THE MULTIDIMENSIONAL NATURE OF HOUSEHOLD FOOD INSECURITY IN RURAL ZAMBIA: A PANEL ANALYSIS

By

Ayala Wineman

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ABSTRACT

THE MULTIDIMENSIONAL NATURE
OF HOUSEHOLD FOOD INSECURITY IN RURAL ZAMBIA:
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Food security is recognized as a multifaceted condition of complex causality that is related to, yet distinct from, poverty and hunger. Given its broad definition, it is no surprise that food security eludes precise measurement. This study considers there to be three components of household food security (quantity, quality, and stability), and attempts to address the "concept-to-measurement" gap in food security by building an index that spans these three dimensions. A panel data set is used for descriptive analysis of food security indicators in rural Zambia in 2000/01, 2003/04, and 2007/08. A multidimensional index of food security for rural Zambia is then developed using principal component analysis. This composite index is used to explore the spatial patterns of food security in Zambia over time, to assess correlates of food insecurity, and to measure the impacts of climate shocks on food security for different types of households, including female-headed households. Results indicate that both seasonal rainfall and temperature have a significant impact on a household's food security score, although not for all individual components of the food security index. The paper concludes with a consideration of the merits and shortcomings of developing a composite food security index.

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TABLE OF CONTENTS

LIST OF TABLES ... **vi**

LIST OF FIGURES ... **viii**

KEY TO ABBREVIATIONS ... **ix**

1. INTRODUCTION ... **1**

2. AGROECOLOGY AND RURAL LIVELIHOODS IN ZAMBIA ... **3**

3. FOOD SECURITY MEASUREMENT ... **6**

3.1 Definition and drivers ... 6

3.2 The three components: quantity, quality, and stability ... 7

3.3 Indicators of household food security ... 12

3.4 Construction of a composite index of food security ... 14

4. DATA SOURCES ... **17**

5. FOOD SECURITY INDICATORS IN ZAMBIA, 2001-2008 ... **19**

5.1 Income-based measures of welfare ... 19

5.2 Non-income food security indicators ... 23

5.3 Descriptive statistics ... 26

5.4 Correlation among indicators ... 38

5.5 Food security profiles ... 40

6. THE MULTIDIMENSIONAL FOOD SECURITY INDICES ... **42**

6.1 Construction of the indices ... 42

6.2 Composition of the indices ... 44

6.3 Suitability and factor loadings ... 46

6.4 Descriptive statistics ... 49

7. APPLICATIONS OF THE FOOD SECURITY INDICES ... **61**

7.1 Correlates of food sufficiency and food security (cross-sectional methods) ... 61

7.2 Correlates of food sufficiency and food security (panel methods) ... 69

7.3 Avenue of climate impacts on food security ... 77

8. DISCUSSION & EVALUATION OF THE FOOD SECURITY INDICES............................ 80

APPENDIX.. 91

REFERENCES.. 102

LIST OF TABLES

Table 5-A: Poverty indicators from 2001 to 2008 20

Table 5-B: Poverty indicators across subgroups in 2008 20

Table 5-C: Transition matrix of household income per capita for 2004 and 2008 23

Table 5-D: Descriptive statistics of various food security indicators over time 26

Table 5-E: Food security indicators by gender of household head in 2008 31

Table 5-F: Food security indicators in 2008, by agro-ecological zone 32

Table 5-G: Transition matrix of calories/adult equivalent/day for 2004 and 2008 34

Table 5-H: Location of calorie-deficient households in 2008 36

Table 5-I: Correlation matrix of food security indicators in 2008 39

Table 5-J: Food security profiles in 2008 41

Table 6-A: Elements of the food sufficiency and food security indices 45

Table 6-B: Factor loadings for multi-year indices: FSU and FSI 47

Table 6-C: Factor loadings for 2008: FSU and FSI 48

Table 6-D: FSU and FSI in 2008 50

Table 6-E: FSU and FSI across years 53

Table 6-F: Transition matrix of food sufficiency score from 2004 to 2008 55

Table 6-G: Transition matrix of food security score from 2004 to 2008 55

Table 6-H: Income and food security indicators, 2004 and 2008 56

Table 6-I: Food security indicators in 2004 and 2008 56

Table 6-J: Type I and II errors when income and FSI are used as targeting criteria 57

Table 6-K: Persistence of food security from 2001 to 2008 57

Table 6-L: Proportion of households by FSU and FSI trajectory 58

Table 6-M: OLS regression of change in FSU and previous FSU 60

Table 7-A: Logit and OLS regressions of household food sufficiency/ FSU score in 2008 63

Table 7-B: Determinants of being always food secure or insecure, 2001 67

Table 7-C: Determinants of FSU and FSI with HH fixed effects: 2001, 2004, and 2008 72

Table 7-D: Effect of lagged FSU and FSI with HH fixed effects: 2001, 2004, and 2008 76

Table 7-E: Impact of climate shocks by poverty level: 2001, 2004, and 2008 77

Table 7-F: Effect of climate on individual elements of the FSU: 2001, 2004, and 2008 79

Table 9-A: Cost of monthly food basket and basic needs basket per adult equivalent by province91

Table 9-B: Income indicator definitions 92

Table 9-C: Food security indicator definitions 92

Table 9-D: Other independent variable definitions 95

Table 9-E: Rainfall and temperature variables 97

Table 9-F: Calorie content of common foods consumed in Zambia 97

Table 9-G: Demographic and agricultural variables for 2001, 2004, and 2008 98

Table 9-H: Demographic and agricultural variables across subgroups in 2008 100

Table 9-I: Example of food sufficiency score calculation 101

LIST OF FIGURES

Figure 3-1: The four pillars of food security 10

Figure 3-2: An alternate framework: four domains of food security 11

Figure 3-3: Household food security framework in this thesis 12

Figure 5-1: Distribution of per capita income in 2008 21

Figure 5-2: Distribution of per capita income in 2008 among MHHs and FHH widows 21

Figure 5-3: Distribution of income per capita over the panel years 22

Figure 5-4: Distribution of calories/ae/day for 2001, 2004, and 2008 28

Figure 5-5: Distribution of calories by gender of household head 32

Figure 5-6: Distribution of months without food stocks in 2008 by agro-ecological region 35

Figure 5-7: CDF of calories/adult equivalent/day by agro-ecological zone 37

Figure 5-8: CDF of proportion of calorie requirements met, by agro-ecological zone 37

Figure 6-1: Radar graph of food security indicators for 2008 51

Figure 6-2: Distribution of FSU and FSI across years 52

Figure 6-3: Geographic pattern of average district FSU for 2001, 2004, and 2008 54

Figure 6-4: FSU and change in FSU, 2001 to 2004 and 2004 to 2008 59

Figure 7-1: Seasonal weather and food sufficiency 74

Figure 9-1: Agro-ecological zones in Zambia 91

Figure 9-2: Timeline of food security indicators 95

KEY TO ABBREVIATIONS

AE	Adult equivalent
AEZ	Agro-ecological zone
CSO	Central Statistical Office
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FFV	Fresh fruits and vegetables
FHH	Female-headed household
FSU	Food sufficiency index
FSI	Food security index
FSRP	Food Security Research Project
GDP	Gross domestic product
GRZ	Government of the Republic of Zambia
ha	Hectare
HH	Household
kcal	Kilocalorie
KMO	Kaiser-Mayer-Olkin measure of sampling adequacy
LCMS	Living Conditions Monitoring Survey
MACO	Ministry of Agriculture and Cooperatives
MHH	Male-headed household
TLU	Tropical livestock unit
WFP	World Food Program
ZMK	Zambian kwacha

1. INTRODUCTION

This thesis will analyze a longitudinal data set of households in rural Zambia in order to measure household food security, inclusive of vulnerability to future food shortfalls. Accurate measurement drives the diagnosis of food insecurity, the exploration of its determinants, and the design of effective policies to bolster household welfare. Measurement is necessary to understand whether a situation is getting better or worse and whether food insecurity is chronic or transitory. It reveals information about who is food insecure in a population and where insecurity is concentrated. Measurement, if done well, can also bring to light the nature of food insecurity, detailing whether it is a problem of food availability or economic access, of diet quantity or quality. It is a prerequisite for any analysis of the causes of food insecurity in a population, which in turn allows for appropriate interventions to address insecurity. Barrett (2010) further stresses the importance of developing measures that account for the multiple dimensions of food security and exhibit predictive power.

This study aims to broaden our understanding of food security measurement and dynamics, first by analyzing the relationships among various food security indicators and tracking these individual measures over time. It then develops a relatively simple measure of food security in the form of a single composite index that incorporates indicators of its multiple dimensions. This composite index is applied to household survey data from Zambia to address the following questions:

- Where are food insecure households found within Zambia?
- What is the nature of the food insecurity problem?
- How has food insecurity changed over time?
- To what extent does this food security index correlate with money-metric indicators of welfare?

- What are the determinants of food insecurity?
- Through what avenues do rainfall shocks affect food security?

Few other existing studies use a multidimensional measure of food security to address these kinds of questions, and to the author's knowledge, no other study thoughtfully reflects on the merits and shortcomings of using such a composite index. This thesis seeks to fill that gap in the literature.

Chapters 2 and 3 will present background information on agro-ecology and livelihoods in Zambia and a literature review on food security concepts and measurement. Chapter 4 will describe the data sources used in this study. Chapter 5 will provide descriptive statistics of various poverty measures and food security indicators in Zambia, disaggregated by region and gender of household head. Chapter 6 will detail the construction of a food sufficiency index and food security index using principal component analysis and will include descriptive statistics of the indices. Chapter 7 will present several applications of the indices, including econometric analyses of the determinants of food security and of the persistence of food insecurity. A separate analysis will examine the impact of rainfall shocks on food security. Chapter 8 will offer conclusions and a summary of lessons learned from the application of the composite indices of food security developed in this paper.

2. AGROECOLOGY AND RURAL LIVELIHOODS IN ZAMBIA

Zambia is a landlocked country characterized by low population density, and it is divided into 9 provinces[1] and 72 districts. Although it is among the most urbanized of sub-Saharan African countries, roughly 45 percent of the population live in rural areas and depend on agriculture for their livelihoods (Jain 2006).

Zambia's approximately one million farmers can be grouped into three categories: small-scale farmers (with up to five hectares of farming land), emergent farmers (with 5 to 20 hectares), and large-scale commercial farmers (with over 20 hectares). As of 2003, approximately 94 percent were small-scale farmers, 5.5 percent were emergent farmers, and commercial farmers accounted for less than 0.5 percent (Siegel and Alwang 2005). While most large-scale commercial farmers are located near urban centers, most small-scale farmers are rural, and about 95 percent of rural households are engaged in crop production. There is one main cropping season, and among small-scale farmers, crop production depends almost entirely on rainfall (Jain 2006).

Zambia is divided into four agro-ecological zones distinguished by divergent rainfall patterns (Figure 9-1). Zone I, located in the south, is relatively dry with unpredictable and poorly distributed rainfall and limited potential for crop production. This zone also experiences high temperatures during the growing season, which limits the range of potential crops (Kambikambi 2006). Zone IIa covers the central-eastern part of the country and has the highest agricultural potential, with fertile soil and rain that is evenly distributed throughout the growing season. Zone IIb is characterized by lower rainfall, sandier

[1] In 2011, this was changed to 10 provinces.

soils, and high risk of drought. Finally, zone III in the north experiences high rainfall, although this pattern has produced leached, acidic, and unfertile soils (Jain 2006).

The farming systems and crops vary by agro-ecological region: Zone I is dominated by subsistence crop production, largely using family labor. The region is suitable for production of drought tolerant crops (e.g. cotton, sesame, sorghum, millet), though poor soils and unreliable rainfall make farming risky. Alternative livelihood activities include goat rearing, mat and basket making, and fishing (Siegel 2008).

Zone IIa is characterized by a maize regime and is the most mechanized and commercialized region. Cash crops, including cotton, irrigated wheat and soybeans are also grown here. Much of this zone is located along the north-south "line-of-rail", and it is the most populous zone with over four million inhabitants. This area has better access to infrastructure, higher use of inputs, and a higher share of medium- and large-sized farms using improved technologies (Siegel and Alwang 2005). The existence of medium- and larger-scale farms in the area is beneficial to smallholders through labor linkages and the existence of outgrower schemes, and also through demonstration effects. In contrast, Zones I and III are characterized by a virtual absence of medium- and larger-scale commercial farms (Siegel 2008). In sharp contrast to zone IIa, zone IIb exhibits substantially lower capacity for crop production, with Kalahari sands covering the degraded soils.

Zone III is planted with a cassava and maize regime and is dominated by subsistence production. The rural areas of this region have the lowest population density in Zambia, and farmers use very low-input shifting and semi-permanent cultivation techniques (Saasa et al. 1999). *Chitemene* (slash-and-burn) and *fundakila* (using decomposing plant matter to improve soil fertility) are two widely used, traditional methods of cultivation. In zone III, farmers rely on hand hoes rather than oxen, and crops have been grown mainly from local varieties rather than improved cultivars (Kambikambi 2006).

The year-to-year variability in rainfall and other climatic conditions is important in determining crop output in most parts of Zambia. Drought has been the biggest shock to food security in the country during the last two decades (Muchinda 2001, cited in Jain 2006), with large shortfalls in maize yield consistently occurring in seasons with below normal rainfall. In some years the yield has been only 40 percent of the long-term average, owing to long dry spells within the growing season and the shorter rainy seasons which have become more common over the past several decades. Droughts in the 1990s disastrously reduced crop yields, particularly in the south, and extreme climate events have also resulted in substantial losses of livestock and fertile soil (Jain 2006). At the same time, Zambia sometimes experiences heavy localized floods that also threaten agricultural production. The general climate outlook for southern Africa will be characterized by a decrease in precipitation, a rise in temperatures, and a higher frequency and severity of extreme weather events (Kotir 2011). Thus, the general consensus among climatologists is that climate change will act as a multiplier of existing threats to food security in southern Africa.

3. FOOD SECURITY MEASUREMENT

3.1 Definition and drivers

The definition of food security is generally understood as a situation whereby "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 2002). Conversely, food insecurity exists when people do not have such access, and households experience food insecurity whenever they are unable to absorb, reduce or mitigate the impact of a negative food shock (Misselhorn 2005; Webb et al. 2006). With this understanding, food insecurity is not the result of an agricultural failure to produce sufficient food; rather, it is a failure of local livelihoods to guarantee food access (Devereux and Maxwell 2001). Food insecurity is related to, yet distinct from, concepts such as poverty and malnutrition (Webb et al. 2006), and is experienced at a range of spatial scales from households to regions, as well as a range of time scales.

The failure of early attempts to alleviate food insecurity has arguably been due to their overwhelming emphasis on food availability and the primacy of agricultural solutions (Ziervogel et al. 2006). While food security clearly depends on agro-climatic conditions and aggregate food production, it also depends on socio-economic conditions, including the distribution, access, and affordability of food. People in rural areas depend on agriculture and natural resources to generate cash income as well as food for home consumption, and food production affects both supply-side and demand-side indicators of food security. A meta-analysis of food insecurity in southern Africa suggests that future determinants of food security lie primarily beyond agricultural production (Misselhorn 2005). An exclusive focus on improving crop yields necessarily neglects the interrelated economic (e.g. poverty, unemployment, and market failures) and socio-political factors (e.g. conflict, poor governance, and a high disease burden) that create increasingly vulnerable and unstable communities in the region (Kotir 2011; Misselhorn 2005). Thus, measuring any change in food security and identifying its cause is a complex task (Maredia 2009).

It is important to note that aggregate food availability is a poor predictor of other food insecurity indicators, and food insecurity "does not arise exclusively –or even predominantly– because of covariate shocks to an entire population" (Barrett 2002). Furthermore, research that calculates average food availability from national food production and imports cannot shed light on how this food is distributed among communities, households, and individuals (Misselhorn 2005). Rather, the correlates and causes of food insecurity are likely to be found at the level of households and individual livelihoods.

3.2 The three components: quantity, quality, and stability

This paper considers there to be 3 components of household food security: quantity, quality, and the stability of the first two components. However, this conceptual framework deviates a bit from some more conventional frameworks. This section will introduce the more common conceptualizations of food security and will explain the rationale for this divergence.

Most works consider there to be three interlinked components embedded in the definition of food security: (1) the availability of food in terms of its physical presence in a given country/household; (2) the access to food as reflected by people's ability to obtain food from own stock/home production, or through market purchases, gifts or borrowing; and (3) the utilization of food, in terms of the ability to derive full biological benefits from food, based on food safety and nutritional/ socio-cultural value (Thompson et al. 2010).

Food availability is a function of the combination of domestic food production and food stocks, commercial food imports, and food aid, as well as the determinants of these factors. The term 'availability' is usually used in reference to food supplies at the regional or national level (Riely et al. 1999). Access depends on the range of food choices open to people, given their income, market prices, market accessibility, employment, distribution of wealth, and formal or informal safety net arrangements. Access rests on having adequate resources, or entitlements, to acquire a sufficient quantity of food, and while consumers' purchasing power in the form of real incomes and food prices is important, entitlements are not necessarily monetary. Instead, they include all commodity bundles within a person's control, given the legal, political, economic, and social arrangements of the community. Thus, they may also include traditional rights, such as a share of common resources (Morton 2007). Whereas availability reflects the supply side of food security, access reflects the demand side and in practice typically results in inequality of inter- and intra-household food distribution. Access is directly compromised by adverse shocks such as unemployment spells, price spikes, or the loss of livelihood-producing assets. The access lens is therefore able to highlight the close relationship between food security, poverty, and social, economic, and political marginalization (Barrett 2010). However, the multidimensional nature of individual or household access makes it complicated to measure. Access rests on a wide variety of activities, and the lack of a 'typical' set of activities makes it difficult to define a universal set of indicators (Swindale and Bilinsky 2006).

Utilization is related to health and reflects concerns about whether individuals make good use of the food to which they have access (Barrett 2010). There are two forms of food utilization: physical and biological utilization. Physical utilization reflects the level of a household's physical means to safely use the food available, and depends on the sanitary conditions along the entire food chain (Morton 2007).

This may include adequate housing, access to potable water, cooking utensils, cultural feeding hierarchies, family structure, and caretaker behavior, knowledge, and workload. Biological utilization is a measure of the body's ability to effectively use the nutrients consumed, and it depends on hygiene, infestation (e.g., hookworms), increased nutrient demand resulting from infection, and dietary quality (Renzaho and Mellor 2009). Particular attention is given to micronutrient deficiencies, and utilization encompasses both food consumption in the short term (e.g., breast-feeding, food intake, food habits and practices) and nutritional status parameters in the long run.

Availability, access, and utilization, also referred to as the three 'pillars' of food security, are inherently hierarchical, with availability as necessary but not sufficient to ensure access, and access as necessary but not sufficient for effective utilization. While local, regional, and national food production are extremely important determinants of food security, the inability of poor households to secure food through markets and non-market channels may limit their food security, even when food is abundant (Barrett 2010). Of course, this conceptualization includes several feedback loops, with appropriate utilization necessary for achieving adequate access (via health and other human capital effects), and access necessary for maintaining food availability (through enhanced labor productivity and the avoidance of resource depletion). These feedback loops mean that there are both upstream and downstream linkages associated with food security interventions (Webb and Rogers 2003).

Researchers and development agencies increasingly identify a fourth conceptual pillar of food security that is alternately labeled as stability or vulnerability (Figure 3-1; adapted from Gregory et al (2005) and expanded)). At the household level, vulnerability can be thought of as the likelihood that at a given time in the future, a household will have a level of welfare (often expressed in terms of income or consumption) below some benchmark, such as the expenditure required to meet the minimum caloric requirement per capita per day (Hoddinott and Quisumbing 2003). This concept is forward-looking and related to expectations and uncertainty. The definition of food security includes a consideration of its temporal dynamics by noting that security must exist 'at all times', and the term 'food security' connotes certainty of future well-being. Along these lines, food insecurity reflects uncertain access to enough and appropriate foods, and is therefore a dynamic problem that can be best conceptualized as an *ex ante* status rather than a purely *ex post* outcome (Barrett 2002). The definition of food security means that either a currently inadequate diet or a high probability of an inadequate diet in the future both render a person food insecure (Christiaensen and Boisvert 2000). According to Barrett (2002), a useful conception of food security must consider changes over time and people's perceptions of and responses to these changes (e.g. consumption smoothing), and must reflect uncertainty and risk.   Without viable expectations of the other three dimensions of food security, a household is subject to uncertainty that affects all of its investment and disinvestment decisions.

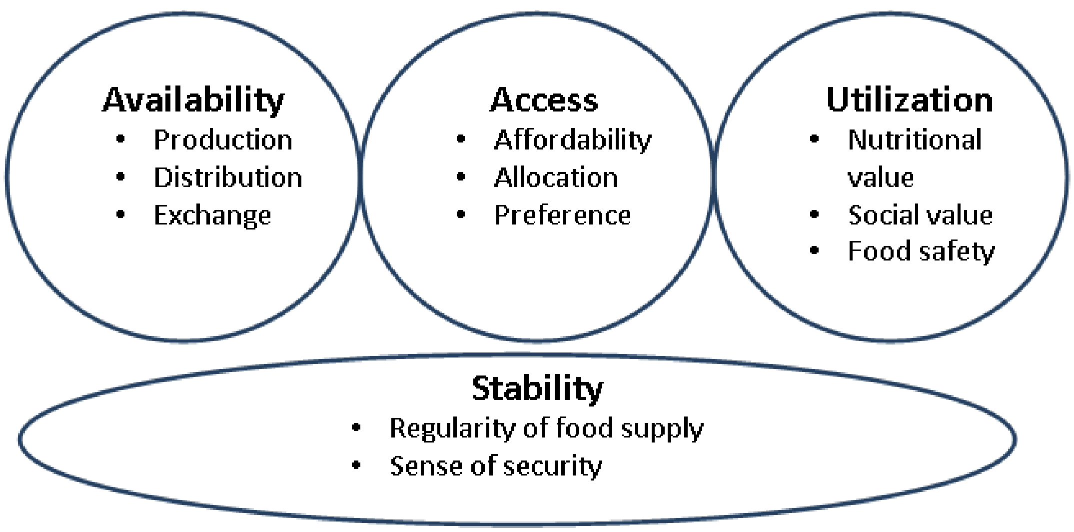

Figure 3-1: The four pillars of food security
Note: For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

It should be noted that this widely used framework is not the only way that food security has been conceptualized. A similar food security conceptual framework includes four slightly different aspects, as outlined in Figure 3-2 (adapted from Campbell (1991)). This framework is often used to describe how food insecurity is experienced and managed at the household or individual level, where availability and access cannot readily be distinguished. The first two domains capture the physiological adequacy of food, while the next two are psychological and social in nature. Note that the health and sanitation components of utilization are absent here.

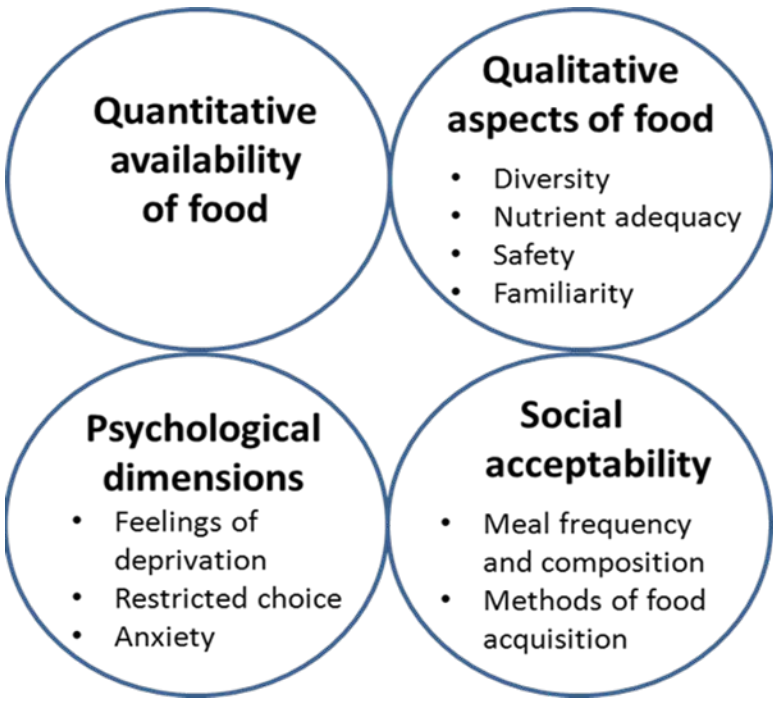

Figure 3-2: An alternate framework: four domains of food security

Due to the nature of the household-level data available for this paper's application, this paper will adopt a third framework that combines aspects of Figures 3-1 and 3-2. It will regard food security as comprised of 3 components: food quantity available in the household, food quality as captured by diet diversity and the presence of important nutrients, and the stability of adequate food supplies (Figure 3-3). It should be noted that this is not intended to be the *most* comprehensive framework, but rather the one most appropriate for the present analysis.

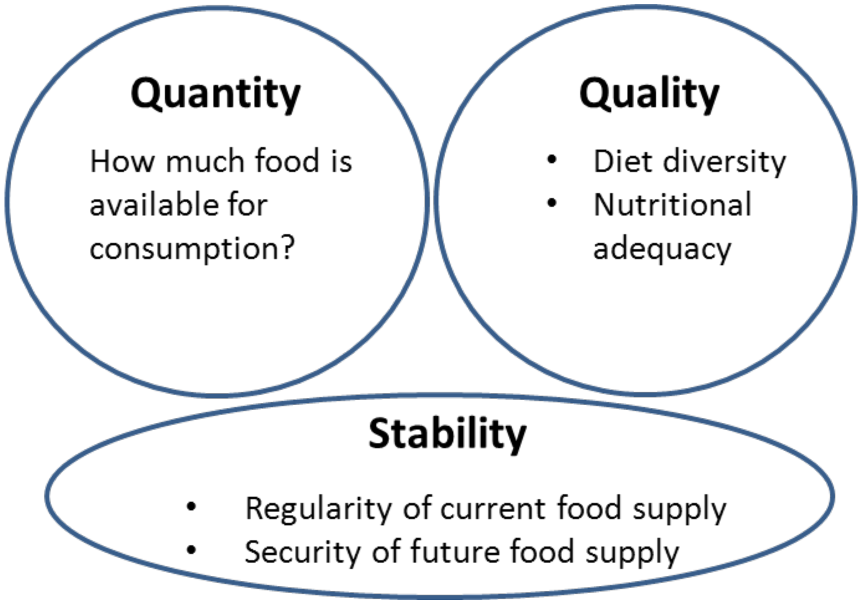

Figure 3-3: Household food security framework in this thesis

3.3 Indicators of household food security

The accurate measurement of food security is necessary to recognize crises as they occur, to target resources toward those most in need or at risk of sliding into hunger, to track the impact of food security-focused interventions, and to quantitatively analyze the dynamics of food security. Policymakers need to know how many people are at risk of food insecurity, who and where they are, and how best to reach them. While accurate measurement of household food security is essential for effective research and well-targeted policies and programs, there is no standard methodology for measuring food security, and despite an improved theoretical understanding of food security, the FAO notes that there exists no "perfect single measure that captures all aspects of food insecurity" (FAO 2002). Food security is an unobservable, cross-cutting, multifaceted process of complex causality, and there are considerable conceptual and measurement problems associated with estimating the incidence and intensity of food insecurity (Barrett 2002). For this reason, it is rare for impact assessments of food security interventions or agricultural development programs to include an indicator explicitly called 'food security' (Maredia 2009).

Commonly used indicators of household-level food availability may include variables such as household crop or food production (e.g., average cereal yields per hectare or food production per capita) or livestock ownership (Renzaho and Mellor 2009). Although there are no exact indicators of access failure, commonly used proxy measures include household income relative to food prices, food expenditures, and per capita food, calorie and nutritional intake. However, each of these proxies is a partial measure of the multifaceted phenomenon of food access (Webb et al.2006), and the pathways or mechanisms through which these indicators affect food security are implied rather than empirically determined and calculated (Maredia 2009; Webb et al. 2006). A common indicator of utilization is the growth/ nutritional status of children under five years of age as measured by height and weight (Webb et al. 2006), or ‘hygiene’ measures, such as type of latrine or source of water (Coates et al. 2003). Readers should note that in this study, indicators will be classified a bit differently, as indicated in Figure 3-3.

While most measures reflect past or current levels of food security (e.g. past or current food production and income; current expenditures and dietary diversity; or current health and nutritional status), ideal food security indicators would also reflect stability/vulnerability, or the probability of adequate consumption in the future. Vulnerability is essentially forward-looking, and is determined by the risks a household or individual faces in making a living, the livelihood options available, and the ability to handle this risk (Alinovi et al. 2009). Indicators of vulnerability include a household's asset stock as a measure of wealth, land owned as a measure of production security, and an index of income diversification (Coates et al. 2003). A simple access-based indicator of vulnerability is how much 'buffer' there is in current income for accommodating higher food prices. A food security indicator concerned with caloric sufficiency but not the proportion of income spent on food may misclassify a household as food secure (Maxwell et al. 1999; Løvendal and Knowles 2007). Other indicators include access to assets and asset liquidity, and crop and income diversification. Measures of stability should account for the choices and tradeoffs households face when allocating their resources over time to balance current access and jeopardizing future food consumption (Wolfe and Frongillo 2000).

Though many of these indicators are similar, they are also somewhat unique in what they are measuring (Barrett 2010), and different indicators capture different dimensions of food security. The FAO concludes that "no individual measure suffices to capture all aspects of food insecurity" (FAO/FIVIMS 2003), and the absence of such a 'gold standard' measure of food insecurity makes it unreasonable to use a single benchmark to proxy a (non-existent) gold standard. In light of the multidimensional nature of food security, it is generally agreed that a suite of indicators and methods are needed for its assessment (CFS 2011). These different measures are needed for complementary analysis and the triangulation or cross-referencing of indicators (a convergence of evidence approach) (Coates 2003; Maxwell et al. 1999; Migotto et al. 2005). In particular, conventional measures based only on household expenditures are considered to miss many aspects of food security, and a non-monetary approach illuminates some of the deeper mechanisms of food insecurity (e.g. vulnerability, persistence) that are often overlooked by conventional, money-metric analysis (Dasgupta and Baschieri 2010).

3.4 Construction of a composite index of food security

Several papers have combined various food security indicators into a single composite index. This seems to build on the literature of multidimensional poverty indices (e.g. Alkire and Foster 2007), and it allows for the ranking of different countries, regions, populations, or households in terms of the severity of food insecurity. Such an exercise may be useful in order to target resources and policies toward those most in need and to track changes over time. An index may be constructed in five steps: (1) identification of the dimensions of food security, (2) selection of indicators for each dimension, (3) standardization of indicators, (4) weighting of indicators, and (5) ranking of units (e.g. households or countries) according to summed scores. When building such an index, the main challenges are to select the most appropriate indicators and to calculate the weights attached to each component in order to best represent their values in practice.

The WFP's Vulnerability Analysis and Mapping Unit applies Principal Component Analysis (PCA) to generate a food security and vulnerability index for household profiling (WFP 2009). PCA is a statistical technique that can reduce the dimensions found among multiple variables into a single measure that captures as much as possible of the variation in the original data set (Abeyasekara 2005). Thus, from a handful of food security indicators, PCA can identify a latent food security variable and can assign a food security score to each household. The Famine Early Warning System Network (FEWSNET) outlines a method to construct a household index of chronic vulnerability. Elements in the index may include drought risk, the diversity of income portfolios, and reliance on export crops. These variables are each converted into comparable units (z-scores), weighted, and summed to generate a simple ranking of households (FEWS 1999). Demeke et al. (2011) use PCA to create a food security index for Ethiopia that includes several household-level variables related to food availability/access and vulnerability. The authors find the index to be highly correlated with factors such as per capita consumption expenditures and value of food consumption per month, which seems to validate the index as a reliable measure of household food security. Alinovi et al. (2009) also use PCA to build an index of resilience to food insecurity, considering resilience to be a latent variable comprised of income and food access, assets, access to public services, and social safety nets, as well as two cross-cutting dimensions: stability and adaptive capacity.

Although these studies each build an index that measures either food security or one of its aspects, none includes a discussion of the merits and limitations of doing so. While the argument for creating an index is compelling, there may be drawbacks to collecting diverse factors into one score, particularly when trying to understand the determinants of food security and the channels of impact. For example, Ravallion (2011) notes that while he does not deny that poverty is multidimensional, he is skeptical about the value of a single (uni-dimensional) index for sound development policy making in practice. His reasoning is that, in practice, policymakers can already refer to multiple indicators to measure different aspects of poverty, but the use of a single index measure necessarily relies on assumptions regarding which aspects of poverty should have been included in the measure and how they should be weighted. The same argument can be levied at the construction of a multidimensional food security index. While an acknowledgement of food security's multiple dimensions merits consideration, it is not clear that collapsing these dimensions into a single composite index can be useful. This thesis will explore this very question.

4. DATA SOURCES

This analysis uses nationally representative panel data on rural farm households in Zambia. Households were surveyed in 2000/01, 2004, and 2008 and asked about their activities and income over the previous 12 months, as well as household changes over the previous 4 years. Hence the surveys refer to the 1999/2000, 2002/03, and 2006/07 agricultural years, and the 2000/01, 2003/04, and 2007/08 marketing years. The first wave is comprised of both the 1999/2000 Post-Harvest Survey conducted by the Zambian Central Statistical Office (CSO) and Ministry of Agriculture and Cooperatives (MACO), and the CSO/MACO/Michigan State University Food Security Research Project (FSRP) Supplemental Survey. The second and third waves are Supplemental Surveys. 6,922 households were interviewed in 2001; 5,419 of these households were re-interviewed in 2004; and 8,094 households were included in the 2008 survey, including both panel and non-panel households. In total, 4,286 households were re-interviewed in all three waves of the panel survey.

Data on the calorie content of food items are taken from the Food Consumption Table for Use in Africa (FAO 1968) and the Tanzania food composition table (Lukmanji et al. 2008). Information on the contents and provincial prices of a basic needs basket in Zambia is drawn from the Zambia Living Conditions Monitoring Survey (LCMS) (CSO 2004). Data on historical prices of food items at the provincial level are taken from the FAO Global Information and Early Warning System (FAO 2013). Historical rainfall and average temperature data are obtained from records collected by 35 meteorological stations run by the Zambian Meteorological Department.

In this paper, panel analyses include the balanced panel of households interviewed in all three waves, while cross-sectional analyses include all households interviewed in a given year. Population or panel weights are included in all relevant analyses. In panel regressions where a test for attrition bias rejects the null hypothesis of no bias, attrition-adjusted weights created with the inverse probability weighting procedure (Woodridge 2002) are used. Monetary values are inflated to 2007/08 values using the consumer price index, and the exchange rate for this year was 3,829 ZMK = 1 U.S. dollar. No effort was made to impute missing data points.

5. FOOD SECURITY INDICATORS IN ZAMBIA, 2001-2008

5.1 Income-based measures of welfare

In many studies, income is used as a general welfare measure or as an indicator of the 'access' dimension of food security. Here, income is calculated as the sum of the value of agricultural production (retained or sold), income from the sale of live or slaughtered animals, any salary or wages earned, whether in cash or in kind, any gifts or remittances received by the household, and the net revenue from household own-business activities. Given data limitations, income here is calculated differently in longitudinal analyses, where only information captured in all three years is used, and in cross-sectional analyses for 2008, where all information captured in this last year is used.

In this paper, the poverty rate is conceived in two ways: (1) The dollar-per-day poverty rate is defined as the proportion of households whose annual per capita income is below one U.S. dollar per day. This threshold is used because it was the World Bank international poverty line until 2008 (Chen et al. 2008), while most of the data were collected before this date. (2) The moderate poverty rate is defined as the proportion of households whose average monthly income is below the cost of a basic needs basket (in per adult equivalent terms), or the collection of food and non-food items required to purchase or acquire a minimum standard of caloric intake and essential non-food items. The extreme poverty rate is defined as the proportion of households unable to afford even the minimum monthly per adult equivalent food basket. The cost of these baskets in each province was obtained from the 2002-03 Living Conditions Monitoring Survey (CSO 2004; Table 9-A), and the definition of extreme poverty is similarly borrowed from this report.

Several definitions are also employed for female-headed households (FHHs), where "FHH widow" captures households that self-identify as both female-headed and widowed. "FHH nm" stands for FHH in which there is no prime-age (15 – 59 years) male member of the household, and the rationale here is that these households would be most vulnerable to gender discrimination, whereas FHHs that contain adult men might be better placed to access the same resources as male-headed households (MHHs). Note that these definitions of FHH are not mutually exclusive. Definitions of all variables included in this study are provided in the appendix (Tables 9-B through 9-E), and population sampling weights are used for all descriptive statistics in this chapter. Throughout this report, binary variables will be denoted with 1=, where a value of 1 indicates "yes" or "true", and a value of 0 indicates otherwise. A proportion of 0.75 means that 75 percent of observations have a value of 1.

Table 5-A: Poverty indicators from 2001 to 2008

Indicator	2001	2004	2008
1=HH below $1-per-day poverty line	0.91	0.89	0.88
1=HH unable to afford basic needs basket	0.93	0.89	0.89
1=HH unable to afford food basket	0.88	0.83	0.82
Median net income per capita (ZMK)	289,030	373,682	366,667

Table 5-B: Poverty indicators across subgroups in 2008

					Agro-ecological zones			
Indicator	All households	FHH widow	FHH nm	|t|	I	IIa	IIb	III
1=HH below $1-per-day poverty line	0.87	0.91	0.89	3.78	0.91	0.86	0.91	0.87
1=HH unable to afford basic needs basket	0.88	0.91	0.90	3.82	0.93	0.87	0.91	0.88
1=HH unable to afford food basket	0.81	0.86	0.83	3.93	0.87	0.79	0.84	0.82
Median net income per capita (ZMK)	384,000	321,000	349,027	3.29	288,419	433,483	337,894	364,518

These figures illustrate that the poverty rate is sensitive to the definition of the poverty cutoff. The t-statistics in the fourth column of Table 5-B compare the mean values for widowed FHHs and all other households. However, using any of these poverty cutoffs, FHHs exhibit a higher rate of poverty. The actual distributions of per capita income are shown in Figures 5-1 and 5-2. Figure 5-3 shows that this distribution has changed over 2001, 2004, and 2008, although there is not a consistent trend over time.

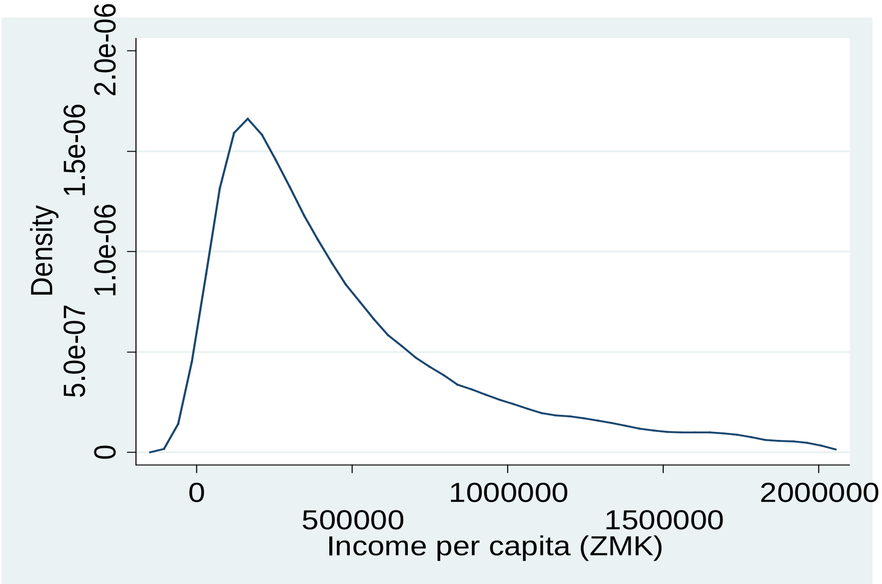

Figure 5-1: Distribution of per capita income in 2008

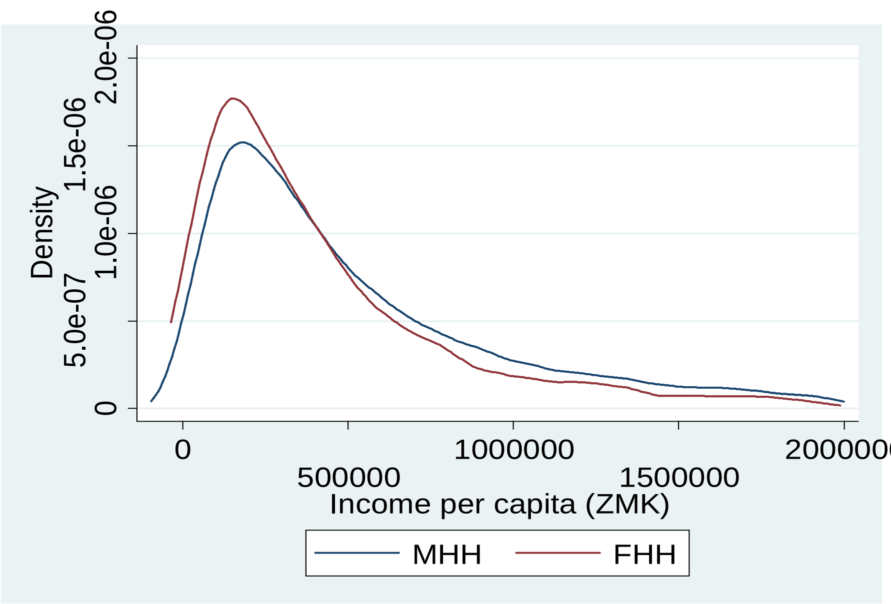

Figure 5-2: Distribution of per capita income in 2008 among MHHs and FHH widows

Note: In almost all figures, outliers are omitted for clarity of visual presentation. An outlier can therefore be defined as an observation that lies beyond the range displayed in each figure.

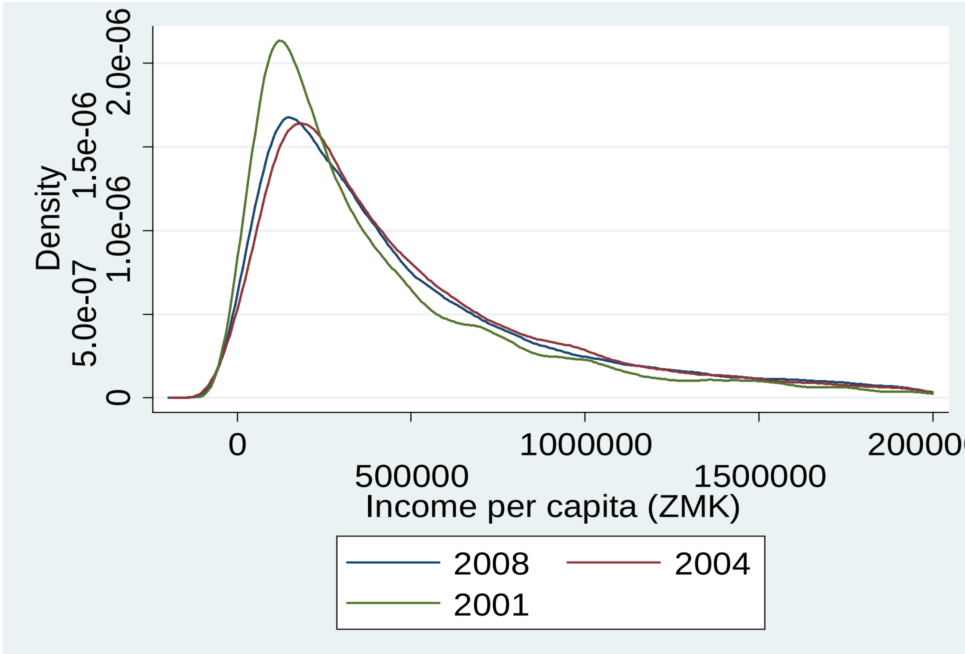

Figure 5-3: Distribution of income per capita over the panel years

In terms of average per capita income, Zambia experienced a significant improvement from 2001 to 2004 (t-stat = 6.73), but no significant difference between 2004 and 2008 (t-stat = 0.61).

It should be noted that the appropriateness of an income flow measure of household wealth has been called into question. This is because a flow-based measure of poverty can be extremely stochastic due to random price and yield fluctuations and irregular earnings from remittances and gifts. Another critique of survey measures of household income is that measurement error is expected to be relatively high for a single-visit survey that elicits recall data on 12 months of agricultural production and non-farm income. In this study, the value of assets (usually considered a more stable indicator of household welfare) will be considered an indicator of food security vulnerability, rather than a proxy for wealth. Keep in mind that this does not capture the household's stock of human capital, and is therefore still an imperfect measure of vulnerability.

A transition matrix of income for 2004 and 2008 (Table 5-C) shows that households do not readily experience large changes in income status. The income brackets were formed as quintiles in 2004, so that category 1 represents the poorest 20 percent of households in that year, and the same cutoffs were maintained in 2008. Of households that started out in the poorest category, 35 percent remained in that income bracket four years later, while 10 percent moved up to the highest bracket.

Table 5-C: Transition matrix of household income per capita for 2004 and 2008

	Income status 08				
Income status 04	**1**	**2**	**3**	**4**	**5**
1	0.35	0.21	0.20	0.14	0.10
2	0.28	0.25	0.20	0.16	0.12
3	0.21	0.21	0.21	0.21	0.15
4	0.17	0.17	0.20	0.23	0.23
5	0.09	0.13	0.16	0.22	0.40

5.2 Non-income food security indicators

The food security indicators included in this thesis are listed in Table 5-D, and definitions are available in Table 9-C. Panel values are used in all panel analyses, and non-panel values are calculated for 2007/08 and used only in cross-sectional analyses from that year. Where these diverge, the panel variables consider only the information that is consistently recorded across all years of the survey, while the non-panel variables often include additional information added in 2008.

Calories are calculated by converting the volume of agricultural products harvested or food items procured/ received into calorie content, and the conversion values are presented in Table 9-F. It should be emphasized that these values are a rough estimate, though it is not immediately obvious whether they are an over- or under-estimate of calories available to a household. It may be an underestimate because the survey does not include information on food eaten away from home, the collection of wild foods, the purchase of non-staple food items (such as fruits, vegetables, oils, or animal products), or food obtained in socially unacceptable ways, such as by stealing. At the same time, it may be an overestimate because the calculation of retained calories does not account for losses in storage, nor does it consider food provided to guests.

The household status of food-energy deficiency (light) is calculated using the total calories produced or acquired by the household, relative to age and sex-specific caloric requirements and assuming a light level of activity (Smith and Subandoro 2007). Accordingly, the statuses of food-energy deficiency (moderate) and (intense) are calculated using the calorie requirements for moderate and intense levels of activity. Each household's total energy requirement is calculated by multiplying the number of household members in each age-sex category by the corresponding energy requirement, weighting the individuals by time spent at the homestead, and summing across household members. An additional 500 calories is added for each child younger than one year old at the end of the survey period in order to account for the higher energy needs of breastfeeding mothers.

The household endowment of livestock reflects what each household owned at the beginning of the reporting period, 12 months prior to the survey. The calculation of edible tropical livestock units (TLU) in 2008 excludes work oxen, as this variable is intended to capture the availability of meat products to the household. The number of crops is a simple sum of the different crops or fruits/vegetables produced and retained by a household, excluding any cash crops that are not edible. This is a very coarse indicator of dietary diversity, as it does not account for the inclusion of different food groups in the household's diet. Because it is a simple sum, it also potentially includes crops that are grown in a very small amount. The binary variable indicating whether a household participates in a transfer network (i.e. whether it received *or* provided any remittances or gifts) is intended as a proxy for social capital, assuming that a household that engages in such exchange has access to a network that can serve as a social safety net in the event of an idiosyncratic food shortfall. It should be noted that when this variable is used in a regression (as in Chapter 7), it is highly susceptible to reverse causality.

The proportion of crop value sold is intended to be an indicator of surplus production. This assumption is not perfectly straightforward, and a household may sell crops and still be a net buyer (Barrett 2008). The value of productive assets is estimated for each year to reflect what each household owned at the beginning of the reporting period. This is considered to be an indicator of vulnerability because assets serve as a safety net during negative shocks and also determine a household's ability to improve its situation (Carter and Barrett 2006). For 2008 this includes both the value of farm equipment and work oxen, while for multi-year analyses it includes only farm equipment (see Table 9-C for details of variable construction).

As mentioned earlier, it is important to be aware of the limitations of using this survey to measure food security: The survey only asks about the purchase of staple foods. Yet according to the 2002-03 LCMS, fruits and vegetables comprise, on average, 20 percent of food purchases among households in Zambia (CSO 2004). The purchase of cooking oil or meat could be important, yet overlooked, sources of calories or protein. Although the survey asks about the collection of forest products and wild fish as an income source, it does not account for a household's consumption of these goods. It also accounts for food produced/acquired but not food consumed, although losses in storage could drive a sizable wedge between these two values (World Bank 2011). In terms of the stability dimension of food security, the survey does not ask about access to credit or degree of debt in a household, although these could have important implications for a household's vulnerability.

Particularly with regard to food purchases and food earned as in-kind wages, the survey responses are subject to recall error over the course of a 12-month recall period. Most food security measures that try to capture food consumption do so with much shorter time-frames, such as one day or two weeks, and this is due to concern over recall errors that could arise with a longer recall period (Beegle et al. 2012). This study develops a much coarser estimate of food availability over a 12-month time period, with reference only to large purchases.

5.3 Descriptive statistics

Table 5-D presents descriptive statistics of these food security indicators for each year.

Table 5-D: Descriptive statistics of various food security indicators over time

	2001	2004	2008	|t| difference 01/08	|t| difference 04/08
QUANTITY					
Total calories acquired/ ae/ day (median)	2,413.47	2,537.08	2,336.31	0.44	1.93[2]
1=Food energy deficient (light)	0.53	0.50	0.54	1.07	4.39
	(0.50)	(0.50)	(0.50)		
1=Food energy deficient (moderate)	0.61	0.58	0.61	0.12	4.16
	(0.49)	(0.49)	(0.49)		
1=Food energy deficient (intense)	0.68	0.65	0.68	0.17	4.50
	(0.47)	(0.48)	(0.47)		
QUALITY					
Tropical livestock units	1.82	2.58	2.35	4.12	1.25
	(6.90)	(12.87)	(8.42)		
Number of different field crops retained	1.91	2.32	1.89	1.13	20.23
	(1.20)	(1.33)	(1.17)		
1=HH produces eggs or milk	0.31	0.14	0.47	20.34	43.01
	(0.46)	(0.35)	(0.50)		

[2] Test for difference in mean calories/ae/day

Table 5-D (cont'd)

1=HH produces some vegetables/fruits	0.16	---	0.38	29.08	---
	(0.37)		(0.49)		
STABILITY					
Value of productive assets (ln)	1.82	2.45	2.19	4.69	2.89
	(4.62)	(5.21)	(4.94)		
Number of income sources	1.91	1.85	2.18	19.33	22.45
	(0.84)	(0.84)	(0.85)		
Number of months without any food stocks (of cropping HHs)	---	1.31	1.84	---	12.19
		(2.36)	(2.47)		
1=Maizecass (HH had food in stock at end of survey period)	---	0.60	0.40	---	23.17
		(0.49)	(0.49)		
1=HH participates in transfer network	0.50	0.64	0.83	45.13	24.66
	(0.50)	(0.48)	(0.38)		
Proportion of crop value sold	0.15	0.20	0.29	27.58	18.09
	(0.23)	(0.25)	(0.33)		
No. skilled off-farm workers	0.12	0.15	0.23	14.55	15.26
	0.37	0.40	0.48		
Proportion food expenditure relative to income	0.09	0.08	0.12	8.41	10.38
	(0.19)	(0.18)	(0.21)		
Hectares cultivated	1.44	1.56	1.42	0.79	5.3
	(1.34)	(1.47)	(1.63)		
No. observations	6,922	5,419	8,094		

Values are averages with standard deviations in brackets.

These results reflect stagnancy in the number of calories per adult equivalent[3] available to households each day. The first t-statistic is a test of the difference in mean (not median) calories between 2001 and 2008, and it does not indicate a significant trend. The actual distribution of calories across panel years is presented in Figure 5-4, which illustrate that a higher proportion of households in 2001 and 2008 report a relatively lower number of calories accessed – though the difference is small. This nonlinear trend in calories over the panel years mirrors the trend in income (Table 5-A and Figure 5-3), and it is clear that

[3] Adult equivalent is a measure that adjusts the size of a household to reflect its caloric consumption needs based on the age and gender or each individual in the household (WHO 1985).

although 2004 was a relatively good year for households in Zambia, by 2008 several food security indicators had returned to their 2001 levels. In other words, although many of the t-statistics for a difference in mean values between years are significant, the trend often changes direction between 2001/04 and 2004/08. However, it does seem that households are marketing an increasing proportion of their crop production, producing more skilled off-farm workers, and collecting income from a greater number of sources.

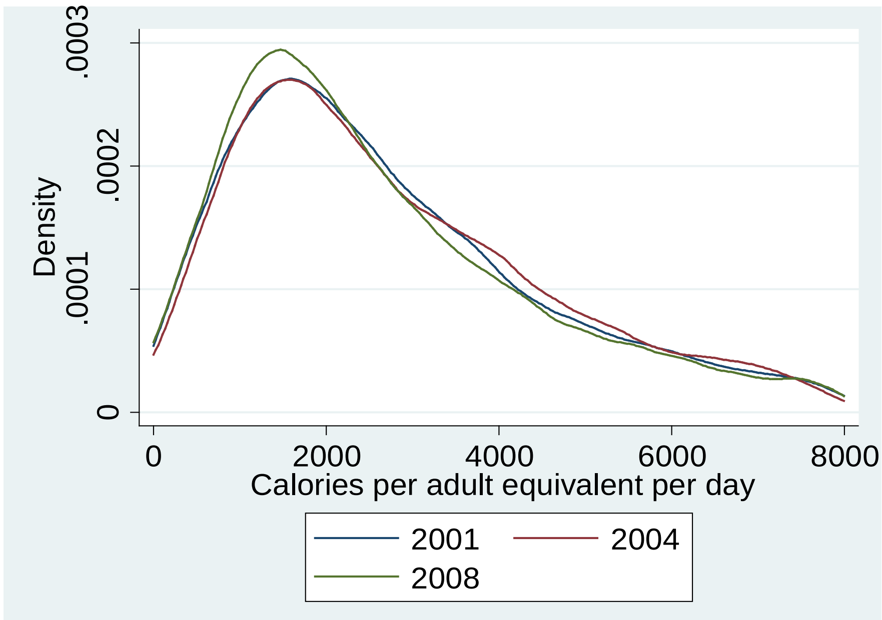

Figure 5-4: Distribution of calories/ae/day for 2001, 2004, and 2008

The cutoff point for a household being considered food energy deficient is at the age- and gender-specific calorie requirements suggested by Smith and Subandoro (2007) for three different activity levels. These cutoffs produce markedly divergent rates of food energy deficiency, although with any cutoff, the proportion of households that exhibit food energy deficiency is lower than those that cannot afford a basic needs food basket based on income calculations (Table 5-A). This is a noteworthy finding, as it suggests there may be a problem with how the food basket is priced in the LCMS (CSO 2004), or alternatively a problem with how income is calculated. In this thesis crop income is measured at farmgate prices, whereas the LCMS probably prices its food basket at retail prices. This may suggest that we are underestimating the real incomes earned by households, resulting in a deceptively high measure of extreme poverty.

The inclusion of participation in a transfer network as an indicator of stability may appear questionable as such participation in a given year may be the direct cause or consequence of current food security status. However, a cursory glance at transfer network patterns suggests that participation alone does not unambiguously relate to either food sufficiency or insufficiency. Fifteen percent of households participate only as receivers, 25 percent participate as givers, 43 percent of households both give and receive within their transfer network, and the remaining 17 percent neither give nor receive in 2008. Only the last category receives a value of zero for “transfer network participation”, with the intention of capturing a household’s access to a network rather than specifically whether they are recipients or benefactors of assistance.

Tables 5-E and 5-F present descriptive statistics for 2008, disaggregated by gender of household head and agro-ecological zone. Where applicable, the non-panel values are used. In this table, FHHs are defined alternately as widowed FHHs or FHHs without any prime-age male residing in the household. Note again that these categories are not mutually exclusive; rather they are both included to explore the implications of defining FHHs differently. It is quite surprising to observe that these definitions of FHHs, which produced somewhat poorer households according to income measures, actually display significantly higher calories per capita and correspondingly lower rates of food energy deficiency. One possible explanation to reconcile these results with an *a priori* expectation of lower food security is that only FHHs that are sufficiently empowered remain as independent households, whereas FHHs that are unable to achieve relative food security in Zambia are absorbed into the households of extended family (Geisler 1993). This hypothesis seems to be borne out by the 2008 data, in which 10.12 percent of households contain a woman who is not the head of household and is widowed, separated, or divorced. Meanwhile, just 2.6 percent of households contain a man in this position. The discrepancy suggests that the FHHs captured in this household survey may represent the “survivors”, and this pattern underscores how the categorization of households as male- or female-headed does not truly capture the gender dynamics of food security. This point will be revisited in Chapter 8.

FHHs do report a higher average number of months without any food stocks and lower measures of dietary diversity, making their lower rate of calorie deprivation all the more surprising. These FHHs exhibit lower average values of several other stability indicators: They cultivate smaller areas of land, have fewer productive assets, and are less likely to participate in a transfer network. Figure 5-5 further indicates that the significantly higher calories reported by FHHs may be attributed to those households at the high end of the spectrum, where both categories of FHHs cross the density curve of MHHs. In other words, a greater proportion of FHHs are doing relatively well, as compared with the general population.

In the appendix, Tables 9-G and 9-H display the average values, for each year and for sub-groups in 2008, of other demographic and agricultural variables that will be included in later analyses related to the correlates of food security.

Table 5-E: Food security indicators by gender of household head in 2008

	All HHs	FHH widow	FHH nm	|t| FHH widow/ others difference
QUANTITY				
Total calories acquired/ ae/ day (median)	2,521.40	2,581.34	3,186.06	4.7
1=Food energy deficient (light)	0.52	0.50	0.42	1.53
	(0.50)	(0.50)	(0.49)	
1=Food energy deficient (moderate)	0.59	0.56	0.47	2.23
	(0.49)	(0.50)	(0.50)	
1=Food energy deficient (intense)	0.67	0.63	0.53	3.1
	(0.47)	(0.48)	(0.50)	
QUALITY				
Tropical livestock units	1.88	1.09	0.55	4.15
	(6.92)	(3.64)	(2.07)	
Number of different crops or vegetables/fruits retained	2.72	2.55	2.32	3.13
	(1.97)	(1.80)	(1.83)	
1=HH produces eggs or milk	0.47	0.40	0.33	4.94
	(0.50)	(0.49)	(0.47)	
1=HH produces some vegetables/fruits	0.38	0.31	0.29	5.1
	(0.49)	(0.46)	(0.45)	
STABILITY				
Value of productive assets (ln)	8.31	4.85	3.14	19.85
	(6.49)	(6.42)	(5.60)	
Number of income sources	2.18	1.93	1.86	4.5
	(0.85)	(0.82)	(0.76)	
Number of months without any food stocks (of cropping HHs)	1.84	2.19	2.10	4.97
	(2.47)	(2.62)	(2.72)	
1=Maizecass (HH had food in stock at end of survey period)	0.40	0.44	0.42	4.34
	(0.49)	(0.50)	(0.49)	
1=HH participates in transfer network	0.83	0.70	0.68	1.83
	(0.38)	(0.46)	(0.47)	
Proportion of crop value sold	0.31	0.24	0.26	7.06
	(0.33)	(0.32)	(0.35)	
No. skilled off-farm workers	0.23	0.09	0.08	10.31
	(0.48)	(0.32)	(0.28)	

Table 5-E (cont'd)

Proportion food expenditure relative to income	0.13	0.15	0.15	2.75
	(0.22)	(0.24)	(0.25)	
Land access (ha)	2.65	1.83	1.43	3.22
	(9.27)	(4.12)	(3.23)	
Proportion of population	1.00	0.14	0.10	
No. observations	8,094	1,095	821	

The last column refers to the difference in means between all households and widowed FHHs.

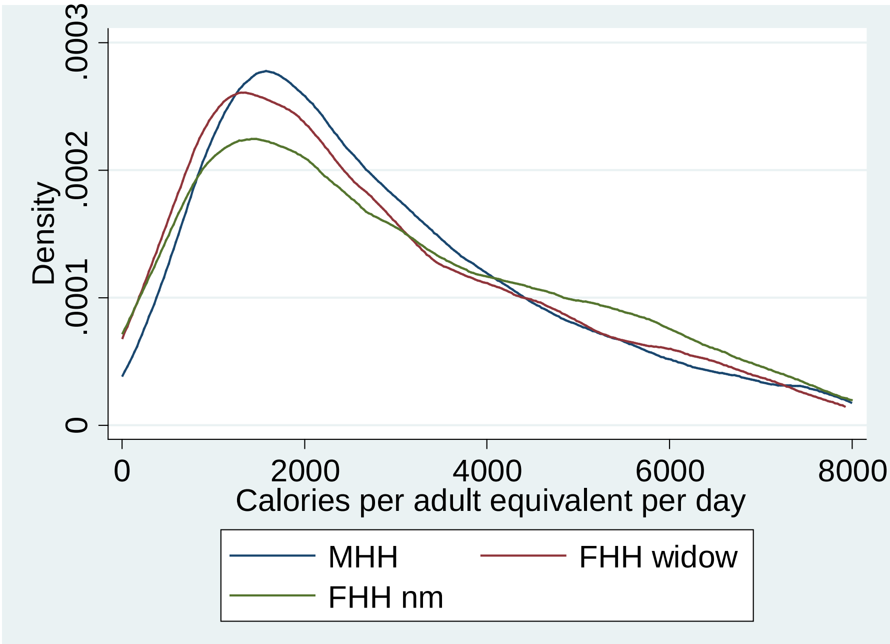

Figure 5-5: Distribution of calories by gender of household head

Table 5-F: Food security indicators in 2008, by agro-ecological zone

	Agro-ecological zones			
	I	**IIa**	**IIb**	**III**
QUANTITY				
Total calories acquired/ ae/ day (median)	2,185.99	2,823.79	1,765.98	2,245.90
1=Food energy deficient (light)	0.57	0.44	0.64	0.56
	(0.50)	(0.50)	0.48	0.50
1=Food energy deficient (moderate)	0.67	0.52	0.70	0.63
	(0.47)	(0.50)	0.46	0.48
1=Food energy deficient (intense)	0.73	0.62	0.74	0.69
	(0.44)	(0.49)	0.44	0.46

Table 5-F (cont'd)

QUALITY				
Tropical livestock units	3.30	3.25	1.55	0.55
	(7.44)	(9.64)	(6.30)	(2.24)
Number of different field crops retained	2.25	2.73	1.54	2.99
	(1.57)	(1.86)	(1.10)	(2.13)
1=HH produces eggs or milk	0.54	0.57	0.30	0.40
	(0.50)	(0.49)	(0.46)	(0.49)
1=HH produces some vegetables/fruits	0.29	0.45	0.14	0.37
	(0.45)	(0.50)	(0.35)	(0.48)
STABILITY				
Value of productive assets (ln)	7.93	9.95	3.97	7.71
	(7.01)	(6.22)	(6.22)	(6.21)
Number of income sources	2.11	2.19	2.14	2.18
	(0.84)	(0.86)	(0.76)	(0.85)
Number of months without any food stocks (of cropping HHs)	2.75	2.42	2.36	1.10
	(2.79)	(2.51)	(2.88)	(2.07)
1=Maizecass (HH had food in stock at end of survey period)	0.22	0.21	0.36	0.60
	(0.42)	(0.41)	(0.48)	(0.49)
1=HH participates in transfer network	0.80	0.84	0.78	0.83
	(0.40)	(0.37)	(0.42)	(0.38)
Proportion of crop value sold (out of cropping HHs)	0.18	0.33	0.26	0.31
	(0.28)	(0.32)	(0.38)	(0.34)
No. skilled off-farm workers	0.18	0.27	0.15	0.22
	(0.43)	(0.51)	(0.39)	(0.47)
Proportion food expenditure relative to income	0.16	0.14	0.16	0.12
	(0.26)	(0.21)	(0.25)	(0.21)
Land access (ha)	2.27	2.96	1.46	2.64
	(4.17)	(11.80)	(1.97)	(7.90)
Proportion of population	0.06	0.4	0.08	0.45
No. observations	517	3,108	655	3,798

A transition matrix of household calorie status (Table 5-G) indicates that households move around more readily with regard to calorie consumption as compared with income (Table 5-A). Again, the categories of calorie status were formed as quintiles of calories/adult equivalent/day in the year 2004, with these cutoffs maintained in 2008. Thus, of households in the lowest calorie bracket in 2004, only 26 percent remained in that bracket four years later. This is somewhat surprising, as it is often found that consumption (a "realized" welfare achievement) is smoother than income (a "potential" welfare opportunity), whereas these results indicate greater movement in household consumption.

Table 5-G: Transition matrix of calories/adult equivalent/day for 2004 and 2008

	Calorie status 08				
Calorie status 04	**1**	**2**	**3**	**4**	**5**
1	0.26	0.26	0.18	0.16	0.14
2	0.24	0.25	0.17	0.19	0.15
3	0.19	0.22	0.20	0.20	0.18
4	0.19	0.19	0.19	0.22	0.21
5	0.10	0.14	0.17	0.27	0.32

An assessment of the number of months without food stocks, among cropping households, shows that the distribution differs according to agro-ecological region (Figure 5-6). Specifically, zone III in the north exhibits a much higher proportion of households in 2008 that report that they always had food stocks in the previous 12 months. This is probably due to the dominance of cassava in the region, as cassava can often be left in the field until it is ready to be consumed, rather than requiring a harvest during a specific season. Alternatively, this may be due to localized flooding during the 2006/07 agricultural season that negatively, and disproportionately, affected the other agro-ecological zones (UNICEF 2007).

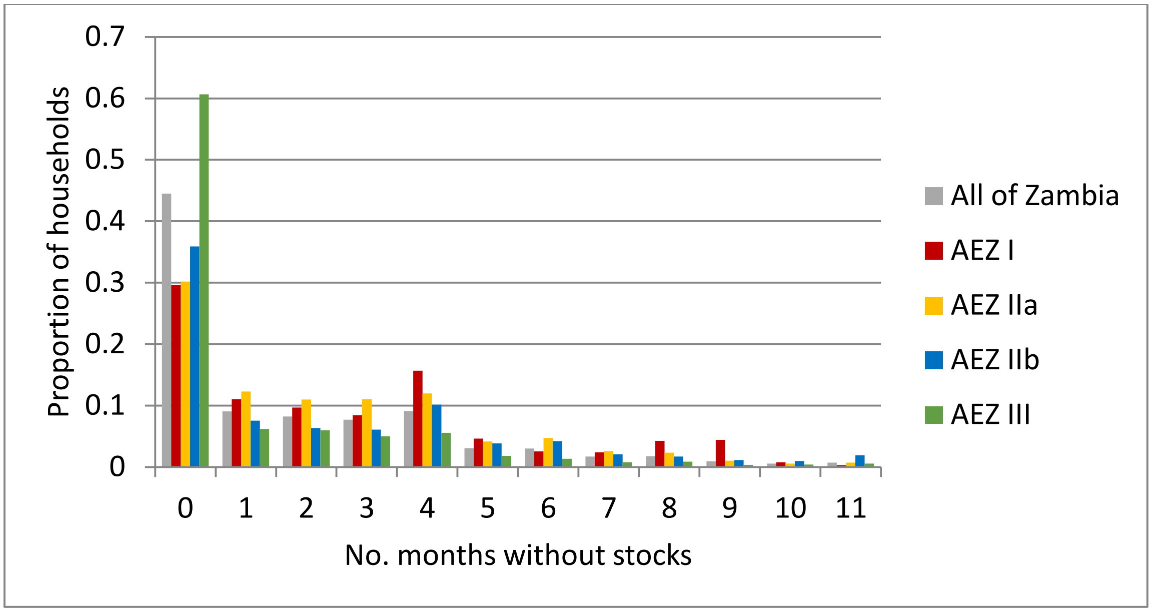

Figure 5-6: Distribution of months without food stocks in 2008 by agro-ecological region

Food energy deficient households are not equally distributed across Zambia's provinces. Table 5-H presents estimated numbers of households that do not meet their calorie requirements for a moderate level of activity. While the highest density of calorie deficient households is found in Luapula, the greatest number of calorie-deficient households can be found in Northern and Eastern provinces. This information should be of interest to development agencies interested in evaluating the cost-effectiveness of geographically-targeted food security programs.

Table 5-H: Location of calorie-deficient households in 2008

Province	Number energy-deficient HHs	Number energy-deficient individuals	Energy-deficient HHs / km^2	Proportion of province rural population (HHs)	Proportion of national rural population (HHs)
Central	107,100	740,827	1.14	0.55	0.06
Copperbelt	63,972	394,184	2.04	0.63	0.04
Eastern	154,643	992,772	2.24	0.51	0.09
Luapula	145,694	858,346	2.88	0.81	0.09
Lusaka	32,732	209,158	1.50	0.67	0.02
Northern	184,825	1,102,541	1.47	0.58	0.11
North West	71,460	456,770	0.48	0.54	0.04
Southern	100,953	692,357	1.19	0.49	0.06
Western	131,933	791,477	1.04	0.71	0.08
Total calorie-deficient	993,311	6,238,432			0.59
Total Zambia	1,669,861	9,627,873			

Figure 5-7 presents the cumulative distribution of calories (per adult equivalent, per day) in each agro-ecological zone. As zone IIa first-order stochastically dominates the other zones, it is clear that this region fared better in 2008 in terms of this indicator. A similar trend is seen when evaluating the proportion of household calorie requirements that are met (Figure 5-8), where zone IIa sees the highest proportion of households exceeding their requirements.

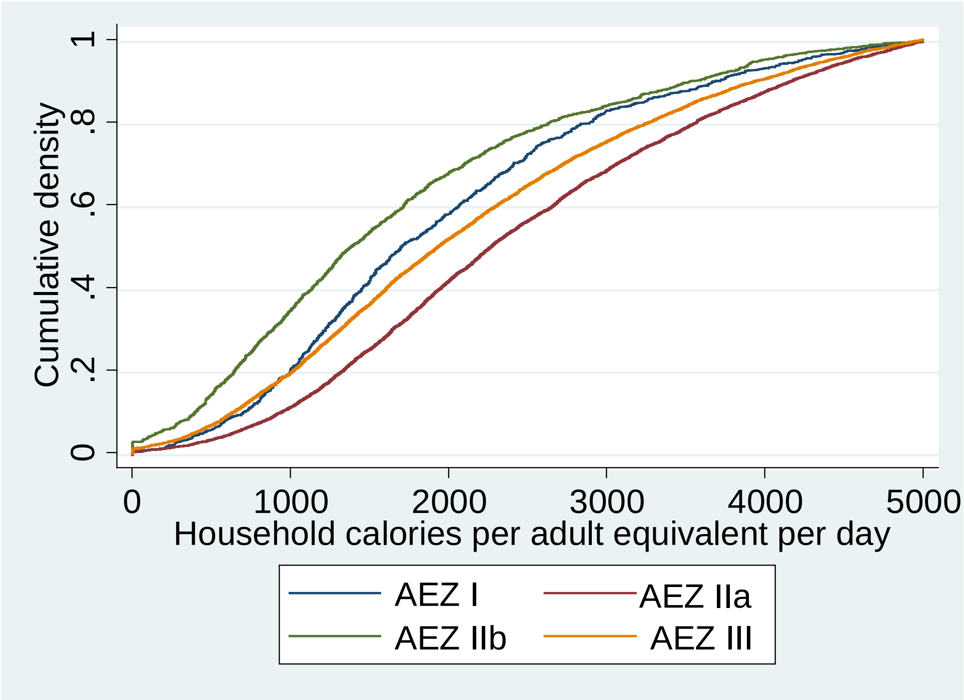

Figure 5-7: CDF of calories/adult equivalent/day by agro-ecological zone

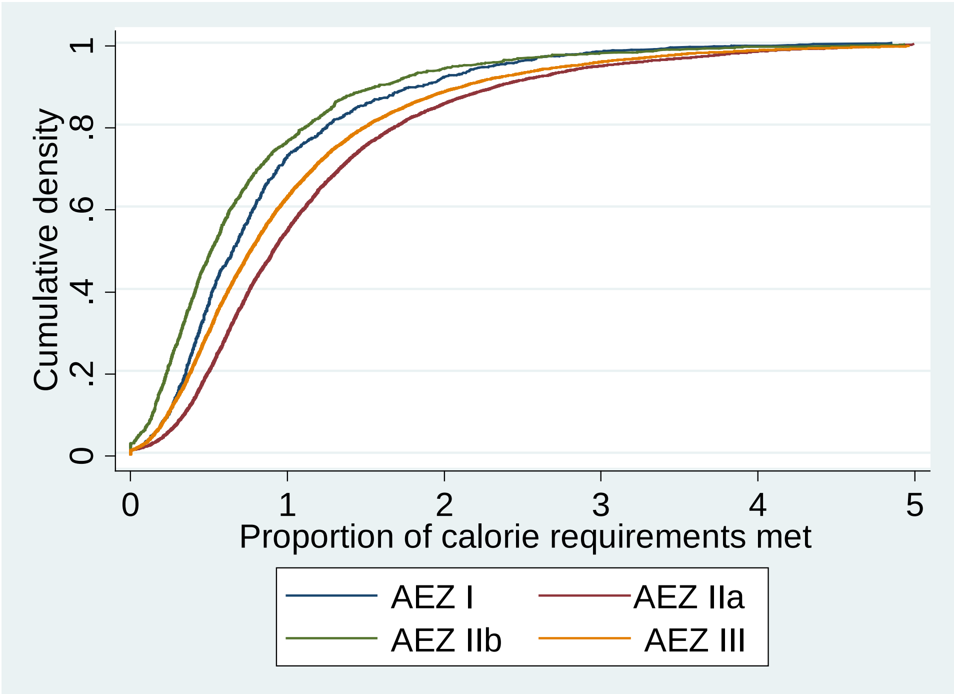

Figure 5-8: CDF of proportion of calorie requirements met, by agro-ecological zone

5.4 Correlation among indicators

Table 5-I shows the correlations between the various food security and income indicators in 2008. Although many of the variables are significantly correlated in the expected directions, the magnitude of the coefficients seems small. The number of months without food stocks and the proportion of income spent on food purchases are generally negatively correlated with variables associated with food security. The number of income sources claimed by a household has a very weak correlation with the other indicators.

Although not presented here, a similar correlation table was constructed for each agro-ecological zone separately. The correlation coefficients often suggest that food security indicators are similarly related in the different regions. However in zones IIb and III, the indicators for whether a household produces fruits or vegetables is negatively correlated with total calories, while in zone IIb a similar negative relationship is seen between calories and whether a household produces milk/eggs. These patterns are unexpected and merit further consideration. As will be discussed in Chapter 6, this is taken into consideration in the construction of a country-wide food security index.

Table 5-I: Correlation matrix of food security indicators in 2008

	Calories	Income	Prod-uctive assets	Ha cultivated	Land access	No. crops	TLU
Calories	1						
Income	0.34***	1					
Productive assets	0.14***	0.36***	1				
Hectares cultivated	0.29***	0.28***	0.30***	1			
Land access	0.11***	0.11***	0.11***	0.26***	1		
No. crops	0.16***	0.18***	0.14***	0.25***	0.08***	1	
TLU	0.15***	0.21***	0.25***	0.31***	0.30***	0.05***	1
Milk/eggs	0.10***	0.15***	0.24***	0.23***	0.07***	0.23***	0.18***
Garden	-0.02**	0.13***	0.12***	0.09***	0.05***	0.60***	0.06***
Prop. crops sold	-0.21***	0.15***	0.17***	0.08***	0.02***	-0.17***	0
Maize/cassava in storage	0.19***	0.11***	0	0.12***	0.05***	0.31***	0
Months w/out food	-0.22***	-0.19***	-0.13***	-0.17***	-0.06***	-0.26***	-0.06***
Income sources	0.03***	0.30***	0.06***	0	0	0.16***	0
No. skilled off-farm workers	-0.05***	0.35***	0.17***	-0.08***	0.03**	-0.11***	0
Prop. food expenditures	-0.11***	-0.35***	-0.12***	-0.17***	-0.04***	-0.23***	-0.08***
Transfer network	0.05***	0.17***	0.07***	0.06***	0.04***	0.09***	0.04***

	Milk/eggs	Garden	Prop. crops sold	Maize/ cassava	Months without stocks	Income sources	Off-farm workers
Milk/eggs	1						
Garden	0.16***	1					
Prop. crops sold	-0.02**	0.03***	1				
Maize/cassava	0.05***	0.12***	-0.17***	1			
Months	-0.07***	-0.08***	-0.11***	-0.57***	1		
Income sources	0.11***	0.15***	-0.10***	0.06***	0	1	
No. off-farm workers	-0.04***	-0.04***	0.14***	-0.06***	0.02***	0.16***	1
Prop. food expenditures	-0.08***	-0.11***	0.038***	-0.25***	0	-0.11***	-0.05***
Transfer network	0.10***	0.10***	0.04***	0.03***	-0.04***	0.37***	0.07***

	Prop. food exp.	Transfer network
Prop. food expenditures	1	
Transfer network	-0.05***	1

5.5 Food security profiles

The last descriptive exercise will use the household-level information from 2008 to create a series of "food security profiles" using cluster analysis. Clustering is used to group households into categories such that households within a category are similar to one another but dissimilar to households in other categories (Babu and Sanyal 2009). The households within a cluster should resemble one another along a range of indicators or food security dimensions, and this technique can be therefore used to recognize patterns among the food security indicators. Similarity is measured with the error sum of squares between households in a cluster and the cluster mean, and once the number of clusters is specified, a "k-means" cluster procedure will classify households to minimize this error sum of squares. Non-panel variables are used in this cluster analysis, and results are provided in Table 5-J. Households with any missing observations are dropped from the analysis, and a fourth category that includes just several dozen very wealthy households is not presented here. Please note that this clustering process was done without consideration of household weights, and the number of clusters was determined arbitrarily to elicit a set of food security profiles that seem to "tell a story".

The cluster analysis readily categorizes households into groups of low, medium, and high food security, in which all the indicators align as one would expect. Approximately one third of the Zambian rural population is categorized into the "low" group: These households do not own any productive assets and have low average values of all other food security indicators, and about one quarter of these households are FHH widows. At the other end of the spectrum, the "high" food security group experiences (on average) the shortest length of time without food stocks and the highest level of crop diversity. Most of these households come from agro-ecological zone IIa.

Table 5-J: Food security profiles in 2008

Average values	Low	Category Medium	High
Calories/AE/day	3,367.40	3,544.79	5,938.91
Calories/AE/day (median)	2,191.12	2,524.63	4,111.29
Crops retained	2.41	2.94	3.26
1=HH produced milk or eggs	0.33	0.52	0.86
1=HH has garden	0.31	0.42	0.49
Months without food stocks	3.10	2.43	1.17
Hectares cultivated	0.91	1.54	3.89
1=Participation in transfer network	0.79	0.84	0.92
TLU	0.31	1.15	16.18
Value of productive assets (ZMK)	0	1,454,971	9,166,691
1= FHH widows	0.24	0.08	0.08
1=AEZ I	0.07	0.05	0.12
1=AEZ IIa	0.30	0.44	0.71
1=AEZ IIb	0.15	0.04	0.07
1=AEZ III	0.48	0.47	0.10
No. observations	2,702	4,576	566
Proportion of population	0.33	0.57	0.07

6. THE MULTIDIMENSIONAL FOOD SECURITY INDICES

6.1 Construction of the indices

From the array of food security indicators calculated in Chapter 5, it can be difficult to extract a household's overall status of food security. To do so, it may be useful to construct a multidimensional index that incorporates the most important indicators from each dimension of food security. However, the construction of such an index can be highly subjective, particularly with regard to the weights assigned to each element of the index. This thesis uses principal component analysis (PCA) to construct a composite food security index, such that the weights are derived objectively from the data.

PCA is a type of factor analysis that can reduce dimensions, or uncover latent variables, by extracting a linear combination that best describes the co-variance among all elements and transforms them into one index. The first principal component is the linear combination capturing the greatest variation among the set of variables. This is converted into factor scores, which serve as weights for the creation of an index for each household. In other words, from an initial set of *n* correlated variables ($X_1, X_2 \ldots X_n$), PCA creates *m* uncorrelated principal components where each is a linear weighted combination of the initial variables as follows:

$$PC_m = a_{m1}X_1 + a_{m2}X_2 + a_{m3}X_3 + \ldots + a_{mn}X_n$$

Here, a_{mn} represents the weight for the *m*th principal component and the *n*th variable. The components are ordered so that the first component explains the largest amount of variation in the data subject to the constraint that the sum of the squared weights is equal to one. Each subsequent component explains some additional but smaller proportion of variation of the variables. As data reduction is the primary objective of this exercise, only the first component will be used.

Once the first component is identified, the food security index for each household is derived as follows:

$$FSI_j = \sum F_i [\frac{X_{ji} - X_i}{S_i}]$$

Where FSI_j is the Food Security Index, which follows a normal distribution with a mean of 0. F_i is the weight for the i^{th} variable in the PCA model (the square of a_{mi}), X_{ji} is the j^{th} household's value for the i^{th} variable, X_i and S_i are the mean an d standard deviations of the i^{th} variable for overall households. Essentially, the FSI is the sum of the weighted z-scores for each variable.

Each PCA index is based on a scale which is relevant only to that estimation, such that a set of indices from different estimations cannot be meaningfully compared. As this study uses three rounds of household panel data, it is necessary to generate an index that is comparable over time. To this end, following the approach of Cavatassi et al. (2004), data for the three rounds are pooled (including all households interviewed in each year) and principal components are estimated over the combined data. The resulting weights are then applied to the variable values for each round of the survey. As discussed in section 6.2, the principal components are carefully inspected to discern whether the variables used to construct the index and their respective weights remain similar in all the three rounds, as this condition enables the comparison of changes over time (Vyas and Kumaranayake 2006). The pooled estimate is used in panel analyses, while a separate index is computed for 2008 and used in cross-sectional analyses.

6.2 Composition of the indices

The selection of indicators included in the indices is driven by both the food security literature and the goal of maximizing the variation explained by the first principal component. For example, the use of hectares cultivated, rather than land access (i.e. potential hectares cultivated) results in a greater amount of variation explained. Two versions of the index are created: The first is the Food Sufficiency Index (FSU), based mostly on the quantity and quality measures of food security. The second index is called the Food Security Index (FSI) and is based on the quantity, quality, and stability measures. Thus, the FSI explores the merit of including indicators of future vulnerability in the index. The variables included as elements of each index are listed in Table 6-A.

Table 6-A: Elements of the food sufficiency and food security indices

Multi-year index	2008 index (non-panel variables)
Calories (ln)	Calories (ln)
No. crops	No. crops/ vegetables/ fruits
Tropical Livestock Units	Tropical Livestock Units (edible)
Produces milk/ eggs	Produces milk/ eggs
	Months without food stocks
Land cultivated (ha)	Land cultivated (ha)
Participates in transfer network	Participates in transfer network
Value of equipment owned	Value of assets, including oxen

Food sufficiency index (FSU)

Food security index (FSI)

Each index for 2008 includes indicators of the various dimensions of food security: quantity (total calories), quality (crop count, TLU, milk/eggs), and stability (months without food stocks, proportion of crop value sold, access to a social safety net, value of assets, and size of land cultivated). Traditional multivariate methods are based on continuous variables. In this analysis, one or two categorical variables are included in a given index, but because they are outnumbered by continuous variables, it should not harm the analysis (Abeyasekara 2005).

Unfortunately, there is no indicator of stability in the FSU for multi-year analysis. This is because the 2001 survey did not capture information on cassava stocks, and a variable that only covers the stability of other crop stocks would misrepresent the food security situation in zone III where cassava is widely consumed. Another point to note is that non-cropping households (which comprise about 5 percent of households in rural Zambia) are included in this index construction exercise, and are given a value of 0 for crops retained if they did not produce any crops and a value of 12 for months without food stocks.

It is also unfortunate that no measure of income diversification is included in the FSI. Several variables were considered, including the number of income sources from which a household draws income and the number of household members that participate in skilled work or work that requires a capital investment. However, each variable is often associated with distress rather than stability. It seems that non-farm income options are so limited in rural Zambia that they cannot be meaningfully regarded as a component of a household's underlying food security status.

6.3 Suitability and factor loadings

All of the original variables are loaded onto one factor that explains the most variance in the original components. For the multi-year indices, Table 6-B provides the factor loadings of the first principal component, as well as the eigenvalue (proportion of variance explained) and Kaiser-Meyer-Olkin (KMO) statistic. The factor loadings can also be thought of as the square root of the weight assigned to each variable. To construct the multi-year indices, all households interviewed in each year are included, using population weights. The PCA is not rotated as this does not seem to enhance the results.

Table 6-B: Factor loadings for multi-year indices: FSU and FSI

	Factor loadings			
Food sufficiency index (FSU)	**Pooled years**	**2001**	**2004**	**2008**
Component				
Calories (ln)	0.64	0.65	0.65	0.55
No. different crops retained	0.6	0.62	0.56	0.54
Tropical livestock units	0.33	0.27	0.38	0.56
Household produces milk or eggs	0.35	0.34	0.35	0.60
KMO	0.52			
Proportion variation explained	0.35	0.4	0.33	0.39
Number observations	20,435	6,922	5,419	8,094

	Factor loadings			
Food security index (FSI)	**Pooled years**	**2001**	**2004**	**2008**
Component				
Calories (ln)	0.39	0.41	0.39	0.36
No. different crops retained	0.34	0.38	0.29	0.33
Tropical livestock units	0.39	0.40	0.37	0.42
Household produces milk or eggs	0.31	0.24	0.37	0.34
Hectares cultivated	0.52	0.53	0.51	0.50
Participates in transfer network	0.12	0.05	0.18	0.09
Value of productive assets (ln)	0.45	0.44	0.44	0.46
KMO	0.65			
Proportion variation explained	0.29	0.29	0.27	0.31
Number observations	20,435	6,922	5,419	8,094

In the multi-year indices, the data reduction of the PCA explains 35 percent of the original variation of the data for the FSU. For the FSI, this value is 29 percent. These values are similar to those seen in other studies that use PCA to develop a food security or vulnerability index: Filmer and Pritchett (1998) use the first principal component of PCA to construct a household wealth index, where the first factor explains 25.6 percent of the variation in the data. Dasgupta and Baschieri (2010) construct an index of vulnerability to climate change, where the first principal component explains 25 percent of the variation, and Demeke et al. (2011) similarly use PCA to build an index of food security in Ethiopia, where the first factor explains 32.5 percent of the variation.

The factors that load most heavily on the FSU are calories and crop diversity, and the value of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.52. A large KMO value (greater than 0.5) indicates that correlations between pairs of components can be explained by the other variables in the index (Kaiser 1974). It should be noted, however, that this value is close to the cutoff of acceptability. In deciding to pool the data from all years of the panel, it is important to verify that the pattern of factor loadings do not change fundamentally from year to year, when the exercise is repeated for each year independently. An inspection of the yearly values in Table 6-B confirms that it is acceptable to create a pooled index. An example of how these factor loadings are used to create the food sufficiency score for a specific household is available in the appendix (Table 9-I).

Table 6-C provides the same information for the indices derived when using only the year 2008. When applicable, these variables are non-panel values. TLU now includes all animals besides oxen, which are considered productive assets, and the FSU now includes an indicator of stability (months without food stocks).

Table 6-C: Factor loadings for 2008: FSU and FSI

Food sufficiency index (FSU)		**Agro-ecological zones**			
Component	**All of Zambia**	**I**	**IIa**	**IIb**	**III**
Calories (ln)	0.41	0.38	0.48	0.43	0.31
Number of different crops retained	0.52	0.343	0.46	0.57	0.59
Edible tropical livestock units (TLU)	0.28	0.49	0.33	0.25	0.16
Household produces milk or eggs	0.39	0.46	0.36	0.29	0.42
Number of months with no crop stocks	-0.57	-0.48	-0.56	-0.58	-0.60
KMO	0.60				
Proportion variation explained	0.36	0.36	0.38	0.39	0.34
Number observations	7,909	489	3,074	612	3,734

Table 6-C (cont'd)

Food security index (FSI)		**Agro-ecological zones**			
Component	**All of Zambia**	**I**	**IIa**	**IIb**	**III**
Total calories (ln)	0.34	0.30	0.39	0.34	0.28
Number of different crops retained	0.38	0.33	0.34	0.48	0.48
Household produces milk or eggs	0.35	0.36	0.31	0.26	0.35
Number of months without food stocks	-0.41	-0.37	-0.43	-0.47	-0.48
Hectares cultivated (ha)	0.46	0.43	0.44	0.44	0.48
Participates in transfer network	0.13	0.05	0.14	0.02	0.13
Edible tropical livestock units	0.32	0.42	0.32	0.28	0.23
Value of productive assets, including oxen (ln)	0.34	0.41	0.36	0.31	0.20
KMO	0.71				
Proportion variation explained	0.29	0.30	0.32	0.31	0.26
Number observations	7,909	489	3,074	612	3,734

The principal component tends to load positively on variables which contribute to food security, and negatively on variables which contribute to food insecurity. For 2008, Table 6-C displays the results when these indices are created for each agro-ecological zone separately. It would be problematic if the pattern of factor loadings differed between regions, but a visual inspection shows that the importance of different variables to food security is relatively consistent across zones. The number of observations for which each index can be calculated is slightly lower than the number of households interviewed in 2008 due to missing observations.

6.4 Descriptive statistics

The average and standard deviation of these indices in 2008 are shown in Table 6-D. As expected, the average value for all households is zero, as the PCA always produces a relative index centered at zero. It is clear that female-headed households have lower average scores, as compared with the general population, and this is true whether FHHs are defined as widowed households or FHHs without a prime-age male (FHH nm). However, it seems that FHHs without a prime-age male experience lower food security than the alternative definition of FHHs. Among agro-ecological zones, the drier regions (zone I and IIb) experience lower average food sufficiency, and only zone IIa has a positive average value for both the FSU and FSI. Interestingly, zone I fares much better with regard to its average FSI, while zone III fares much worse. This is surely because of the high disease burden for livestock in zone III, compared with the important cultural role of livestock in zone I.

Table 6-D: FSU and FSI in 2008

				Agro-ecological zones			
	All HHs	**FHH widow**	**FHH nm**	**I**	**IIa**	**IIb**	**III**
Food sufficiency score	0.00	-0.18	-0.34	-0.04	0.17	-0.68	0.00
	(1.41)	(1.30)	(1.36)	(1.32)	(1.50)	(1.36)	(1.31)
Food security score	0.00	-0.42	-0.68	-0.05	0.33	-0.89	-0.13
	(1.51)	(1.35)	(1.29)	(1.44)	(1.67)	(1.38)	(1.31)

To understand what is driving the average value in each agro-ecological zone, it is necessary to analyze the average values of each element of the index. The radar graph in Figure 6-1 displays the average values for the FSI elements for each zone. Note that for this figure, one of the food security indicators (months *with* food stocks) was adjusted so that higher values represent greater security. These values are normalized z-scores, such that a value of zero represents the median level in Zambia. A higher score farther from the center of the graph is relatively good, while a value closer to the center represents a lower level of welfare. Zones I, IIa, and III exhibit relatively "smooth" circles, though zone I stands out in terms of the low number of months with food stocks, and zone III stands out on terms of high crop diversity and time spent with food stocks. Zone IIb consistently scores low for indicators of food security, and the low value for number of crops/FFV retained seems to stem from the much lower prevalence of gardens in the region (Table 5-F).

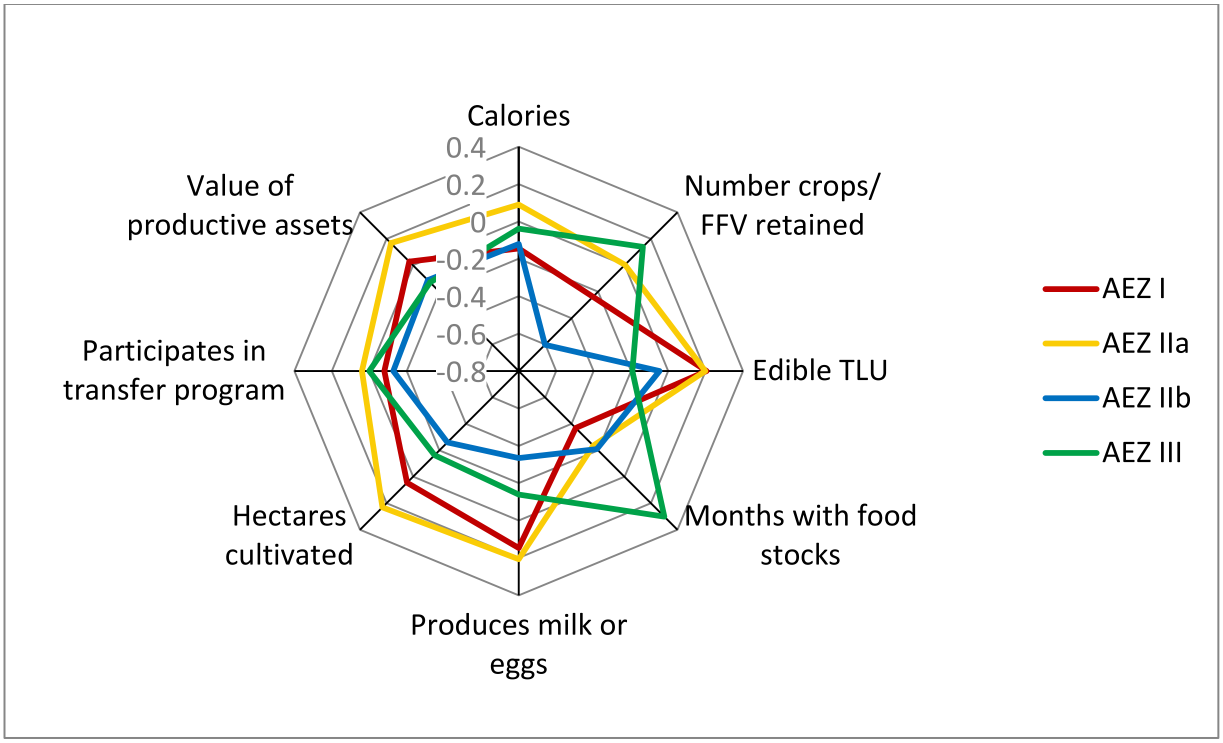

Figure 6-1: Radar graph of food security indicators for 2008

The distribution of the FSU scores and FSI scores across years is presented in Figure 6-2. The FSU seems to change little from year to year, while there is more variation in the FSI, where the year 2008 exhibits a leftward shift.

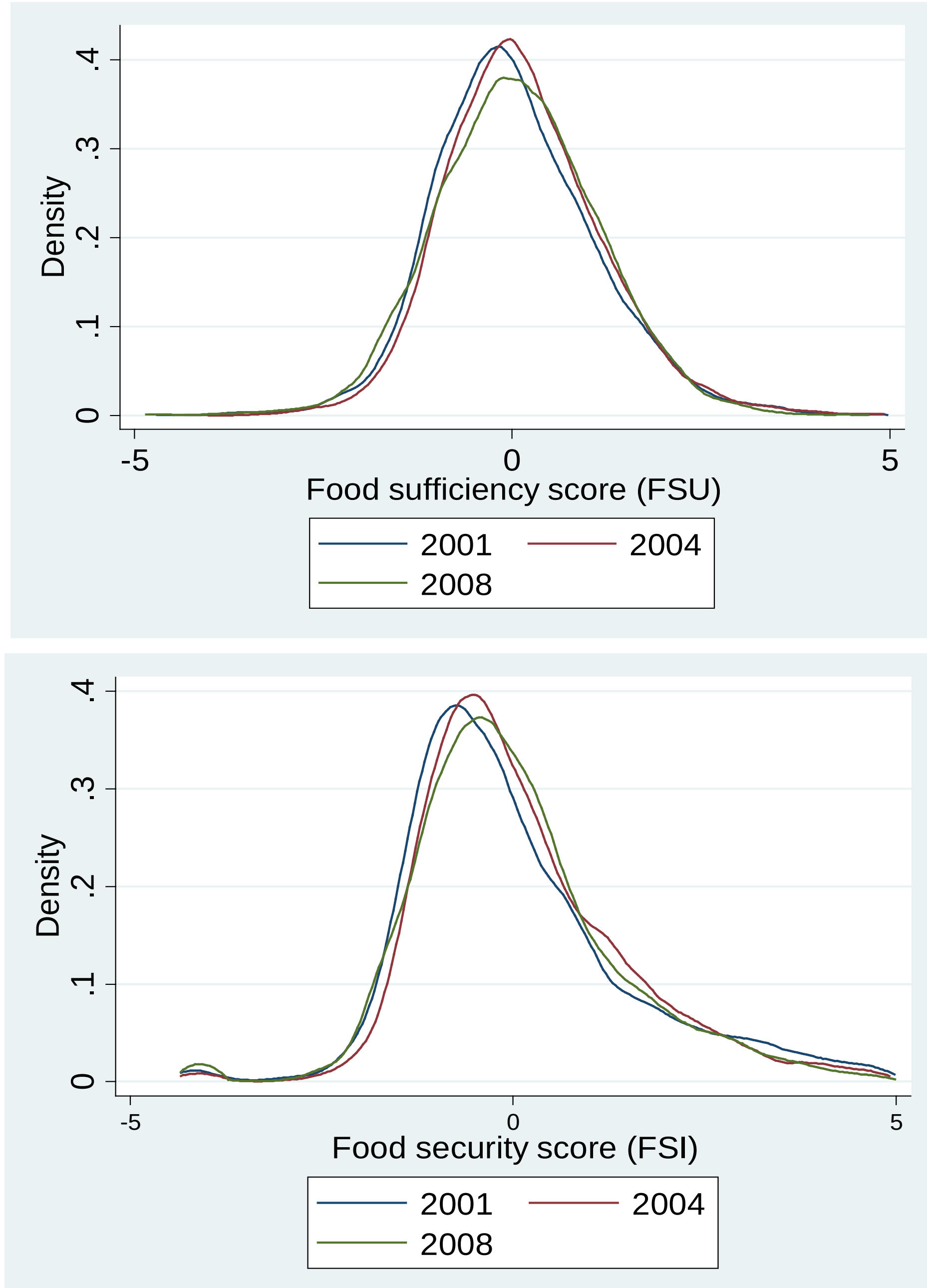

Figure 6-2: Distribution of FSU and FSI across years

The average score and standard deviation of the FSI and FSU for each year are displayed in Table 6-E. T-tests show that from 2001 to 2004, Zambian households experienced a significant increase in food sufficiency and security. From 2004 to 2008, the average values of food sufficiency dropped while food security improved ever so slightly. Although statistically significant, it seems the difference from 2004 to 2008 may be so small as to be practically insignificant – reflecting once again a situation of stagnancy in Zambia over this time period.

Table 6-E: FSU and FSI across years

		Years				
	All HHs	**2001**	**2004**	**2008**	**|t| 2001 & 2004**	**|t| 2004 & 2008**
FSU	0.00	-0.10	0.05	0.03	3.9	2.88
	(1.18)	(1.14)	(1.16)	(1.23)		
FSI	0.00	-0.15	0.04	0.07	2.87	6.08
	(1.42)	(1.29)	(1.41)	(1.50)		

The spatial pattern of how food security has changed over time can be seen in the maps of Figure 6-3, which shows the average value of the FSU for each district. While the relative degree of food insecurity does change, there are clearly pockets of insecurity, namely in zones IIb and III. The pattern in 2008 closely reflects the location of flooding in Zambia in the 2006/07 agricultural season (UNICEF 2007). It seems that this index can be effectively used to gauge the household impact of short-term shocks. At the same time, a pattern observed in a single year should not be conflated with regional food security over the long-term, and this fluctuation demonstrates the value of precisely this sort of longitudinal analysis.

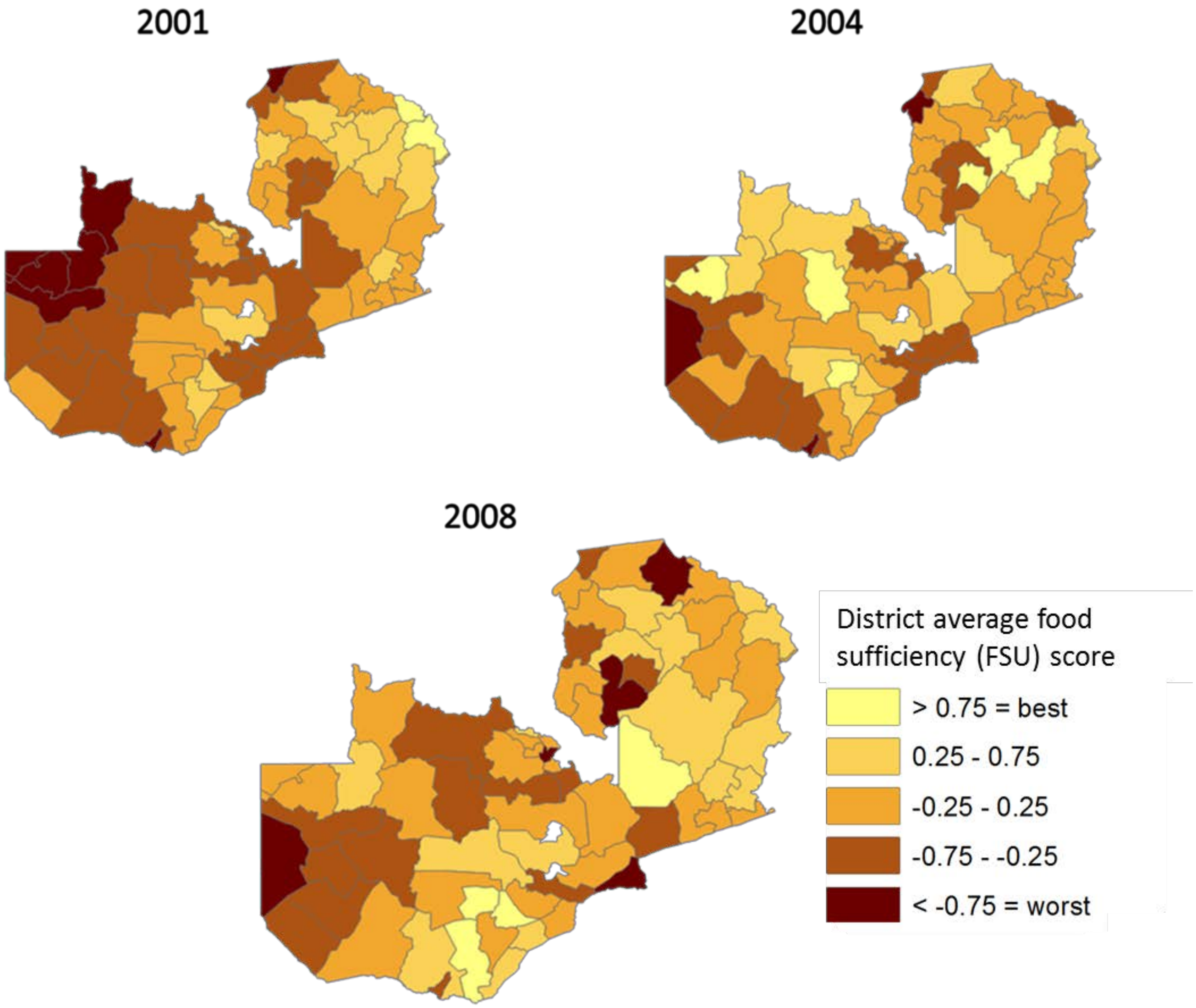

Figure 6-3: Geographic pattern of average district FSU for 2001, 2004, and 2008

A transition matrix of households' food sufficiency scores (Table 6-F) from 2004 to 2008 shows that households do not tend to move very far along the FSU scale. The status categories are derived from the FSU quintiles of 2004. Of the households that fall into the first quintile in 2004, 31 percent retain the same status in 2008. For the food security scores (Table 6-G), this pattern is even more pronounced: Of the households that fall into the top quintile in 2004, 52 percent retain the same status in 2008.

Table 6-F: Transition matrix of food sufficiency score from 2004 to 2008

	FSU status 08				
FSU status 04	**1**	**2**	**3**	**4**	**5**
1	0.31	0.26	0.20	0.19	0.08
2	0.26	0.24	0.22	0.18	0.11
3	0.18	0.21	0.22	0.20	0.20
4	0.16	0.14	0.19	0.24	0.25
5	0.10	0.14	0.17	0.19	0.36

Table 6-G: Transition matrix of food security score from 2004 to 2008

	FSI status 08				
FSI status 04	**1**	**2**	**3**	**4**	**5**
1	0.32	0.27	0.18	0.13	0.04
2	0.32	0.32	0.26	0.20	0.09
3	0.19	0.18	0.24	0.24	0.14
4	0.12	0.14	0.22	0.25	0.21
5	0.06	0.09	0.10	0.17	0.52

Given this trend, it is useful to think about the predictive power of various indicators in terms of how well they would predict a household's status 4 years in the future. Table 6-H presents the correlation coefficients between household income (in both 2004 and 2008) and a series of food security outcomes in 2008. All correlations are positive and strongly significant, though the magnitude of the relationship between income and food security drops precipitously when income is related to food security four years in the future. Interestingly, income in 2008 is most strongly related to calories in 2008, while income in 2004 is most strongly correlated with the FSI in 2008.

One might also want to assess the predictive power of food security indicators in 2004 (Table 6-I). The correlation between FSI in 2004 and 2008 is 0.55, which makes sense as many of the components of this index might be consistent within a household from one year to the next. In terms of predicting a household's food sufficiency experience in 2008, FSI outperforms FSU.

This is as expected, as the FSI specifically includes indicators of vulnerability to future food shortfalls. In terms of predicting the proportion of calorie requirements met in 2008, none of the 2004 indicators exceed a correlation of 0.17.

Table 6-H: Income and food security indicators, 2004 and 2008

	2008			
	FSI	**FSU**	**Calories (ln)**	**Proportion of calorie requirements met**
Income (ln) 2008	0.40***	0.39***	0.43***	0.41***
Income (ln) 2004	0.19***	0.13***	0.13***	0.11***

Table 6-I: Food security indicators in 2004 and 2008

		2008			
		FSI	**FSU**	**Calories (ln)**	**Proportion of calorie requirements met**
2004	**FSI**	0.55***	0.40***	0.19***	0.17***
	FSU	0.35***	0.33***	0.15***	0.13***
	Calories (ln)	0.21***	0.19***	0.16***	0.14***
	Proportion of calorie requirements met*	0.18***	0.14***	0.12***	0.17***

*assuming moderate level of activity

A final exercise in assessing the relative predictive power of the FSI is a thought experiment, in which the goal is to identify in 2004 the households that will be food insecure in 2008. A household is targeted if it is in the lowest one-third of either the income or FSI distribution in 2004. The targeting is considered accurate if the household would be targeted in 2004 *and* is in the lowest one-third of the FSU distribution in 2008. A type I error is a 'false positive', where the household is targeted when it should not have been, and a type II error is a 'false negative', where the household is not targeted when it should have been.

Table 6-J displays the proportion of 2008 households that fall into each category, given the income and FSI targeting criteria. This outcome suggests that the FSI from 2004 does a better

job of accurately targeting households that will be poor in 2008. If the FSI is accepted as a practical measure of food security, then a household's FSI score in 2004 is a better predictor of food sufficiency four years later, as compared with a money-metric indicator, and income-poverty status alone seems insufficient to identify households that are vulnerable to food insecurity. However, the two targeting criteria have different patterns of type I and II errors, and using the FSI results in 12 percent of 2008 households being overlooked when they should have been targeted.

Table 6-J: Type I and II errors when income and FSI are used as targeting criteria

	Income 2004	FSI 2004
Accurate targeting	0.34	0.65
Type I error	0.63	0.23
Type II error	0.03	0.12

Are households merely "bouncing around" the food security indices without a pattern? Table 6-K presents the percent of households that are always, sometimes, and never secure, in terms of food sufficiency or food security. Here, a household is categorized as "always food insecure" if its FSU or FSI score is in the lowest one-third of the distribution for all three waves of the panel. A household is considered "sometimes" food insecure if its score is in the lowest one-third for one or two years, and never food insecure if its score is never in the lowest one-third.

Table 6-K: Persistence of food security from 2001 to 2008

	FSU	FSI
Always food insecure	0.08	0.09
Sometimes	0.54	0.50
Never	0.38	0.41

Table 6-K breaks down the proportion of households that experience the following trajectories in terms of their FSU score and FSI score: A positive change from 2001 to 2004 and another

positive change from 2004 to 2008 (+ +); A positive followed by a negative change (+ -); a negative followed by a positive change (- +); and two negative moves down the index (- -). For food sufficiency, 22 percent of households consistently moved higher on this scale, while 34 percent consistently fell lower, and the remaining households (~43 percent) experience a change in their direction of movement. This pattern of movement is mirrored in the food security index, which suggests strong consistency between the two indices.

Table 6-L: Proportion of households by FSU and FSI trajectory

Trajectory	FSU	FSI
+ +	0.22	0.25
+ -	0.14	0.14
- +	0.30	0.29
- -	0.34	0.33

Figure 6-4 shows the relationship between the FSU in years 2001 or 2004 and the subsequent change in FSU from that year to the next panel year. Although there is a good deal of variation, the trend is generally negative: A higher FSU is correlated with a negative (or smaller positive) change in the FSU. If a higher FSU were correlated with greater security, one might expect to see a quadratic relationship between FSU in a given year and the subsequent change in FSU. However, the regression results presented in Table 6-M indicate that this is not the case. This pattern does not necessarily indicate that households are haphazardly "bouncing around", as a higher food security score leaves less potential for additional improvement. As well, it may be overreaching to conclude that the variability in food security in this short time frame represents the longer-term trends of household movement. (See Naschold and Barrett (2011) for an analogous discussion of how to interpret stochastic income over varying time frames.) However, this does illustrate that household experiences regularly fluctuate in the short term.

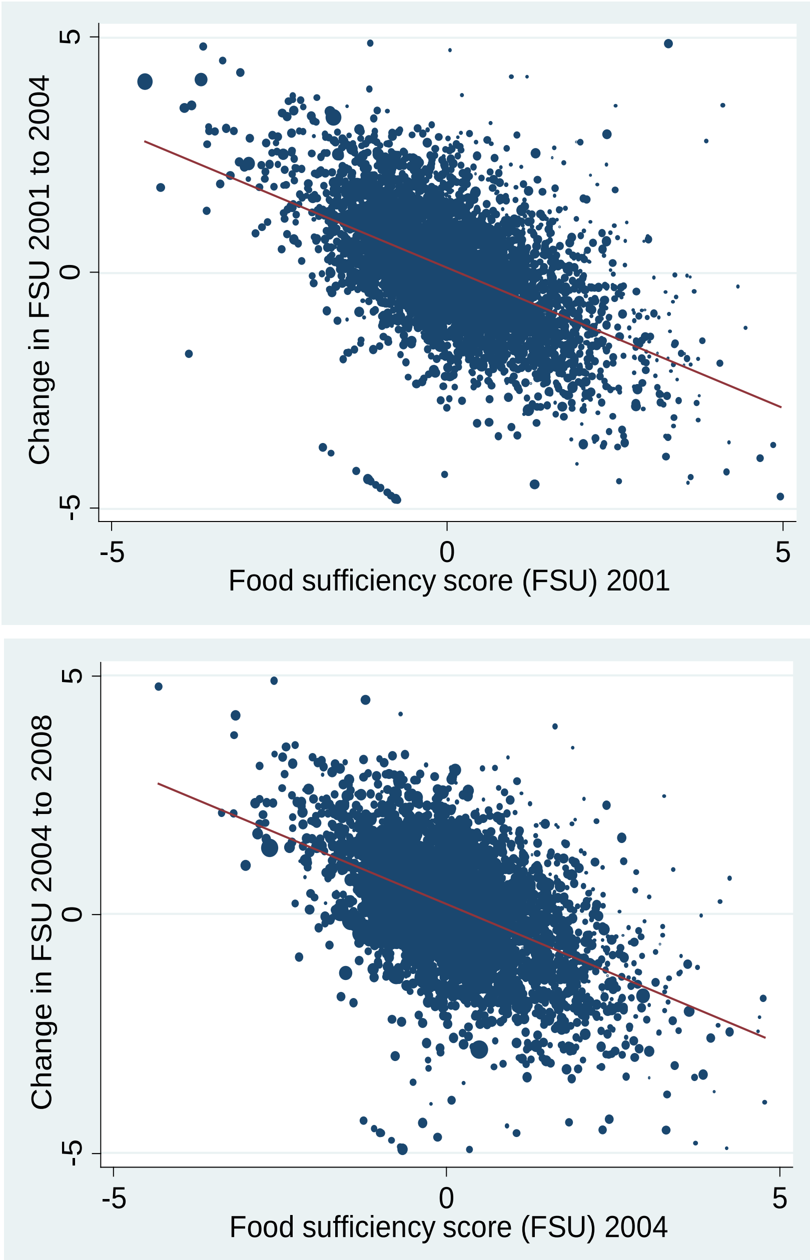

Figure 6-4: FSU and change in FSU, 2001 to 2004 and 2004 to 2008

Table 6-M: OLS regression of change in FSU and previous FSU

Explanatory variables	ΔFSU 2004-08 OLS
FSU 2004	-0.658***
	(0.024)
$[FSU\ 2004]^2$	0.003
	(0.003)
Constant	0.124***
	(0.024)
Observations	4,340
R^2	0.302

*** p<0.01, ** p<0.05, * p<0.1

7. APPLICATIONS OF THE FOOD SECURITY INDICES

7.1 Correlates of food sufficiency and food security (cross-sectional methods)

7.1.1. Probability of being food insufficient

In this chapter, the food sufficiency and food security indices are applied to various exercises aimed at identifying the correlates and determinants of food security. The selection of variables included in the models is guided by the food security literature and the significant determinants that have been identified in similar contexts (Feleke et al. 2005; Garrett and Ruel 1999; Misselhorn 2005; Tschirley and Weber 1994), the variables that seem like they may plausibly affect food security, and data availability. Section 7.1.1 is limited to cross-sectional analyses of the 2008 data in order to take advantage of the larger number, and more nuanced definitions, of food security indicators and regressors that are available only in this last wave of the panel survey. Although attempts are made to ensure the regressors are exogenous, readers should be cautious when interpreting the coefficients in section 7.1. Because time-invariant household fixed effects cannot be captured in cross-sectional regressions, the coefficients are best interpreted as measures of partial correlation rather than causation. In addition, it should be noted that because the dependent variable is a normalized food security score unique to this population, the coefficients are a bit difficult to interpret. Readers are encouraged to focus on the sign, significance, and relative magnitude of the coefficients rather than their specific value.

A first attempt to identify the correlates of food insufficiency is done with a logit regression, in which the dependent variable is an indicator of being in the bottom one-third of the FSU distribution in 2008. This is modeled as

$$w_i = \alpha + \beta_i X_i + \varepsilon_i$$

where $w_i = ln(p_i/(1-p_i))$, $p_i = prob\ (y_i = 1 \mid x_i)$, $y_i = 1$ if the i^{th} household is food insecure and 0 otherwise, and X_i = a vector of socioeconomic and geographic characteristics of the i^{th} household. Each district is matched with a meteorological station in Zambia, where rainfall and temperature records reference the 2006/07 agricultural season. Average partial effects are presented in the first column of Table 7-A. In column 1, a positive value means that an increase in the explanatory variable leads to an increase in the predicted probability of being food secure. Conversely, a negative coefficient means that an increase in the explanatory variable results in a decrease in the probability of being food secure.

Among the notable results is the lack of significance of being a female-headed widowed household. The insignificance here does not negate the fact that female-headed widowed households have significantly lower FSU than the general population (Table 6-D), but it indicates that once all of these other factors are controlled for, there is no residual causal relationship between widowhood and food insufficiency. Rather, their status is explained by the other household characteristics included as controls in this regression. *Ceteris paribus*, a higher dependency ratio is actually associated with sufficiency; this is surprising, given the importance attributed to the burden of a high dependency ratio in other studies (Kennedy and Peters 1992).

Several explanatory variables relate to a household's endowment of social capital: Relation to the village chief is a significant determinant of food sufficiency, while the number of years a household has resided in the village is not significant. Participation in a transfer network (the receipt *or* provision of cash or goods) is associated with being food sufficient, though this potentially exhibits reverse causality as it may have been directly determined by a household's food security experience. For example, if households receive remittances during times of distress, this would attenuate the detected relationship between social capital and avoidance of insufficiency. Alternatively, if households provide assistance to others during a good year, their food sufficiency status makes it possible for them to participate in a transfer network. One option would have been to use a household's transfer network status from 2004, as this could be exogenous with 2008 food sufficiency. However, this would have sharply limited the sample size, so the household's 2008 transfer network status is included with the caveat that it is most certainly endogenous.

The variables related to a household's asset endowment tell a consistent story: A higher value of productive assets (including work oxen) and larger area of land cultivated are significant determinants of sufficiency. The variables related to information access (ownership of a radio and receipt of agricultural information services) are also positively correlated with sufficiency. It is interesting to see that a higher proportion of crop value marketed is negatively associated with food sufficiency, though the relationship may be driven by inclusion of a dummy variable for production of a cash crop. Finally, rainfall is a significant determinant of food sufficiency in the expected quadratic relationship, and a joint F-test of significance of average season temperature (F = 8.41, prob > F = 0.000) reveals that temperature is also a determinant of food sufficiency in a quadratic manner.

Table 7-A: Logit and OLS regressions of household food sufficiency/ FSU score in 2008

	(1)	(2)
	1=Food sufficient	FSU 2008
Explanatory variables	Logit	OLS
HH size	-0.013***	-0.020**
	(0.002)	(0.008)

Table 7-A (cont'd)

Dependency ratio	0.076**	0.163*
	(0.030)	(0.084)
Maximum education	0.000	0.004
	(0.002)	(0.007)
Maximum women's educ.	0.002	0.009
	(0.002)	(0.006)
1=FHH widow	0.009	-0.048
	(0.018)	(0.046)
1=HH head recently died	-0.019	-0.073
	(0.030)	(0.076)
Age of HH head	0.003	0.013**
	(0.002)	(0.006)
Age^2 of HH head	-0.000	-0.000*
	(0.000)	(0.000)
1=Owns radio	0.040***	0.079***
	(0.012)	(0.031)
1=Agricultural services	0.075***	0.303***
	(0.011)	(0.030)
Km to main road (ln)	-0.006*	-0.002
	(0.003)	(0.009)
1=HH related to chief	0.060***	0.237***
	(0.011)	(0.029)
Years in village (ln)	0.003	0.045***
	(0.007)	(0.015)
1=Transfer network	0.061***	0.232***
	(0.014)	(0.037)
No. skilled workers	-0.041***	-0.099**
	(0.015)	(0.041)
1=Woman works off-farm	-0.001	0.030
	(0.029)	(0.095)
Proportion income on food	-0.407***	-1.248***
	(0.032)	(0.073)
1=Cash crop	0.032	0.296***
	(0.020)	(0.048)
Kgs nitrogen/ ha maize (ln)	0.013***	0.063***
	(0.004)	(0.009)
1=Grows maize	0.023	0.412***
	(0.015)	(0.039)
1=Owns water pump	0.098	1.392***
	(0.073)	(0.457)
Proportion crop value sold	-0.254***	-1.262***
	(0.020)	(0.061)
Value of productive assets (ln)	0.006***	0.027***
	(0.001)	(0.003)
Hectares cultivated	0.161***	0.262***

Table 7-A (cont'd)

	(0.010)	(0.026)
1=Zone IIa	-0.000	-0.106
	(0.027)	(0.070)
1-Zone IIb	-0.066**	-0.379***
	(0.033)	(0.083)
1=Zone III	0.129***	0.327***
	(0.032)	(0.085)
mm important rain (ln)	3.510***	11.575***
	(0.867)	(2.124)
Important rain^2	-0.262***	-0.862***
	(0.066)	(0.162)
Season temperature (°C)	0.062	0.558***
	(0.079)	(0.208)
Season temperature^2	-0.001	-0.011**
	(0.002)	(0.004)
Constant		-47.399***
		(7.469)
Observations	7,234	7,234
R^2		0.445

Average partial effects (column 1) and OLS coefficients (column 2) with robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.1.2 Correlates of food sufficiency score

Similar results are seen when food sufficiency is maintained as a continuous variable. An ordinary least squares regression of households in 2008 is modeled as

$$FSU_i = \alpha + \beta_i X_i + \varepsilon_i$$

where FSU_i = the Food Sufficiency score of household *i* in 2008, and X_i = a vector of socioeconomic and geographic characteristics of the i^{th} household. The results are presented in column 2 of Table 7-A. The unit of the dependent variable is 1 standard deviation of the FSU distribution. However, because this is a population-specific index, the sign and significance of the coefficients are probably more important than their magnitude.

An older household head is generally associated with higher food sufficiency, although the size of the coefficient is small. Consistent with the results of column 1, the coefficient on FHH widows is not significant, although the sign is in the expected direction. A higher proportion of income spent on market food purchases is negatively related to food sufficiency, which suggests that households that are more reliant on the market for their food needs experience more insecurity. It should be acknowledged that this variable certainly suffers from simultaneity bias, as it is measured during the same time period as the dependent variable. In other words, even if a household does not alter its food purchase behavior in a bad year, the proportion of household income devoted to food purchases would necessarily rise as income falls. The coefficient is probably biased downward.

Among the geographic variables, zone I (in the south) is used as the reference zone, and a household located in zone IIa or zone III is predicted to have a similar or significantly higher food sufficiency score. This is consistent with the descriptive results shown in Figure 6-3, where only zone IIb stands out as being less food secure than zone I. It is interesting to note that remoteness, as measured by distance to a main road, is not found to be associated with food sufficiency.

7.1.3 Correlates of the persistence of food security

The correlates of the persistence of food security are explored by first classifying households into 3 mutually-exclusive and exhaustive categories as always food insecure, always food secure, or sometimes food secure. A household is considered food insecure in a given year if its FSU score is in the lowest one-third of the multi-year FSU index, and it is classified as always food insecure if it is food insecure in all 3 years of the panel, always food secure if it is never in the lowest one-third of the distribution, or sometimes food secure if its classification changes at least once over the study period. This follows the approach developed by Demeke et al. (2011), and also responds to the appeal of Hulme (2003) regarding the importance of studying the causes of *chronic* poverty relative to *transient* poverty.

A multinomial logistic model (ML) is used to identify the determinants of being either always food secure or insecure. The ML model provides partial estimates of the effects of each explanatory variable on the probability that a household experiences one of the discrete outcomes listed above, relative to a base category. In this case, the base category is the status of being sometimes food secure, and the average partial effects are presented in Table 7-B. The explanatory variables are restricted to initial household conditions in 2001, and readers should be cautious about interpreting these values in a causal manner: Rather the purpose of this exercise is to capture the partial correlations between each explanatory variable and a household's long-term food security experience.

Table 7-B: Determinants of being always food secure or insecure, 2001

Explanatory variables (2001)	(1) 1=Never food secure Logit	(2) 1=Always food secure Logit
HH size	0.005***	-0.012***
	(0.002)	(0.003)
Dependency ratio	0.027	0.103**
	(0.029)	(0.043)
Maximum education	-0.004*	0.007**
	(0.002)	(0.003)
Maximum women's educ.	0.001	0.007**
	(0.002)	(0.003)
1=FHH widow	0.012	0.031
	(0.016)	(0.026)

Table 7-B (cont'd)

1=HH head recently died	-0.014	-0.035
	(0.060)	(0.094)
Age of HH head	-0.002	0.005
	(0.002)	(0.003)
Age^2 of HH head	0.000	-0.000*
	(0.000)	(0.000)
1=Owns radio	-0.020*	-0.016
	(0.012)	(0.016)
Km to main road (ln)	-0.001	0.011***
	(0.003)	(0.004)
1=Transfer network	-0.012	0.048***
	(0.011)	(0.015)
No. skilled workers	0.029**	-0.029
	(0.014)	(0.024)
1=Woman works off-farm	0.025	-0.020
	(0.028)	(0.055)
Proportion income on food	0.031	-0.131***
	(0.019)	(0.047)
1=Cash crop	0.013	0.058*
	(0.030)	(0.030)
Kgs nitrogen/ ha maize (ln)	0.001	0.020***
	(0.004)	(0.005)
1=Grows maize	-0.014	0.085***
	(0.012)	(0.021)
1=Owns water pump	-0.128**	-0.074
	(0.057)	(0.080)
Proportion crop value sold	-0.016	-0.101***
	(0.029)	(0.036)
Value of productive assets (ln)	-0.008***	0.011***
	(0.002)	(0.002)
Hectares cultivated	-0.083***	0.106***
	(0.012)	(0.007)
1=Zone IIa	-0.003	0.072**
	(0.020)	(0.033)
1=Zone IIb	0.079***	-0.096**
	(0.022)	(0.043)
1=Zone III	0.001	0.067**
	(0.021)	(0.034)
1=Zero tillage	0.022	-0.073**
	(0.015)	(0.029)
1=Intercrop	-0.023**	0.032**
	(0.011)	(0.016)
1=Crop rotation	-0.027**	0.096***
	(0.011)	(0.015)

Table 7-B (cont'd)

Observations	4,023	4,023

Average partial effects with robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results are not particularly surprising, as the same variables significantly contribute to the probability of being persistently secure as had affected the food sufficiency score (Table 7-A). The results presented are all relative to the base outcome of being sometimes food secure. For example, in column 2 a one-year increase in the maximum education level results in an increase in the probability of being always food secure, as opposed to being sometimes food secure. The results indicate that, even holding the household maximum education level constant, a higher maximum education level for women is a positive determinant of long-term food sufficiency. Ownership of a radio is correlated negatively with the probability of being always insecure rather than sometimes secure, but this is not a significant determinant of being located further along on the security spectrum. Several farm management variables fall under the heading of conservation farming: Practicing crop rotation from year to year is associated with long-term food sufficiency, as is intercropping. However the correlation between practicing zero tillage and being food secure is ambiguous.

7.2 Correlates of food sufficiency and food security (panel methods)

7.2.1 Correlates of food sufficiency and security scores, controlling for household fixed effects

All previous regressions have not controlled for unobservable household characteristics that may determine food security. For example, a farmer that applies more effort may experience a higher level of food security, but such traits are not captured in the data. If an explanatory variable is correlated with an omitted variable, the coefficient from an OLS regression will be biased. A fixed effects model controls for these unobservables and should therefore more likely provide unbiased estimates of the coefficients. The appropriateness of a fixed-effects model is confirmed with Hausman tests, which in each case reject the null hypothesis (Prob > χ^2 = 0.000) that there is no systematic difference in coefficients between a random effects and fixed effects model.

The next several models exploit the variation found within multiple observations on a single household to understand the correlates of food security. The model is

$$Y_{it} = \gamma + \beta X_{it} + \alpha_i + \varepsilon_{it}$$

where Y_{it} = the dependent variable of household *i* at time *t*, X_{it} = a vector of socioeconomic characteristics and agricultural practices of household *i* at time *t*, and α_i = unobserved household fixed effects that are time-invariant. All explanatory variables that are time-invariant, such as geographic location or relationship to the village chief, are necessarily dropped from this analysis. As a regression-based test for attrition bias rejects the null of no bias (p-value = 0.000), attrition-adjusted weights are used. Column 1 of Table 7-C presents the results of this model when FSI_{it} is the dependent variable. Many of the coefficients have maintained their sign, even after accounting for household fixed effects. The indicator for FHH widow is still included here, although now the coefficient represents the marginal effect of *becoming* a widow, rather than the effect of a long-term status as FHH widow. However, it is noteworthy that becoming a FHH widow has a significantly negative impact on food security. This may be driven by the choice of dependent variable as the FSI index includes both productive assets and land cultivated, which are held in smaller amounts by FHHs (Table 5-E). Household size is no longer significant, and neither is the maximum education level. It now appears that having a woman work off-farm is associated with a higher FSI score.

Column 2 of Table 7-C presents the results of this model when FSU_{it} is the dependent variable. Attrition bias (p-value = 0.000) is again addressed with attrition-adjusted weights. An F-test of joint significance of the temperature variables indicates that they are significant in the typical quadratic manner (F = 4.78, prob > F = 0.009). Intercropping in the previous agricultural season, having rotated the main crop on a field, and using a no-tillage method of land preparation all positively impact food sufficiency after harvest. This short-term effect is interesting, as the impacts of conservation farming techniques are expected to be seen over a longer time horizon (Haggblade and Tembo 2003).

It might be worrisome that these multi-year indices do not incorporate a variable for the stability of current food supply or the maintenance of food stocks. To explore how this omission affects the results, the analysis is repeated for just years 2004 and 2008 when data are available for the indicator of having maize or cassava in storage from the previous harvest. This indicator is used in the construction of a brand new FSU index, and the results are presented in column 3 of Table 7-C. This model does not exhibit attrition bias, and it seems clear that the pattern does not change markedly when this stability variable is included in the FSU index.

Table 7-C: Determinants of FSU and FSI with HH fixed effects: 2001, 2004, and 2008

Explanatory variables	(1) FSI OLS	(2) FSU OLS	(3) FSU (2004 and 2008 only) OLS
HH size	0.001	-0.056***	-0.067***
	(0.007)	(0.006)	(0.009)
Dependency ratio	-0.082	0.033	0.064
	(0.081)	(0.070)	(0.113)
Maximum education	0.004	0.001	-0.001
	(0.007)	(0.006)	(0.009)
Maximum women's educ.	0.008	0.004	0.001
	(0.006)	(0.006)	(0.008)
1=FHH widow	-0.199***	-0.081	-0.057
	(0.052)	(0.051)	(0.077)
1=HH head recently died	-0.060	-0.056	-0.081
	(0.073)	(0.067)	(0.082)
Age of HH head	0.042***	0.022**	-0.008
	(0.011)	(0.010)	(0.015)
Age^2 of HH head	-0.000***	-0.000**	0.000
	(0.000)	(0.000)	(0.000)
1=Owns radio	0.138***	0.087***	0.083**
	(0.028)	(0.024)	(0.035)
1=Transfer network		0.127***	0.091**
		(0.023)	(0.035)
No. skilled workers	0.070*	0.006	-0.038
	(0.037)	(0.032)	(0.046)
1=Woman works off-farm	0.172*	0.079	0.156
	(0.089)	(0.077)	(0.105)
Proportion income on food	-0.528***	-0.341***	-0.734***
	(0.062)	(0.061)	(0.086)
1=Cash crop	0.465***	0.228***	0.291***
	(0.051)	(0.040)	(0.057)
Kgs nitrogen/ ha maize (ln)	0.037***	0.043***	0.036***
	(0.009)	(0.007)	(0.010)
1=Grows maize	0.487***	0.556***	0.536***
	(0.041)	(0.044)	(0.070)
1=Owns water pump	0.608***	0.229*	0.113
	(0.226)	(0.125)	(0.224)
Proportion crop value sold	0.056	-0.704***	-1.031***
	(0.060)	(0.057)	(0.080)
Value of productive assets (ln)		0.023***	0.009*
		(0.003)	(0.005)

Table 7-C (cont'd)

Hectares cultivated		0.212***	0.201***
		(0.014)	(0.023)
1=Zero tillage	0.030	0.075**	0.212***
	(0.040)	(0.036)	(0.062)
1=Intercrop	0.209***	0.231***	0.382***
	(0.031)	(0.030)	(0.051)
1=Crop rotation	0.216***	0.212***	0.319***
	(0.028)	(0.026)	(0.038)
mm important rain (ln)	1.342*	1.217**	1.984***
	(0.775)	(0.615)	(0.712)
Important rain^2	-0.117*	-0.094*	-0.138**
	(0.063)	(0.050)	(0.058)
Season temperature (°C)	0.570***	0.258	0.274
	(0.204)	(0.199)	(0.306)
Season temperature^2	-0.012***	-0.006	-0.007
	(0.004)	(0.004)	(0.006)
1=2004	0.056**	0.047*	
	(0.028)	(0.026)	
1=2008	0.299***	0.175***	-0.252***
	(0.042)	(0.037)	(0.035)
Constant	-12.689***	-7.946**	-9.496**
	(3.462)	(3.113)	(4.212)
Observations	11,869	11,869	7,846

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Because both rainfall and temperature enter the model in a quadratic manner, the coefficients can be used to determine the "optimal" levels for food sufficiency or food security. In column 2, the optimal rainfall (from mid-December through February) occurs at 647.68 mm, and the optimal average season temperature occurs at 21.5°C (Figure 7-1). The household average for seasonal temperature over the panel years is 23.06°C, which indicates that any additional warming will be harmful to food sufficiency. This is potentially an important finding in light of the expected higher average temperatures in southern Africa associated with climate change (Kotir 2011). At the same time, the optimal temperature in terms of the FSI score (column 1) is 23.75°C, which suggests that additional warming may be beneficial for food security until a critical point, after which it will be deleterious. Similarly, the household average for rainfall during this interval is 543.82 mm, which indicates that any decrease in rainfall would be harmful to food sufficiency. Attempts to break apart this impact by agro-ecological zone were not successful, though this will be discussed as a direction for future research in Chapter 8.

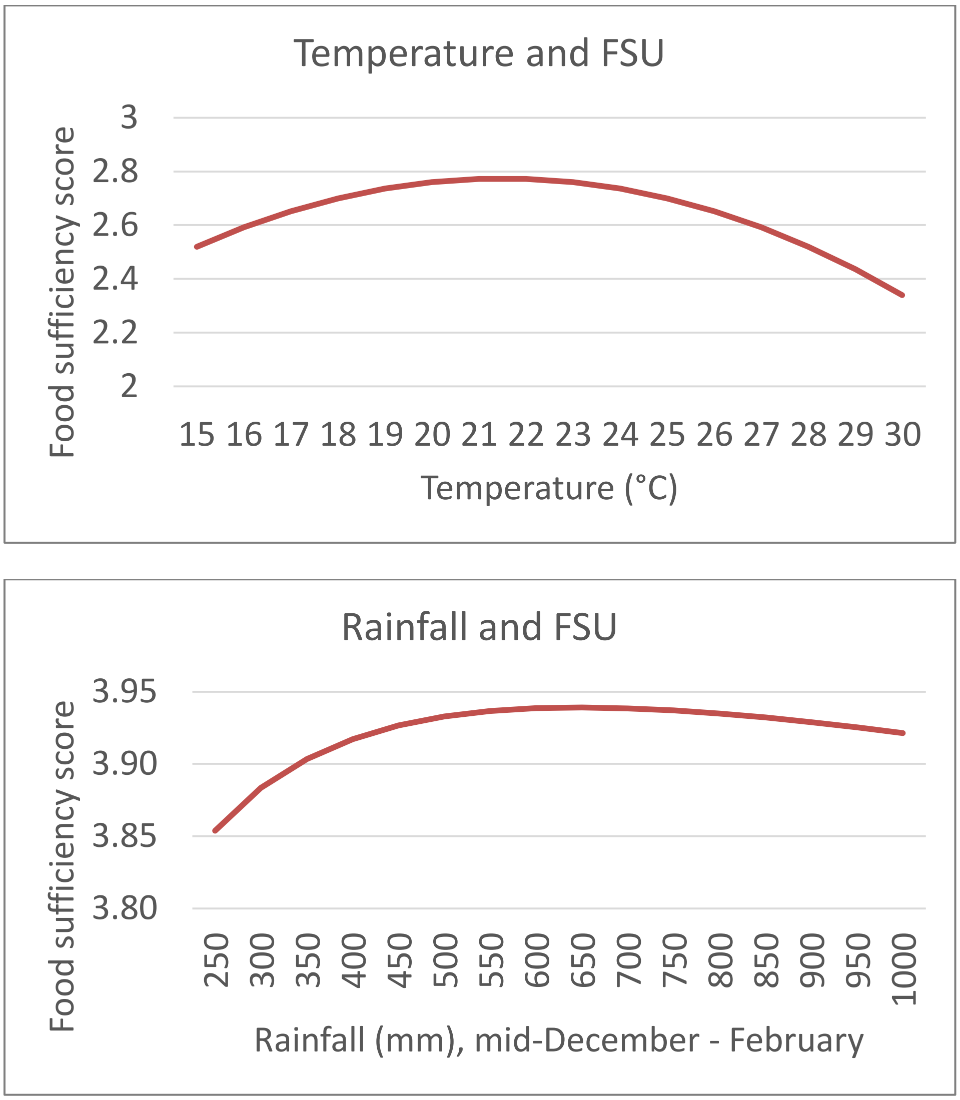

Figure 7-1: Seasonal weather and food sufficiency

7.2.2. Persistent effects of food security and food sufficiency

In order to explore the persistent effects of a household's FSU or FSI score, it is useful to implement a dynamic panel method that includes as a regressor the lagged FSU or FSI score. In a cross-sectional regression, a lagged dependent food security score will be biased upward in the presence of serial correlation, which is found to be present in regressions of the FSU and FSI ($\hat{u}_{2008}$ regressed on $\hat{u}_{2004}$; p-value = 0.000 in both cases). A fixed effect model can address the household effects that influence both past and current food security experiences of a household. However the inclusion of a lagged dependent variable within a fixed effects model results in a coefficient that is biased downward, a phenomenon known as the Nickell bias (Nickell 1981). This is especially true in a "small T, large N" context. To overcome this problem, the Arellano-Bond Generalized Method of Moments estimator (Arellano and Bond 1991) is used here, in which a first-differenced model is used in combination with an instrumental variable method to address the endogeneity of the lagged dependent variable. The instrumental variables used for the lagged variables include all level terms of the regressors from the previous period, and for this reason, only one lag can be included with this three-wave panel. The model is

$$\Delta Y_{it} = \alpha + \beta_1\, \Delta Y_{i,t-1} + \beta_i \Delta X_{it} + \Delta\, \varepsilon_{it}$$

where ΔY_{it} is the differenced dependent variable (e.g. $FSU_{2008} - FSU_{2004}$) and $\Delta Y_{i,t-1}$ is the differenced lagged dependent variable (e.g.$FSU_{2004} - FSU_{2001}$). The instrumental variables for $\Delta Y_{i,t-1}$ include all $X_{i,t-2}$ (e.g. control variables from 2001). Results are presented in Table 7-D, and although only the coefficients on the lagged variables are reported, all other HH characteristics used in Chapter 7 are included here as controls.

In column 1, the FSI is regressed on the household's lagged FSI score, in addition to the standard controls from the current period. The lagged value is strongly significant, indicating that the FSI indeed exhibits persistence and is not determined only by current shocks to the household. In column 2, the FSU score is regressed on the lagged FSU score, and again the coefficient is significant. In column 3, the FSU is regressed on lagged FSI with the aim of discerning whether the FSU or the FSI is the stronger determinant of future food sufficiency. The slightly larger coefficient on the lagged FSI suggests that the extra variables included in the FSI, with the aim of capturing a household's vulnerability to future food shortfalls, do a better job of predicting future food sufficiency. However, the difference seems rather small.

Table 7-D: Effect of lagged FSU and FSI with HH fixed effects: 2001, 2004, and 2008

Explanatory variables	(1) FSI GMM	(2) FSU GMM	(3) FSU GMM
Lagged FSI	0.248***		0.160***
	(0.031)		(0.033)
Lagged FSU		0.138***	
		(0.031)	
Observations	4,155	4,155	4,155

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.2.2 Impact of climate shocks on food sufficiency

In Table 7-E, the impact of rainfall on food sufficiency is studied with the samples restricted to those households that are poor or not poor (according to the $1-per-day cutoff) in any year. Although only the coefficients on climate variables are reported, all other HH characteristics used in Chapter 7 are included here as controls. Among poor households (column 2), the standard relationship is found in which there is an optimal amount of rainfall that maximizes food sufficiency. However, among non-poor households (column 1), the coefficients on rainfall variables are not significant, and F-tests of joint significance confirm that neither rainfall nor temperature is a significant determinant of food sufficiency. Several other climate variables are also determinants of FSU for poor households: A longer rainy season in associated with a higher food sufficiency score, and this is probably because a longer rainy season is more likely to provide adequate rain early in the season to feed a rainfall-sensitive maize crop. In addition, a longer rainy season provides the opportunity to add mixed beans or other fast-maturing crops to the household's harvest. Average season temperature is also significant. These findings highlight the vulnerability of poor households to climate outcomes, while wealthier households are buffered from such climate risks.

Table 7-E: Impact of climate shocks by poverty level: 2001, 2004, and 2008

	(1)	(2)
	FSU (Not poor)	FSU (Poor)
Explanatory variables	OLS	OLS
mm important rain (ln)	0.481	1.844***
	(4.078)	(0.668)
Important rain^2	-0.018	-0.145***
	(0.344)	(0.054)
Deviation from mean rainfall (ln)	0.043	-0.008
	(0.078)	(0.013)
Start of rainy season	-0.083	0.014
	(0.180)	(0.022)
Length of rainy season (days)	-0.734	0.559***
	(1.673)	(0.203)
Season temperature (°C)	-0.774	0.413*
	(1.743)	(0.239)
Season temperature^2	0.020	-0.010**
	(0.036)	(0.005)
No. hot dekads	-0.157	0.011
	(0.101)	(0.010)
F-test rainfall (Prob > F)	0.428	
F-test temperature (Prob > F)	0.736	
Observations	1,326	10,732

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.3 Avenue of climate impacts on food security

The final application of the food security indices developed in this thesis is to explore the avenue of impact of rainfall and temperature shocks on food security. In all regressions in this section, control variables related to household characteristics are included in the econometric analysis, although the coefficients on these controls are not presented here. The model is

$$Y_{it} = \gamma + \beta W_t + \beta X_{it} + \alpha_i + \varepsilon_{it}$$

where W_t = a vector of rainfall and temperature variables of the household's district during the agricultural season relevant to time *t*. For all but one regression in this section, a test of attrition bias fails to reject the null of no bias at a 5 percent level of significance, and attrition-adjusted weights are therefore used.

In column 1 of Table 7-F, the FSU is regressed on climate and control variables. As we have seen before, the relationship between rainfall/ temperature and food sufficiency is quadratic, such that they both have a positive but diminishing impact of food sufficiency until the optimal level is reached, after which additional rainfall or additional warming decreases food sufficiency. In columns 2 – 5, this regression is repeated for each element of the FSU index separately, with the aim of understanding the causal path through which climate affects this index.

The relationship between rainfall and calories is similar to that found with the total index, and similar coefficients are also seen when the number of crops retained is the dependent variable. However rainfall seems to have a different relationship with the production of milk/eggs, and is not a significant determinant of TLU. At the same time, temperature seems to be important for all elements of the FSU, though there does not seem to be an "optimal" temperature when the dependent variable is calories. The lesson seems to be that climate affects the various elements of this food sufficiency index differently. In terms of food security policy development, this disaggregated analysis is important to identify the interventions that might bolster household resilience to climate shocks. For example, certain livestock management practices may diminish the relationship between climate shocks and a household's likelihood of producing milk or eggs.

Table 7-F: Effect of climate on individual elements of the FSU: 2001, 2004, and 2008

	(1)	(2)	(3)	(4)	(5)
	FSU	Calories (ln)	Crops retained	Milk/ eggs	TLU
Explanatory variables	OLS	OLS	OLS	Probit	OLS
mm important rain (ln)	1.373**	1.269**	0.832	-0.052	-1.571
	(0.653)	(0.620)	(0.582)	(0.825)	(8.249)
Important rain^2	-0.107**	-0.099**	-0.051	-0.004	0.083
	(0.053)	(0.051)	(0.048)	(0.852)	(0.652)
Season temperature (°C)	0.417*	-0.088	0.925***	0.184***	1.068
	(0.219)	(0.232)	(0.230)	(0.001)	(1.068)
Season temperature^2	-0.010**	0.000	-0.020***	-0.004***	-0.018
	(0.004)	(0.005)	(0.005)	(0.002)	(0.022)
F-test rainfall (Prob > F)			0.000	0.000	0.443
F-test temperature (Prob > F)		0.000			0.084
Observations: 12,058					

OLS coefficients or average partial effects (column 4) with robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

8. DISCUSSION & EVALUATION OF THE FOOD SECURITY INDICES

8.1 Summary of findings

This thesis first offers information on a range of household-level food security indicators in Zambia. The proportion of households below the money-metric poverty lines (Table 5-A) is far higher than the proportion of households that are found to be food-energy deficient (Table 5-D). As the extreme poverty line is based on the cost of a food basket that meets calorie needs without attention to macronutrients (Table 9-A), it seems these two calculations should be aligned. This suggests there may be a problem with the food basket prices listed in the 2002-03 LCMS, or alternatively with the way household income is calculated in the panel data set. Other food security indicators related to diet quality and stability fail to reveal a clear, linear trend between 2001 and 2008, as the average values fluctuate and seem to closely reflect varying conditions during the previous agricultural season. For example, the number of months spent without any stocks from own-production increased markedly between 2004 and 2008. However, the 2006/07 agricultural season was characterized by localized floods (UNICEF 2007), and the accompanying drop in food security measures should not be interpreted as a general trend in the well-being of Zambian households. Rather, most explorations of the time trends reveal stagnancy in the food security situation of Zambian households.

In 2008, it seems that female-headed households (whether defined as FHH widows or FHH nm) generally experience higher levels of food quantity, although lower average values of other indicators suggest that they do not unambiguously experience higher levels of food security. For example, FHHs are less likely to produce milk or eggs, have a garden, or retain a diverse set of crops from own-production. They tend to gather their income from a less diverse livelihood base, and are less oriented toward the market as sellers (Table 5-E). It is therefore difficult to determine whether FHHs experience an overall level of food security that differs from other households in Zambia, and this underscores the potential value of generating a composite index of food security.

Geographic patterns of food security are immediately evident, as zone IIa consistently exhibits favorable values of food security indicators, often followed by zone III (Table 5-F). It is not clear that these variables share the same relationship in each agro-ecological zone, and this will present some complications when generating a food security index that is comparable over space. For example, zone I has a relatively high average value of TLU, although other food security indicators are low, while the reverse is true for zone III. Another interesting pattern is seen in the distribution of months without food stocks, in which the cassava belt (zone III) exhibits much higher levels of food stability than other regions. Although the government of Zambia has recently focused much of its agricultural policy on promoting the production of maize, this finding highlights the importance of cassava to Zambia's food security.

The mobility in calorie status evident in the transition matrix from 2004 to 2008 (Tables 5-G and 5-H) suggests that households may be less able to smooth consumption, relative to income, than is commonly thought. For example, a household in the fourth calorie bracket in 2004 was equally likely to find itself in the first bracket as to remain in the same bracket. This represents a wide spectrum of potential welfare for the household, and it calls attention to the importance of consumption-smoothing mechanisms to the maintenance of household welfare.

The FSU and FSI are constructed from a subsample of food security indicators that seem to best span multiple dimensions of food security, and also seem to have similar meanings across the four agro-ecological zones. While the FSU is designed to reflect only food sufficiency and consistency within the previous 12 months, the FSI includes variables that plausibly reflect a household's vulnerability to future food shortfalls. When the two indices are calculated for each household, it becomes clear that FHHs have lower food sufficiency and food security scores, on average, than the general population (Table 6-D). Figure 6-3 demonstrates that western Zambia is persistently worse off than other regions. A transition matrix for the FSU (Table 6-F) shows a lower mobility of households, as compared with the transition matrix based on calories alone. This is as expected, as the livestock included in the index can take considerable time to accumulate, and can also serve as a buffer against crop failure.

In general, it is surprising that the FSU and FSI scores in 2004 are not more tightly correlated with food security indicators in 2008 (Table 6-I). For example, the correlation coefficient between the 2004 FSI and 2008 calories is just 0.19. This, among other results, casts doubt on the quality of the FSI or perhaps on the merit of creating a FSI that explicitly accounts for vulnerability. The relationship between a household's FSU and its subsequent change in FSU further complicates the story, as it is unclear whether or how households are moving along a "path" of food sufficiency. Higher food sufficiency scores are associated with negative movements along the FSU spectrum (Figure 6-4), and this might imply that a higher FSU score is not associated with lower vulnerability.

The final portion of this thesis employs the food sufficiency and security indices in econometric analyses to discern the correlates and determinants of food security. Many of the results are as expected: Assets associated with agricultural production and information access are positively associated with food sufficiency. Several variables relate to women: The maximum level of women's education in the household is sometimes (though not always) associated with higher FSU and FSI scores, which draws attention to the importance of girls' education in Zambia. The coefficient on FHH widow is not significant in cross-sectional regressions, which suggests that these households do not experience lower FSU scores due specifically to their widowed status. (Keep in mind that in panel regressions, the variable denoting FHH widowed status references the impact of a household *becoming* a FHH widow rather than the characteristic of *being* a FHH widow.)

In panel regressions that control for HH fixed effects –such as knowledge, motivation, and ability– several variables related to farm management may be interpreted causally: Planting a cash crop is associated with higher food security, even though households may now be somewhat more dependent on the market to acquire their food. The use of crop rotation, intercropping, and minimum tillage land preparation are all positively associated with food sufficiency (Table 7-C). However the impact of improved fallow techniques in the previous agricultural season seems more ambiguous. In the panel regressions, both rainfall and temperature continue to be significant determinants of food security in a quadratic manner.

The final exercise relates to the impact of climate shocks on FSU. Rainfall and temperature are understood to be exogenous, which allows for a causal interpretation of the coefficients (Tables

7-E and 7-F). Specifically for poor households, the early-growing season rainfall positively affects food sufficiency until a maximum point, after which it reduces the FSU score. Given the occurrence of both droughts and floods in Zambia, this pattern makes sense. At the same time, the climate variables seem to have little or no explanatory power for households that are not poor. This affirms the vulnerability of poor households to climate shocks, and points toward the possible value of weather-indexed insurance or other measures that reduce this vulnerability. Section 7.3 shows that climate affects each element of the FSU index differently (Table 7-H). Although informative, this complicates the challenge of developing interventions to improve household resilience to climate shocks.

8.2 Does using a food security index shed light on the story of food security?

As noted in Chapter 3, the idea of using a multidimensional index of welfare, whether in reference to poverty or food security, is regarded with some skepticism (Ravallion 2011). The benefit would seem to be that the food security score encompasses the many dimensions of food security and reveals a household's latent food security status. This allows for a straightforward description of the state of food security in Zambia and enables a statistical analysis that links explanatory variables with a household's overall experience of food security.

However, the results of section 7.3 do reveal the shortcomings of such an index: The initial result shows that seasonal rainfall is a significant determinant of food security in a quadratic relationship. This is an important finding, as southern Africa is expected to experience drier growing seasons and more erratic rainfall in the coming decades (Kotir 2011). At the same time, the policy implication is not entirely clear until the index is decomposed and a regression is run on each of its components separately. The realization that temperature is a determinant of the number of crops retained suggests that agricultural extension officers may encourage crop mixes that include less heat-sensitive crops, even if these are less profitable or produce fewer calories per hectare. The realization that climate shocks in the preceding agricultural season do not seem to affect TLU indicates that including TLU in a household's livelihood portfolio may reduce the household's vulnerability to climate shocks. In addition, following a season of low rainfall, households may require assistance with other food sufficiency indicators but not necessarily with TLU ownership. These avenues of impact and potential intervention would not be readily deduced when using the index in its composite form.

A final note on the information lost when constructing a food security score is that it is possible for households with very different characteristics to be given the same score. For example, a household in zone I may have plenty of livestock along with an extended season without food stocks. A household in zone III may have few livestock but still experience consistency in its food supply. The score for each household will be similar, even though the underlying experience of food security is quite different and merits a unique intervention or policy response.

The inclusion of variables associated with vulnerability (i.e. the extra variables added to the FSI) seems useful but does not add a great deal to the analysis. For example, the correlation coefficient between the FSU in 2004 and the FSU in 2008 is 0.33, while the value linking the FSI in 2004 and the FSU in 2008 was 0.40 (Table 6-I). *A priori*, it might have been expected that FSU would be more variable and susceptible to transitory shocks, while the asset and social network variables included in the FSI render it a better representation of the household's overall capacity to mitigate negative shocks to food security. However it is not clear that this thesis would have suffered had it excluded consideration of these indicators of vulnerability, despite their conceptual appeal.

8.3 Limitations of the study

Several caveats are warranted that have not been adequately emphasized: This data set was not collected with the intention of measuring consumption or food security, and it is therefore necessary to identify proxies for even the three dimensions of food security considered here: quantity, quality, and stability. For example, rather than capturing whether households consume specific nutrients (e.g. protein) in their diet, the homestead production of milk or eggs, or ownership of livestock, is used as a proxy for the likely presence of animal protein in the diet. Yet there may be a weak relationship between household production and consumption of these products. When measuring food quantity in the household, this study does not account for the possible draw-down of food stocks from the start of the study period, although whenever possible it does note whether the household possessed such stocks. Some other possible errors involved in conflating household production and acquisition of certain products with food sufficiency have already been outlined in Chapter 5.

This study considers all food security measures at the household level, but is unable to address the intra-household distribution of resources (i.e. the food security of individual members within the household). Essentially, it assumes a unitary household model in which food is allocated according to relative needs rather than bargaining power. However, it is well known that intra-household distribution of food often does not follow this pattern (Haddad et al. 1997). Some individuals may be residing in food insecure households but still experience food security, and *vice versa*. It is also unclear that the associational or causal relationships identified in this thesis would apply at the individual level. Take the matter of gender: although the results often indicate that being a FHH widow does not explain a household's food sufficiency status, it may be that at the individual level, gender does affect one's food sufficiency experience. Indeed, the data set reveals that widowed or separated women are often absorbed into other households, suggesting that a survey that is only able to account for the female-headed households that have "survived" is a poor instrument for gauging the food security impact of being a woman or of being widowed.

Given that there is no "gold standard" indicator of food security available in the data set, it is difficult to validate the two indices constructed in this study. Had a module of household consumption been included in the surveys, the indices' validity could have been explored through their correlations with these more accurately measured consumption outcomes (see Headey and Ecker 2012). Given the data limitations, the merit of the indices is largely based on their conceptual soundness rather than statistical validation.

8.4 Directions for future research

Future research might build on this exercise by attempting to validate the food sufficiency and food security indices using another data set that includes additional information on household experiences, including their consumption and anthropometric outcomes. Even if such information were available only in a cross-section, it could still be used to test the relationship between the indices and realized food security experiences. It would also be useful to further explore the causal relationship between certain right-hand-side variables included in the regression analysis (e.g. social capital, women's economic opportunities) and a household's food security experience. This can only be done when exogeneity of the explanatory variables has been established. In terms of the impact of different agricultural practices on a household's future foods security, a dynamic analysis would have been better suited to discern the longer-term impact of conservation farming techniques.

In order to understand the determinants of food security, it may be more useful to disaggregate the entire exercise by agro-ecological zone. This would allow the weights on the elements of the FSU or FSI indices to differ by zone. Although it would no longer allow for the country-wide comparison of results, it may reveal stronger determinants of food security within a given region. Another direction for research relates to the differences between households that are categorized into different trajectories of the FSU and FSI (Table 6-L). Are households on an upward track systematically different from those on a downward path or those whose scores fluctuate back and forth? What life events or household decisions seem to characterize households in these different categories?

A final direction for research is to explore the long-term effects of climate shocks, as in Hoddinot (2006). This thesis only studies the effect of climate in a given agricultural season on the immediate food sufficiency outcome in the following year. The results generally indicate that a level of rainfall or temperature that is too high or too low will negatively affect food sufficiency. This regression analysis holds constant the household's ownership of productive assets at the start of the reporting period during which food sufficiency is measured. However, the significance of these short-term impacts may be overshadowed by their long-term effects on food security, particularly if households are forced to liquidate their assets in response to a negative shock.

APPENDIX

APPENDIX

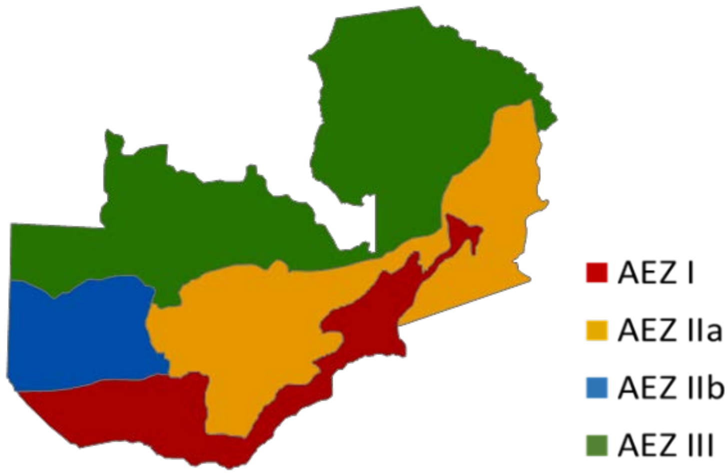

Figure 9-1: Agro-ecological zones in Zambia

Table 9-A: Cost of monthly food basket and basic needs basket per adult equivalent by province

Province	Food index (Paasche)	Food basket (ZMK)	Basic needs basket (ZMK)
Central	0.86	107,995	154,277
Copperbelt	0.87	109,250	156,071
Eastern	0.83	104,228	148,896
Luapula	0.87	109,250	156,071
Lusaka	1	125,575	179,392
Northern	0.89	111,763	159,660
Northwestern	0.9	113,018	161,454
Southern	0.99	124,320	177,598
Western	0.9	113,018	161,454

Note: Values are taken from the 2002-03 Living Conditions Monitoring Survey (CSO 2004), with prices expressed in 2007/08 kwacha. The food basket meets a recommended minimum calorie requirement of 2,094 kcal/ person/ day. However, the food basket is not constructed to reflect protein and micronutrient needs. Furthermore, this calorie-per-day recommendation is far lower than that suggested by Smith and Subandoro (2007), where an individual given a weight of one adult equivalent is recommended to consume 2,900 calories, assuming a moderate level of activity.

Table 9-B: Income indicator definitions

	Construction	
Indicator	**Panel**	**Non-panel**
Gross income	Includes gross value of harvested crops & vegetable sales; total income from live & slaughtered animals; value of eggs and milk produced; gross income from off-farm wages and business, including in-kind income; and remittances	Gross income (panel) plus value fruits/vegetables retained and value of fish consumed and sold
Net income	Gross income minus total fertilizer cost and business expenditures	Gross income (panel) minus total fertilizer and transportation costs and business expenditures
Income poverty	1 if HH has net income/ adult equivalent/ day less than $1, 0 otherwise	1 if HH has net income (non-panel)/ adult equivalent/ day less than $1, 0 otherwise
Food basket poverty	1 if HH cannot afford the cost of a monthly food basket with net income	uses non-panel measure of income
Basic needs poverty	1 if HH cannot afford the cost of a basic needs basket	uses non-panel measure of income

Table 9-C: Food security indicator definitions

	Construction	
Indicator	**Panel**	**Non-panel**
QUANTITY		
Total calories acquired	Sum of: calories produced from field crops minus sales; calories from milk and eggs produced minus sales; and calories from staple food purchases, of food items common to all years	Sum of: calories produced from field crops and vegetables/ fruits minus sales; calories from milk and eggs produced minus sales; calories from staple food purchases, of all food items included in SS 2008; calories from food items received as in-kind wages; and calories from food items received as remittances

Table 9-C (cont'd)

Calories per adult equivalent per day	Adult equivalents per household calculated from formula of Smith and Subandoro (2007), with males aged 30 – 60 years considered to be 1 adult equivalent	
Food energy deficient (light)	1 if HH meets its calorie requirements (assuming light activity level), 0 otherwise	1 if HH meets its calorie requirements (using non-panel calculation of calories and assuming light activity level), 0 otherwise
Food energy deficient (moderate)	1 if HH meets its calorie requirements (assuming moderate activity level), 0 otherwise	1 if HH meets its calorie requirements (using non-panel calculation of calories and assuming moderate activity level), 0 otherwise
Food energy deficient (intense)	1 if HH meets its calorie requirements (assuming intense activity level), 0 otherwise	1 if HH meets its calorie requirements (using non-panel calculation of calories and assuming intense activity level), 0 otherwise
QUALITY		
Tropical Livestock Units (TLU)	Units of panel livestock owned at start of the reporting period (12 months prior to interview)	Units of non-panel livestock owned at start of the reporting period, excluding oxen
Number of different field crops or vegetables retained	Number of panel field crops retained by HH after sales	Number of non-panel field crops and vegetables/fruits retained by HH after sales
Household produces eggs or milk	1 if HH produces eggs or milk, 0 otherwise	
Household produces some vegetables/fruits	1 if HH produces vegetables or fruits, 0 otherwise (only available for 2001 and 2008)	
STABILITY		
Number of months without any food stocks	(not used in panel analyses)	No. months since the HH last reported running out of a food stock
HH had maize or cassava in stock at end of reporting period	1 if HH had either maize or mature cassava in stock/ in the field at end of reporting period, 0 otherwise	

Table 9-C (cont'd)

Value of productive assets	Value of panel equipment owned at start of the reporting period (ploughs, harrows, and ox-carts)	Value of all non-panel equipment, machinery, and oxen owned at start of reporting period
Number of income sources	Number of income sources from the following groups: on-farm income, agricultural wage income, non-agricultural wage or salary income, business income, and remittances	
Transfer network	1 if HH gave *or* received any cash or commodities (remittances or gifts), 0 otherwise	
Proportion of crop value sold	Proportion of value of crops produced that were sold	Proportion of value of non-panel crops produced that were sold
No. skilled off-farm workers	Number of individuals in HH that engage in non-agricultural/ skilled income generating activities	
Proportion food expenditure	Proportion of HH net income (panel) spent of food purchases	Proportion of HH net income (non-panel) spent of food purchases
Hectares cultivated	Hectares cultivated	
Land access (ha)	(not used in panel analyses)	Landholding size plus land rented or borrowed in

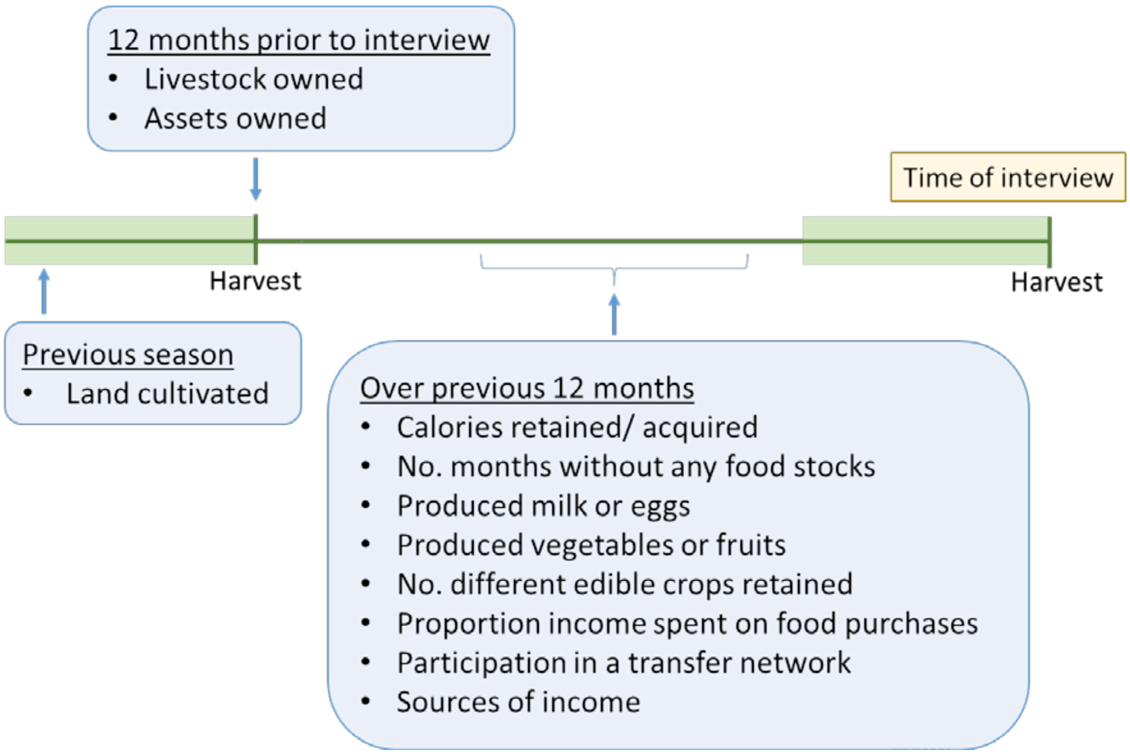

Figure 9-2: Timeline of food security indicators

Table 9-D: Other independent variable definitions

	Construction	
Indicator	**Panel**	**Non-panel**
HH size	Number of HH members, weighted by time spent at the homestead in past 12 months	
Dependency ratio	Number of household members not between ages 15 - 59/ total household size (weighted by time spent at home)	
Maximum education in HH	Maximum level of education among prime-age adults. Through high school, this corresponds to years of school completed, and thereafter corresponds to further academic achievements	
Maximum women's education	Highest level of education reported by a female in the HH	
Death of head	1 if HH head had died in previous 4 years, 0 otherwise	
Radio	1 if HH owns radio at time of interview, 0 otherwise	

Table 9-D (cont'd)

Women off-farm	1 if HH had a prime-age woman working off-farm, 0 otherwise	
Relation to chief	N/A	1 if HH is related to village chief, 0 otherwise
Number years in village	N/A	No. years HH has resided in current village
Female-headed household definitions		
FHH widow	1 if HH identifies as FHH and head is widowed, 0 otherwise	
FHH no adult male	1 if HH identifies as FHH and there is no prime-age (15-59) male member of the HH, 0 otherwise	
Farming practices		
Intercrop	1 if HH had any fields intercropped, 0 otherwise	
Zero tillage	1 if HH had any fields that had been prepared using zero tillage, 0 otherwise	
Crop rotation	1 if HH had any fields used for a different crop from the previous agricultural season, 0 otherwise	
Cash crop	1 if HH produced tobacco or cotton, 0 otherwise	
Fertilizer	1 if HH acquired any fertilizer, 0 otherwise	
Water pump	1 if HH owns water pump, 0 otherwise	
Services	(not used in panel analysis)	1 if HH receive advice on amount of seed or fertilizer to use; minimum tillage techniques; and crop residues; optimal planting date; and nitrogen-fixing crop rotation, 0 otherwise
Nitrogen per ha maize	Kgs nitrogen acquired per hectare maize planted (0 for households that do not plant maize). This assumes that households have applied compound D as basal fertilizer and urea as top dressing.	
Maize HH	1 if household planted any maize, 0 otherwise	

Table 9-E: Rainfall and temperature variables

Variable	Construction
Season rainfall (mm)	Total precipitation recorded from November through March
Deviation from long-term mean	Absolute deviation from average growing season rainfall (1990/91 – 2009/10)
Length of growing season (days)	Number of days from first dekad with > 20 mm rainfall to last dekad with >20 mm rainfall
Rain start	Number of dekads after November 1 until > 20 mm rainfall within a dekad
Season variance	Variance in dekadal rainfall over the season (November through March)
Rain stress	Number of 20-day periods in growing season with < 40 mm rainfall
Important rainfall (mm)	Total precipitation from mid-December through February
Average temperature (Celsius)	Average dekadal temperature over the growing season
No. hot dekads	Number of dekads during growing season with average temperature over 25°C

Note: Missing observations were imputed using an average of the observations of nearby meteorological stations of similar altitude. In total, 13.75 percent (245/1,782) of dekadal rainfall observations were imputed in this manner, and 34.23 percent (616/1,782) of temperature observations were imputed. Though the rate of missing temperature observations is high, it was determined that because temperature is less localized than rainfall, imputation would likely produce suitable temperature estimates.

Table 9-F: Calorie content of common foods consumed in Zambia

Food items purchased/received	kcal/kg	Field crops	kcal/kg	Vegetables and fruits	kcal/kg
roller meal	3680	maize	3570	oranges	430
breakfast meal	3530	sorghum	3500	bananas	880
maize meal from grinding mill	3530	rice	3440	pineapple	470
cassava chips	3570	millet	3410	guavas	640
cassava flour	3510	sunflower	4860	avocado	1210
wheat flour	3640	groundnuts	5490	watermelon	220
wheat bread	2330	soya beans	4050	mangoes	600
buns/ fritters	3300	irish potatoes	820	tangerines	490
		mixed beans	3670	lemons	290
Miscellaneous	**kcal**	bambara nuts	3670	grapefruit	340
milk (per liter)	790	cowpeas	3380	fresh groundnuts	5490

Table 9-F (cont'd)

egg (per unit)	140	velvet beans	3600	cabbage	260
fish (per kg)	3340	sweet potatoes	1210	rape	220
oil (per kg)	8840	raw cassava	1490	spinach	260
				tomato	210
				onion	410
				okra	360
				eggplant	320
				pumpkin	5110
				chilies	3120
				chomoli	220
				cauliflower	250
				carrots	400
				lettuce	200
				green beans	340
				green maize	1520
				impwa	400
				pumpkin leaves	270
				sweet potato leaves	490
				cassava leaves	910
				bean leaves	360
				chinese cabbage	250
				sugarcane	620

Source: Lukmanji et al. 2008; Wu Leung et al. 1968

Table 9-G: Demographic and agricultural variables for 2001, 2004, and 2008

Demographic variables	**2001**		**2004**		**2008**	
HH size	5.84	(2.96)	5.91	(2.91)	5.77	(2.80)
Dependency ratio	0.52	(0.21)	0.45	(0.22)	0.55	(0.22)
Age of HH head	45.53	(15.26)	48.50	(15.01)	48.33	(15.30)
Maximum education (level)	7.03	(3.36)	7.18	(3.41)	7.54	(3.44)
Maximum woman's education (level)	5.00	(3.38)	5.31	(3.40)	5.61	(3.42)
1=HH includes a skilled off-farm woman worker	0.02		0.03		0.05	
1=Death of head in previous 4 years	0.01		0.05		0.04	
1=HH self-identifies as female-headed	0.23		0.24		0.24	
1=FHH widow	0.10		0.13		0.14	
1=FHH with no adult male	0.10		0.07		0.11	

Table 9-G (cont'd)

Agricultural practices & access to information (proportions of cropping HHs)			
1=Fertilizer	0.23	0.29	0.31
1=Cash crop	0.09	0.18	0.16
1=Water pump	0.01	0.01	0.01
1=Services	---	0.47	0.50
1=HH owns radio (of all HHs)	0.34	0.47	0.58
1=Sell crop	0.65	0.64	0.65
1=Plant maize	0.78	0.81	0.77
1=Zero tillage	0.08	0.10	0.03
1=Intercrop	0.35	0.20	0.12
1=Crop rotation	0.53	0.68	0.71

Table 9-H: Demographic and agricultural variables across subgroups in 2008

Demographic variables	All HHs		FHH widow		FHH nm	
HH size	5.77	(2.80)	4.42	(2.69)	3.13	(2.06)
Dependency ratio	0.55	(0.22)	0.61	(0.26)	0.69	(0.28)
Age of HH head	48.33	(15.30)	59.24	(12.73)	53.55	(16.64)
Maximum education (level)	7.54	(3.44)	7.01	(3.39)	5.27	(3.61)
Maximum woman's education (level)	5.61	(3.42)	5.04	(3.62)	4.43	(3.66)
1=HH includes a skilled off-farm woman worker	0.05		0.06		0.11	
1=Death of head in previous 4 years	0.04		0.20		0.12	
1=HH self-identifies as female-headed	0.24					
1=FHH widow	0.14					
1=FHH with no adult male	0.11					
Agricultural practices & access to information						
Proportions of cropping households						
1=Fertilizer	0.31		0.25		0.17	
1=Cash crop	0.16		0.09		0.06	
1=Water pump	0.01		0.01		0.00	
1=Services	0.53		0.52		0.43	
1= HH owns radio (of all HHs)	0.58		0.33		0.26	
1=Sell crop	0.65		0.55		0.49	
1=Plant maize	0.77		0.75		0.66	
1=Zero tillage	0.03		0.03		0.03	
1=Intercrop	0.12		0.11		0.12	
1=Crop rotation	0.71		0.70		0.65	

Table 9-H (cont'd)

Demographic variables	Zone I		Zone IIa		Zone IIb		Zone III	
HH size	5.88	(2.62)	6.06	(3.01)	5.46	(2.61)	5.56	(2.63)
Dependency ratio	0.57	(0.21)	0.56	(0.21)	0.55	(0.22)	0.54	(0.22)
Age of HH head	49.23	(15.88)	48.93	(15.43)	49.41	(16.52)	47.49	(14.84)
Maximum education (level)	6.78	(3.44)	7.80	(3.56)	6.59	(3.42)	7.58	(3.29)
Maximum woman's education (level)	5.23	(3.13)	5.87	(3.56)	4.99	(3.39)	5.55	(3.32)
1=HH includes a skilled off-farm woman worker	0.03		0.06		0.03		0.06	
1=Death of head in previous 4 years	0.05		0.05		0.03		0.04	
1=HH self-identifies as female-headed	0.24		0.24		0.31		0.23	
1=FHH widow	0.13		0.03		0.04		0.03	

Table 9-H (cont'd)

1=FHH with no adult male	0.11	0.08	0.15	0.12
Agricultural practices & access to information				
Proportions of cropping households				
1=Fertilizer	0.06	0.43	0.06	0.27
1=Cash crop	0.08	0.35	0.01	0.03
1=Water pump	0.01	0.01	0.00	0.00
1=Services	0.50	0.69	0.27	0.50
1= HH owns radio (of all HHs)	0.44	0.64	0.37	0.58
1=Sell crop	0.45	0.70	0.38	0.68
1=Plant maize	0.95	0.93	0.77	0.62
1=Zero tillage	0.00	0.06	0.00	0.01
1=Intercrop	0.13	0.02	0.08	0.21
1=Crop rotation	0.55	0.78	0.39	0.74

Table 9-I: Example of food sufficiency score calculation

Multi-year food sufficiency index (FSU)	
Component	**Factor loading**
Calories (ln)	0.64
No. different crops retained	0.6
Tropical livestock units	0.33
Household produces milk or eggs	0.35

		z-scores					
HH	**Year**	**Calories**	**Crop count**	**TLU**	**Milk/ eggs**	**Formula for calculation of food sufficiency score**	**Food sufficiency score**
1	2001	0.76	0.78	1.72	1.45	*0.64^2·(calorie z-score) + 0.60^2·(crop count z-score) + 0.33^2·(TLU z-score) + 0.35^2·(milk/eggs z-score)*	2.04
1	2004	2.35	1.58	-0.07	1.45		2.94
1	2008	3.73	-0.02	-0.23	-0.69		2.06

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