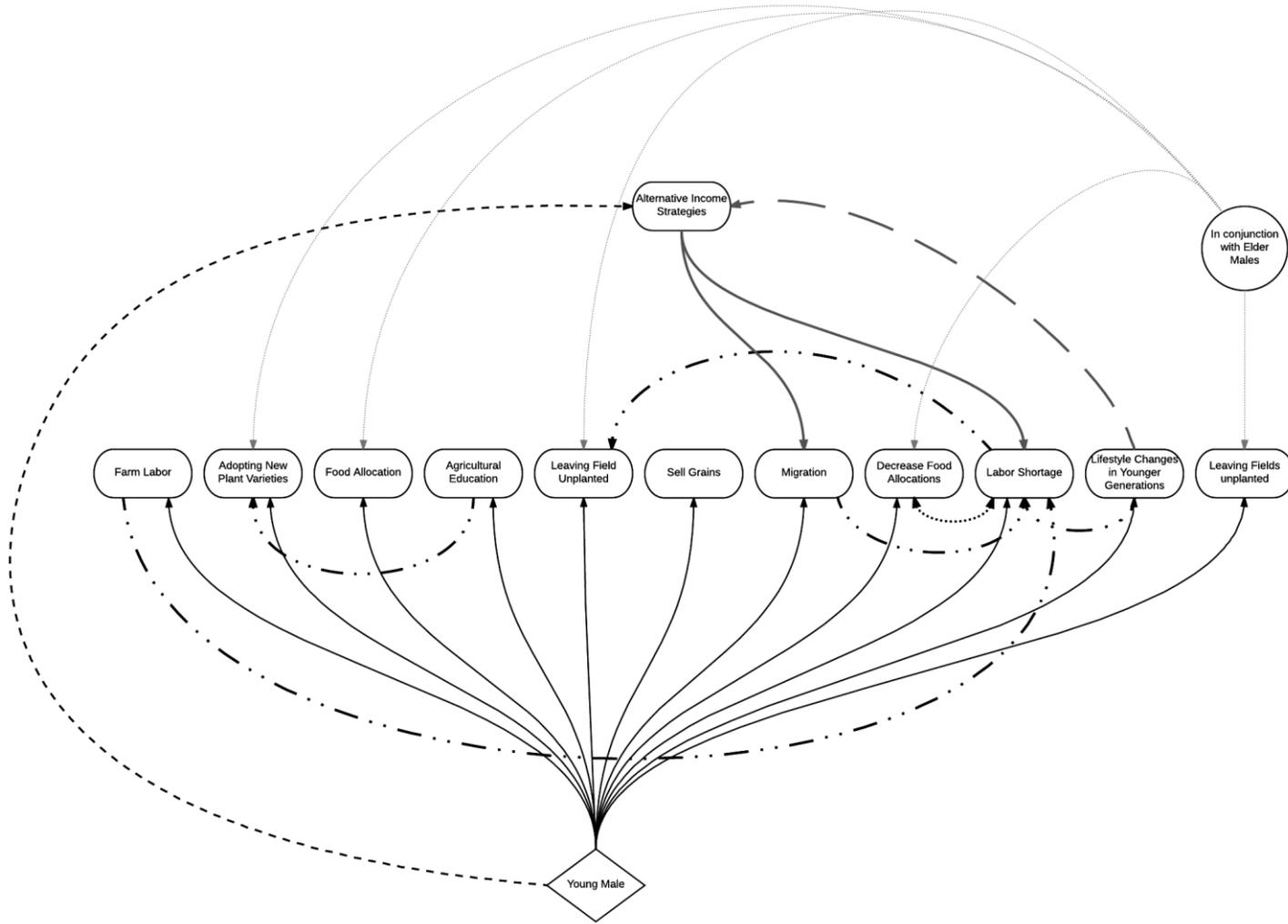


Figure 18. Many Young Men may choose to find alternative income strategies to support themselves and their families.

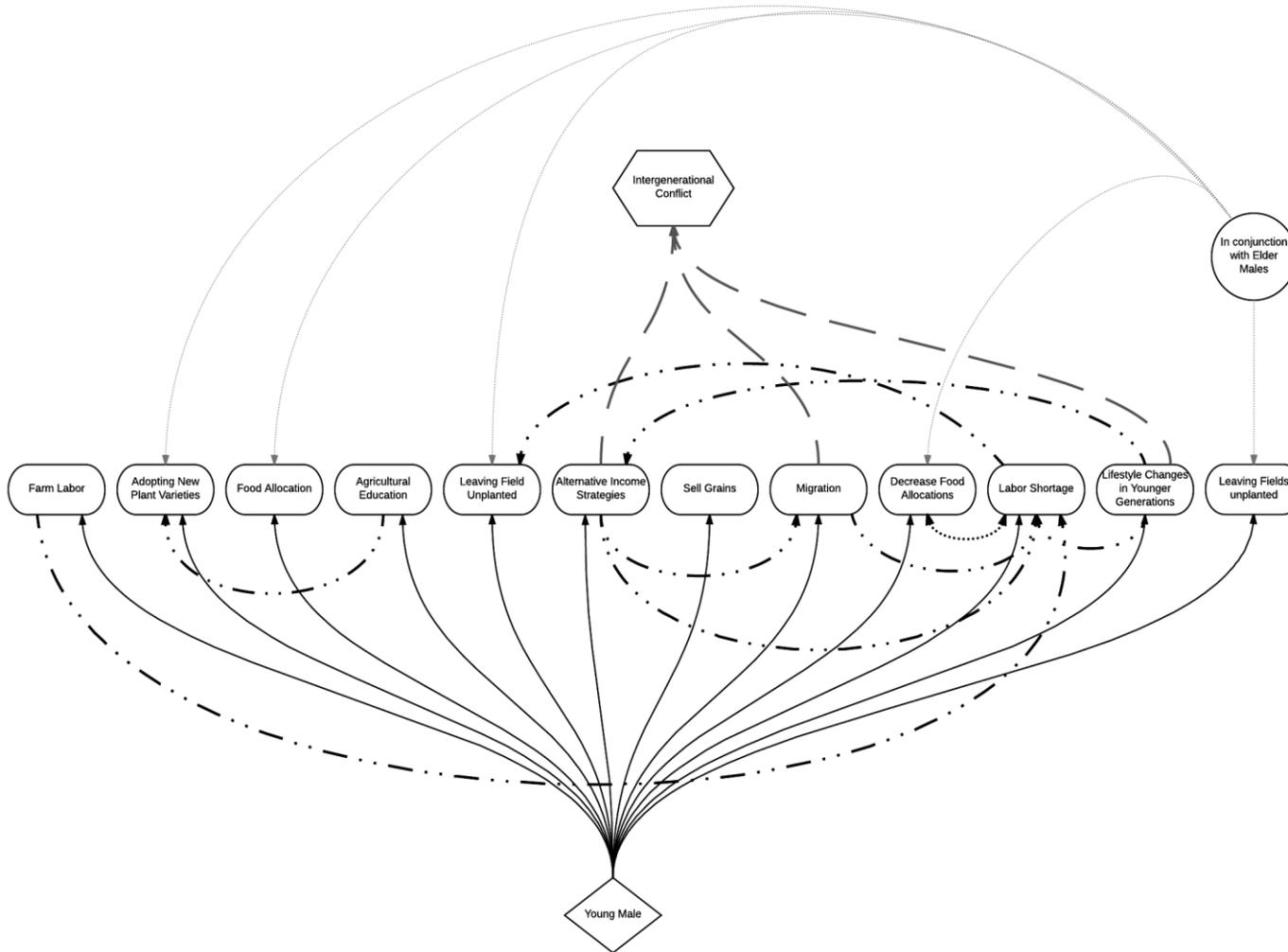


Figure 19. Young Men can create conflict by their decision to leave agriculture, but they also can face it when their own children choose to live different lifestyles.

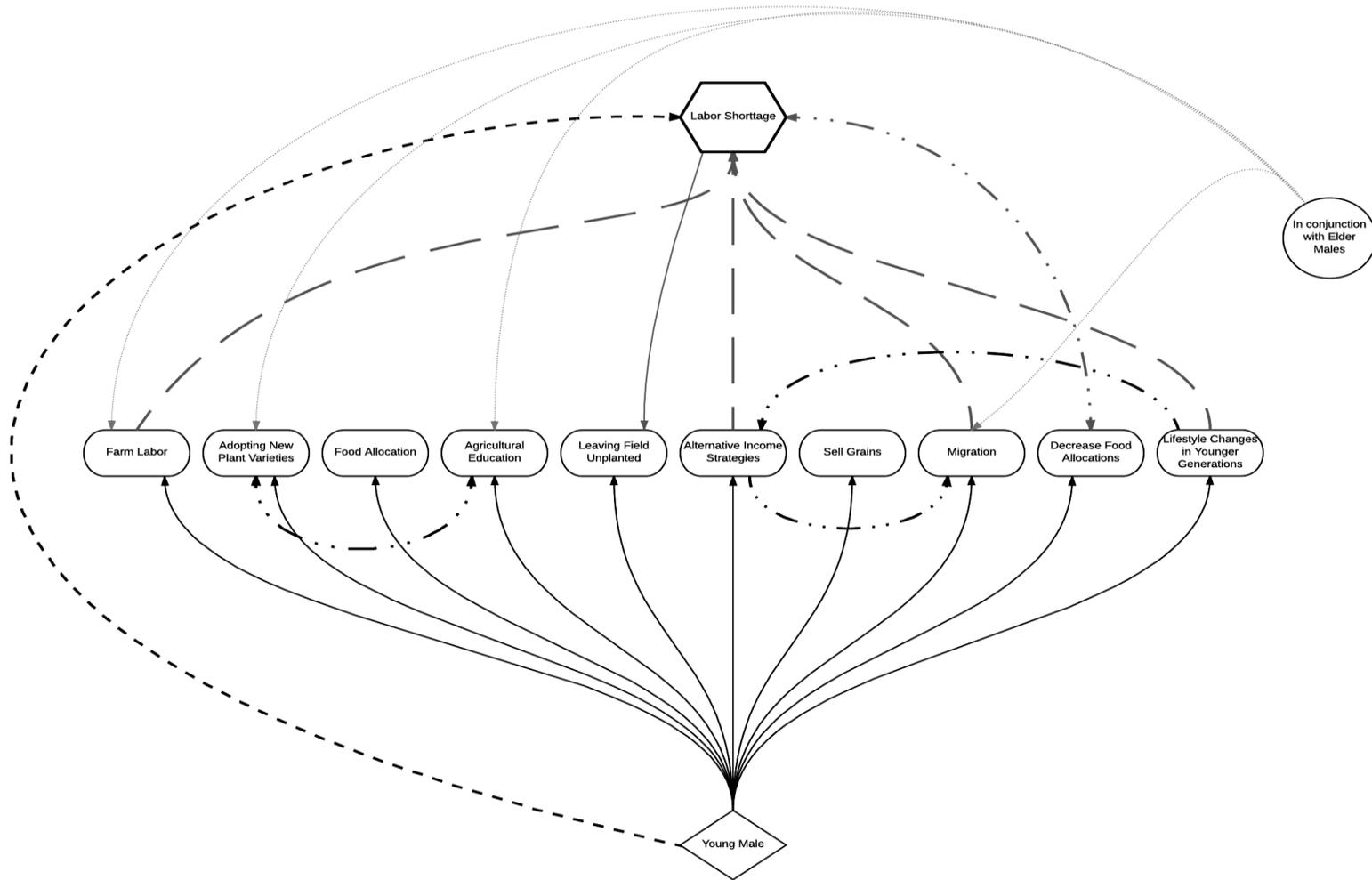


Figure 20. Young Men can create a labor shortage by leaving the farm, as well as be affected by it when they have less people to help them work the fields.

4.3 Elder Women and adaptive behaviors

Elder Women have little power within the family over the main crop fields, but do typically hold domain over gardening, the younger women and children. This lack of power is evidenced by their models, and the limited effect that the main hubs have on their behaviors, as well as the smaller number of decisions they have direct control over. While they have a small role in the decision-making for the family, they provide a significant amount of labor. As an Elder Woman from Sincina states “We cultivate and store the cobs in the attic, every day the men give us a quantity to prepare. We pound the cereals for cooking.” They are doing all the work to prepare food for the family, but it is the men who are deciding what the food is, and how much will be used. However, these women use gardens as supplements to their diets giving them some control over what is eaten as well as a source of income to buy personal items or food for the family (Figure 21). These gardens can produce vegetables, fruits, and nuts that are essential to a complete diet (Figure 6). But, because of climate change these gardens are under the same threat as the family cereal production due to the changes in rain patterns (Figure 22). This has led some women to rely on wells as a source of water. They are also forming agricultural collectives as a way to pool money and agency so that they can increase their ability to adapt (Figure 23). Unlike Young Women, these women do not have the option to migrate due to age, and their strong connection to children and husbands that would be difficult to abandon for long periods of time (Figure 24).

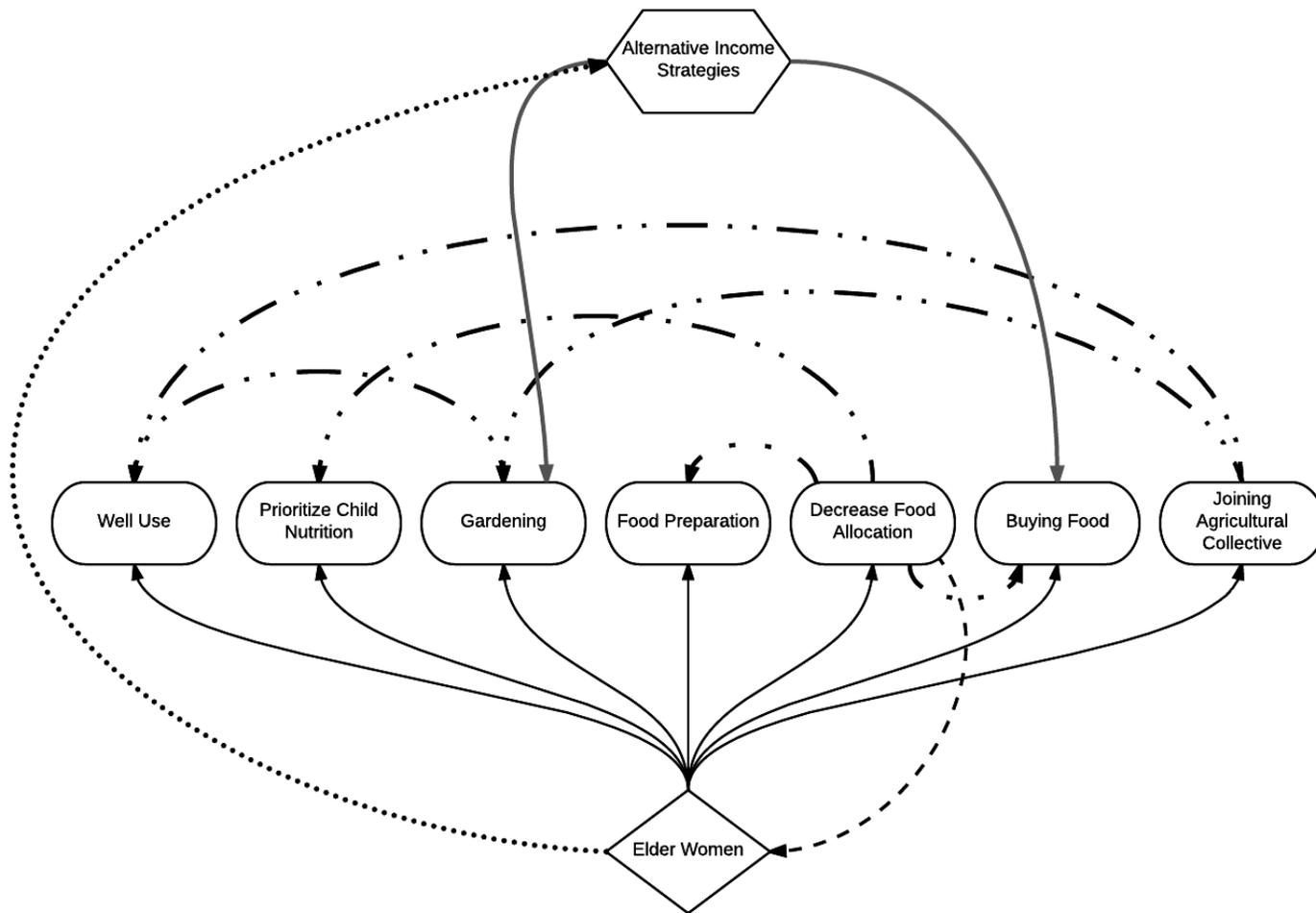


Figure 21. Alternative income strategies can positively impact the lives of Elder Women by allowing them to buy more food or garden items that will generate income.

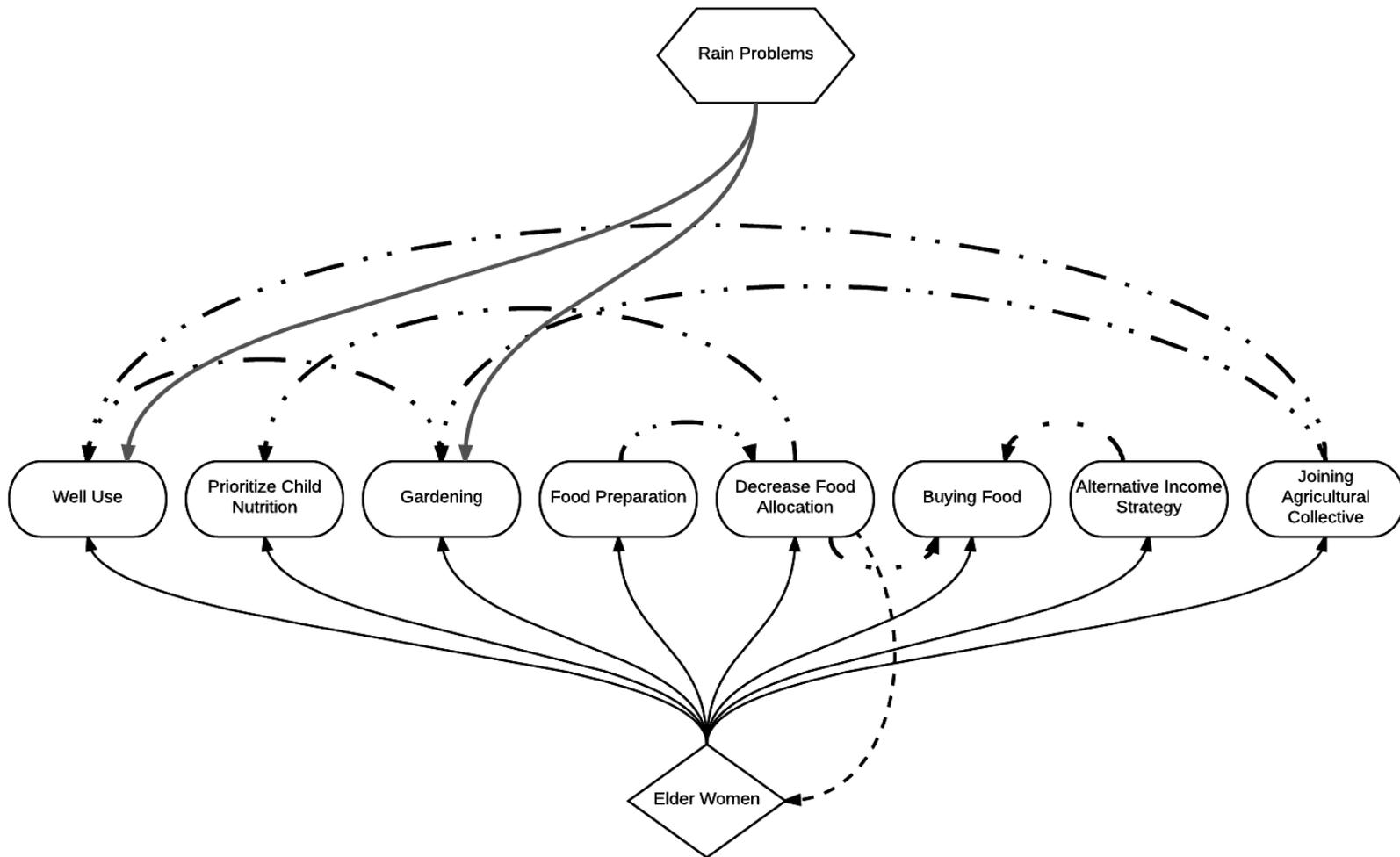


Figure 22. Rain problems can affect Elder Women’s gardens, which can in turn impact their food security

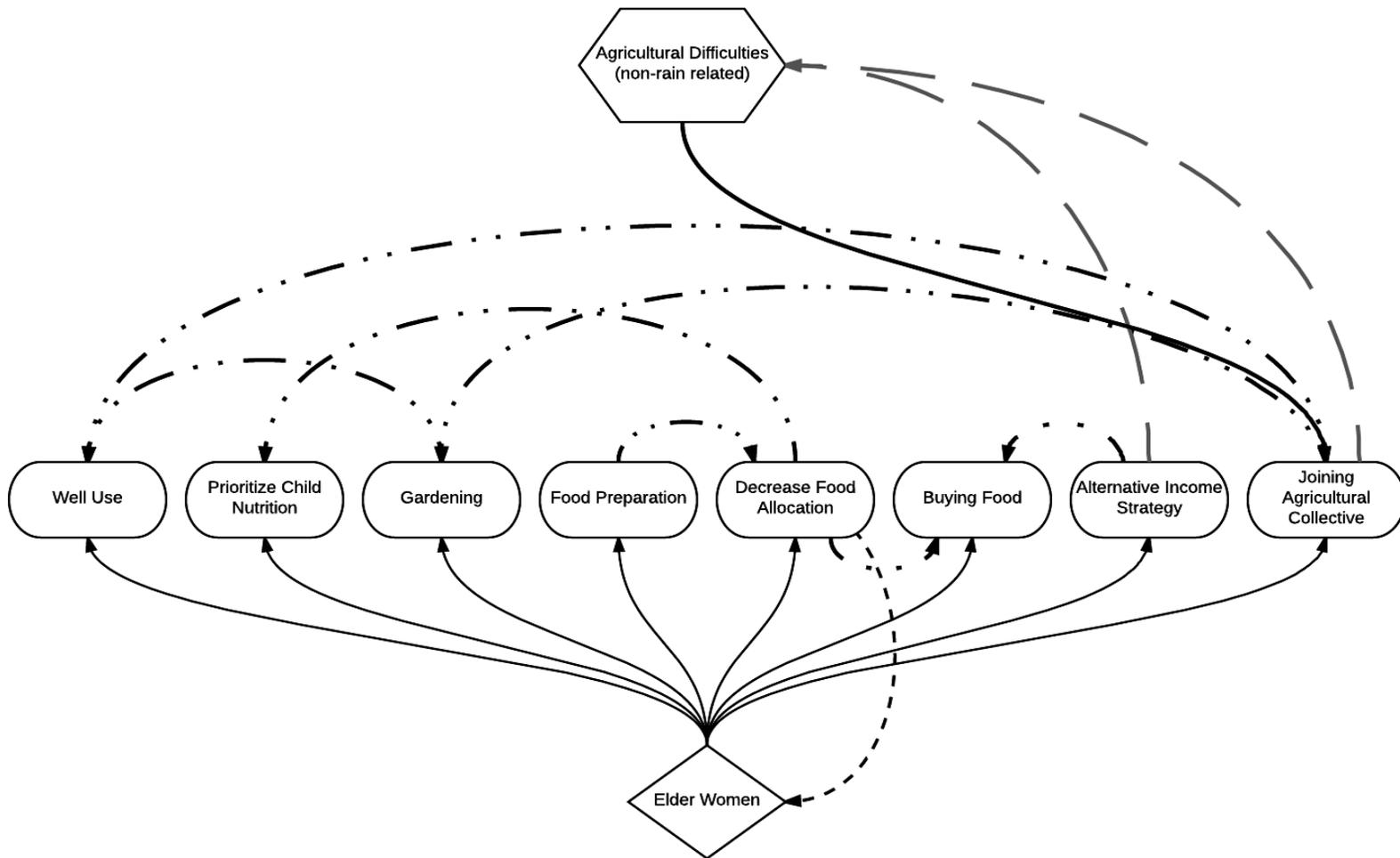


Figure 23. Agricultural difficulties affect all family members, but women have chosen to address some of them using agricultural collectives.

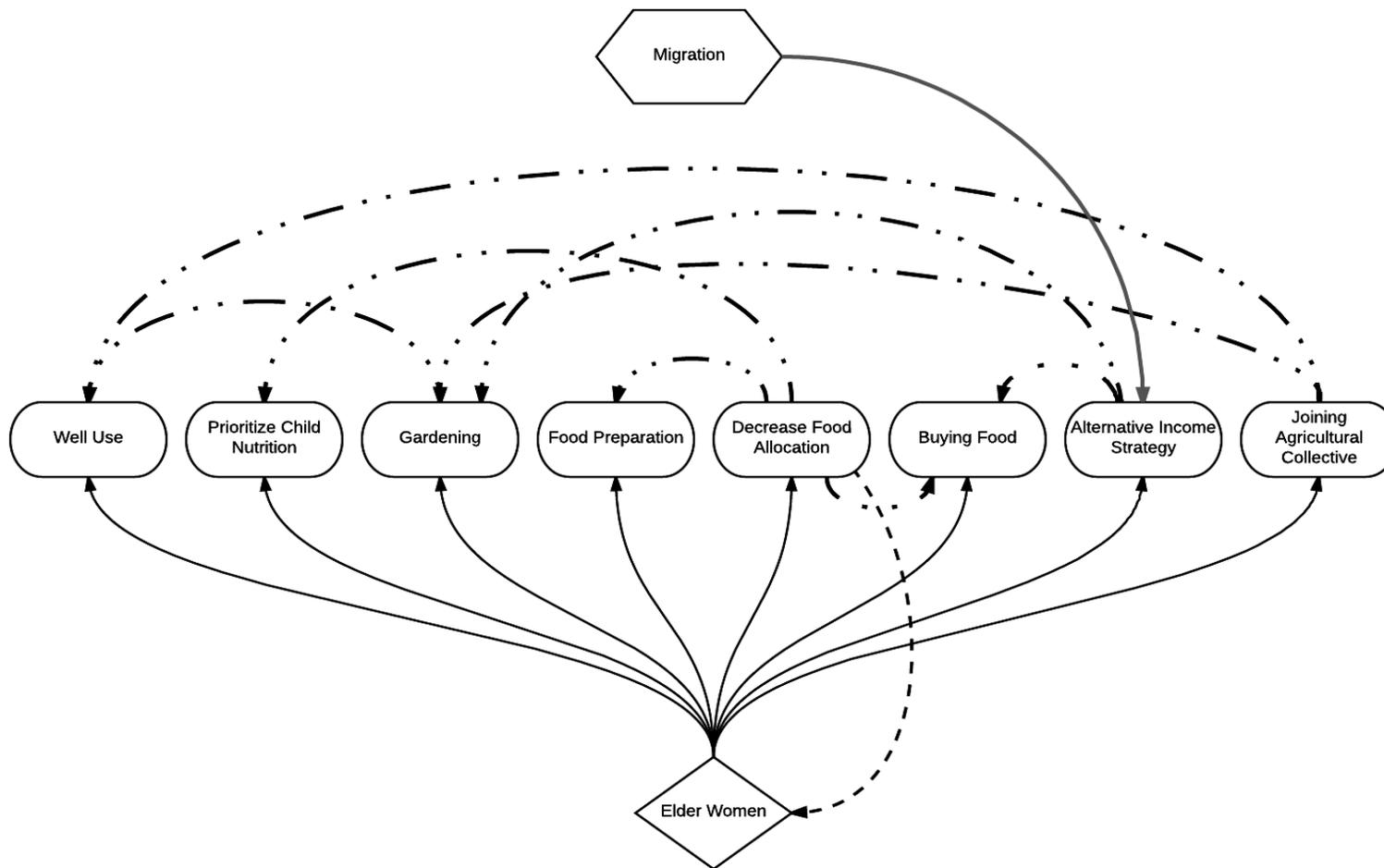


Figure 24. Elder Women do not have a close relationship to migration, only feeling the effects it can have on the whole family. This is because they are unable to migrate due to greater commitments on the farm and within their families than younger members.

The women in our interviews also expressed similar sentiments to those of the Elder Males when it came to youth, their migration, and their abandonment of agriculture. Many believe that young people are lazy, or don't care about agriculture since they don't want to work in the fields and would rather pursue education and/or jobs in the cities (Figure 25). Like the Elder Males they are affected by the labor shortages created by this migration since they rely on the family's farming operations for the bulk of their food, and when young people leave their absence has the potential to decrease agricultural outputs (Figure 26). Additionally, these women rely on young people to help in their gardens, especially if they are unable to do the physical labor themselves, meaning that when their younger family members move away they could potentially lose out on the additional food and income these gardens provide.

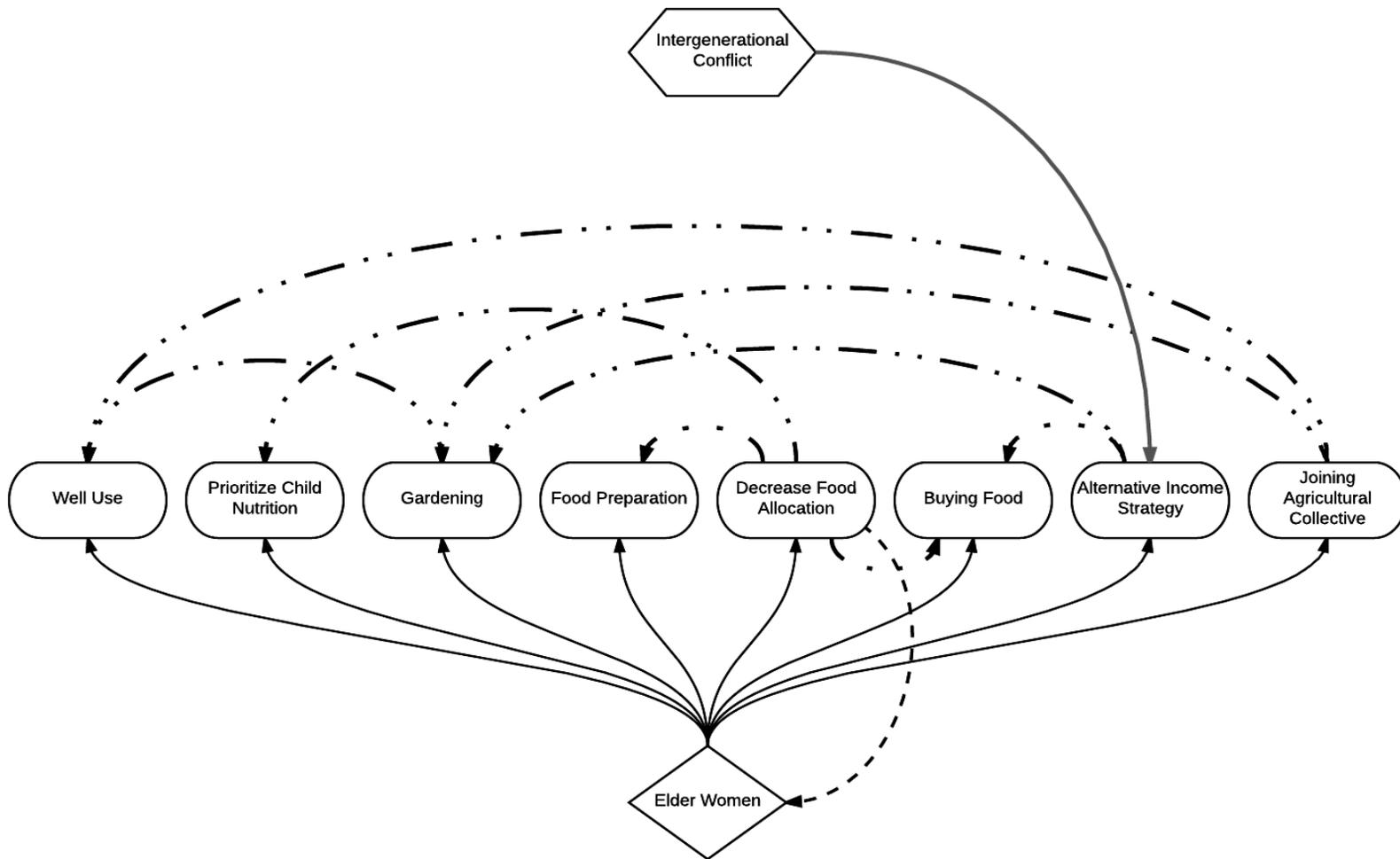


Figure 25. Elder women face conflict with younger generations when the latter leave farming to find better paying jobs, often un urban areas.

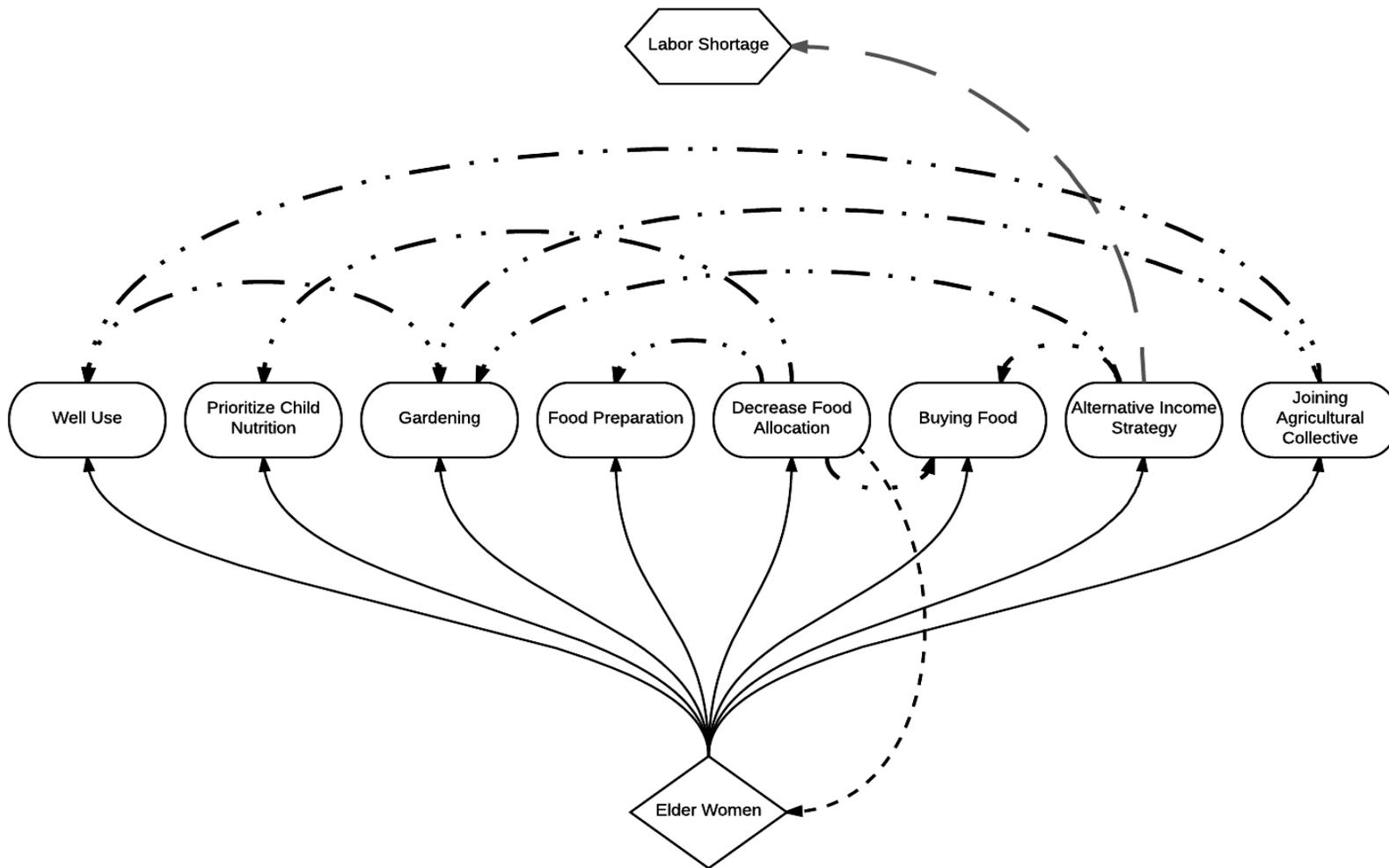


Figure 26. Elder Women don't create the labor shortage, but are impacted by its effects on agriculture and their gardening.

4.4 Young Women and adaptive behavior

Young women's models operate largely the same, but are less complicated as they are typically the lowest ranking adults within the family structure. However, they can still influence others' behaviors indirectly. For example, in **Figure 27** there is a model showing how Young Women's behavior impacts their food security. While they don't make direct decisions in terms of agriculture, food, or food allocations they can indirectly influence food security for themselves and the family via migration. There has been a rise in young women, especially those who are unwed, moving to larger urban centers to secure paying work such as maids, market vendors, and farm laborers- this mirrors a trend seen amongst young males (Figure 28). When these women migrate out, it can potentially increase their own food security if they can move to more prosperous areas and secure gainful employment, but can decrease that of their family's as there is less labor for food production (Figure 29). They also can affect food security through activities such as gardening which provides additional food stuffs or cash, and alternative income strategies which provide an income that can be used to purchase food or other items to assist in agricultural production (Figure 30). In addition to modeling how these behaviors affect food security, our diagrams also show how food security affects these women's behaviors, and the consequences that arise from these behaviors.

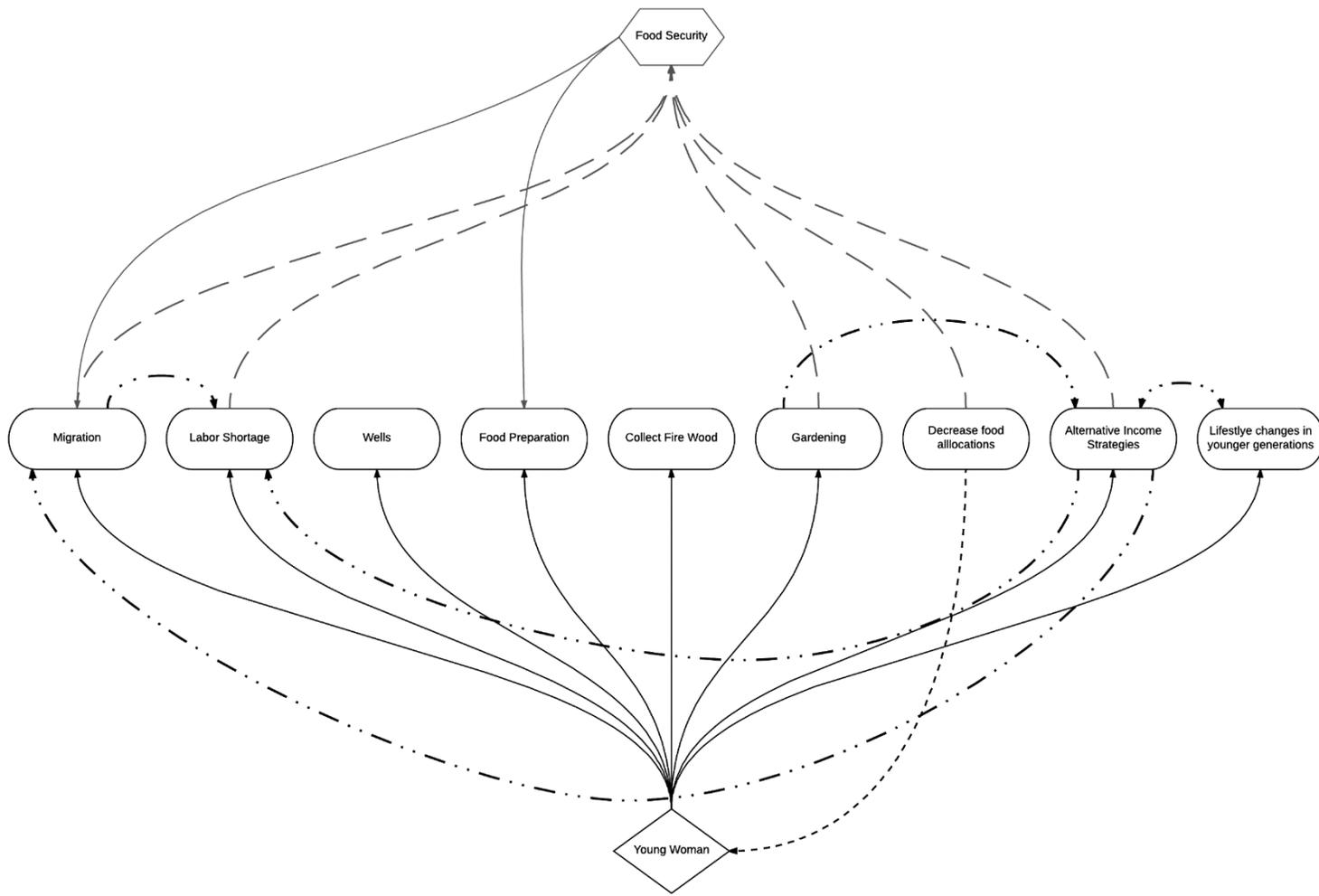


Figure 27. Young Women and their relationship to food security, through the decisions they make.

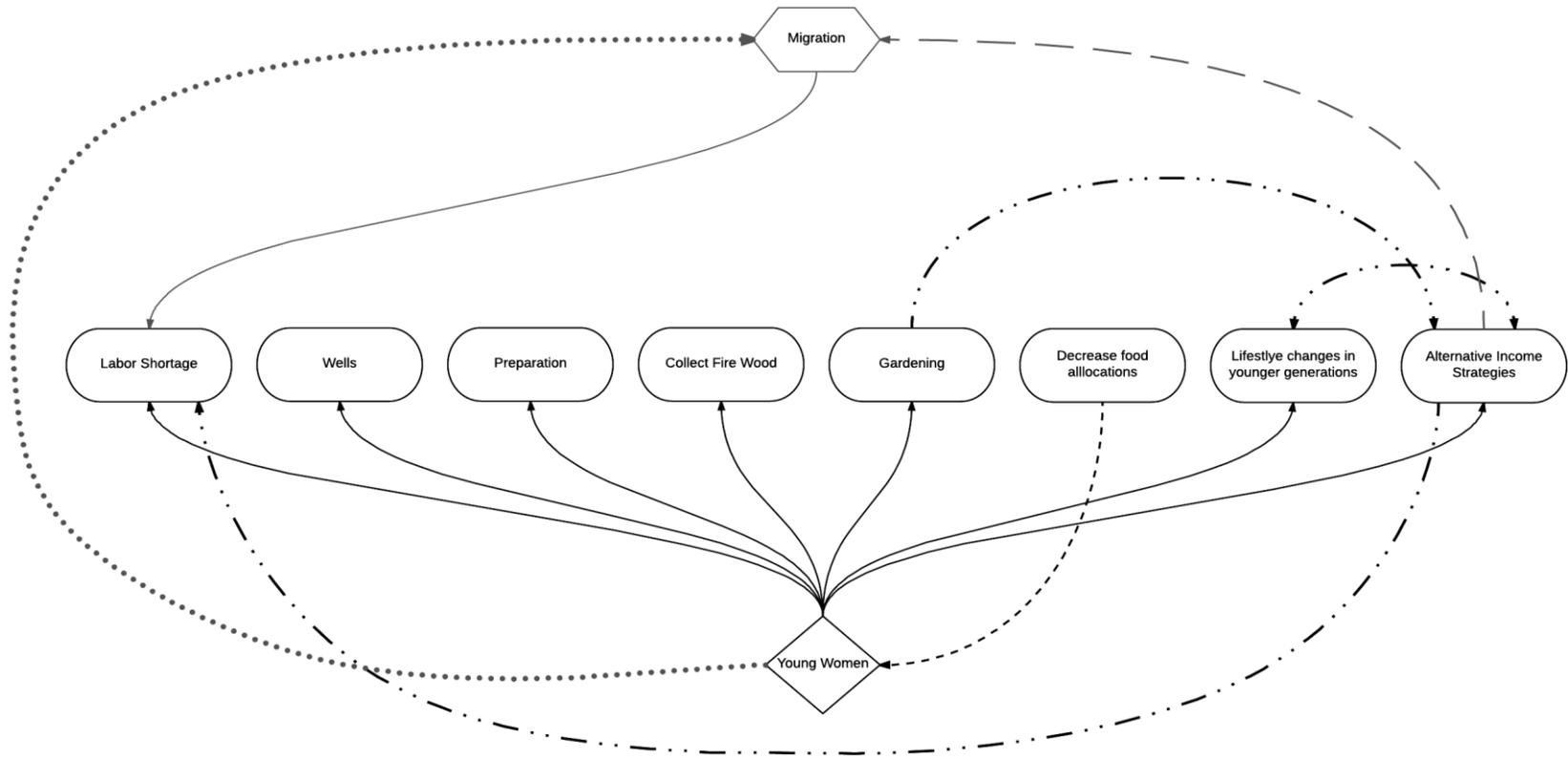


Figure 28. Young Women and how their decision to migrate affects them and their family.

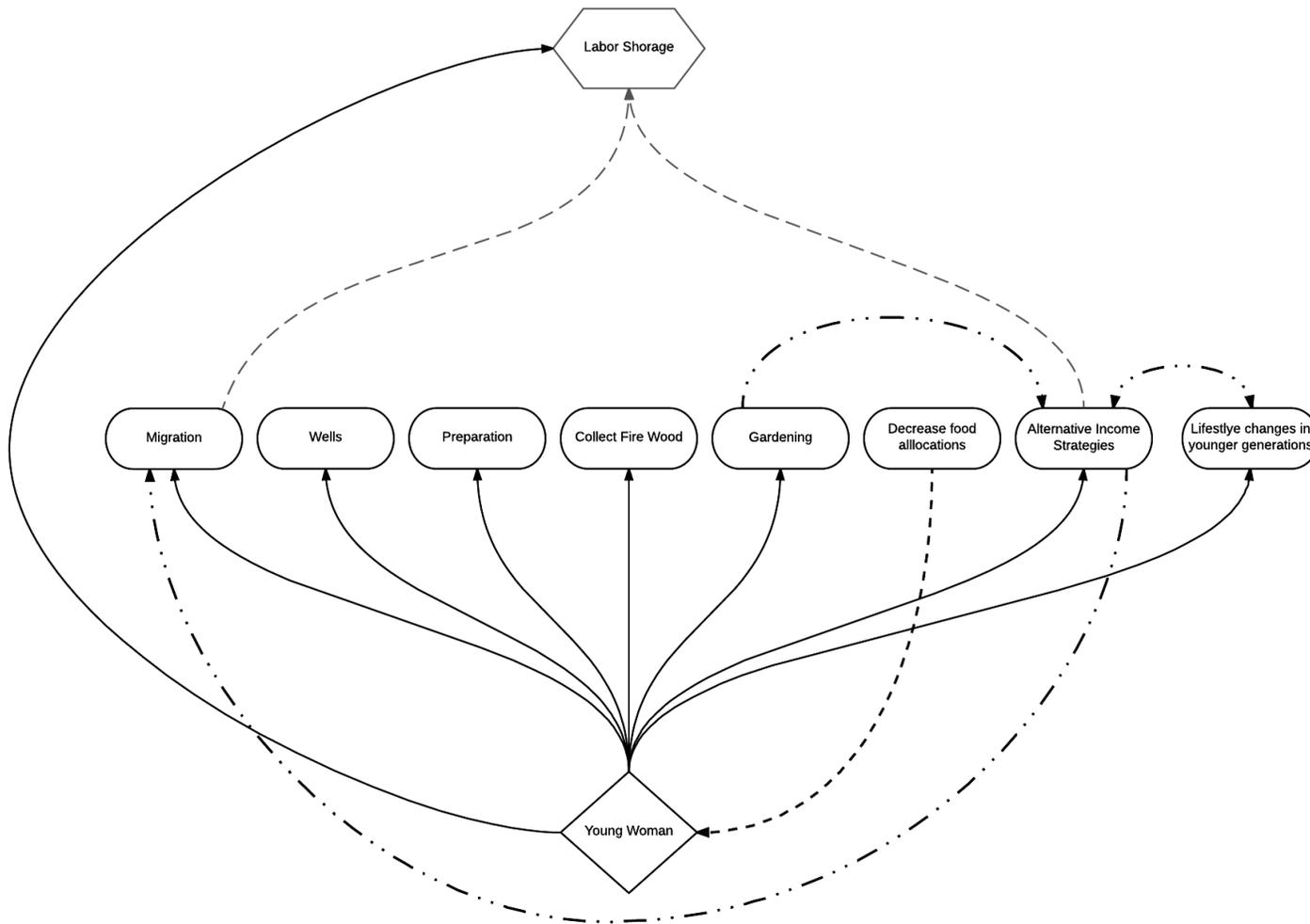


Figure 29. How young women can contribute to a family's labor shortage

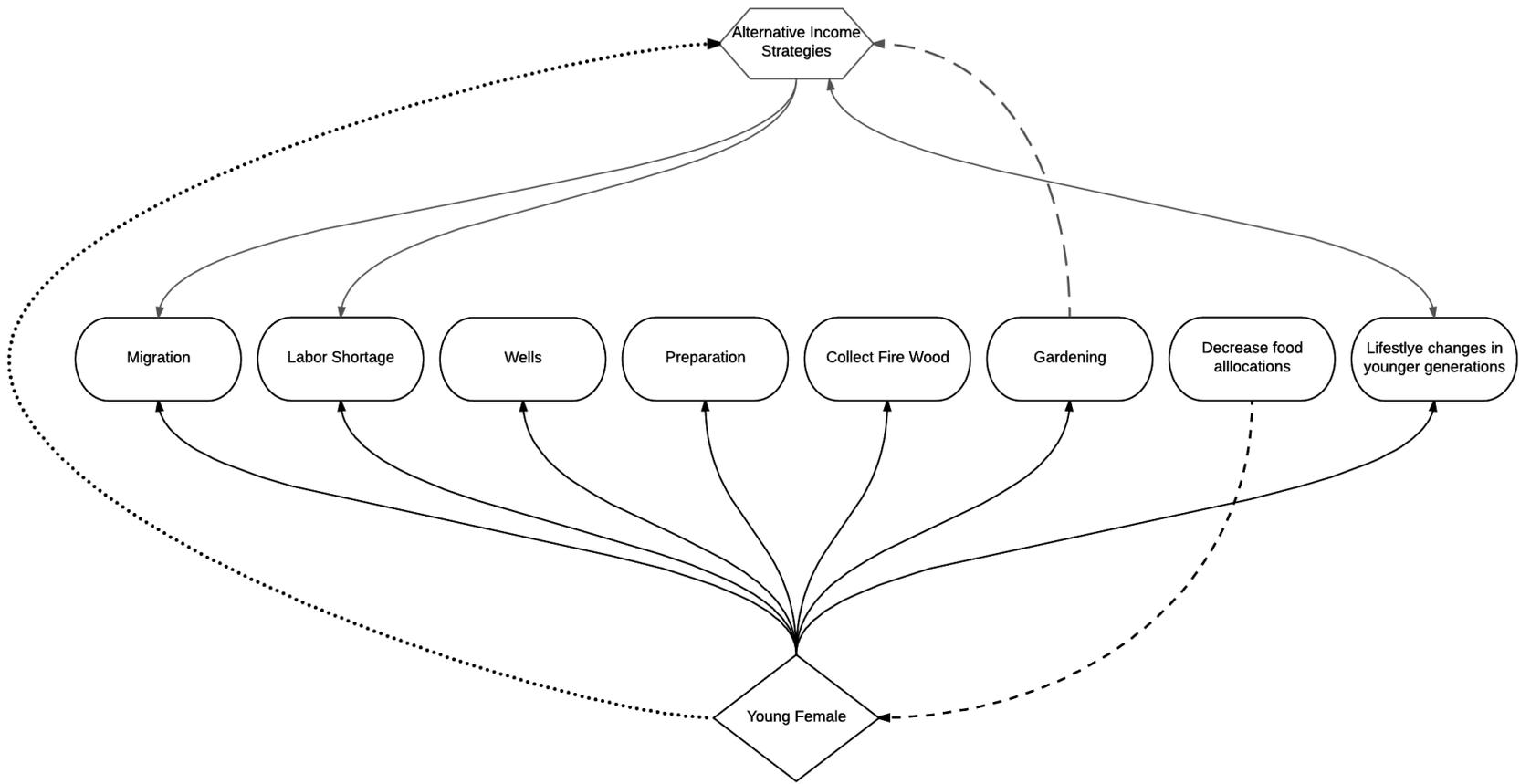


Figure 30. Young Women’s decisions to seek alternative incomes can have both positive and negative effects.

This concept of migration is not only a main hub, but a recurring intermediate node within the models for other hubs. This is due to it being one of the only adaption strategies available to Young Women, the other being their pursuance of alternative income sources. These two strategies often combine, as was the case for a Young Woman from Molobala who said, “I go to Djoro once a year and about three months to work in the rice fields, I bring rice, we eat two times a week on a good time [sic].” By migrating she can bring in extra income, in this case it is in the form of rice, which supplements her families decreasing yields. Migration was also a source for the final hub, intergenerational conflict, as many of the older members of the families expressed a belief that migration was due in part to children becoming lazy and not wanting to work in agriculture (Figure 31). Another hub that is having significant effects on these women is “rain problems” (Figure 32). While this is not one that any member of the family directly effects, it is one that significantly affects all family members. Among Young Women it creates a need for them to garden more to substitute for yield decreases amongst the larger crops, and increases reliance on wells which are expensive to dig and are therefore less available to families lacking adequate financial resources (Figure 33).

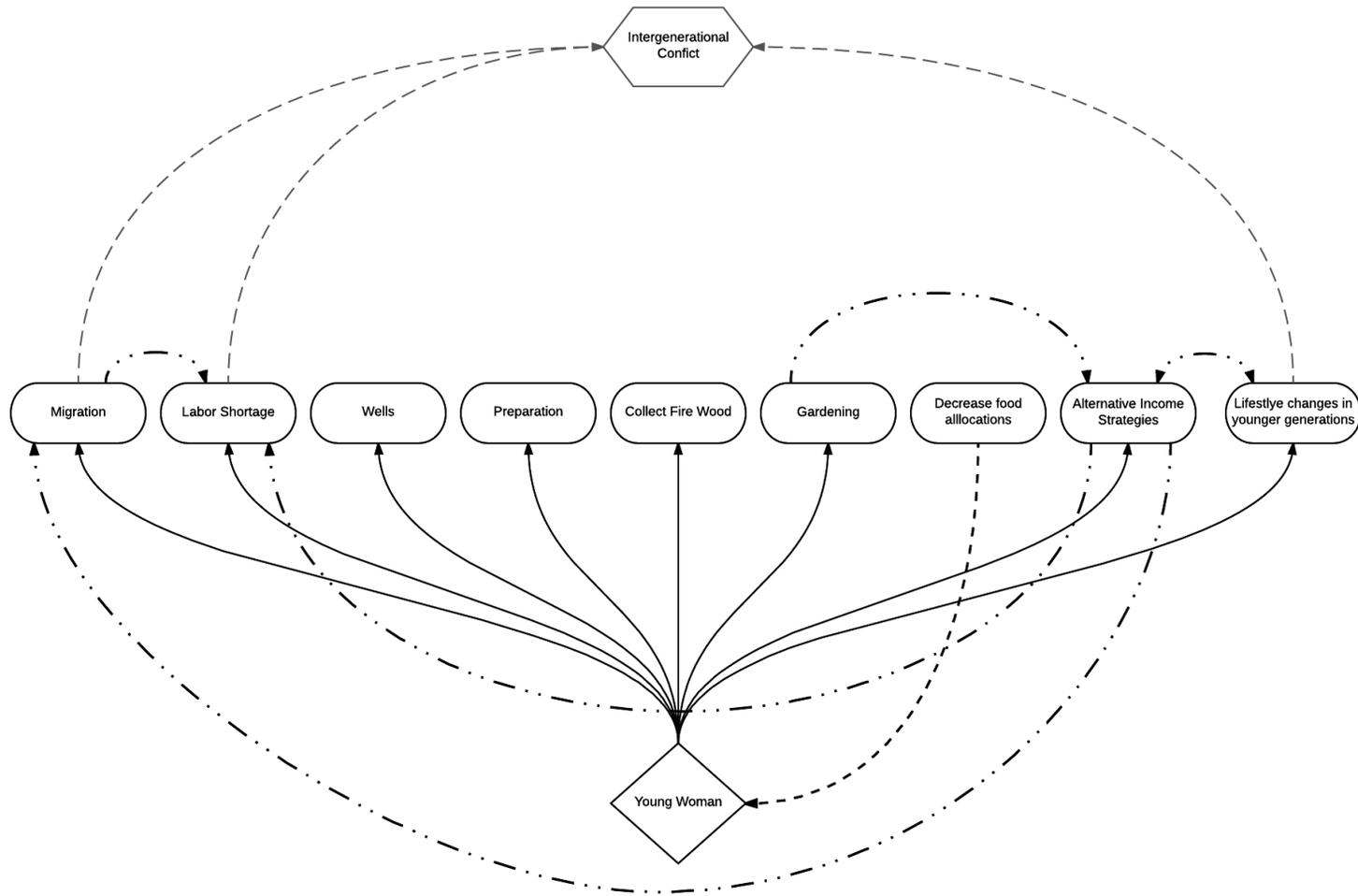


Figure 31. This model shows how young women’s decisions lead to conflict with older generations.

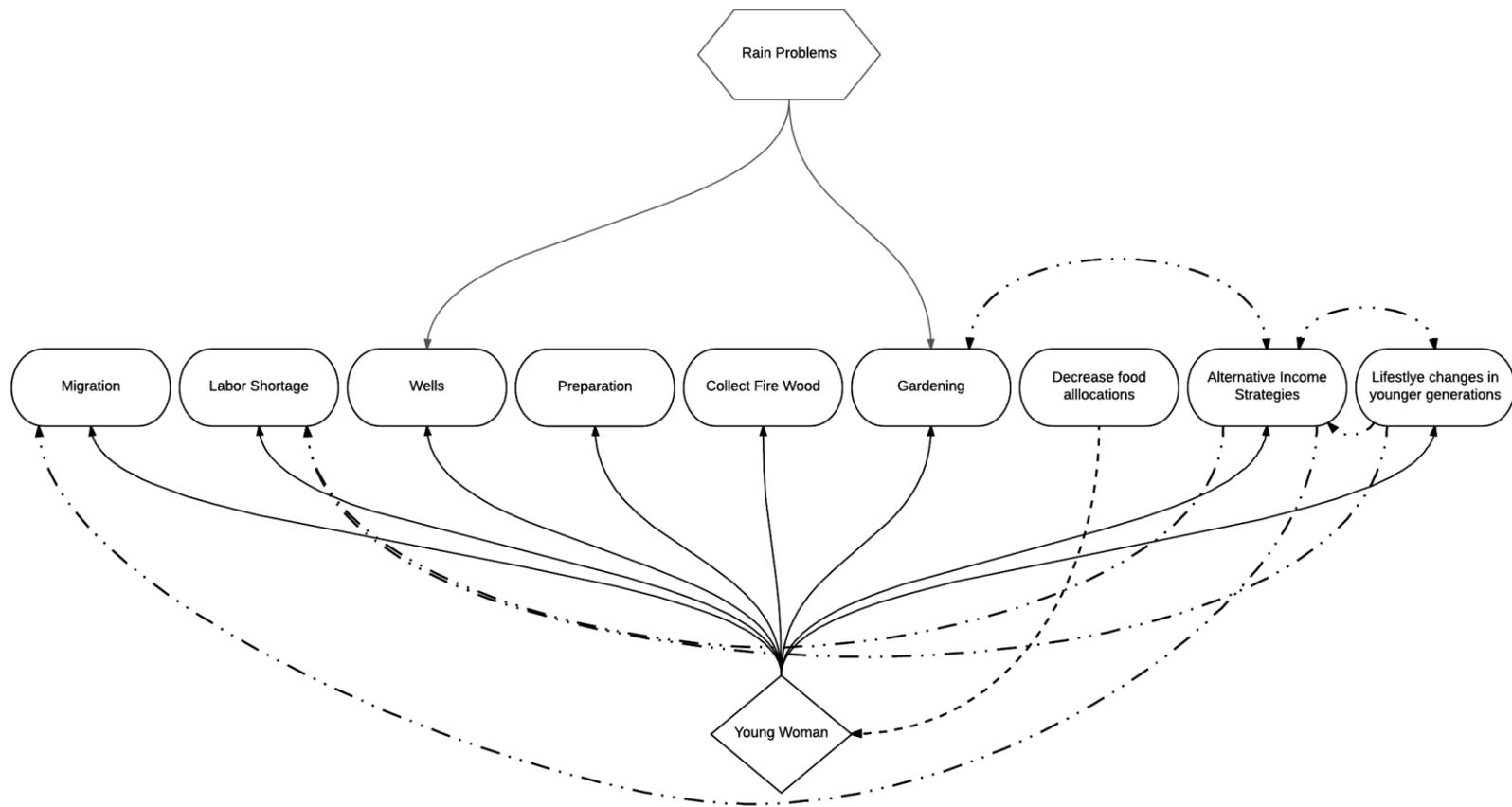


Figure 32. How rain problems are affecting the decisions made by the Young Women.

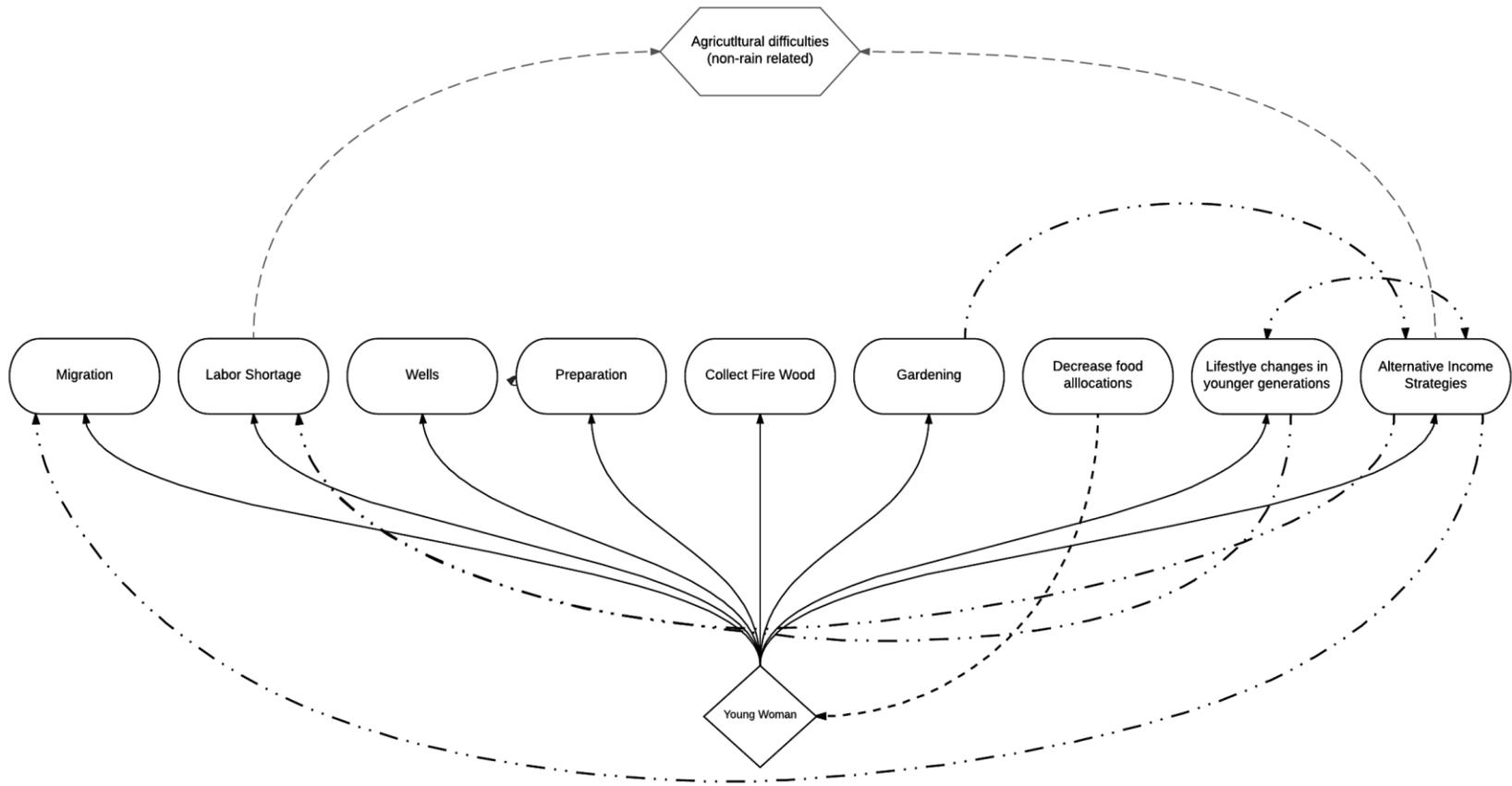


Figure 33. How Young Women’s behaviors can negatively impact family agriculture

5. Discussion

The models created for this project show that climate change is having far-reaching impacts beyond a decrease in agricultural production and food security. As subsistence farmers, our interviewees' lifestyles and wellbeing are interdependent with their farming. An example of this, is how agricultural failures can lead to youth migration, conversely migration can lead to agricultural setbacks due to these farmers' reliance on physical labor. This interdependence only serves to compound any difficulty within the system as it "increases the probability of ruin, ultimately to the point of certainty (Taleb et. al, 2014)." When there is a strain in one part of the system it can have ripple effects throughout the entire system. So, as climate change begins to alter rain patterns and decrease yields there are side effects beyond agricultural output. There are economic impacts from a lack of revenue or a need to spend a limited cash supply on food, food security impacts as most of the farmers' diet comes from their own crops, and social impacts when families are unable to handle the strain break apart. While information on agricultural yields, rainfall amounts, and nutrition can be easily discerned with quantitative methods, and traditional survey style investigations, mental models have allowed us to more closely examine the social impacts of climate change, and its effect on food security in this region.

The main social impact being the transformation of traditional lifestyles and family structure, and while not entirely due to climate change it has played a significant role. Throughout our interviews there were mentions by both young people and their

family members of the younger generations leaving agriculture all together to takes jobs in other areas. While this provides economic opportunity, and freedom to these young people, it takes a toll on those left behind. As is illustrated by a woman from Kaniko who, when asked about challenges her agriculture faces, said “our children leave here and go to work in the fields of the rich”. These farmers are unable to afford expensive farm equipment and much of their agriculture relies on labor, making the absence of even one or two people critical. So, when young people leave to work on other farms, or in urban centers, it creates a gap that is almost impossible for farmers to fill. However, many of these young people are leaving because as climate change hurts their agriculture there are more opportunities in other areas to support themselves, as well as their families. Also, because of stress from decreasing food security, many heads of households are choosing to break up their large multigenerational family units, either permanently or during the dry season when food is most scarce. These family units have typically been a source of support, and the loss of social capital from their breakdown could make it harder for them to successfully adapt to their new climate.

By modelling farmers’ decisions, like the ones that alter the family structure, we have been able to see how they affect not only those making them, but the whole family. Such is the case with the models for young people and their impact on food security. Our models have allowed us to see that while migration helps in the short term, in the long run it creates problems for the family members left behind. This is because when there is a decrease in food security and the younger generations emigrate it sets up a positive feedback loop. When food security decreases young people may choose to leave the

farm, but their absence creates a labor shortage. This shortage then leads to further decreases in food security because there is not enough labor to keep up production. The decreased production could possibly lead to more young people leaving, and the whole process repeating itself (Figure 16; Figure 28).

Even where they have begun to adapt, changes to the traditional family and farm structure could hinder their efforts. One example of where potential problems could arise is with agricultural collectives, more specifically women's collectives. Women have been shown to have distinct social networks from men that they rely on more heavily, and use to address environmental issues (Agarwal 2000). These networks provide women a way to pool together resources and power, things they often lack when compared to their male counterparts. This is evident in our research when some of the women, especially the older women, discuss forming agricultural collectives. In these groups, they are able to assist each other with farm labor as well as economic needs, as evidenced by the following quote from an Elder Woman in the village of M'Pessoba where a collective of women purchased wells for their needs:

“The collective garden exists since 7 years and every year we save money to fit out a water source because the problem of water is a challenge for us... We thus watered with the water that we draw from the domestic wells. ...We fitted out 6 traditional wells in the garden with the money of our saving.”

They are also better able to have their needs and concerns heard when they form a collective as is seen later in the same interview:

“We got organized and went to Koutiala to find of the help with the PGR (Project of Rural Gestion⁴) ...[and] were provided training for rice cultivation. We asked for a field to the village chief, who gave us a field.”

Without this collective action, they would most likely would not have been able to receive help from the PGR, or convinced the chief to provide them a field, and they would not have individually brought in enough income to outfit a well.

While these collectives are helping women to adapt to a harsher climate, if the number of young women who remain in these rural areas continues to decrease these groups could fall apart as their members become too old to be active, or pass away.

Another area of concern as families break apart, is finances. Many families are already operating under strained finances due to their economy being largely cashless while the need for buying goods grows. As large family units, they work corporate fields and can pool resources and labor, but if they continue to breakup, or dwindle in size, this benefit could be lost. People would have to start buying things on their own instead of relying on the families’ communal resources further straining finances, which for many are in an already precarious situation.

6. Conclusion

In dryland West Africa, and Mali specifically, agriculture has always been a difficult endeavor in the sub-Saharan climate. But as the climate changes, what was once a challenging environment is becoming an increasingly inhospitable one. This is

⁴ Management

decreasing agricultural outputs which not only has economic and food security implications, but social ones as well. As evidenced in the information we gathered from interviews, and the subsequent mental models, the strain from decreasing yields is leading to families breaking apart, and contributing to the choice of younger generations to leave their rural villages for better opportunities in urban centers. Families splitting apart and the migration of youth is leading to a breakdown in social networks that have traditionally provided support to people when hardships arise. And while moving away from polygamy and increasing urban populations are not an inherently negative trend, they have ramifications for these farmers that need to be addressed. Many of the elder family members expressed that children were lazy and/or uninterested in agriculture, a sentiment which maybe the expression of an underlining fear that there will be no one there to take over their farms or care for them when they get older. These farmers are aware agriculture is becoming more difficult, and there is concern that if family members leave them then they will no longer have the networks that they rely on in times of hardship. Further work that concentrates on addressing climate change in this region should focus on how to protect, and in some cases, grow these networks to increase resiliency.

One way to do this, that already exists in some areas and is proving beneficial, is through farming collectives. They allow people to advocate for government assistance, organize educational programs, purchase new seed varieties that are better adapted to the climate, and pool monetary resources. In our interviews, many individuals discussed being members of these groups, and the benefits they received. Some of the most

effective organizations were the women's collectives. By building on women's distinct social networks these groups have been able to provide women with larger gardens, agricultural education, and money to install community wells. This suggests that for someone looking to address the issues arising in this region related to agriculture, forming more of these women's collectives could be a potential starting point.

Another recurrent issue was the financial strain that has been placed on these families as their need to buy more food and fertilizer grows, and their family sizes (and therefore communal resources) dwindle. While we do not believe urban migration and a decrease in polygamy are inherently negative, there is a need for a support system to be created that can replace what is lost as Mali continues to modernize, and adapt to a changing climate. This work should include provisions that could address the serious financial issues that these farmers are facing as they try and adapt to the changing climate.

Even though the need to address climate change and the factors causing it are critical, for many the effects of climate change are already being felt in a significant way. For these people, who are usually some of the world's more vulnerable populations, the more urgent need is to adapt. By looking at more than just the economic and agricultural impacts of a changing climate, as this project has done, we believe a more complete picture of the problems at hand can be ascertained. And by examining these issues from a more holistic perspective, solutions for how to adapt will better address the needs of those already being burdened by a changing climate.

CHAPTER 3

For my third, and final, chapter I have chosen to include a reflection of my time in graduate school. My time here at NC State has been a transformative one where I have grown academically, professionally, and personally. In two short years, I have seen myself improve in many ways that I could have never imagined when I started here.

The biggest contribution to this growth has been through the research project on which this thesis is based. When the information for this project was first introduced to me I had heard of Mali only once or twice before. And when terms like food security, qualitative coding, and mental models were mentioned I was completely lost. However, with guidance from my advisor I developed a project that I not only understood, but that I felt would contribute useful information to the understanding of how climate change is affecting our planet's vulnerable populations.

This project began with me completing a literature review that is found in chapter one of this document. It is broken down into four categories that reflect overarching themes that were important to my project. Having these four themes helped me to focus what information I needed to research to have a better understanding of the current situation in Mali. From the information used in this literature review I developed a coding rubric that influenced the rest of my project as it was the basis for my coding. Qualitative coding was something that I had never even heard of, let alone done, and the prospect of doing it was daunting at first. However, once I began, and felt comfortable in my capabilities, it was an easy process that has been crucial to the completion of my project.

After I completed the coding, the biggest task of the entire project came next; converting information from the interviews into models. This required a great deal of time reviewing the codes that I, and fellow Master's student Dresden McGregor, did to find recurring themes and patterns within the data. I then converted these into influence diagrams. These diagrams serve as physical representations of how our participants were thinking about climate change, and the effects it is having on them and their food security. Once the models were created it allowed me to see my data in a way that I had never been able to before, and revealed new insights on my information. These insights allowed me to have a deeper understanding of the situation that these farmers are facing and what possible solutions there are to help them better adapt to their changing climate.

I thoroughly enjoyed doing this type of research as I feel it has provided relevant and useful information that can help vulnerable populations adapt. I have also enjoyed looking at environmental issues from a social science perspective. Coming from a biology background I was used to only analyzing problems in our environment when it came to plants, animals, or other non-human organisms. But this approach overlooks the fact that humans have the largest influence of any species on our environment, and face some of the worst effects from its degradation (often due to our own actions). By using social science methods to investigate climate change's impacts on farmers, I have been able to see the problem from more than an issue of rainfall amounts, and crop yields. This work has shown how families are being torn apart because of climate change's effects, and how this will only serve to decrease these farmers abilities to adapt. However, I have also been able to see how support networks, especially those of women, can help grow people's resilience to a changing

climate. Coming to these conclusions, and completing a research project, are things that I never would have thought possible before graduate school and show how much I have grown in my time at NC State.

In addition to learning from my research, the courses I have taken during my masters have served to teach me a significant amount of information that will serve me long after I've graduated. Whether it was general skills such as critical thinking or writing for multiple audiences, or more specific ones like writing educational objectives or conducting a meeting; I have learned many things in the last two years that have helped my grow not only academically and professionally, but personally as well.

Starting here as a twenty-one-year-old who had only graduated from college three weeks prior was scary to say the least. At first, I felt lost and overwhelmed surrounded by people who seemed to know what was going on while I felt clueless. But overtime I began to figure things out and saw my abilities, and therefore my confidence, grow. I have become someone who isn't afraid to reach out to strangers, put myself in situations that I would have been too nervous to attempt before, or take risks to get to a place that I want to be. And while academic and professional skills are important, it is the growth that I have made personally that will help me in the long run, and as I move into the next steps of my career.

Overall this has been a very positive experience that I am grateful to have been able to have. The lessons I have learned during my masters have been invaluable and have made me someone who will be more successful both professionally and personally.

REFERENCES

- Agarwal, B. (2000). Conceptualising environmental collective action: why gender matters. *Cambridge Journal of Economics* 24(3), 283-310.
- Akeredolu, M., Asinobi, C.O., and Ilesanmi, I. (2007) Gender and trends in production constraints among the Bambara People of Mali. *Proceedings of the 23rd annual meeting of the Association for International Agricultural and Extension Education*, 1-13.
- Becker, L.C. (1990). The collapse of the family farm in West Africa? Evidence from Mali. *Geographical Journal*, 313-322.
- Benjaminsen, T.A., Aune, J.B., and Sidibé, D. (2010). A critical political ecology of cotton and soil fertility in Mali. *Geoforum* 41(4), 647-656.
- Bledsoe, C. (1990). Transformations in sub-Saharan African marriage and fertility." *The Annals of the American Academy of Political and Social Science*, 115-125.
- Bocoum, I., Dury, S., Egg, J., Herrera, J., and Prevel, Y.M. (2014). Does monetary poverty reflect caloric intake? *Food Security* 6(1), 113-130.
- Brown, M. E., and Funk, C.C. (2008). Food security under climate change. *NASA Publications*.
- Brown, M.E., Hintermann, B., and Higgins, N. (2009). Markets, climate change, and food security in West Africa. *Environmental science & technology* 43(21), 8016-8020.
- Butt, T.A., McCarl, B.A., Angerer, J., Dyke, P.T., and Stuth, J.W. (2005) The economic and food security implications of climate change in Mali. *Climatic change* 68(3), 355-378.

- Coulibaly, J.Y., Sanders, J.H., Preckel, P.V., and Baker, T.G. (2015). Will cotton make a comeback in Mali? *Agricultural Economics* 46(1), 53-67.
- De Haen, H., Klasen, S., Qaim, M. (2011) What do we really know? Metrics for food insecurity and undernutrition." *Food Policy* 36(6), 760-769
- Dougnon, I., Sanogo, S., Coulibaly B., Diamoutene, A.K., and Morton, J.F. (2010). Leaving farmers as orphans: agricultural privatisation and reform of farmer organisations in Mali. *IPPG Discussion Papers* 38, 1-14.
- Dunlap, R.E. (1998). Lay perceptions of global risk public views of global warming in cross-national context. *International Sociology* 13(4), 473-498.
- Falconnier, G. N., Descheemaeker, K., Van Mourik, T.A., Sanogo, O.M., and Giller K.E. (2015). Understanding farm trajectories and development pathways: Two decades of change in southern Mali. *Agricultural Systems* 139, 210-222.
- Godfray, H. Charles J., Beddington J.R., Crute I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty J., Robinson, S., Thomas S.M., and Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science* 327(5967), 812-818.
- Hanjra, M.A., and Qureshi, M.E. (2010). Global water crisis and future food security in an era of climate change. *Food Policy* 35(5), 365-377.
- Hertrich, V., and Lesclingand, M. (2012). Adolescent migration and the 1990s nuptiality transition in Mali. *Population studies* 66(2), 147-166.
- Hussein, K. (2002). Food Security: Rights, Livelihoods and the world food summit—five years later. *Social Policy & Administration* 36(6), 626-647.

- Isaïe, D., Sanogo, S., Coulibaly, B., Diamoutene, A.K., and Morton, A.F. (2010) Leaving farmers as orphans: agricultural privatisation and reform of farmer organisations in Mali." (2010).
- Laris, P., Foltz, J.D., and Voorhees, B. (2015). Taking from cotton to grow maize: The shifting practices of small-holder farmers in the cotton belt of Mali. *Agricultural Systems* 133, 1-13.
- Madhavan, S. (2002). Best of friends and worst of enemies: competition and collaboration in polygyny. *Ethnology*, 69-84.
- Mayne, R. (2006). Causing hunger: An overview of the food crisis in Africa. *Oxfam Policy and Practice: Agriculture, Food and Land* 6(2), 97-135.
- Mercy, A., Asinobi, C.O., and Ilesanmi, I. (2007). Gender and trends in production constraints among the Bambara People of Mali. *Proceedings of the 23rd annual meeting of the Association for International Agricultural and Extension Education*, 1-13.
- Mertz, O., Mbow, C., Reenberg, A., and Diouf, A. (2000). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental management* 43(5), 804-816.
- Misselhorn, A.A. (2005). What drives food insecurity in southern Africa? A meta-analysis of household economy studies. *Global environmental change* 15(1), 33-43.
- Solivetti, L. M. (1994). Family, marriage and divorce in a Hausa community: A sociological model." *Africa* 64(2), 252-271.

- Sommerfelt, T., Hatløy, A., and Jesnes, K. (2015). Religious Reorientation in Southern Mali—
A summary. *Fafo Report*, 1-20
- Sultan, Benjamin, Roudier, P., Quirion, P., Alhassane, A., Muller, B., Dingkuhn, P., Ciaï, P.,
Guimberteau, M., Traore, S., and Baron, C. (2013). Assessing climate change impacts
on sorghum and millet yields in the Sudanian and Sahelian savannas of West
Africa." *Environmental Research Letters* 8(1), 1-9.
- Sylla, M. B., Elguindi, N., Giorgi, F., and Wissler, F. (2016). Projected robust shift of climate
zones over West Africa in response to anthropogenic climate change for the late 21st
century. *Climatic Change* 134(1-2), 241-253.
- Taleb, Nassim N., Read, R., Douady, R., Norman, J., Bar-Yam, Y. (2014). The Precautionary
Principle (with Application to the Genetic Modification of Organisms). *Extreme Risk
Initiative —NYU School of Engineering Working Paper Series*. (1-17).
- Tappan, G., and McGahuey, M. (2007). Tracking environmental dynamics and agricultural
intensification in southern Mali. *Agricultural Systems* 94(1), 38-51.
- Thurston, A. (2013). Towards an Islamic Republic of Mali. *Fletcher F. World Affairs* 37(2),
45.
- Tilman, David, Balzer, C., Hill, J., and Befort, B.L. (2011). Global food demand and the
sustainable intensification of agriculture. *Proceedings of the National Academy of
Sciences* 108(50). 20260-20264.
- Tone, S., Hatløy, A., and Jesnes, K. (2015). Religious Reorientation in Southern Mali—A
summary. *Fafo Report*.

- Traore, B., Corbeels, M., van Wijk, M.T., Rufino, M.C., and Giller, K.E. (2013). Effects of climate variability and climate change on crop production in southern Mali. *European Journal of Agronomy* 49, 115-125.
- Tschakert, P. (2007). Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change* 17(3), 381-396.
- Verisk Maplecroft. Food Security Risk Index 2013. Accessed 10 February 2015. Retrieved from: https://maplecroft.com/about/news/food_security_risk_index_2013.html
- What are mental models? Accessed 15 September 2017. Retrieved from: <http://mentalmodels.princeton.edu/about/what-are-mental-models/>
- Wittig, R., König, K., Schmidt, K., and Szarzynski, J. (2007). A study of climate change and anthropogenic impacts in West Africa. *Environmental Science and Pollution Research-International* 14(3), 182-189.
- Wooten, S. (2003). Women, men, and market gardens: gender relations and income generation in rural Mali. *Human organization* 62(2), 166-177.