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# Mental models of food security in rural Mali

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## Abstract

Recent estimates indicate that 12% of the global population is likely to have suffered from chronic hunger, due to lack of enough food for an active and healthy life. West Africa, specifically across the Sahel countries, is acutely vulnerable to food insecurity concerns. Mali is emblematic of this problem with approximately 4.6 million citizens considered food insecure. Food security poses formidable challenges. Studies have shown that in order to understand food insecurity and identify steps for effective intervention, there is a need to apprehend the food systems and food in/security in a holistic way beyond production alone. Understanding the behavioral aspects of food security is critical in the African context where agriculture, while oriented toward basic subsistence, remains embedded in social system including the social dynamics of households, extended families, and communities. This exploratory work focuses on developing a nuanced understanding of food security and adaptive behaviors to current challenges to food security at the household level with a distinct focus on inter- and intra-family behavioral dynamics in rural, southern Mali. Using mental models methodology, we developed two influence diagrams and a set of sub-models that represent rural households' mental models of food security under traditional conditions and under conditions of external pressures. These models suggest that food security in rural Mali is at considerable risk due to the influence of external challenges, such as climate change, on traditional behaviors and a lack of easily accessible corresponding behavioral adaptations.

**Keywords** Mental models · Food security · Climate change · Agriculture · Mali

## 1 Introduction

Recent estimates indicate that 12% of the global population is likely to have suffered from chronic hunger, due to lack of enough food for an active and healthy life (FAO 2013). West Africa, specifically within the Sahel's countries, is acutely vulnerable to food insecurity. The West African Sahel has

experienced long and severe droughts in the 20th and 21st centuries (Nicholson et al. 1998) which have had dramatic environmental, economic, and social impacts in the region. A particularly wet period in the 1950s was followed by a persistent period of severe drought in the 1960s and the 1970s, affecting millions of people and creating a shift in the climatic pattern and food insecurity in the region (Brooks

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2004). According to the Harmonised Framework survey, 37 million people are food insecure in the Sahel, with (21%) of them facing severe food insecurity and requiring emergency assistance (ECHO 2016). Food insecurity in Mali is therefore emblematic of that regional picture where up to 4.6 million Malians are food insecure (UN-OCHA 2012).

Since independence from France in 1960, food security in Mali has been a pressing issue for successive ruling governments. In spite of repeated political promises by multiple governments, food security remains a critical issue. Food insecurity is exacerbated by poverty, biophysical conditions, and the political environment and conflict, specifically in Northern Mali. Furthermore, erratic production of primarily rain-fed agriculture owing to rainfall variability is one of the major drivers of food insecurity in the region. Increase in climate variability, higher temperatures, and incidences of droughts are likely to exacerbate the vulnerability of rural subsistence farming households in the region (Roudier et al. 2011).

Most studies associate food insecurity with structural causes. It is believed that political commitment, effective institutions, good policies, a comprehensive approach in governance, and adequate levels of investment can contribute to winning the fight against hunger and poverty (FAO 2013). The structural response to food insecurity in Mali consisted of policy reforms ostensibly focused on enabling increased agriculture production. The *Loi d'Orientation Agricole* (LOA), a comprehensive agricultural development framework enacted in 2006, regulates agricultural production in the country to promote sustainable and competitive agriculture. The LOA advocates for land tenure reform that enables long-term investment in agriculture lands. It supports farmers' access to inputs (fertilizer), equipment, and government subsidies, with an emphasis on farmer's organizations and collectives as a central element in the agriculture development process.

Alongside the aggregate policy reform, specific responses to food insecurity include: food assistance consisting of food or cash transfers; emergency school feeding and nutrition programs in the conflict-prone Northern part of the country; and donors' support to households with basic agriculture inputs for kitchen garden as well as children's treatment of malnutrition.

While these specific responses to food insecurity are known to contribute to enhancing food security, they remain largely unsustainable. Furthermore, national policies to achieve food security are full of promise for agriculture production, but lack the specificity needed to address the complex granular socioeconomic contextual reality, which goes beyond the biophysical aspect of food production. There is now ample evidence that neither trickle-down effects in high-potential areas nor structural adjustment measures initiated in many African countries have sufficiently generated

the intended results of increased farm incomes and sustainable food security (Kuyvenhoven 2004).

Overall, sustainable food security poses formidable challenges and requires comprehensive efforts and special measures. Studies have shown that to understand food insecurity and identify steps for effective intervention, there is a need to apprehend the food systems and food insecurity/security in a holistic way which goes beyond production alone (Staatz 1994). Most farmers in West Africa rely on subsistence levels of production and are unable to invest in agricultural technology and machineries to boost their yields (Brown et al. 2009). Food security is the outcome of food system processes all along the food chain, from the producers/farmers who cultivate food, to global/national/local markets who distribute food, to consumers who buy, utilize, and consume food. Understanding the behavioral aspects of food security is critical in the African context where agriculture, while oriented toward basic subsistence, remains embedded in social system including the social dynamics of households, extended families and communities (Richards 1990). In light of these considerations, this study focuses on assessing the different aspects of food security qualitatively at the household level in Mali. This exploratory work focuses on developing a nuanced understanding of food security and adaptive behaviors to current challenges to food security at the household level with a distinct focus on inter- and intra-family behavioral dynamics in rural, southern Mali (the Koutiala district). Methodologically, we make use of mental modeling techniques (Wood et al. 2012; von Winterfeldt and Edwards 2007) to guide our research, and theoretically we build on previous work that examines food security, climate change, and farming practices in this region of the world. While the Malian context is unique, it does provide potential insight into broader food security issues found across the Sahel region.

## 2 Theoretical background

### 2.1 Food security

Food security is often defined in terms of four interconnected parts that operate at multiple scales: food availability (whether enough food is produced for a given population); food access (whether a population is able to purchase or obtain adequate food); food utilization (whether the food is prepared and consumed in optimal ways to ensure safety and proper nutrition); and food stability (whether a population is able to obtain food over time) (Barrett 2010; FAO 2009). A fifth dimension of food security that informs the other parts is the concept of culturally appropriate foods, which is tightly linked to the idea of food sovereignty (Menezes 2001). Beyond proper food availability, access, utilization,

and stability, there is a need for food systems to provide access to food that is culturally appropriate. Despite some level of conceptual clarity, food security can still be difficult to measure. Staatz et al. (1990) stressed the need to develop standards to measure food security for people in the Sahel zone. In the years following the famines of the 1970s, governments stressed the need to address food security at the national level. However, these early studies of food security in Southern Mali often failed to capture food stress at household and individual scales. A gap in knowledge of food security on small scales prevents policymakers from fully understanding and addressing the issues households face. Hussein (2002) advocated for multi-level collaboration between stakeholders and policy makers and stressed the need for policy makers to view food as a right, and to deepen understanding of the “root causes” of food insecurity. However, as suggested by prior articles (Staatz et al. 1990; Hussein 2002), gathering detailed information on the locations and identities of food-stressed people is very challenging.

Hanjra and Qureshi (2010) discussed food security through a natural resources lens. The authors briefly discussed climate change as a stressor, as it is expected to impact water resources and agriculture yield. Reduced access to suitable water resources will be a barrier to providing enough food to feed an expanding human population. Butt et al. (2005) used climate projections to develop impact scenarios upon Malian crops. The authors found that in the absence of actions to cope with the most extreme effects of climate change, large swaths of the population will be at risk of hunger and malnutrition. Some of the potential pathways to adaptation include development and utilization of heat-tolerant crops in addition to improving land quality.

More recently, Traore et al. (2013) explored climate variability in southern Mali over a period of four decades, from 1965–2005. During that time, a slight increase in minimum daily temperature was observed, though little change in maximum temperatures was noted. Seasonal rainfall changed from year-to-year; an increase in dry days during growing season led to a shift in the annual distribution of precipitation. Among the crops studied (cotton, sorghum, groundnut, and maize), cotton crops were the most sensitive to the precipitation shifts observed during growing season. That said, interruptions to regular precipitation events during rainy season, along with decreased soil quality, may negatively affect agricultural activities in the region (Traore et al. 2013). A set of scenarios used to model crop sensitivity to climate change across West Africa found that regardless of rainfall amounts, temperature increases equaling or exceeding 2 °C will likely have a strongly negative impact on crop yields. Given the greater sensitivity of crops grown in the Sudanian region, farmers in southern Mali may experience more dramatic crop decreases as climate change advances. Some research shows more modernized cultivars may help counteract the

negative effects of increased temperatures (Sultan et al. 2013). These studies on the effect of climate variability on food security allude to the importance of climate change in understanding food security in this part of the world.

## 2.2 Climate change

Large-scale climate shifts were first noticed in the 1970s and 1980s in the form of increased persistence of droughts, but the trend has continued, putting traditional lifeways at risk. In recent years, precipitation shifts, fauna migration, and land use changes across Burkina Faso help illustrate the trends much of Western Africa is experiencing, as the Sahel expands southward into the Sudanian zone (Wittig et al. 2007). Sylla et al. (2016) evaluated three climate projections to explore potential changes across West Africa. The models reflected an increase in dry conditions across the region, in addition to increased temperatures. An increase in aridity across the Sahel is expected to develop by the end of the twenty-first century. Increased temperatures, which drive aridity, are expected to place increased stress on water resources, leading to a more challenging agricultural context.

There is a limited set of research examining the climate change perceptions of people living in the Sahel. Existing research has focused on farmers in Senegal. Tschakert (2007) explored the impact of climate change on subsistence farmers in Senegal. Surveys indicate climate adaptation is hindered by health challenges, difficulty in acquiring jobs, and lack of infrastructure in villages. Tschakert (2007) also used focus groups and “conceptual mapping activities” to develop models of Senegalese farmers’ understanding of the drivers and risks of climate change. The models suggest a poor understanding of the complexity of climate change. Past studies on adaptation of Malian farmers to climate variability and droughts show that farmers have a high perception of these climate trends (Mertz et al. 2009) and have been using various adaptation strategies to adapt to these changes. Village grain banks, labor sharing, informal lending institutions, etc., form a collective social capital which the farmers draw from during times of need. Similarly, Mertz et al. (2009) noted that farmers in the Sahel have always faced the need to adapt to climate variability. Studies have shown that the resilience of rural communities in Africa to climate change and variability is influenced by social learning and communications across multiple institutional scales, community reorganization, and adaptive capacities (Osbaht et al. 2008).

The increasing effects of climate change are expected to make culturally significant activities (like farming or herding practices) more difficult. Exploring the cultural threats posed by climate change is essential to ensure policies to promote climate resilience are feasible and relevant to

vulnerable communities (Adger et al. 2013). Nielsen and Reenberg (2010) found culture also impacts a community's ability to adapt to climate change. Several factors impact a group's ability to adapt, given differences in gender and socioeconomic level. Within rural households, families often adopt a variety of adaptation strategies. Nielsen and Reenberg's (2010) study focused on the factors that prevented the development of climate resilience among the Fulbe people, who are located in Northern Burkina Faso. Though the results cannot be generalized beyond the Fulbe, it highlights the need to understand the cultural factors that enhance or inhibit climate resilience in sub-Saharan communities (Nielsen and Reenberg 2010). A gender-focused study conducted by Aberman et al. (2015) explored climate vulnerability through the lens of gender. Given that men and women have differing levels of access to resources, a person's ability to navigate climate shifts is affected by gender. Malians were included in a cross-cultural study that explored gender dynamics within groups involved in agricultural activities that are threatened by climate change. Across the four countries included in the study, authors found women's access to adaptive resources are often constrained by gender norms, but climate vulnerability can be moderated through community support and pooled resources. The impact of climate change on food security is also closely tied to local agricultural practices.

### 2.3 Malian agriculture

Mali experienced rapid agricultural growth throughout the second half of the twentieth century, but in recent years, the southern cotton-producing region has experienced lower cotton yields, along with increased use of fertilizer. Soil analyses were not able to confirm degradation, as the quality of samples from cultivated fields and fallow fields were similar. Benjaminsen et al. (2010) suggested declines in yields can be attributed to expansion into lower-quality tracts of land. Laris et al. (2015) challenged this notion, through an analysis of satellite data and interviews with farmers. Since the early 2000s, Malian farmers intentionally switched from cotton to maize. Farmers discussed a perceived need to focus on maize over cotton, as a lack of fertilizer has forced a shift in priorities.

Furthermore, dramatic shifts in precipitation are expected to alter subsistence farmers' abilities to provide food. Farmers who are unable to produce and sell excess food are at an increased economic risk during droughts, when their abilities to provide for their households' needs become stressed. Low financial reserves prohibit farmers from purchasing supplies during times of food stress (Brown and Funk 2008). An analysis suggested traditional farming methods maximized outcomes for food crops (Jolly and Gadbois 1996). This work complements Tappan and McGahuey's (2007)

assessment of Malian communities that implemented soil and water management practices with the support of a government agency. The analysis demonstrated villages that received help experienced better outcomes. Though the research is over a decade old, it may point to best practices. Traore et al. (2013) analyzed the planting patterns of the major crops in Mali. Over a period of three seasons, planting dates and crop duration of cotton, millet, maize, and sorghum were studied. A comparison showed some crops (millet, maize, and sorghum) were more tolerant to late planting, while others (cotton) produced higher yields when planted early. Additionally, crops had differing levels of sensitivity to weather patterns. These findings indicate a potential for climate adaptation; adjusting planting patterns may assist farmers' efforts to adjust to shifting rainfall patterns while maximizing agricultural output.

Beyond agricultural practices, cultural practices significantly influence Malian agriculture. Becker (1990) conducted a study of a Bambara village in the late 1980s. Across the region, a chief, who determines how land is distributed among the heads of household, leads villages. Each head of household is then responsible for managing the land and directs the tasks of younger brothers, sons, and wives. In the mid-1990s, Wooten (2003) explored the gender dynamics of agricultural production in a small Bambara community near Bamako. Though women technically had access to income-generating activities such as gardening, men often dominated the higher income-generating tasks, such as cultivating cash crops like cotton. Given structural restrictions within the community, women are forced into labor-intensive and low-earning activities, like producing charcoal. This imbalance perpetuates women's reliance upon men and prevents women from acquiring resources to expand their income-generating activities.

The research presented in this paper addresses the need to understand food security at household and individual levels. Small-scale knowledge is viewed as an essential part of developing sound policy (Hussein 2002; de Haen et al. 2011). This work builds upon existing research concerning the climate-related stresses Sahelian farmers face, but expands the knowledge through modeling how farmers respond to a variety of climate-related threats. Furthermore, differences in gender and age were also explored, adding depth to the understanding of how culture impacts climate adaptation strategies.

## 3 Methodology

### 3.1 Mental models methodology

The research presented in this article adheres to the application of mental model theory and tools using influence

diagrams to represent key variables and their relation to key actors' decision behavior in a complex decision environment, food security in Mali for subsistence farmers (Wood et al. 2012; von Winterfeldt and Edwards 2007). Mental models are "internal conceptual representations of an external system" (Wood et al. 2012) that allow people to know, perceive, make decisions, and construct behavior in a variety of environments (Gentner 1983). They go beyond "schema" or "images," however, by providing constructs that are "manipulatable," enabling people to predict system states via mental manipulation of model parameters (Cannon-Bowers et al. 1993). The theoretical foundations of mental models are found in the cognitive sciences and the examination of how humans make sense of their environment (Craik 1943). Over the past two decades, there has been growing use of such models in the field of risk communication to develop a greater understanding of complex systems that feature multiple stakeholders, particularly systems that include interactions between individuals and potentially risky hazards (Zaksek and Arvai 2004; Allen et al 2002). In this study, the stakeholders are subsistence Malian farmers and the complex decision environment in question is household food security, which is intimately linked to agriculture and at risk from a number of contextual variables, such as climate change and variability.

The primary source of data for mental model methodologies is in-depth, semistructured interviews of individuals that have either experienced or could potentially experience the phenomenon being examined (Wood et al 2012). It is suggested in the literature that this style of interviews reveals more about the major beliefs, values and perceptions concerning an issue in a given population compared to more structured, close-ended types of interviews (Morgan et al 2002). Interviews are subsequently coded for recurring themes and concepts related to the phenomenon being examined. Themes and concepts are then used to develop an influence diagram that represents the collective mental model of the behavior in question.

### 3.2 Study area

The interviews for this study were collected in the Koutiala district in Mali, an administrative subdivision of the Sikasso Region of southern Mali with a population of about 575,000 people (2009 census) in an area of approximately 8730 km<sup>2</sup>. Most farmers in Southern Mali belong to the Bambara tribal group, who are mostly subsistence farmers within a rain-fed agro-pastoral system. Cotton is the main cash crop and is grown in rotation with sorghum, pearl millet, maize, groundnuts, and cowpeas during the wet season (Traore et al 2013). In Mali, which is a polygynous society, large households, with an average family size of 60–90 household members, are common. The household consists of the entire family

**Table 1** Study villages in Koutiala district

Village name	Distance from Koutiala	Number of interviews
Sincina	3 km	2
Wolobougou	5 km	6
Kaniko	14 km	5
Nampossela	15 km	7
Molobala	34 km	5
M <sup>1</sup> pessoba	45 km	6
Konsseguela	50 km	6

with the head of the household, his wives, and their children. In turn, the children have their own subfamily units of wives and children. Most household structures in Mali are composed of subfamily units (husband, wives and children) living in coexistence and sharing family resources. The farming system in Southern Mali consists of mainly cereals, especially millet, sorghum, and maize, which provide approximately 70 percent of total calorific consumption of Malians (Bingen et al 2000). Household food production among the Bambara is a dynamic process where individual household members farm in the collective plot and have the right to consume from the common granary (Adams 1993). The collective plot is owned by the head of the household and the patriarch. Select individual men (sons of household head) and women (wives of household head) may have user rights to individual plots to produce additional grains and vegetables to provide supplemental income. Active members of the household provide labor to collective plots to cultivate cash and cereal crops which is either sold or stored in the granary for future consumption by the family. The head of household, usually the elder male in the family, is the primary decision maker around food production and allocation and controls the land use and food allocation rights. The head/chief of the household also controls the production and allocation of household labor to produce subsistence consumption goods. Allocation of food is usually done by the head of the household who decides the amount of grains to be given to the women to prepare food. Elder women decide the menu for the meals and the allocation of labor among themselves to prepare the food. Young women in the household are responsible for food preparation, fetching water for household use, collecting shea nuts to make shea butter and firewood in the field, and forming an integral part in farm labor (specially for weeding and harvesting). The younger men and women in the household are also responsible for the labor in the collective and individual plots of land, while young boys are responsible for herding cattle.

We selected six villages for our study based on their distance from the Koutiala city center (Table 1). We did not want to go outside of a 50-km radius of the city center to

**Table 2** Definition of external challenges to food security that were used by the interview coders

External challenge	Definition
Food related	Regarding any changes in food consumption and distribution based on time/season
Technological	Developments in seed varieties, equipment, pesticide use, etc
Environmental	How soil degradation, lack of rainfall, etc., affects food production
Sociocultural	Challenges in way people think, act, and relate to others within the household, and in relation to society

**Table 3** Sources indicates how many interviews contained the code for each coder. References indicates how many times each code was identified by a coder

	Sources				References			
	Coder #1	Coder #2	Coder #3	Avg.	Coder #1	Coder #2	Coder #3	Avg.
Food-related challenges	26	20	21	22.3	35	31	25	30.3
Technological challenges	27	26	28	27	36	35	52	41
Environmental challenges	32	27	30	29.7	41	47	41	43
Sociocultural challenges	21	16	15	17.3	36	28	22	28.7

ensure similarity between villages' agricultural practices. Forty-one interviews were conducted between July 23 and 30, 2015, with 20 male (12 elder and 10 younger) and 19 female (10 elder and 9 younger) respondents who were recruited based on their gender and decision-making roles within the household. The respondents were placed in four categories: (1) Elder men, the primary decision makers within the household, and the owners of the plots within the household; (2) Elder women, the wives of the elder men and managers of individual plots within the household; (3) Younger men, the secondary decision makers of the household and managers/laborers of the collective and individual plots; (4) Younger women, the primary household workers, they help elder men and women and young men within the household with the household activities, and they traditionally have limited say in agricultural decisions. The study sample was determined through purposive snowballing technique (Biernacki and Waldorf 1981) where the initial contact in a village was made through the chief of the village who then referred to eligible respondents from other households in the village who fit our criteria. Interviews were conducted through this referral process until the point of data saturation was reached, where no new information or themes was obtained from the interviews. The respondents were interviewed individually with the average length of the interviews being approximately 60–75 min.

Respondents were asked a set of broad open-ended questions such as: "What is your household day to day experience with food?"; "How does this experience change during the seasons?"; "What challenges around food does your household face today as compared to when you were younger?"; and "What is your perspective on agriculture?". Respondents were also asked questions about their specific roles and responsibilities while farming within their households and the kind of decisions they take on a daily/seasonal

basis. This open-ended question design adheres to principles suggested by Morgan et al. (2002). The open-ended nature of the interviews also allowed respondents to talk about their perceptions of other household member's role in terms of food security. The goal of these broad interview narratives was to develop insight into the individual's cognition and perceptions of agriculture, climate change and food security. Additionally, the interviews focus on individual and household-level decision-making in terms of adaptation to climate risks and food insecurity. The interview narratives are used to develop two influence diagrams of the farmers' mental models of farming and household food security.

### 3.3 Interview analysis

All interviews were recorded, transcribed, and then translated from Bambara to French and English by a transcriber/translator who was a part of the study team's interview process in the field. This ensured that the transcription process was completed with respect to the study context. The transcriptions were crosschecked and reviewed by other team members to ensure consistency and accuracy in the translations.

The research team used Nvivo content analysis software to develop a coding rubric that consisted of 23 concepts that emerged from the interview narratives. The specific coding rubric for "External Challenges" developed from the narratives and their definitions is outlined in Table 2. A team of three coders coded the interviews separately based on the given rubrics, and the interviews were recoded twice to ensure intercoder reliability. Table 3 indicates how many interviews contained each of the challenges by coder (Sources), and how often each challenge was coded across the interviews by each coder (References). For example, Coder #1 coded for "Food Related Challenges" in 26 of

the interviews, and across those 26 interviews Coder #1 coded 35 phrases or sentences as referring to “Food Related Challenges.”

### 3.4 Model development

We collectively developed two influence diagrams using an iterative process once all coding was completed representing participant’s collective mental models of food security. The influence diagram is a holistic collection of all concepts, decisions, and contexts that were described by the interview respondents and as such is a comprehensive qualitative overview of the behavioral aspects around food security of all respondents (Whitley et al. 2017; Zaksek and Arvai 2004; Morgan et al. 2002). There was not a threshold measure for the inclusion of a concept,

Consider the following quote from an elder woman, who described her day-to-day experience with food:

“Every day the head of the family gives a gourd of cereal to the cook. She divides the cereal and gives each half to both women who do not cook in the daytime to crush/pound. She divides then the flour between the breakfast, the lunch and the dinner.”

Based upon reviewing this and other interview transcripts, it became clear that elder women manage the daily dietary needs of their respective households. In Fig. 5, this responsibility was noted in a node labeled “food consumption.” The node was connected to three sub-nodes meant to illustrate the tasks that comprised “food consumption,” and were labeled “menu,” “preparation,” and “distribution.” The above quote most closely follows the tasks related to “preparation” and “distribution.” In addition to discussing the work they perform with regard to food consumption, other elder women described their roles related to household food production and income generation.

The initial diagram was developed by the two of the coders in consultation with one of the project PIs using the LucidChart<sup>1</sup> program. This first model was referred to as the “Status Quo without challenges” model and represents the participants’ collective mental model of food security under status quo conditions in the absence of external pressures (Fig. 1). The first model focused on the individual level tasks that contributed to the four facets of food security (availability, utilization, access, and stability) at the household level. The model was split into four sections (elder men, elder women, young men, and young women). For each of these sections, the realm of decision-making for which a

given class of individuals is responsible for was then linked to specific tasks that were linked to one of the four facets of food security at the household level. For example, elder men are responsible for decisions in the realm income generation for the extended family. A potential way for generating cash is to grow cash crops, which contributes to greater food access and stability at the household level.

The “Status Quo without challenges” model conditions were contrasted with the present reality for interview respondents in the second influence diagram (Fig. 2). The second diagram is referred to as the “Status Quo with challenges” model and represented participants’ collective mental model for food security conditions with the perceived presence of external challenges. This model focused on the same individual level behavioral actions as the first model; however, they were filtered through external challenges identified during the coding process (environmental, technological, food related, and sociocultural) (See Table 2). In cases where adaptations were difficult to achieve or do not currently exist, the challenge represented an insurmountable barrier to achieving food security. The behavioral actions that terminated in the external challenges were still possible, but participants indicated they have become significantly more difficult or time consuming. However, a limited number of adaptations that had the potential to lead to food security were identified, such as the practice of selling cattle to pay for food that is in the realm of elder male decision-making.

## 4 Results

The collected mental models of food security for the household are represented in the influence diagrams of Figs. 1 and 2, under status quo conditions, and the presence of significant external challenges presents a complex system. For clarity, we also present two individual sub-models for each category of family member under status quo conditions and under the presence of significant external challenges. The following section of the paper presents a short description of each model and sub-model (excluding young women, whom are covered in greater detail in Sect. 5) (Sect. 4.1) and an illustration of the external challenges to family food security using direct quotes from the interviews (Sect. 4.2).

### 4.1 Model and sub-model descriptions

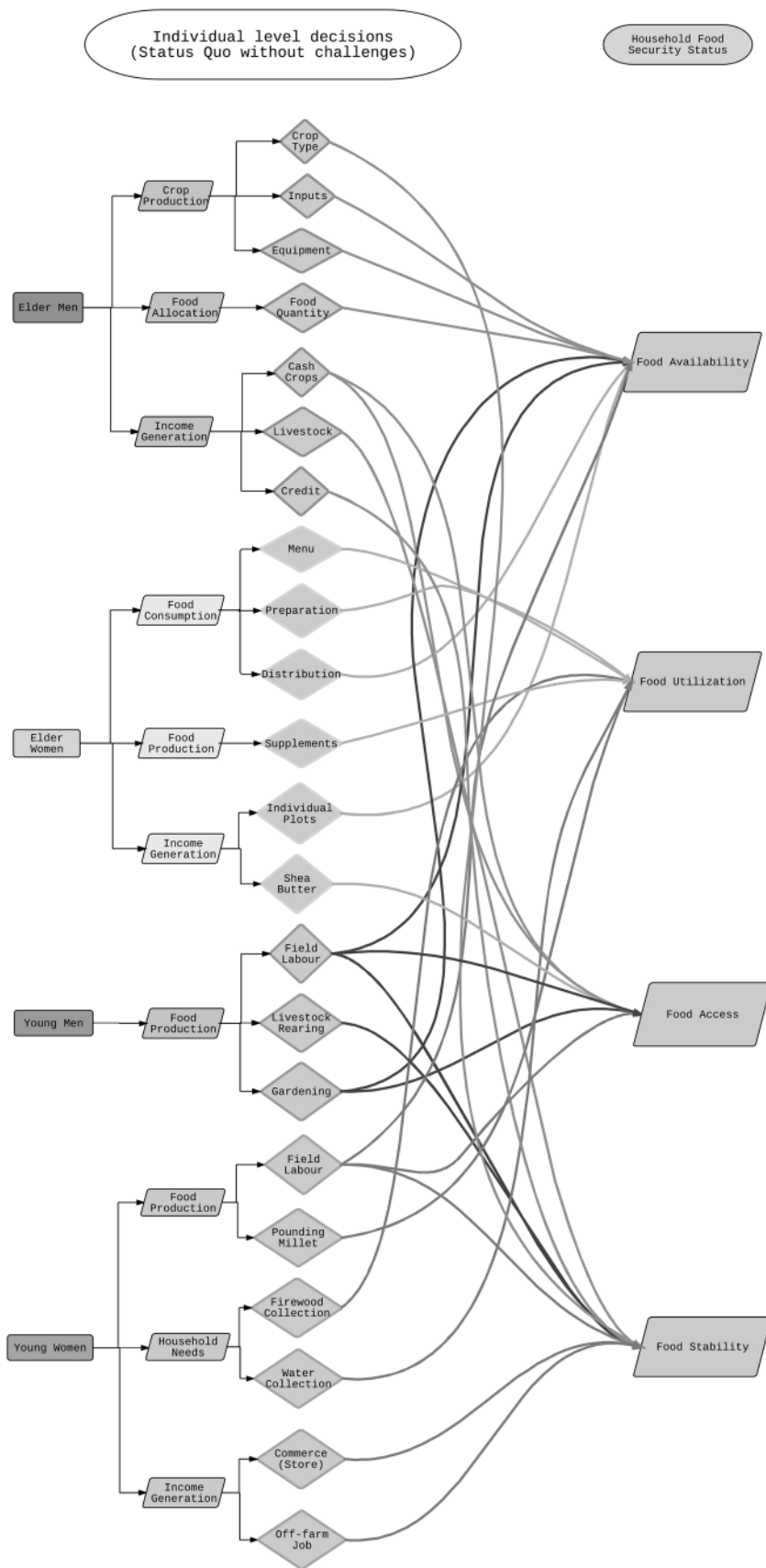
#### 4.1.1 Model descriptions

Status Quo without challenges influence diagram (Fig. 1): This model features each category of family member and their primary responsibilities in terms of food security during normal conditions. Each sub-node is linked to an aspect

<sup>1</sup> Lucidchart is an online model creation software package that allows multiple individuals to work on the same model collectively or individually.



Fig. 1 “Status Quo without challenges” influence diagram represents the participants’ collective mental model of food security under optimal conditions



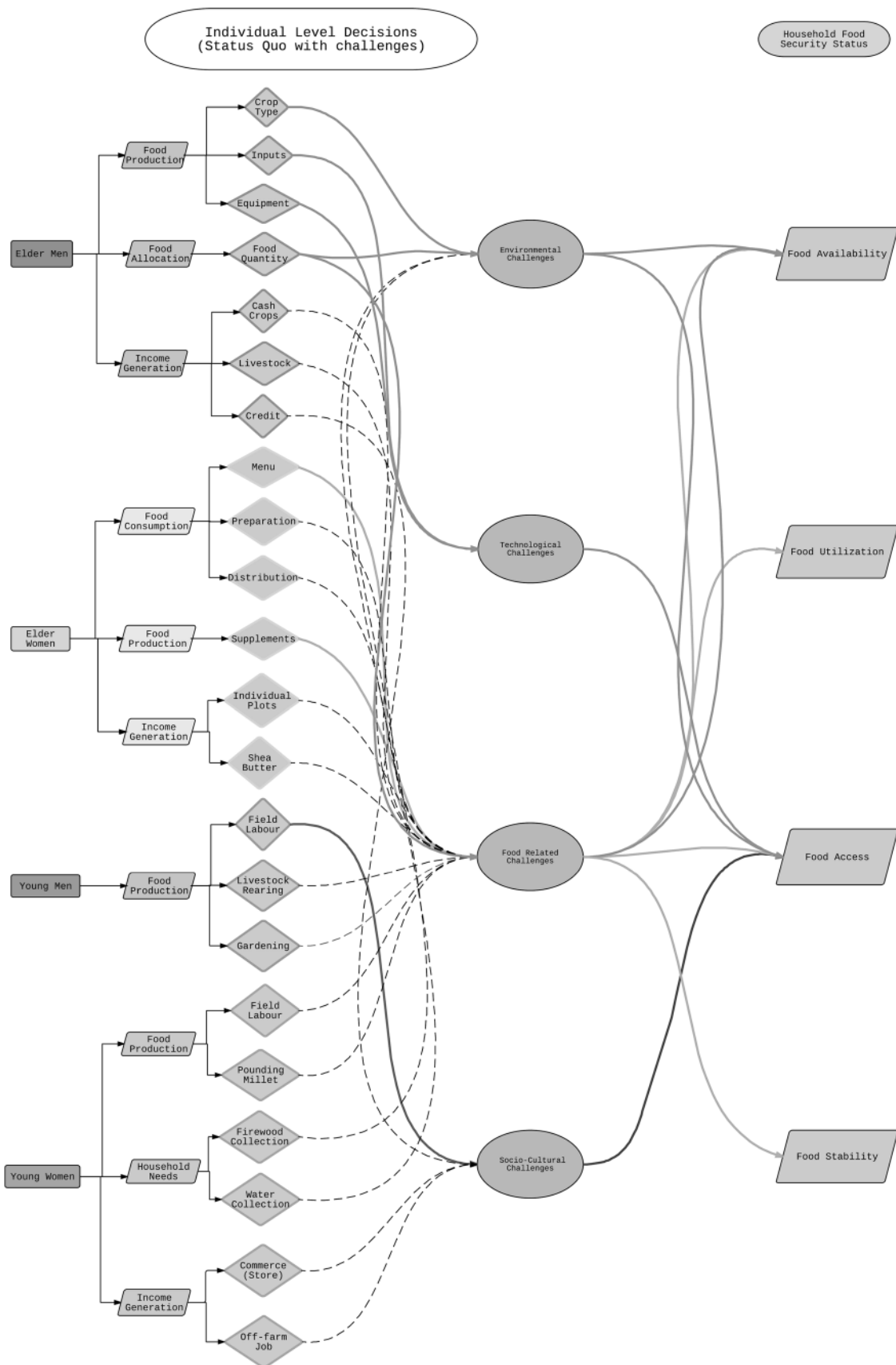


Fig. 2 “Status Quo with challenges” influence diagram represents the participants’ collective mental model of food security with the presence of external challenges

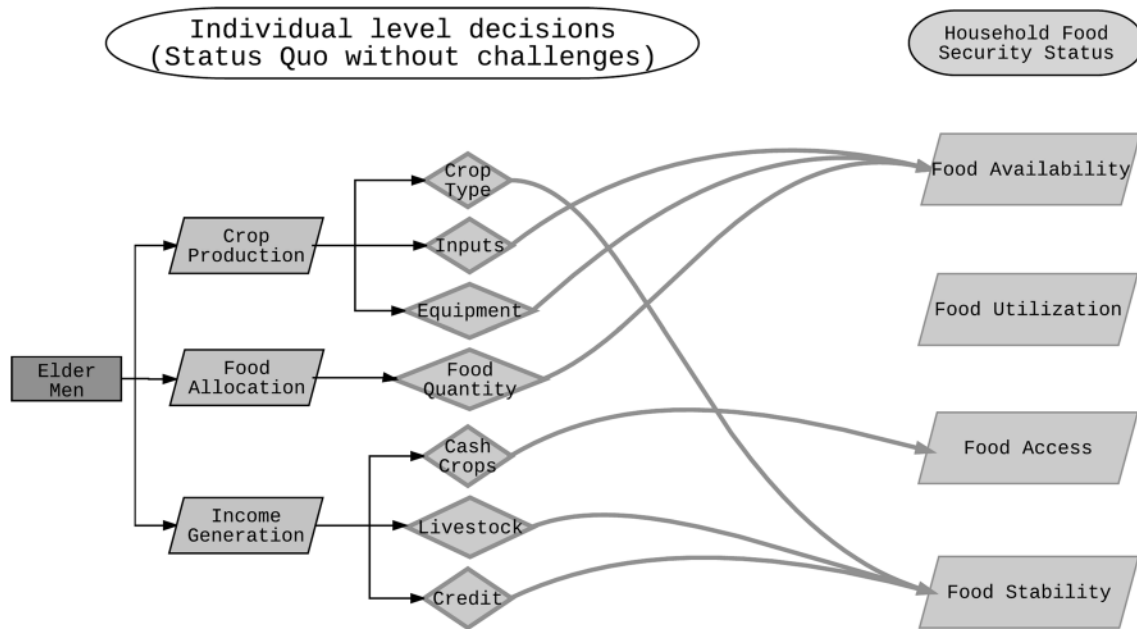


Fig. 3 “Status Quo without challenges” influence diagram with a focus on elder men collective mental model of food security

of food security (availability, utilization, access, or stability) model illustrates how redundant actions on the part of multiple family members lead to a resilient system. This notion is further examined in Sect. 5 of the paper.

Status Quo with challenges influence diagram (Fig. 2): This model introduces a set of external challenges identified by participants that significantly hamper their normal responsibilities in terms of food security. This model illustrates how these challenges significantly reduce the redundancy and subsequent resiliency of food security for a family. This assertion is further explored in Sect. 5 of the paper.

#### 4.1.2 Sub-model descriptions

Elder Men, Status Quo without challenges influence diagram (Fig. 3): This model shows the set of responsibilities that elder men control the decisions for in terms of food security under normal conditions. Elder men are responsible for decisions concerning crop production, food allocation, and income generation. It is important to note that many of the decisions that they make directly influence other family members. For example, they make decisions about what crops will be grown, how much and what type of inputs (fertilizer) will be used, and what equipment will be utilized; however, young men and women provide the labor to implement these decisions.

Elder Men, Status Quo with challenges influence diagram (Fig. 4): This diagram shows how external challenges influence elder men food security responsibilities. Of notice, is how responsibilities related to income generation all

terminate in food-related or sociocultural challenges. Cash crop production (primarily cotton) is often halted to focus on crops to feed the family, livestock is sold to purchase food, and it can be difficult to obtain credit from local banks. These decisions lead to reduced redundancy for activities that secure food access and stability. However, this group can overcome many challenges that it faces, often by shifting greater responsibility to other family members for whom they make decisions. Examples of this process are illustrated in Sect. 5.

Elder Women, Status Quo without challenges influence diagram (Fig. 5): This model shows the set of responsibilities that elder women control the decisions for in terms of food security under normal conditions. Elder women are responsible for decisions concerning food consumption, food production, and income generation. Similar to elder men, many of the decisions that elder women make directly affect other family members. For example, elder women are responsible for most decisions concerning food consumption (setting menus, planning the preparation and distribution of food to other family members); however, young women provide most of the labor for these tasks and are primarily responsible for fetching water and pounding millet, two key aspects of food consumption in this system.

Elder Women, Status Quo with challenges influence diagram (Fig. 6): This diagram shows how external challenges influence elder women food security responsibilities. Of note is how income-generating activities are ceased when faced with food challenges. The production of shea butter and cash crops is often halted to focus on more core activities, such

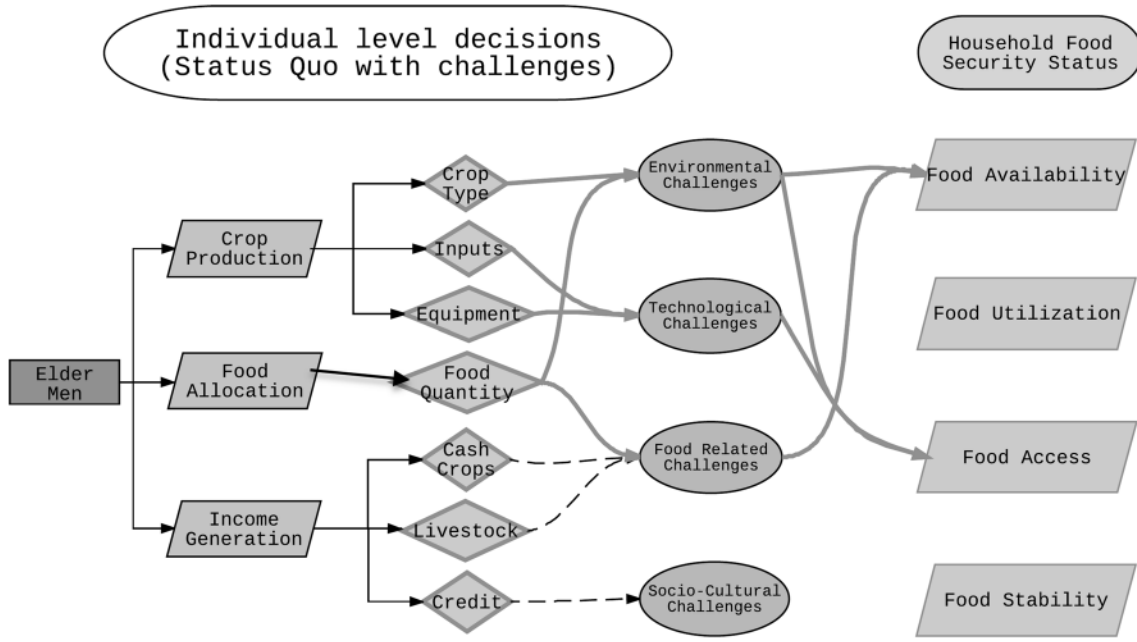


Fig. 4 “Status Quo with challenges” influence diagram with a focus on elder men collective mental model of food security

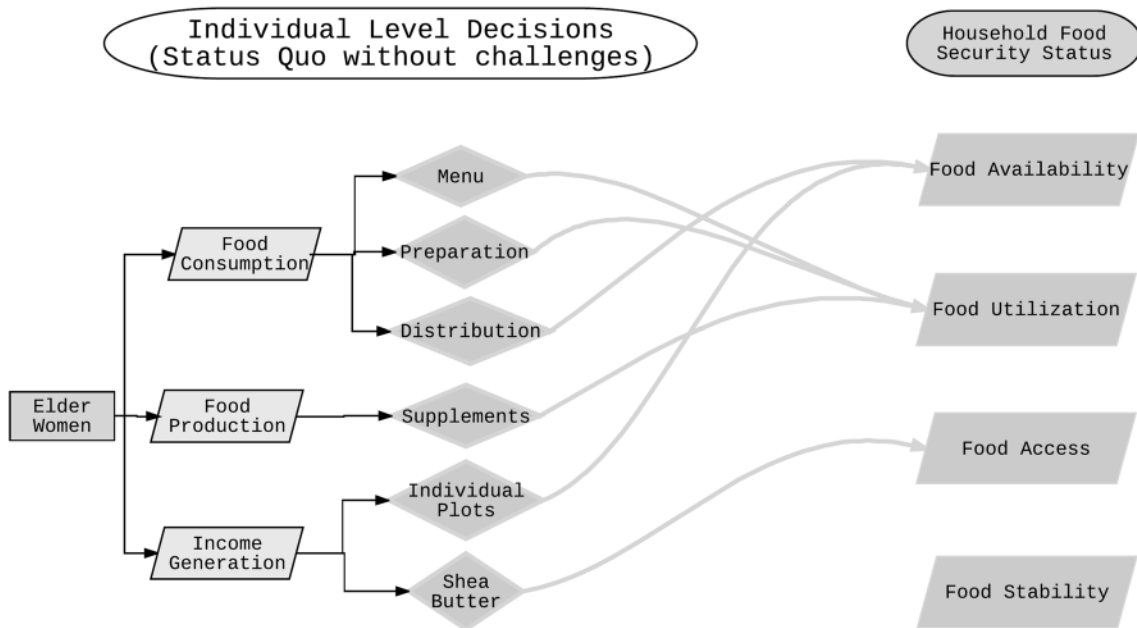


Fig. 5 “Status Quo without challenges” influence diagram with a focus on elder women collective mental model of food security

as the production of supplements (sauces and additives to make food more appealing and nutritious for children). The cessation of these activities reduces the redundancy of tasks that contribute to food availability and access.

Young Men, Status Quo without challenges influence diagram (Fig. 7): This model shows the set of responsibilities that young men control the decisions for in terms of food

security under normal conditions. Young men are primarily responsible for food production via field labor, livestock rearing, and gardening. Gardening refers to the cultivation of a small plot of land sometimes giving by the head of the household to a young male to grow food for his immediate family. Young women often provide additional labor for garden plots.

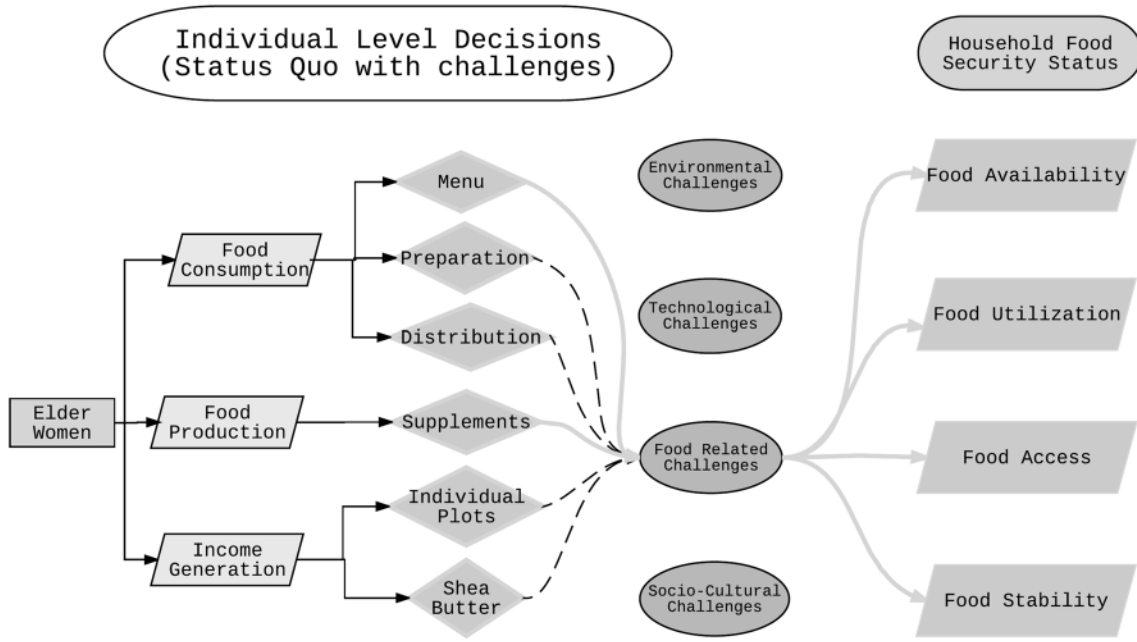


Fig. 6 “Status Quo with challenges” influence diagram with a focus on elder women collective mental model of food security

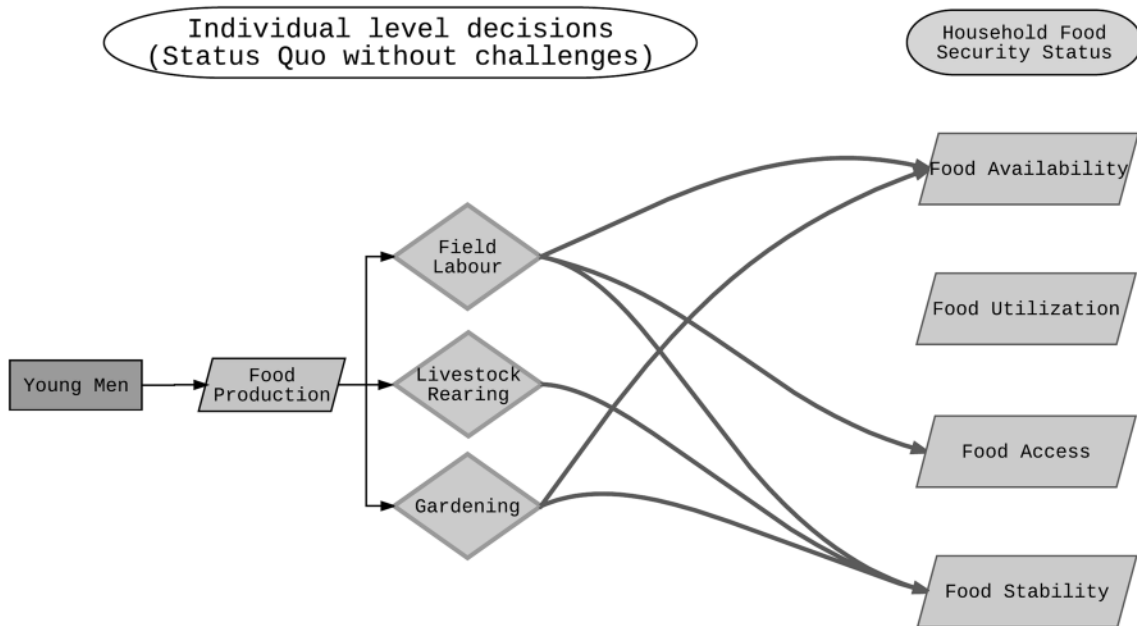


Fig. 7 “Status Quo without challenges” influence diagram with a focus on young men collective mental model of food security

Young Men, Status Quo with challenges influence diagram (Fig. 8): This diagram shows how external challenges influence young men food security responsibilities. Field labor is key for young men. Poor soil or sporadic rain can pose significant environmental challenges to working

their own land; however, they are still able to work on other farms or to migrate to urban areas to provide remittances for food to the family, despite the sociocultural challenge of elder men and women preferring that young men focuses their labor on the family’s land.

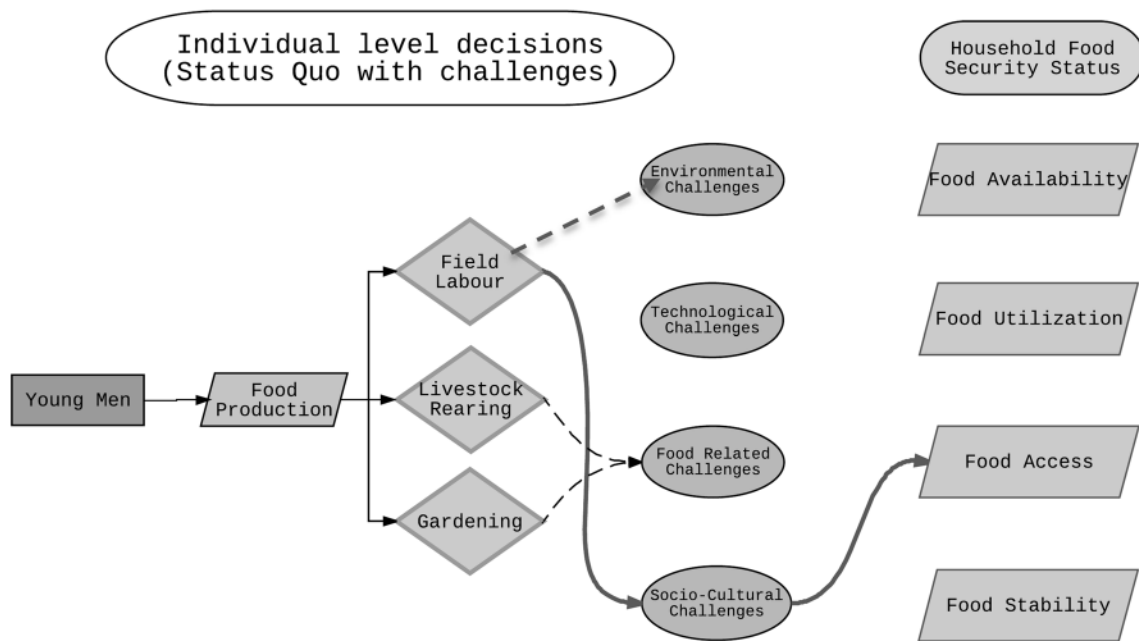


Fig. 8 “Status Quo with challenges” influence diagram with a focus on young men collective mental model of food security

### 4.2 Influence diagrams and threats to food security

The models developed by this work illustrate the acute threat of food insecurity to the well-being of Malian farmers. Specifically, the challenges identified in Fig. 2 at the group level and Figs. 4, 6, 8, and 10 at the individual level (environmental, sociocultural, food related, and technological) have exacerbated the risk of food insecurity for participants in our study. Our work suggests that these challenges loom large in the mental models of our participants as demonstrated by the influence diagrams (Figs. 1–10) and the quotes found below. These challenges to food security have largely been examined in previous work; particularly food-related (Hatløy et al. 2000; Torheim et al. 2004), technological (Tappan and McGahuey 2007; Brown and Funk 2008), and environmental challenges (Wittig et al. 2007; Sylla et al. 2016) are well covered in the extant literature.

Food-related challenges often occur seasonally. At present, households are unable to produce sufficient food to cover an entire year. The following quotes summarize these challenges:

“The food shortage is our big problem. Our produce can feed the family just seven month in the year” – Elder female (This challenge is reflected in Fig. 6, as the food production node and related sub-nodes encounter a food-related challenge, specifically a lack of food during part of the year. To address these challenges requires greater labor in the field or small

gardens on the parts of young men and women in the family)

“It is the periods of food shortage which affect us a lot. Last year we harvested the corn to consume it immediately. The yield is low to meet our entire needs. We buy cereal subsidized by the PAM [UN world food program] but the quantity subsidized also is little to cover the request of the population.” – Young male (see Fig. 8)

In response to these stresses, households have been forced to find ways to generate additional income to provide food. Several interview participants described the need to sell livestock to mitigate food loss.

“When we left at Ziéla head of the family sold its cattle and its equipment, we encountered equipment problems and work but because we were small and we hardly received help.” – Young female (See Fig. 4, the young women that gave this quote is referring to the actions of an elder male to face food-related challenges)

One young man cited “Insufficient equipment. [And] insufficient oxen for plowing” as the primary barriers to cultivating sufficient food. The lack of access to technology increases the burdens placed upon household members:

“Weeding [by hand] is painful.” – Young female

Both of these challenges are reflected in Fig. 4, since elder men control access to farm equipment and the selling

of livestock. As alluded to in Sect. 4.1, these examples illustrate how a challenge in the decision-making realm of one category of the family can have severe impacts for other members of the family that do not have control of decisions related to this challenge.

In response, some older household members explain challenges through the lens of belief, as described below:

“Rain Failure and bad distribution in time: we organize prayer sessions for rain, it rains often and often nothing happens.” – Elder male

Many participants discussed the role of environmental challenges. The lack of reliable rainfall was a widely discussed concern:

“Last year rainfall was insufficient, the yield has decreased. Wells in which we collect water quickly dried up during the dry season we had a serious problem of water for domestic use and for gardening. We need water to sustain the family we go collecting water to the pump to 3 km from home, it puts us behind the entire program of the day.” – Elder female (See Fig. 10, the elder woman who provide this quote is referring to actions that are the responsibility of young women to face environmental-related challenge. In order to address this challenge, young women need to exert a significant amount of labor and time and are unable to delegate it to other members of the family. This is why the dashed arrow ends in the challenge.)

“Yes, rainfall is a challenge. This year for example, we started sowing late. Because the rain was delayed. It started raining on the 10th of July, so insufficient rainfall is a big problem.” –Young male (This challenge is reflected in Fig. 8, where field labor is terminated into the environmental challenge node since labor cannot address the challenge of inadequate or sporadic rainfall)

“We rely on rainfall. When there is no rain, we cannot proceed with the sowing. Fields are also invaded by weeds.” –Young female

This is in contrast to past years, when rainfall occurred on a more predictable scale. One elder female discussed the ease of cultivation in years past:

“There were no major problems, soils were fertile and it rained heavily. We had beef and tillage equipment. We did all the work by hand and yields were good.”

Other environmental concerns, namely soil degradation, were also discussed:

“Land degradation: it is necessary for us to use the manure every two years to have a good yield, our

labor is mainly women and do not like collecting the manure.” –Elder female

This quote illustrates how the need for increased fertilizer, which is in the decision-making realm of elder males (See Fig. 3), is addressed via the labor of another category of family member, young women. This is how elder males are able to overcome the environmental and technological challenges posed by poor soil quality.

However, there is less coverage of the effects of sociocultural changes on food security in the literature. For example, our interviews suggest a paradoxical perception of education. On the one hand, education is highly valued, and on the other, there is concern that education makes children less suitable agricultural workers. This is illustrated in the following quote from an interview with an elder male:

“Children do not like to cultivate. Schooling has spoiled them, they do not study well and they do not work in the field.”

There is a similar worry about the spread of liberal ideals among young people negatively affecting their contributions to household-level food security.

“With more democracy we can[not] educate our children as we have been by our parents or you risk going to jail. In our time at 4 am, our old awoke and spent water on the face and went directly to the field. Never did the sun rise find us at home and we never were back before sunset. We left at dawn and go back at dusk. The person who refused was beaten very hard.” –Elder male

While these observations can be partially attributed to traditional inter-generational conflict (i.e., young people are often perceived as lazy by older generations across cultures), they also represent anxiety about the breakdown of traditional social structures. This anxiety is also expressed by the younger generations:

“Today the heads of families ensure [adequate food] for a period of the year, its every man for himself for the rest [of the year, this includes] the problems of health, clothing, wedding second wife. We often disobey when the leaders do not provide [for] our needs.” –Young Male

“The family heads before was supporting all the problems of the family; everyone obeyed them by what they ensured the well-being of everyone. All properties of the family were collective and under management of the family head. Nobody could make personal sav-

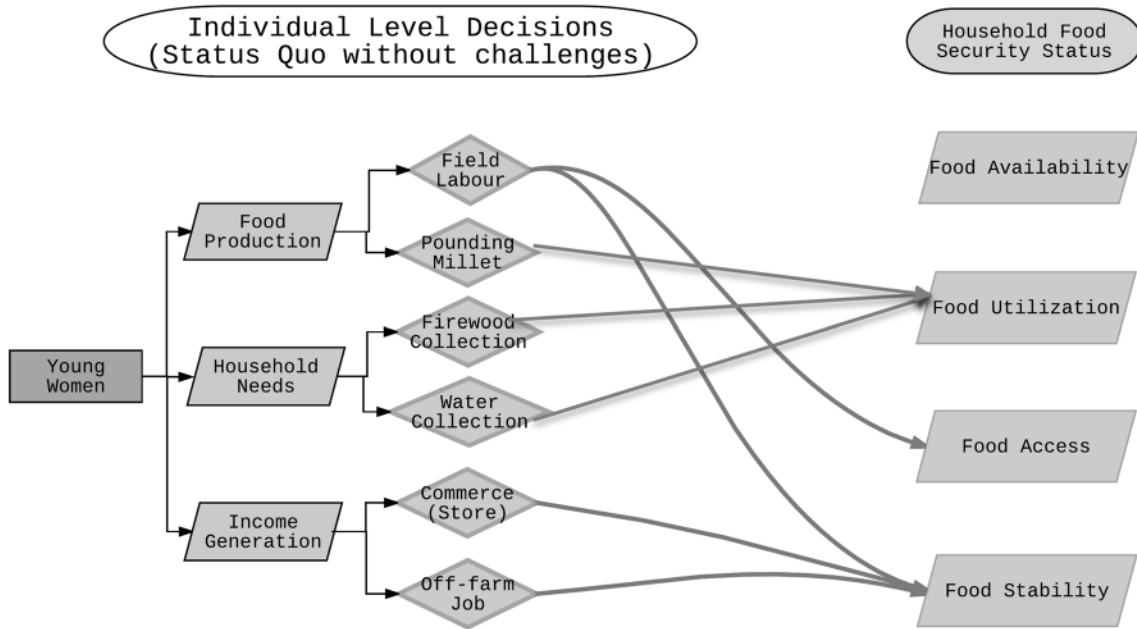


Fig. 9 “Status Quo without challenges” influence diagram with a focus on young women collective mental model of food security

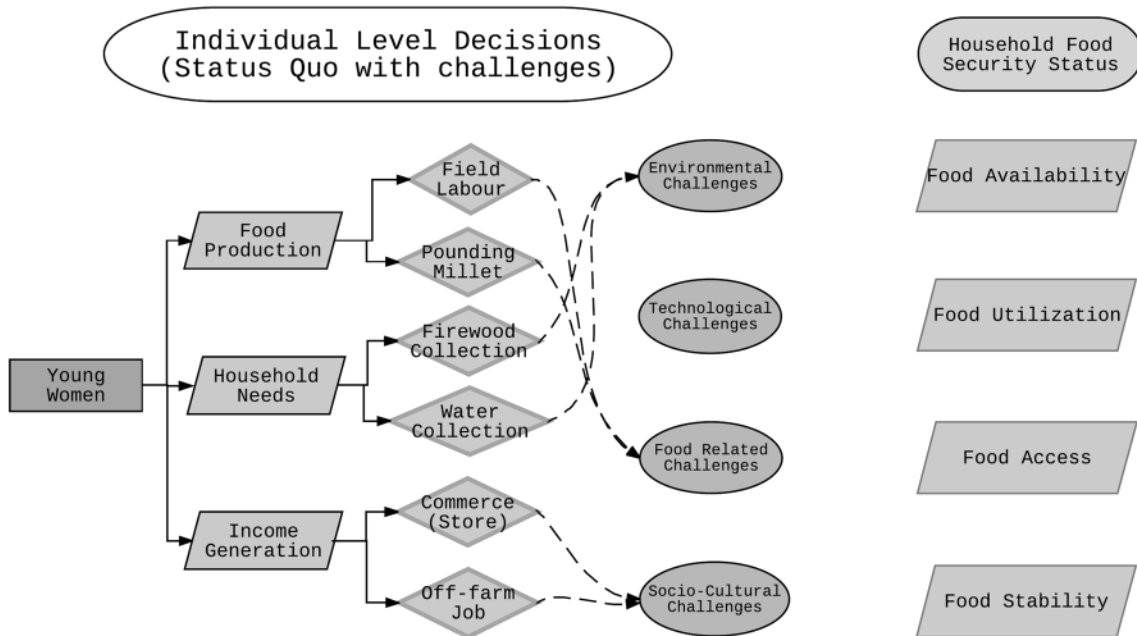


Fig. 10 “Status Quo with challenges” influence diagram with a focus on young women collective mental model of food security

ings. Nobody disobeyed, myself I was chastised by my grandfather when I refused to get into the granary to bring out the millet.”  
 –Young Male

### 5 Discussion

The models developed by this research project have provided an in-depth perspective on food security at the household level in rural Mali. Furthermore, this work has highlighted the precarious nature of young women in



relation to household food security in these large families. Essentially, young women provide a great deal of labor to establishing a food secure household, but are also the most vulnerable to external challenges to household food security. In this section of the paper, we examine this paradoxical situation.

### 5.1 Young women and food security

Current literature has not thoroughly documented the climate adaptation efforts of young women in Mali. Figures 9 and 10 provide a more detailed look at how young Malian women navigate food provisioning, along with the barriers they face in their efforts to feed their households. Our work suggests that young women are key to food security in this system.

In the “Status Quo without challenges” model, young women are responsible for food production, household needs, and income generation (Fig. 9). Each of these responsibilities is further divided into smaller tasks. Food production consists of pounding millet and engaging in field labor. Collecting firewood and water is the main task associated with household needs. It is important to note that each of these four tasks are directly influenced by decisions made by other members of the household. Additionally, some young women generate additional income through commerce and off-farm jobs. Several of these tasks benefit the household through supporting one of the pillars of food security (Barrett 2010; FAO 2009). However, in times of stress, the aforementioned tasks often encounter challenges (environmental, technological, food related, and sociocultural) (Fig. 10). Interviews with young women indicated these challenges were often difficult to navigate by conventional means or without exerting significantly more labor. The influence diagram in Fig. 10 reflects these barriers through dashed links that start at a task and end at a barrier. Furthermore, as indicated in the discussion of the sub-models in Sect. 4.1.2, young women are often responsible for the completion of tasks for which other members of the family control the relevant decision-making process. In short, even under status quo conditions, young women carry a heavy burden for the maintenance of day-to-day household food security. This is in addition to their responsibility as the primary caregiver for children. The paradoxical position faced by young women can be contextualized by examining how food security operates across the larger family structure.

### 5.2 Food security across the family structure

As suggested in earlier sections of the paper, household food security is very much a collective task, and decisions made by one individual has significant ramifications for other household members. Unlike young women, other

segments of the household (see Figs. 3–10) are often able to utilize alternatives in the decision-making processes to adapt to food stress. When faced with environmental challenges, such as sporadic rainfall, elder men are able to adapt to these pressures by changing the type of crops the household will cultivate (Fig. 4). In turn, a change in crop type places food-related stress upon elder women, who are tasked with preparing daily menus. However, many of the elder women discussed their ability to navigate these challenges by directing the younger women in the household to prepare meals that utilize the food that is available (Fig. 6). Young men reported having to find work away from their household’s farm during times of food-related or environmental stress (Fig. 8). Due to decreased decision-making authority, adaptation options are not readily available to young women (Fig. 10). Environmental stresses, like deforestation, have forced young women to spend more time foraging for firewood. Rather than delegating firewood collection to other members of the household, young women must respond to this stress by spending limited funds on firewood or reducing the use of firewood for everyday tasks. As a result, their abilities to contribute to daily household functions decreases. Furthermore, unlike young men, young women face socio-cultural barriers to migrating, such as safety concerns and a lack of off-farm employment opportunities (Fig. 10). In any household, the decisions of one member will affect the decisions and activities of other members, and this is definitely the case for the participants in our study. However, our work suggests that in term of food security young women’s labor and time are disproportionately affected by the decisions of other household members.

### 5.3 Resiliency of food security systems

Our work suggests that these challenges to food security across the family structure, particularly for young women, create risk by significantly reducing the resiliency of food security systems. The concept of resilience originated in ecology as the degree to which a system can continue to function after exposure to stress (Miller et al. 2010). Another perspective on resilience as defined by Holling (1973) is “the persistence of relationships within a system and measure of the ability of these systems to absorb change of state variables, driving variables and parameters, and still persist.” In both approaches, resilience is the capacity of a system to absorb disturbance and retain essentially the same function, structure, identity and feedbacks (Walker et al. 2004; Alliance 2009). Figure 2 represents a system that lacks resiliency largely by a severe reduction in redundancy. The external challenges reduce the set of successful behaviors that farmers can make use of to achieve household food security, exacerbating an already precarious position. Furthermore, as suggested in earlier in this section, the majority

of adaptation options are afforded to elder men and women, which increases the vulnerability of younger members of society. However, it should be noted the traditional practices are not always the best practices, as modernity has benefits. This is reflected in the precarious position that young women find themselves in relation to food security. The patriarchal nature of traditional Malian society has limited the decision-making authority of young women and subsequently the set of related tasks that they control. Figure 10 illustrates the lack of adaption options afforded to young women in comparison with other household members.

This observation resonates with previous studies (Aberman et al. 2015; Wooten 2003), young women (and by extension children, which are largely under their care) are more vulnerable to the challenges of food security than other demographic groups. This suggests the need for future policy programs to specifically focus on the needs of young women and to expand their access to resources in order to increase the range of adaptation behaviors available to them. Additionally, it is important to consider the need to maintain culturally appropriate foods when addressing the resiliency of food security systems. While the food choices in the food systems we examined, even under external pressure, remain culturally appropriate, global trends in food delivery systems challenge the cultural appropriateness and biodiversity of food selections (Johns and Sthapit 2004). These developments also have the potential reduce the overall resiliency of food production systems.

## 6 Conclusion

Efforts to broaden adaptation policies can benefit immensely from the integration of nuanced data that indicates how farmers—differentiated across multiple axes of social, demographic, political, and ecological factors—make decisions on how to adapt to social–ecological change and uncertainty. Factors which are interlinked to each other in determining the adaptive capacity of households (such as resource entitlements, institutions, gender, socioeconomic, behavioral and cultural) require an approach which embraces the complexity of embedded systems. It requires looking at biophysical risks and exposure, sensitivity, and adaptive capacities (sociological, ecological, behavioral and institutional) not in silos but as an integrated complex system where there is a scope for a range of adaptation and resilient outcomes to emerge.

Beyond the policy level, adaptive behavior to climate risks requires decision-making in an environment, which is new and unfamiliar (de Suarez et al. 2012). The adaptive process represents not only a change in the behavior but also a change in the sociocognitive risk perception, mental models, and appraisal of the capacity to adapt (Grothmann and

Patt 2005). In addition, farmer adaptation behaviors depend heavily on changes in the sociocognitive risk perception and behavior, their mental models of risk and impact as well as their appraisal of the capacity to adapt (Grothmann and Patt 2005). These factors are in turn affected by farmers' interactions and social learning among social groups in conjunction with changes in biophysical and climate conditions (Adger 2010; Pelling and High 2005).

Various integrated assessment modeling of climate change has been conducted at the global, regional, and national levels to analyze the consequences of mitigation and adaptation policies and behavior (Fisher-Vanden et al. 2013), but they do not capture the nuances of human adaptive responses to climate change at the local level. The complex interaction of natural and social systems coupled with uncertainty in human responses to climate change warrants further explorations in the ways mental modeling can help us understand climate change adaptation. Our work represents an early, albeit limited, step in developing this more nuanced conception of food security.

## Compliance with ethical standards

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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