

CHILD GROWTH AS A MEASURE OF RESILIENCE
TO FOOD INSECURITY IN BURKINA FASO

by

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ABSTRACT

With the population steadily increasing, the demand for food is of great concern for many developing countries. Agrarian societies in developing nations are of particular concern because their food supply derives primarily from rain-fed agriculture. Increases in drought conditions and lower than average precipitation is only intensifying food insecurity in sub-Saharan Africa (SSA). Burkina Faso is a country facing one of the world's highest fertility and poverty rates, creating a significant population increase in this agricultural-dependent region. In this paper, I analyze household resiliency to food insecurity through an analysis of Demographic Health Survey data using quantile regression. Results from the quantile regression using children under 5 height-for-age, weight-for-height, and weight-for-age z scores reveal that Burkina Faso can focus on improving mother's education, drinking water sources, and develop better livelihood practices to increase resiliency to food insecurity. This project justifies proactive mitigation efforts to help eradicate hunger and poverty as part of the United Nations 2015 Millennium Development Goals.

TABLE OF CONTENTS

ABSTRACT	iii
LIST OF FIGURES	vi
LIST OF TABLES.....	viii
ACKNOWLEDGMENTS	ix
1 INTRODUCTION	1
2 LITERATURE REVIEW	5
2.1 Food Security.....	5
2.2 Resilience.....	7
2.3 Anthropometric Measures	13
3 STUDY AREA	16
3.1 Livelihood Zones.....	18
3.2 Hazards in Burkina Faso.....	27
4 DATA	32
5 METHODOLOGY	35
6 RESULTS	43
6.1 Results From Height-for-Age Z Scores	47
6.2 Results From Weight-for-Height Z Scores	52
6.3 Results From Weight-for-Age Z Scores	54
7 DISCUSSION.....	63
7.1 Height-for-Age Z Score 25th Quantile	63
7.2 Height-for-Age Z Score 50th Quantile	67
7.3 Height-for-Age Z Score 90th Quantile	67
7.4 Weight-for-Height Z Score 25th Quantile	69

7.5 Weight-for-Height Z Score 50th Quantile.....	72
7.6 Weight-for-Height Z Score 90th Quantile.....	73
7.7 Weight-for-Age Z Score 25th Quantile.....	74
7.8 Weight-for-Age Z Score 50th Quantile.....	75
7.9 Weight-for-Age Z Score 90th Quantile.....	75
8 CONCLUSION.....	78
REFERENCES.....	81

LIST OF FIGURES

1. Reference map of Burkina Faso, Africa.....	16
2. Map of Burkina Faso livelihood zones	18
3. Livelihood zone #1: South tubers and cereals.....	21
4. Livelihood zone #2: South-west fruits, cotton, and cereals	22
5. Livelihood zone #3: West cotton and cereals	23
6. Livelihood zone 4: West cereals and remittances	23
7. Livelihood zone #5: Central plateau cereals and market gardening.	24
8. Livelihood zone #6: Per-urban of Ouagadougou	25
9. Livelihood zone #7: North and east livestock and cereals	26
10. Livelihood zone #8: North transhumant livestock rearing and millet.....	26
11. Livelihood zone #9: South-east cereals, livestock, forest, and wildlife.....	27
12. Burkina Faso Map of Hazard Risk.....	29
13. Boxplot of livelihood zones with children under 5 height-for-age, weight- for-height, and weight-for-age Z scores	38
14. Livelihood zones merged with survey data GPS points	42
15. Percent of children under 5 with anthropometric Z scores -2 SD.....	44
16. Children under 5 with -2 SD below the mean for height-for-age Z scores.....	45
17. Children under 5 with -2 SD below the mean for weight-for-height Z scores	46
18. Children under 5 with -2 SD below the mean for weight-for-age Z scores.....	47
19. Map of livelihood zone #5: Central plateau cereals and market gardening	68

20. Map of livelihood zone #9: Southeast cereals, livestock, forestry and fauna zone....	70
21. Food Security Pattern 1988-2009.....	71
22. Livelihood zone #8: North transhumant livestock rearing and millet.....	74
23. Livelihood zone #2: South-west fruits, cotton, and cereals.	76

LIST OF TABLES

1. Significant drought years in Burkina Faso	30
2. Summary statistics	36
3. Data characteristics	37
4. Quantile regression results for HAZ at the 25 th quantile.....	49
5. Quantile regression results for HAZ at the 50 th quantile.....	50
6. Quantile regression results for HAZ at the 90 th quantile.....	51
7. Summary of significant results from height-for-age Z score quantile regression... ..	52
8. Quantile regression results for WHZ at the 25 th quantile.....	53
9. Quantile regression results for WHZ at the 50 th quantile.....	55
10. Quantile regression results for WHZ at the 90 th quantile.....	56
11. Summary of results from weight-for-height Z score quantile regression.....	57
12. Quantile regression results for WHZ at the 25 th quantile.....	58
13. Quantile regression results for WHZ at the 50 th quantile.....	59
14. Quantile regression results for WHZ at the 90 th quantile.....	60
15. Summary of results from weight-for-age Z scores quantile regression.....	61

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1. INTRODUCTION

Food insecurity is a significant problem in developing countries, affecting the health and livelihoods of large populations. The most vulnerable of these populations are women and children (Barrett, 2010). In developing countries, nearly 30% of children have stunted physical development due to hunger and another 8 million children under 5 die annually as a result of the interaction between malnutrition and disease (Bassett & Winter-Nelson, 2010; Engle, Castle & Menon, 1996). Food security is defined as “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life” (WHO, 2012). From this definition, four primary pillars can be extracted: availability, accessibility, utilization, and stability. Food availability is the amount, type, and quality of food a unit or person has at their disposal to consume. Food accessibility refers to the ability of a person to obtain the type, quality, and quantity of food they require. Food utilization is the individual or household capacity to consume and benefit from food (Eriksen, 2007). Stability refers to the political, economic, and climate variables that may affect accessibility and availability to food. Food availability, accessibility, utilization, and stability need to be achieved simultaneously for one to be food secure and where one of these pillars is insufficient is where we see “food insecurity.”

Climate variability and natural hazards threaten food security through their impact on stability as well as food availability, especially in regions that are dependent on rain-

fed agriculture for food and livelihoods. Many countries and regions that are vulnerable to natural hazards are inadequately prepared and lack the capacity to respond to these events (Cannon, Twigg, & Rowell, 2003). Often times the people that are struck the hardest by catastrophic events, such as drought or flooding, are the poor and socially disadvantaged, particularly in the least developed and conflict-ridden states (Clover, 2003). As a result of environmental disaster and market shocks, the poor become more susceptible to hunger through a failure in the food system (Bassett & Winter- Nelson, 2010; Sen, 1990).

A feedback system between food insecurity and poverty exists and continues to reinforce and strengthen one another. Food insecurity intensifies other aspects of poverty by decreasing the capacity for work and resistance to disease, and by negatively impacting children's developmental and educational achievements (Nord & Hopwood, 2007). Food insecurity and hunger are strongly correlated to poverty and contribute to failures in the accessibility pillar (Barrett, 2010; Clover, 2003;). An example of this is the degenerative effects of malnutrition. Malnutrition is a manifestation of food insecurity, which is inherently a product of poverty due to a failure in food accessibility and directly affects the resource base of households in food insecure situations (Clover, 2003).

Deficits in nutrition negatively impact mental and physical development, morbidity, mortality, and access to food. Households with insufficient access to food often times have to consume their own resources such as seeds and livestock, which in turn continues to exacerbate poverty conditions and hunger, further diminishing their resource base (Bassett & Winter-Nelson, 2010). As populations continue to grow, combating food insecurity will be an imperative global objective.

The significance of this global issue is illustrated by the United Nations number one initiative to eradicate extreme poverty and hunger as part of the Millennium Development Goals (MDGs) by 2015. This goal is currently not on track to be achieved by the purposed 2015 date and progress tends to be slow. Food security studies often focus on combating food insecurity through measuring total daily per capita consumption, caloric intake, and identifying vulnerable populations (Maxwell, 1995; Melgar-Quinonez, Zubieta, MKNelly, Nteziyaremye, Gerardo, & Dunford, 2006). However, it has been recognized by international humanitarian donors, emergency responders, and governments that a more viable strategy for international assistance is to focus on resilience in chronically vulnerable populations because it couples shorter-term humanitarian efforts with longer-term development projects to achieve food security (Frankenberger & Nelson, 2013). Means of assessing resilience and food insecurity are vast and complex, with little to no consensus on approach or methodology. Research on resilience to food insecurity in developing countries is especially lacking; the purpose of this study is to utilize child growth and nutrition measures to determine household resiliency to food insecurity in Burkina Faso.

The primary goal of this project is to examine anthropometric measures of child growth and nutrition to assess household resiliency to food insecurity. Determining where resilient and nonresilient households are allows for more effective and efficient allocation of aid and resources to combat food insecurity. The specific goals of this research are the following:

1. To determine where acute and chronic food insecurity exist
2. To determine which households are resilient to food insecurity/food shocks

3. To evaluate spatial distribution of resilient and nonresilient households

The anticipated contribution of this thesis is to provide a means of assessing household resiliency to food insecurity in developing countries. The main importance is to evaluate where the most resilient households reside to improve allocation targeting of limited resources and aid.

2. LITERATURE REVIEW

2.1 Food Security

Food insecurity has been an international issue for decades and evolving perspectives have shifted the way scientists and policy-makers approach and tackle global food problems. Food has been seen as a universal human right since the 1940s (UN, 1948), and the right to food is being recognized as necessary for an adequate standard of living (Maxwell & Smith, 1992). Furthermore, food as a universal human right is increasingly becoming acknowledged as a legal obligation for governments and officials to assure all people have access to food at all times (Kent, 2010). Beyond the legality and mechanical means of delivering goods and services, Kent (2010) argues that the right to food should be based on a general principle of human dignity and respect. The deprivation of food as a basic need is undesirable in its own right and its consequences are seen in nutritional, health, and developmental shortfalls (Nord & Hopwood, 2007). Although it is agreed that food is a basic human right and necessity, it has been difficult to ensure all people at all times have access to the food they need.

In the mid-1970s, perhaps as a response to popular books like Ehrlich's *Population Bomb* (1970), food insecurity was viewed and understood as a global- or national-level issue of food availability (Maxwell & Smith, 1992). Food insecurity was primarily conceptualized as occurring because of an inadequate supply of food being produced to feed the entire population (Clover, 2003). In the 1980s, Amartya Sen

encouraged researchers and policy makers to move away from this Malthusian-based approach to famine and food insecurity and instead suggested that food insecurity resulted from a lack of access to food or to the means to produce food (Sen, 1981).

Today, building on Sen's work, it is widely recognized that food availability, although important, is not the sole source of food insecurity. Instead, we often observe that food insecure households can just as easily be found in communities where there is adequate food supply. In these cases, the distribution and access to the food is unevenly dispersed across communities and households (Bassett & Winter-Nelson, 2010; Maxwell, 1996). Insufficient accessibility to food has become more prominent as the cause or source of food insecurity in recent years.

Everything from monetary capital to social capital can affect an individual or household's access to food. Additionally, utilization of food plays a major role in determining food security. If an individual has enough food accessible and available to them but cannot properly digest or absorb the nutrients due to disease or sickness, then they may not be able to achieve full food security. Having culturally relevant food also plays an important part in food utilization (Maxwell & Smith, 1992). Just having food available and accessible does not warrant food security if that food is not culturally or socially acceptable or appropriate. Additionally, not having the required tools, skills, or heat source to properly prepare food may contribute to underutilization of that food (Tontisirin, Nantel, & Bhattacharjee, 2002). Another consideration is that people will often times go hungry to meet other objectives like preserving assets or livelihoods (Maxwell & Smith, 1992). Food insecurity is no longer seen as simply a failure of agriculture to produce enough food nationally, but instead as a failure of livelihoods to

assure access to sufficient food at the household level (Clover, 2003; Devereux & Maxwell 2001; FEWS, 2010; Sen, 1981).

Monitoring food security can help identify and understand the needs of a population to ensure health and well-being. Identifying the unusually severe conditions plaguing particular subgroups or regions will assist in targeting resource allocation and aid (Bickel, Nord, Price, Hamilton, & Cook, 2000). Food availability, accessibility, utilization, and stability are all elements that make up food security; these elements combined with economic, social, and political factors create a unique, complex issue that challenges the ability of SSA to address food security (Hussein, 2002). Food insecurity is not static; it can vary over time at differing degrees of severity and may occur as a chronic or an acute problem (Baro & Deubel, 2006).

2.2 Resilience

In this study, resilience is defined as the processes of, capacity for, or patterns of positive adaptation during or following exposure to adverse experiences that have the potential to disrupt or destroy the successful functioning or development of the person (Matsen & Obradovic, 2006). It is essential when considering this definition that resilience is human focused and often, people seek to surpass the minimum capacity in coping with disaster (Manyena, 2006). Resilience can also be viewed as an individual's predisposition to resist the potential negative consequences of the risk and develop adequately (Engle, Castle, & Menon, 1996).

One of the most important considerations in understanding this concept is determining resilience of *what to what* (Carpenter, Walker, Anderies, & Abel, 2001). Context is not static and changes depending on temporal, social, and

spatial scale. Resilience can be evaluated from general or specific points of view and from multiple levels of analysis. Measures of resiliency will also vary greatly depending on regional, household, or individual scale. Additionally, these measures must be culturally appropriate and relevant and often times cannot be applied universally (Bassett & Winter- Nelson, 2010; Frankenberger et al., 2012). For instance, in some developing countries, spiritual and supernatural entities are believed to provide more effective protection against threats to child health than individual parental behavior or family circumstances (Engle, Castle, & Menon, 1996).

An imperative gap in the literature is the lack of resilience studies in less developed countries. The difficulty with the resilience research is that it has been limited largely to children and childhood in the industrialized countries (Boyden & Mann, 2005). The United Nations Food and Agriculture Organization's (FAO) estimates only 16 million of the world's 868 million food insecure individuals, just 2% of the global total, live in developed countries (FAO, 2012). Pursuing resilience research in less developed countries is critically needed due to the disproportionate concentration of poverty-stricken populations that are vulnerable to hazards and food insecurity.

Environmental shocks such as droughts, floods, and crop infestation have a significantly higher impact in many less developed countries due to dependence on rain-fed agriculture for food and livelihoods. Resilience research in less developed countries can allow for more effective resource allocations and mitigation efforts that can, in turn, reduce food insecurity.

To facilitate the quantitative measure of food insecurity, analysts use proxy measures across different levels of aggregation (De Haen, Klasen, & Qaim, 2011). For instance, food availability measures are used at the national or regional level; coping

strategy index and dietary diversity measures of income, hunger, and malnutrition are used at the household- and individual-level. Traditionally food security has been evaluated by national food availability measures. This is mainly due to the limited availability and timeliness of household and individual data collected in nationally representative surveys, especially in the low-income countries (Barrett & Lentz, 2010).

However, national food availability is a poor measure of microlevel food security because it neglects waste and the inevitably unequal distribution of food within a population (De Haen, Klasen, & Qaim, 2011). Despite the difficulty of acquiring household and individual data, it is favored because the household- and individual-level of analysis allows for more precise evaluation of resilience than aggregation. Measures based on household and individual data routinely generate higher estimates of food insecurity than those derived from more aggregate data. Additionally, survey-based estimates of food insecurity are more strongly correlated with poverty estimates than national food availability measures (Barrett & Lentz, 2010; De Haen, Klasen, & Qaim, 2011). One may also derive resilience to food insecurity by measuring accessibility to food and markets. However, these access measures generally ignore nutrition shortfalls that affect a great number of people and are strongly linked to a range of disabilities, diseases, and premature mortality (Barrett & Lentz, 2010; De Haen, Klasen, & Qaim, 2011; Müller & Krawinkel, 2005).

Several methods for measuring resilience at a household and individual level exist, yet there remains a lack of consensus as to which methodology works best. Food insecurity within a household is often times problematic to measure because individuals within a household may experience varying levels of food deprivation (Pinstrup-

Andersen, 2009; Von Braun, 1993;). One approach of measuring resilience is to determine a household or individual's available resources to cope with a shock (Cutter, Burton, & Emrich, 2010). Available resources are commonly measured by social, human, natural, physical, and financial capital (Bickel, Nord, Price, Hamilton, & Cook, 2000; Moser, 1998). This method requires arbitrarily selecting a set of variables to measure resiliency, creating several problems. By defining a priori variables to measure resilience, our conclusions will be largely driven by our initial selection of variables (Cumming et al., 2005). Relying on proxies such as income, assets, and social capital may not be useful, especially in SSA. Income may be irrelevant to food insecurity in a situation where most of the food consumed is home grown rather than purchased (Bickel, Nord, Price, Hamilton, & Cook, 2000). Access to food may explain nutritional status in a country like the United States, where primary health care, water, and sanitation are not as great contributors to malnutrition as in many developing countries (Webb et al., 2006). These variables are often hard to quantify and may be impractical measures, especially when considering data acquisition limitations. Assessing or measuring resilience can be difficult, especially when trying to quantify indicators such as social capital.

Alternatively, child growth, the measure used in this analysis as an outcome variable, can indicate a household's available resources (Frongillo & Nanama, 2006; Pinstrip- Andersen, 2009; Saha, Frongillo, Alam, Arifeen, Persson, & Rasmussen, 2009). An alternative approach is to measure food security at a household or individual level using various tools and measurements of nutrition (Barrett, 2010). Since household food security influences an individual's access to food, an individual's nutrition is therefore dependent upon the food security of the household (Bassett & Winter-Nelson,

2010). The most frequently used approaches are the FAO indicator of undernourishment, household food consumption surveys, anthropometric measurements, and medical assessments (De Haen, Klasen, & Qaim, 2011). The most widely cited food insecurity figures are the “undernourishment” estimates generated by the Food and Agriculture Organization (FAO) of the United Nations (Barrett & Lentz, 2010). Anthropometry is favored in food insecurity studies because it provides a measurable effect of food deprivation and provides insight to level of undernutrition.

There are several advantages to using anthropometry for assessing undernutrition as resilience to food security. First, it is measuring directly how food insecurity affects the health and well being of individuals. Additionally, there is tremendous evidence that undernutrition that produces poor anthropometric outcomes contributes to higher morbidity and mortality (Deaton & Drèze, 2009; Klasen, 2008). Second, using several different anthropometric indicators gives a sound sense of both chronic and acute undernutrition. Third, anthropometric data from household surveys allow disaggregation of undernutrition by groups and regions and helps identify groups and localities particularly affected (De Haen, Klasen, & Qaim, 2011). By identifying the most vulnerable members of a household, we can evaluate household resilience to food insecurity using anthropometric measures of nutrition.

In this vulnerable environment, resilience to food shocks can determine future livelihoods and child nutritional and developmental outcomes. Since 1980, there has been a slight decrease in malnourished children in SSA; however, despite this decrease, there are still significantly high numbers of undernourished and malnourished children (De Onis, Frongillo, & Blössner, 2000; Fotso, 2007). There is special interest in

identifying population subgroups that are particularly impacted by food insecurity in order to increase the likelihood of creating successful policies and programs to achieve the MDGs of eradicating poverty and hunger (Fotso, 2007). Additionally, assessing child growth throughout a food insecure region may help identify where the least resilient households exist or where the largest impacts of food insecurity are. This information could be especially useful when trying to identify successful coping strategies, governmental or nongovernmental interventions or policies, and to target limited food aid and resources. During food shocks/stresses, individuals or households may choose food insecurity over losing assets, such as seed stock, livestock, or land (Hoddinott, 2006; Maxwell & Smith, 1992). This strategy may protect assets, but it places risk to the nutrition of the most vulnerable family members, most often women and children (Maxwell & Smith, 1992). In general, the most vulnerable people are the first to suffer from food and nutritional insecurity. Nutritional vulnerability is inherently highest among women and children, in particular children under 5 years old and pregnant or lactating mothers in developing countries (Hoddinott & Kinsey, 2001; Smith, El Obeid, & Jensen, 2000; Webb & Harinarayan, 1999). However, different household members may make different choices about how to allocate resources during food shocks, reflecting the disparity of resiliency throughout a community or region. Concentrating on children under 5 and maternal factors will allow for a comprehensive examination of household resiliency to food insecurity throughout a particular area.

Anthropometric measures are commonly used for children under 5, with measures at least two standard deviations below global reference values widely interpreted as signaling serious problems of wasting (low weight-for-height),

underweight (low weight-for-age), and stunting (low height-for-age) (Pinstrup-Andersen, 2007; WHO, 2010). Moreover, many relief organizations regularly use childhood anthropometry to monitor the success of relief operations in emergency situations (Barrett & Lentz, 2010). It is argued that child nutrition indicators can be used as a household measurement of resilience because they represent the available resources and capacity of a household to recover from shocks (Lekprichakul, Umetsu, & Yamauchi, 2010). Wasting, stunting, and underweight measures are beneficial because they signify time and duration of food or health deprivations and are also outcome rather than a priori variables. There are significant negative long-term consequences for children under 5 suffering insufficient nutrient and food intake.

Early experiences of food insecurity can have a lasting impact that can be felt generationally. Undernutrition at 2 years of age was strongly associated with chronic impoverishment, shorter adult height, less schooling, reduced economic productivity, and for women, offspring with lower birth weight (Alderman, Hoddinott, & Kinsey, 2006; De Haen, Klasen, & Qaim, 2011). Poor measures of height-for-age, weight-for-height, and weight-for-age as a child can result in negative future outcomes as an adult nutritionally, developmentally, and economically. These long-term effects of child growth can have significant impacts on resilience throughout an individual's and household's lifetime.

2.3 Anthropometric Measures

Stunting is defined as low height-for-age and generally indicates chronic malnutrition. Height-for-age measure is less sensitive to temporary food shortages, stunting is considered the most reliable indicator of child's nutritional status (Zere

& stunting is considered the most reliable indicator of child's nutritional status (Zere & McIntyre, 2003). As recommended by the World Health Organization (WHO), children whose indices fall more than two standard deviations below the median of the NCHS/CDC/WHO reference population are classified as stunted (De Onis, Frongillo, & Blössner, 2000; Fotso, 2007). Children under 5 with slow height growths in are found to perform poorly in school, on cognitive tests, and have poorer psychomotor development and motor skills. Additionally, stunted children tend to have lower activity levels, interact less in their environment, and fail to acquire skills at a normal rate (Grantham-McGregor, Fernald, & Sethuraman, 1999; Hoddinott & Kinsey, 2001). There is epidemiological evidence that stature at age 3 is strongly correlated to body size at adulthood. Reduced height in adults is strongly correlated to decreased earnings, low productivity, poor cognitive ability, and premature mortality (Hoddinott & Kinsey, 2001; Martorell, 1999). Stunting is one of the strongest anthropometric measures used in assessing food insecurity because it is indicative of severe long-term effects of food deprivation. Another important indicator in child growth and nutrition is weight.

Wasting is defined as low weight-for-height and is typically associated with acute malnutrition. Wasting is an indication of a recent severe weight-loss and most commonly occurs after a food shock (Black, Allen, Bhutta, Caulfield, De Onis, Ezzati, & Rivera, 2008; Müller & Krawinkel, 2005). Underweight is measured by using weight-for-age, in children under 5 years old. This is considered an anthropometric summary measure that captures both stunting and wasting (Smith, El Obeid, & Jensen, 2000). This indicator is used to monitor progress for the MDG's target to reduce hunger. To monitor this measure, low weight is compared with that expected weight for a well-nourished child of

that age and sex (Black, Allen, Bhutta, Caulfield, De Onis, Ezzati, & Rivera, 2008). Lastly, the nutritional status of a woman before and after pregnancy is critical for the health of the child. Maternal short stature is a risk factor for caesarean delivery. This poses a great risk for both mother and baby when operative delivery is not available. Even if operative delivery is accessible, affordable, and safe, anesthesia and laparotomy increase the risk of maternal morbidity (Black, Allen, Bhutta, Caulfield, De Onis, Ezzati, & Rivera, 2008). Some argue that nutritional outcomes and poor anthropometric status can be the result of things that are unrelated to food security, such as presence of diseases. Furthermore, child malnutrition can be a product of poverty and health, as well as food insecurity (De Haen, Klasen, & Qaim, 2011; Fotso, 2007; Smith, El Obeid, & Jensen, 2000;). Nevertheless, anthropometric status and child malnutrition are considered a good proxy measure for food insecurity (Maxwell & Frankenberger, 1992; Smith, El Obeid, & Jensen, 2000).

3. STUDY AREA

Burkina Faso is a land-locked country in West Africa that lies within the Sahel region. The tropical climate has warm, dry winters and hot, wet summers. The country is mostly flat with hills in the west and a grassy savanna in the north that gradually gives way to sparse forests in the south (CIA, 2013). Rainfall varies acutely from 300 mm annually in the north to 1100mm annually in the south (FEWS, 2010). The capital of Burkina Faso is Ouagadougou, and it is the only urban area in the country; see reference map in Figure 1. The official language is French and a parliamentary republic governs the country. As of July 2013, the total population was estimated at 17,812,961 with an annual population growth rate of 3.06% (CIA, 2013). The poverty rate is approximately



Figure 1. Reference map of Burkina Faso, Africa

46% and the country is ranked 183rd out of 186 countries on the United Nations Development Program (UNDP) Human Development Index (World Bank, 2013).

The largest revenue comes from cotton and gold exports. The economy is especially dependent on the performance of the cotton sector (World Bank, 2013). Natural resources like gold are generally found in the northern region of the country; due to increasing pressure on natural resources and population growth, soil erosion and land clearance for farming is a growing problem throughout the country (FEWS, 2010). Over 90% of the population is engaged in rain-fed subsistence agriculture, which is especially vulnerable to reoccurring drought and climatic shocks (Henry, Schoumaker, & Beauchemin, 2004). Rainfall variability and natural hazards pose a great threat to the agricultural base of the country, affecting the majority of livelihoods in Burkina Faso. Rain-fed agriculture is not only the primary economic source but is also the main food source. The livelihood zones are differentiated by the dominant economic source and occupation of each particular region; see Figure 2.

The transition of livelihood zones from north to south coincides with the amount of rainfall and climate variation of the country. Dry climate, sandy soils, and small amounts of rainfall adhere to more agro-pastoralist livelihoods in the far north, while increased rainfall and fertile soils in the south permit productive agriculture such as cereals (specifically millet, maize, and sorghum), fruit (specifically watermelons, mangoes, and papayas), and cotton. Each zone has its own individual identity that is born from the history, culture, environment, and livelihoods. Some regions have better natural and human resources and others suffer from poor rainfall and access to markets. These livelihood zones provide a better means of assessing food security spatially because they do not rely on political or administrative boundaries. The livelihoods

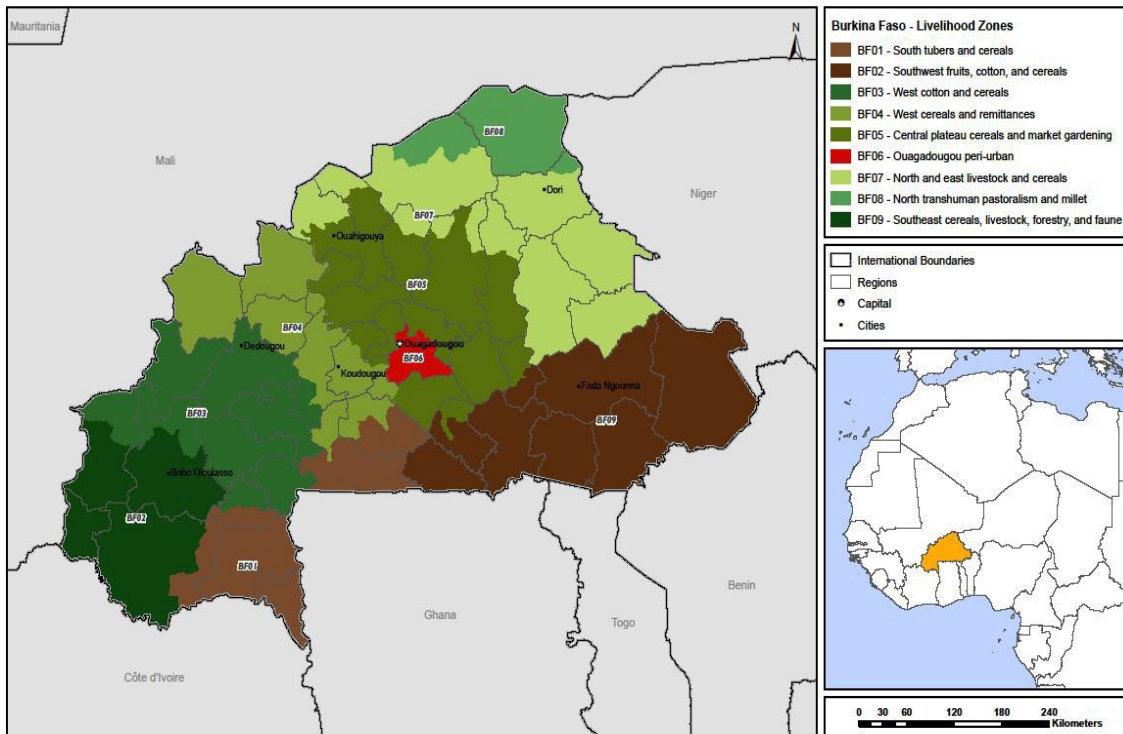


Figure 2. Map of Burkina Faso livelihood zones (FEWS, 2010).

provide a way for policy makers and relief agencies to better address, assess, and respond to crisis based on the needs and resources of the people in a particular region of the country.

3.1 Livelihood Zones

The livelihood zones are a result of a project to fight food insecurity in developing nations by the Famine Early Warning System Network (FEWS NET), an agency created in 1985 by the US Agency for International Development (USAID). FEWS Net provides independent, evidence-based analysis to help government and relief agency decision makers respond to crisis in food insecure countries worldwide (FEWS, 2010). The livelihood approach to FEWS NET analysis is unique and increasingly preferred in

emergency response and development because it provides context on how communities live and designs interventions based on the local livelihoods and circumstances (FEWS, 2010). The construction of livelihood zones involves months of fieldwork that includes interviews at department levels, community meetings, and focus groups at all wealth levels in Burkina Faso. In the livelihood zone context, households are defined as a group of people that live, produce consume, and share resources together (FEWS, 2010).

Administrative boundaries rarely capture the meaningful identities of local communities or livelihoods and are often times negligent to informal cultural or religious boundaries. The livelihood zone approach cuts through the ambiguous administrative boundaries and defines more meaningful and useful designations of people and land.

Factors that influence possible livelihoods are climate, soil, access to markets, and geography. One of the most important physical indicators that affect livelihood zones is rainfall (FEWS, 2010). Rainfall determines the type of agriculture, livestock herding, and income sources available to people in a specific region. In Burkina Faso, livestock herding, gold-mining, and labor migration dominate the north while the south has more cash crops, lush forests, and ability to sell firewood and scavenge for wild food (FEWS, 2010). These differences throughout the country are accountable due to the difference in rainfall quantity and frequency. Other physical attributes that affect livelihood zone possibilities are geomorphology, soil composition, presence of rivers and lakes, and potential for irrigation. Although the physical attributes of the environment affect livelihoods, more importantly is the extent to which people exploit these natural resources.

Wealth is one of the largest indicators because better-off households own larger

farms and in general will produce more crops, income, and be overall more food secure (FEWS 2010). Other important factors of the livelihood zone are livestock holdings, capital, social capital, education, skill, and available labor. The cultural and historical attributes of an area are also an indicator to the type of livelihoods possible. For example cultural and familial ties between the bordering country of Cote d' Ivoire in livelihood zone #4 make remittances a part of their income source and overall survival (FEWS, 2010). It is important to understand the drivers affecting the different livelihood zones and to also know that these are not discrete entities. The zones interact with one another and outside influences like bordering countries that trade goods and services and provide remittance to people in Burkina Faso (FEWS, 2010). These interacting relationships affect food security and livelihoods. Each livelihood zone in Burkina Faso is described and illustrated in Figures 3 through 11.

Livelihood zone #1 is generally food secure but dependent upon rain-fed agriculture and livestock rearing. One of the most distinctive cultivated features in this zone is tubers and yams (FEWS, 2010). The main livestock found here are pigs, sheep, goats, poultry, and cattle. The high level of pigs is due to the large Christian population living in this region (FEWS, 2010). Access to markets and road networks are fairly good in this zone, helping to account for better overall food security.

Livelihood zone #2 is dependent upon rain-fed cultivation but maintains a general food secure population. The most significant crops produced are large volumes of cereals, maize, cotton, cashew nuts, and mangoes (FEWS, 2010). These specialty crops make this area particularly wealthy compared to other livelihood zones. Population is moderately dense but is seeing increasing migration, putting pressure on the land, forest, and fragile

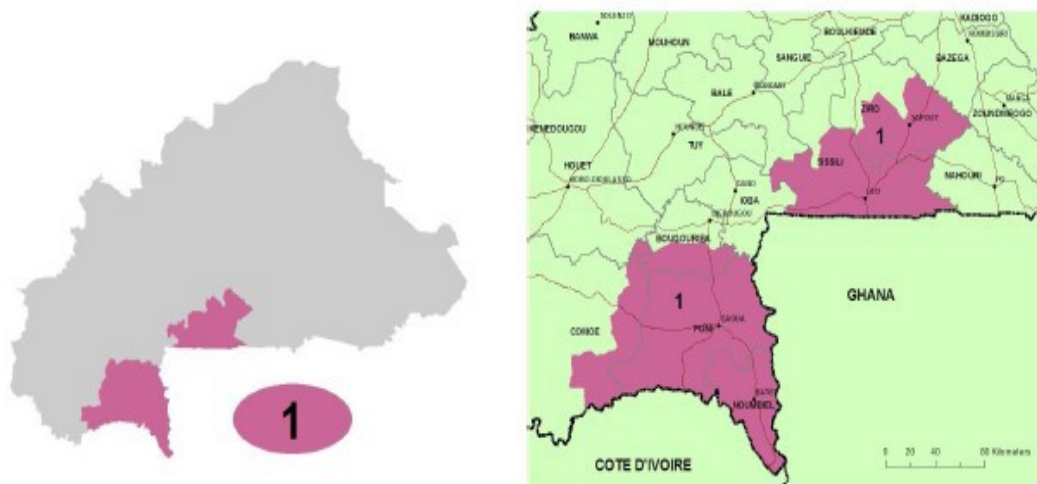


Figure 3. *Livelihood zone #1: South tubers and cereals (FEWS, 2010)*

soil and animals. The overall access to markets is good but secondary roads are poor (FEWS, 2010).

Livelihood zone #3 is predominantly wealthy and food secure. Cereals and cotton are the largest major cash crop in this zone (FEWS, 2010). Livestock is an asset in this region and is not only sold for profit but used in agriculture to help plough the land. The main crops consumed are maize, sorghum, millet, and rice. This area is moderately populated and land pressure and safe drinking water will continue to be a problem into the future for this livelihood zone. Roads in this region are generally good but tend to deteriorate in the rainy season, affecting access to markets at times (FEWS, 2010).

Livelihood zone #4 is less food secure and has less wealth. Poor soils and rainfed agriculture affect the main cultivation of cereals and groundnuts, as well as livestock rearing (FEWS, 2010). One of the largest sources of income in this region is remittance from family members working on cocoa and coffee plantations in Côte d'Ivoire. There is

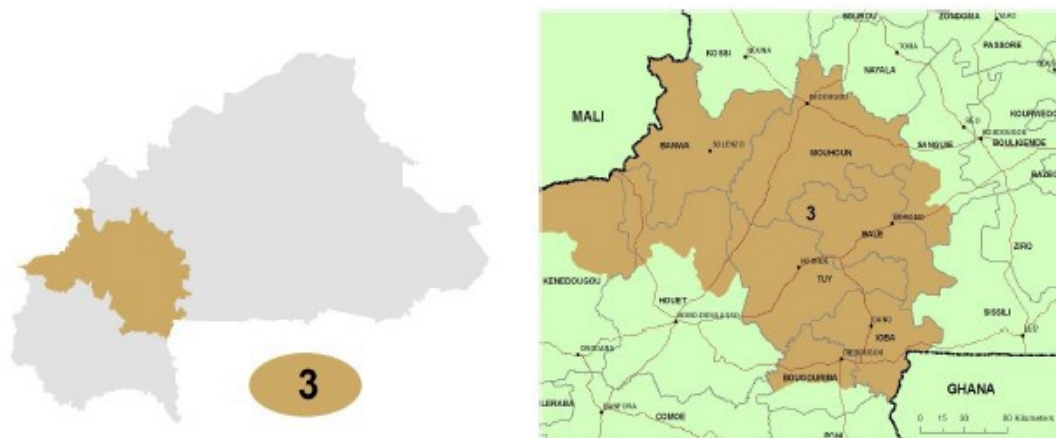


Figure 5. Livelihood zone #3: West cotton and cereals (FEWS, 2010)

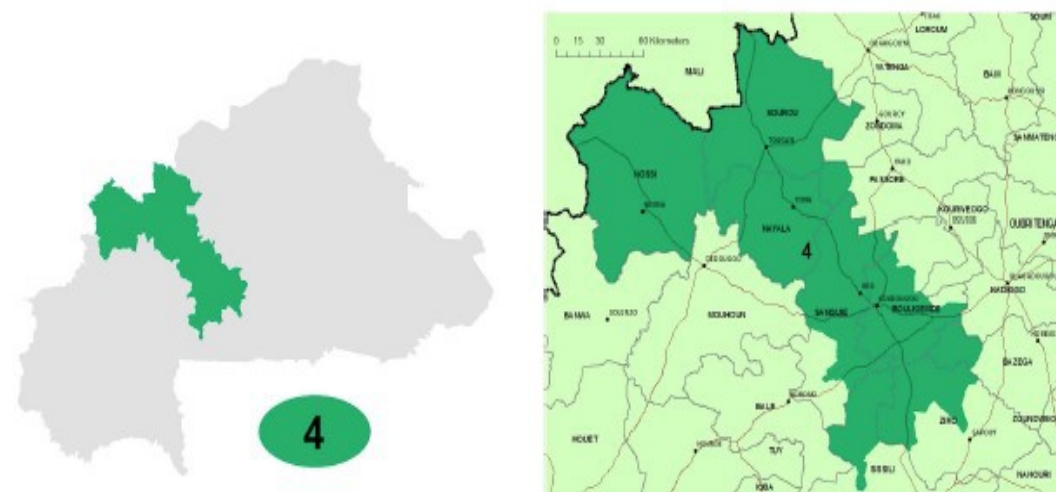


Figure 6. Livelihood zone #4: West cereals and remittances (FEWS, 2010)

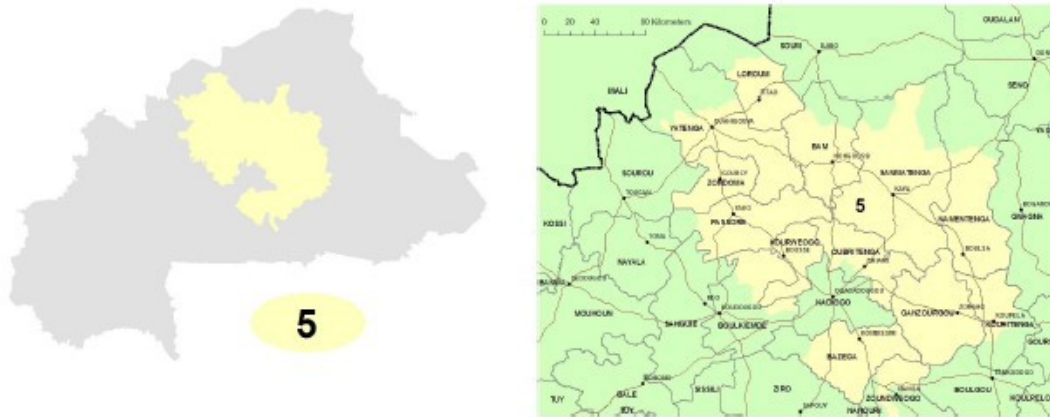


Figure 7. *Livelihood zone #5: Central plateau cereals and market gardening (FEWS, 2010)*

zones but has the highest population density due in part to the fact the country's capital, Ouagadougou is located here. Rain-fed agriculture, market gardening, and livestock rearing characterize this region and it is fairly food secure, partly due to its access to markets and the capital (FEWS, 2010). There is poor soil quality and small land holdings, making livestock an important asset and savings for the people living in this region.

Livelihood zone #7 has higher rates of food insecurity in the west and north compared to the eastern part of this zone because of less reliable rainfall. Gold mining and labor migration is particularly important to the poor households in this region, the better-off households tend to be able to feed themselves with their own harvests (FEWS, 2010). The rain-fed cultivation of millet and sorghum are used for both consumption and cash crops, while livestock are specifically important for cash income. Livestock tends to be difficult because of lack of pasture availability and access to water. Water for human consumption is also problematic in this region (FEWS, 2010). Access to markets is more difficult in this zone with poor roads in the rainy season and isolation from other

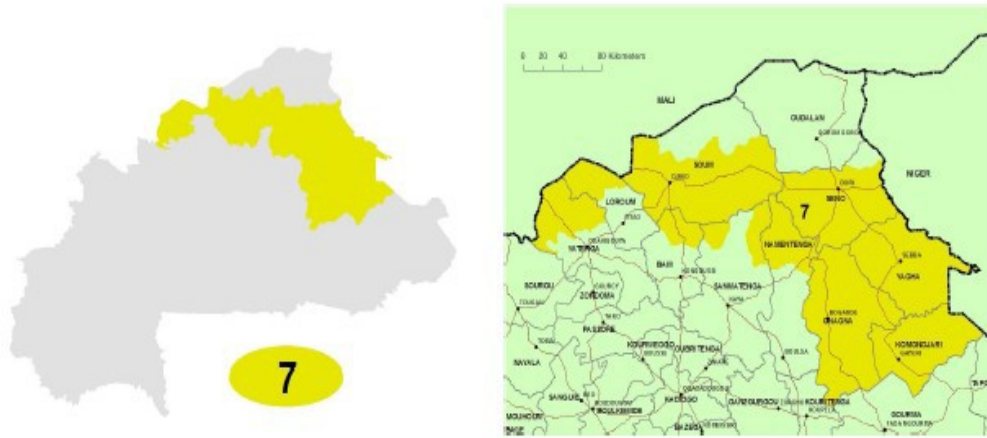


Figure 9. Livelihood zone #7: North and east livestock and cereals (FEWS, 2010)

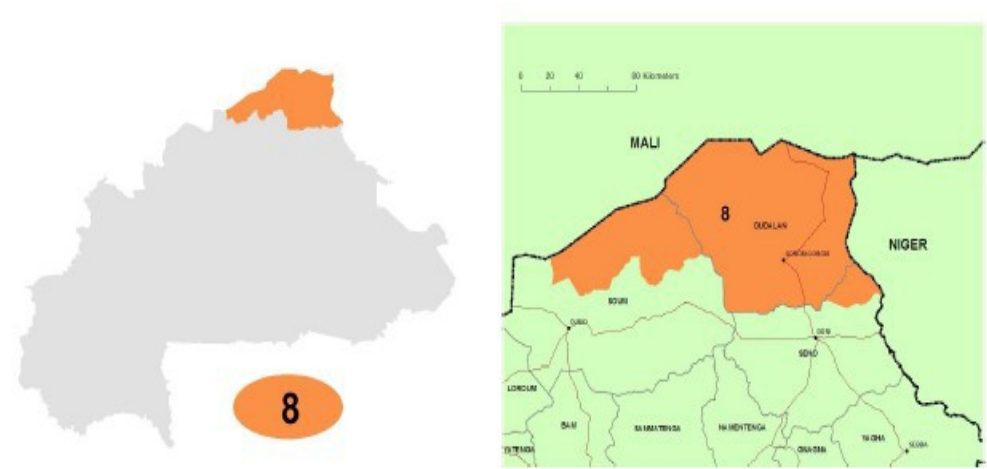


Figure 10. Livelihood zone #8: North transhumant livestock rearing and millet (FEWS, 2010)

range of crop production including sorghum, millet, maize, sesame, rice, peanuts, and cotton. The natural resources also provide a source of income due to the large forests, animal reserves, fishing, and tourism. Water is plentiful for human and animal consumption, as well as agriculture irrigation. Specific fruit that grows here in small quantities are watermelons, bananas, and papayas. Access to markets and roads are good, especially since they rely on trade with bordering countries (FEWS, 2010).

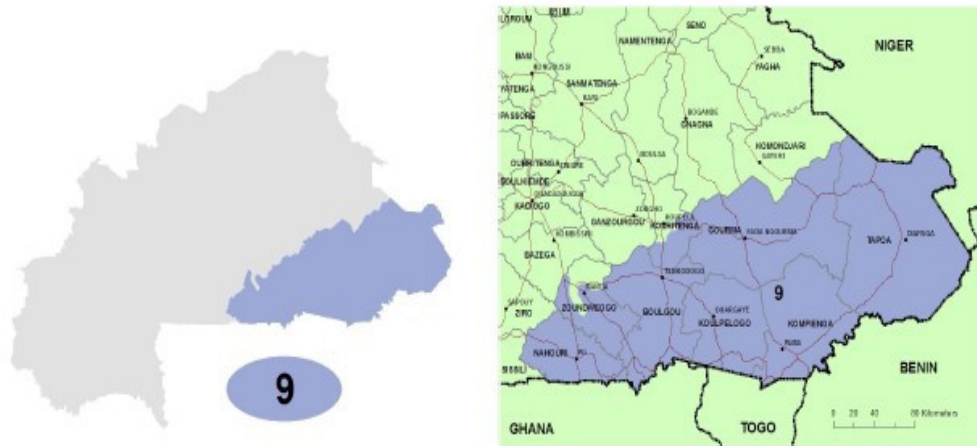


Figure 11. *Livelihood zone #9: South-east cereals, livestock, forest, and wildlife (FEWS, 2010)*

3.2 Hazards in Burkina Faso

Hazards can have a devastating impact on food security and livelihoods, especially those that are dependent on rainfall for agriculture and livestock rearing. Part of the objective for the livelihood zone project by FEWS Net is to identify vulnerable households that are more susceptible to hazards and will have a more difficult time coping and recovering from these types of events. Reducing people's vulnerability to hazards and increasing their capacity to cope is first achieved by recognizing who is vulnerable, to which hazards, where, and why (Blaikie, Cannon, Davis, & Wisner, 2014; FEWS, 2010; Thomalla, Downing, Spanger, Siegfried, Han, & Rockström, 2006). Often times hazards do not occur within or according to political and administrative boundaries; they transcend across regions, boundaries, and people. Current policy is designed within these politically defined boundaries and it is necessary to develop new policies that are structured around the hazard rather than arbitrary human-made

boundaries (Radke, Cova, Sheridan, Troy, Lan, & Johnson, 2000). However, it is useful to identify population groups and regions in a meaningful way when mitigating, responding to, and recovering from hazards. Although hazards do not differentiate across land uses, these differentiations greatly impact a societies ability to cope and recover (Radke, Cova, Sheridan, Troy, Lan, & Johnson, 2000). The livelihood zone approach provides a meaningful designation of land uses and people. These designations are especially valuable during the response and recovery phase following a disaster event because it provides a means to assess vulnerable populations and aid relief agencies.

Northern and central Burkina Faso is more vulnerable to drought due to the unreliable and infrequent precipitation while areas near rivers and bodies of water are more prone to periodic flooding during the rainy season. Data from UNEP's Global Risk Data Platform map the hazard risk in Burkina Faso for drought mortality risk, flood mortality risk, multihazard risk, and fire density from 1997-2008 (see Figure 12). These data allow us to visualize and analyze the spatial distribution of multiple hazard risks throughout Burkina Faso. Much of what makes these hazards detrimental to the people of Burkina Faso is the affect they have on entire livelihoods and food production (Roncoli, Ingram, & Kirshen, 2001).

Droughts are frequent and severe in many countries in Africa due to extreme rainfall variability and the poor capacity of soils to retain moisture (Benson & Clay, 1998). In Burkina Faso, droughts and floods tend to be the most frequent and damaging hazard events because they affect livelihoods, food production, and food security. Crop-based income in the Sahel region is not always dependable due to the high vulnerability of agro-climatic shocks (Reardon & Taylor, 1996). Reoccurring drought and flood

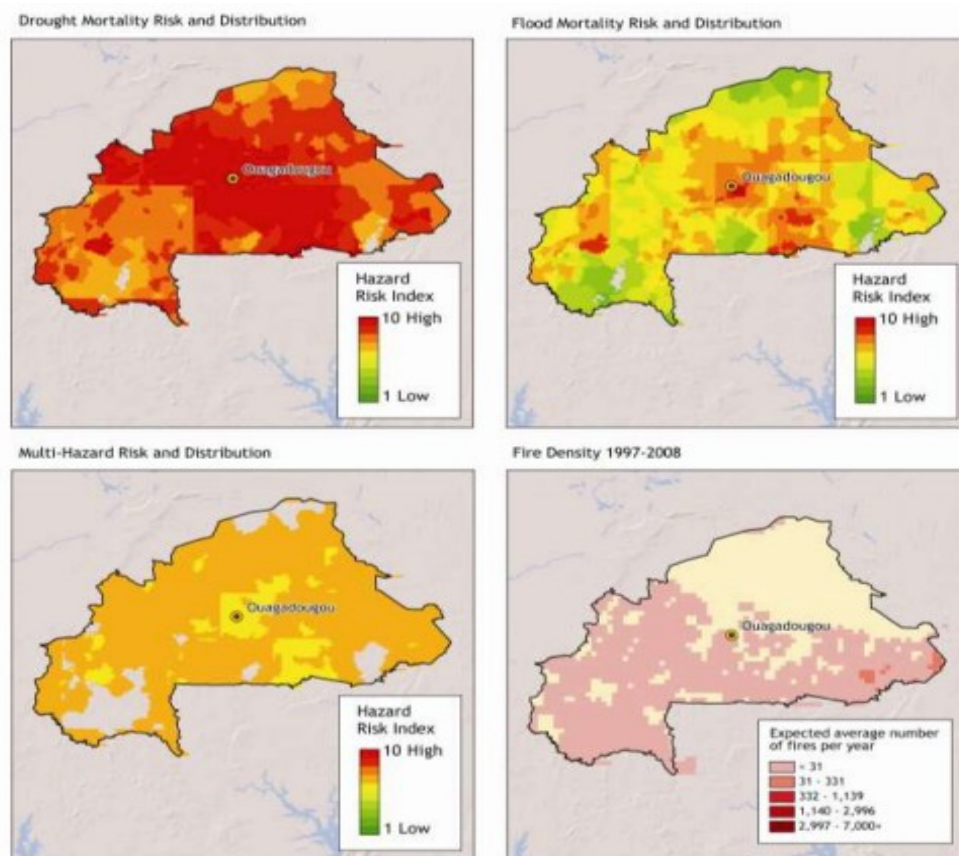


Figure 12. *Burkina Faso Map of Hazard Risk. Drought and flood mortality risk, multihazard risk, and fire density provide a general picture to the severity and spatial distribution of hazards in Burkina Faso. With these data, we can explore the relationship between hazard risk and food insecurity, as these two things often affect a population's livelihood (UNEP's Global Risk Data Platform, Columbia University Center for Hazards and Risk Research (CHRR), and Columbia University Center for International Earth Science Information Network (CIRESIN))*

in recent years has had deleterious effects on the population and food security. Drought is often times difficult to identify and define. Generally a drought is only identified when it impacts human activity (Maybank et al.,1995). In order to be declared a drought, there must be a deficiency or negative departure from normal or expected rainfall in a particular region for a protracted amount of time (Maybank et al.,1995). Drought has large impacts on crop and livestock production and tends to have a greater affect on poor households. Low-income households have fewer cash and food reserves, fewer options

for generating additional income, and tend to be the most in need of assistance during drought conditions, making them more vulnerable compared to better-off households (FEWS, 2010). However, little effort has been made to address root causes of vulnerability to drought and chronic food insecurity in this region (Clover, 2003).

Droughts tend to have a slow onset with a long duration, significantly affecting agriculture and crop yields. The major historical droughts throughout Burkina Faso are in Table 1 (EM-DAT, 2013).

Drought is both spatially and temporally diverse and can affect a country for one growing season or just a single community over several years (Maybank et al., 1995). Impacts from drought range from devastating agricultural communities by destroying crop yields to causing severe food insecurity and malnutrition. Flood events generally have a fast onset and short duration, but these events have large impact on agriculture, destroying entire crops. Major flood events in recent years include 2007 affecting

Table 1. Significant drought years in Burkina Faso

Year of Drought	Number of People Affected
1980	1,250,000
1988	200,000
1990	2,600,000
1995	75,590
2011	2, 850,000

121,043; 2009 affecting 151,000; and 2010 affecting 133,362 people (EM-DAT, 2013). In SSA, the variable weather pattern, drought, and flood are increasing in magnitude and frequency, which is contributing to the fall in crop production (Clover, 2003). The impacts from hazards are not evenly spread throughout the country.

4. DATA

The data applied in this study are the 2010 Burkina Faso survey data from the Demographic Health Survey (DHS). The DHS is a nationally representative population-based survey that provides data on health, nutrition, fertility, family planning, and household characteristics. The DHS is commonly used to design and monitor nutrition interventions in developing countries. DHS is advantageous because it encompasses an entire country and allows its results to be available for use by the public. More specifically, DHS allows us to monitor childhood anthropometry across space and time (De Haen, Klasen, & Qaim, 2011). Survey data are favorable in this study because they allow for causal analyses to some extent, due to the extensive variety of other variables that can be used to assess the factors driving undernutrition. The primary data collected by DHS surveys are executed by using several types of questionnaires. The household questionnaire is used in this study because it collects data on characteristics of the household such as dwelling unit, height and weight for women and children, and records the household make up (DHS, 2013). Each DHS survey is performed in four phases and takes on average 18-20 months to complete. The first phase is the survey preparation and questionnaire design. Next is the training and fieldwork, which involves training field staff and identifying households and individuals for participation. The third phase is data processing; this phase includes editing, coding, entering, and verifying the data. The final phase includes the final report and data dissemination (DHS, 2014).

The sample size for this study is 14,424 households, 17,087 women from age 15-49 and 7,307 men age 15-59. Maternal characteristics include education level, literacy, urban/rural residency, and anthropometric indicators of maternal nutrition. Child data refers to the period between birth and 5 years of age and represents nutritional status by measures of height, weight, and age. We use *z*-scores in child height-for-age, weight-for-age, and weight-for-height. The survey uses the WHO's average as a proxy to compare child *z*-scores. Anything below 0 *SD* would be considered below the average and anything above 0 *SD* would be above the average. When processing *z*-scores, checks are made to verify plausibility. Children with height-for-age *z*-scores less than -6 *SD* or greater than +6 *SD*, with weight-for-age *z*-scores less than -6 *SD* or greater than +6 *SD*, or with weight-for-height *z*-scores less than -4 *SD* or greater than +6 *SD* are flagged as invalid. Children flagged with the out-of-range *z*-scores were not included in the overall totals for anthropometric measures. Additionally, children that were not weighed and measured are also excluded from both the denominator and numerator of the overall children under 5 surveyed (Rutstein & Rojas, 2006).

In this particular DHS household survey in Burkina Faso, grouping of households that participate are geo referenced; these groupings are called clusters. The coordinates are collected in the field using GPS receivers; the accuracy is approximately less than 15-20 meters for most clusters (DHS, 2014). In order to maintain participant's confidentiality, the GPS latitude/longitude coordinates were randomly displaced for all surveys. Urban clusters contained between 0 - 2 kilometers of error. Rural clusters contained between 0 - 5 kilometers of error with a further 1% of the rural clusters displaced up to 10 kilometers (DHS, 2014). The geo-referenced clusters were used in this

study to represent the spatial distribution of not only the survey but also the results from the statistical analysis of the data.

Due to the nature of DHS surveys women of reproductive age (15-49) are selected in the sample. The household surveys for Burkina Faso contained 14,424 females between the ages of 15-49 (DHS, 2013). The purpose of DHS surveys is to collect data pertaining to marriage, fertility, family planning, reproductive health, child health, and HIV/AIDS. The household survey collects data on each member of the household such as the sex, age, education, and relationship to the head of the household, as well as household resources like water source, type of toilet facilities, materials used to construct house, ownership of consumer goods, and use of iodized salt. This information on the household allows surveyors to select women for further individual surveys and to select children under 5 for measurements pertaining to height and weight and test for anemia (Rutstein & Rojas, 2006). The DHS uses ISSA1, a special software package to process its surveys. ISSA1 has the ability to handle complex data such as hierarchical files as well as export data to statistical packages such as SPSS, SAS, and STATA. The ability for the data to be exported allows for easy access and utility for the public.

5. METHODOLOGY

The variables selected from the 2010 Burkina Faso DHS household survey included mother demographic characteristics, child health measures, and economic indicators (see Table 2). Next, the data were converted into a CSV file from SPSS to be used in the statistical software program R. The statistical software system R is the preferred program because of its accessibility and affordability; R is an open software program free to use by the public. Once the data were in R, several statistical methods were applied to explore the characteristics and relationships among the variables. Standard exploratory data analysis was performed to get an initial comprehension of the data characteristics (see Table 3).

There are at least 10% of children under 5 with low anthropometric z scores present in both urban and rural environments, sex of children, and in all ranges of mother's education. This indicates that child malnutrition rates are prevalent throughout the country under several different circumstances. Each livelihood zone also presented the prevalence of low anthropometric measures for children under 5. In Figure 13, the box plots represent the spread of anthropometric z scores for children under 5 in each livelihood zone. Each zone shows the spread of z scores for each indicator; the general average for all livelihood zones in each indicator are at or below 0. With averages throughout the country at or below the World Health Organization standard, child health in Burkina Faso is a significant issue to be addressed. After exploratory statistical

Table 2. *Summary statistics*

Variable	<i>n</i>
Child height-for-age <i>z</i> score	4,150
Child weight-for-age <i>z</i> score	4,150
Child weight-for-height <i>z</i> score	4,150
Urban rural residency	4,150
Mothers education	4,150
Partners education	4,150
Water source	4,150
Sex of head of household	4,150
Marital status	4,150
Sex of child	4,150
Livelihood zone number	4,150

analysis, a linear regression was applied to the data to observe relationships among the variables. In addition, the results from the linear regression are used to compare against the results from quantile regression, the method of choice for this study. When quantile regression was applied to the data, it was analyzed at the 25th, 50th, and 75th quantile (0.25, 0.5, and 0.75), respectively. Using the library package “quantreg” in R, three quantile regressions were run using each dependent variable with all of the independent variables.

Quantile regression is an approach that contrasts from classical linear regression methods by offering a mechanism for estimating the full range of conditional quantile functions and not just at the conditional mean function (Koenker, 2001). The ability of quantile regression to estimate an entire family of quantiles makes it a more complete

Table 3. *Data characteristics*

Variable	Children under 5 with Height-for-Age below -2 <i>SD</i>	Children under 5 with Weight-for-Height below -2 <i>SD</i>	Children under 5 with Weight-for-Age below -2 <i>SD</i>
Urban Residence	21.3 %	14.5%	18.2%
Rural Residence	37.3%	15.7%	27.2%
Sex of Child: Male	36.8%	16.5%	27.2%
Sex of Child: Female	32.3%	14.4%	24.1
Mother: No Education	37%	16.2%	27.2%
Mother: Primary Education	25.8%	14.5%	19.9%
Mother: Secondary or Higher Education	10.9%	10.3%	12.6%

method for statistical analysis. The potential application for quantile regression is vast and ever expanding. This method has been utilized in studies concerning pediatric medicine, population and demographic studies, in economics to study issues like determinants of wage and income inequality, ecological studies, and in policy research (Koenker, 2001).

In this study, quantile regression is the methodology of choice because it provides a more precise explanation of all areas of the distribution. Quantile regression is a method that estimates the functional relations between variables for all portions of a probability distribution (Koenker & Bassett, 1978). As opposed to a linear regression, quantile regression has the ability to analyze the distribution in several increments. This is especially useful in nutritional studies because often times we are interested in what is occurring at the extremes, like malnourishment and obesity. Averages do not always answer our questions and can often skew the results that do not allow us to see the full picture. Literature surrounding research and policy has traditionally depended upon

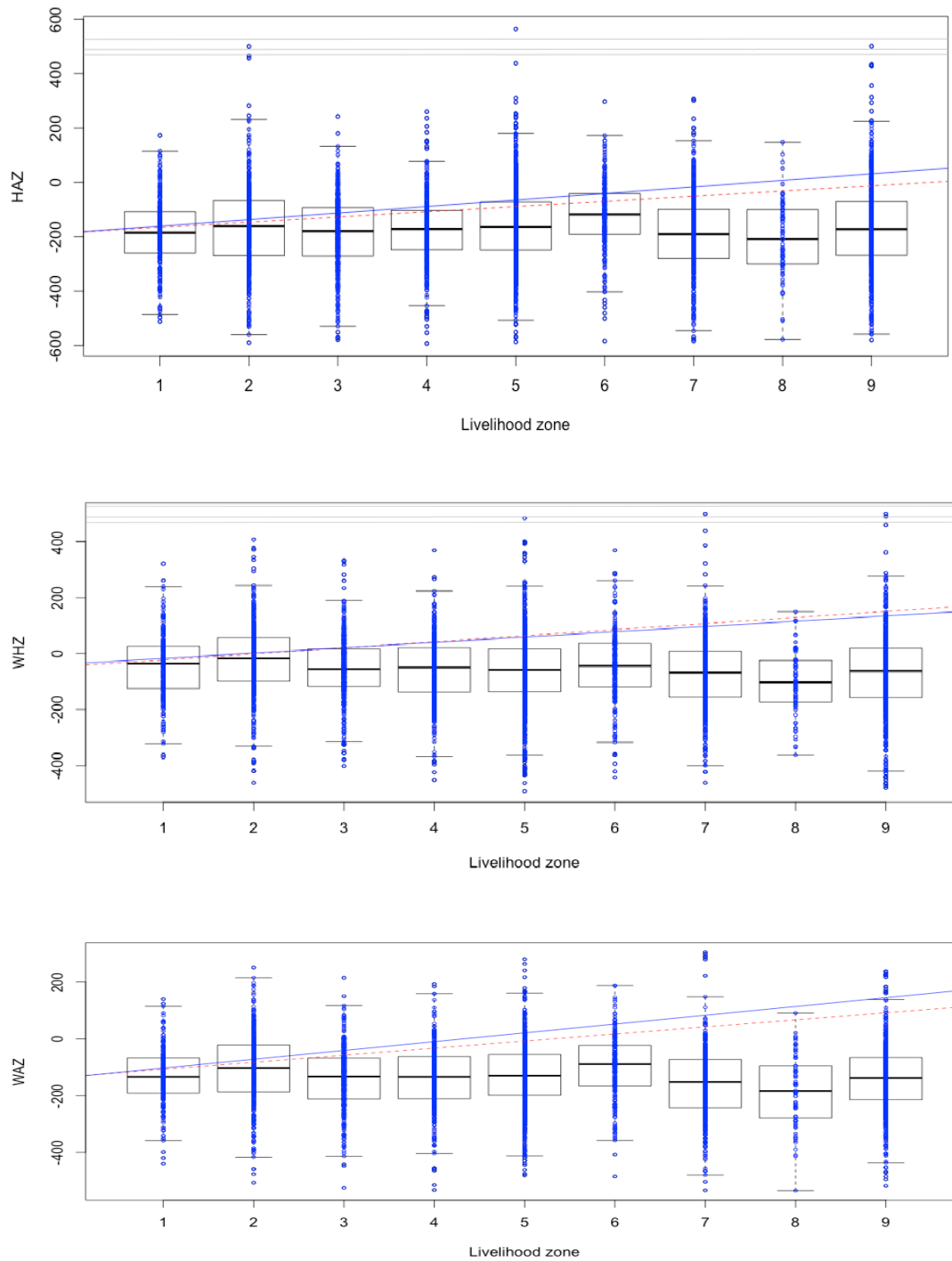


Figure 13. Boxplot of livelihood zones with children under 5 height-for-age, weight-for-height, and weight-for-age Z scores.

standard linear regression or binary outcome models for its methodology (Sweeney, Davenport, & Grace, 2013). One way we combat this limited scope of regression is to apply a quantile regression analysis to our data. This allows us to look at the entire distribution of the data not just the middle. We focus on the lower extremes of the data because this is where child malnutrition occurs. If we only focus on the average of the data, we would focus on the children who are healthy or normal, which would not provide very meaningful information on child malnutrition rates. Narrowing our focus to the lower quantile will aid in understanding the driving factors that are leading to lower than average child health outcomes.

A standard linear regression was also applied to help compare our target population with the average or healthy children in our sample. The linear regression explains the phenomena that are occurring in the middle of our distribution where the children who meet the WHO's standard for normal height and weight occur. Quantile regression was used to estimate the relationship among variables across the distribution. Specifically, we focus on the lower quantile because this is where children with lower anthropometric z scores are located in the distribution. Children under the age of 5 with two standard deviations below the mean for height-for-age, weight-for-age, and weight-for-height z scores are considered stunted, wasted, and undernourished, respectively. The height-for-age index provides an indicator of linear growth retardation among children.

Children who are less than two standard deviations below the mean of the WHO standard reference population in terms of height-for-age may be considered stunted or short and chronically malnourished. The weight-for-height index looks at body mass in relation to body length. Children who are less than two standard deviations below the

mean of the standard reference population in terms of their weight-for-height are considered wasted or too thin and acutely malnourished. Wasting represents the failure to receive adequate nutrition in the period immediately before the survey and may be the result of recent illness episodes, especially diarrhea, or of seasonal variations in food supply. Weight-for-age takes into account both these chronic and acute malnutrition measures and is often used to monitor nutritional status on a longitudinal basis (USAID, 2010). This method was chosen for the study because it has the advantage of looking at all quantiles of a distribution rather than focusing only on the mean of the distribution, as in a standard linear regression. Additionally, quantile regression has the benefit of having a more complete view of possible causal relationships between variables by estimating the conditional quantiles of a response variable distribution in a linear model. This study was less concerned with the average of distributions because concentrating exclusively on changes in the means may underestimate, overestimate, or fail to distinguish real non-zero changes in heterogeneous distribution (Cade & Noon, 2003). An advantage of quantile regression is that the objective function is a weighted sum of absolute deviations, which gives a more robust measure of location and the estimated coefficient vector is not sensitive to outlier observations on the dependent variable (Buchinsky, 1998). What this allows for is the possibility of potentially different solutions to occur at distinct quantiles and can be interpreted as a difference in the response of the dependent variable to changes in the regressors at various points of the distribution. The capability to focus on the lower and upper extremes of a distribution is particularly useful in this study. Often times in linear regression, the outliers or areas of upper and lower extremes become convoluted because of the focus on the mean of the distribution. A disadvantage with the

quantile regression approach is that there is extra processing time and an increase in complexity in both the execution of the method and interpretation of the results. The lack of popularity in this approach is also a disadvantage, but with more studies and disciplines adopting this methodology, it proves to be a versatile approach.

An anticipated problem we attempted to mitigate in this study was the missing and incomplete data values. Survey data in developing countries often times can be incomplete due to issues with collecting data from rural places, language and cultural barriers, as well as access to particular populations that may not want to participate in a study. To combat this problem, all missing or incomplete survey answers were coded as NA to avoid affecting the results. After removing incomplete and missing data, we still had a significant amount of valid responses to make a meaningful study. Each livelihood zone has varying amounts of data, but we judged that each zone had a sufficient amount to produce significant interpretations. In order to get the data organized into livelihood zones, the GPS points were merged with the survey data by a common indicator called cluster numbers. The newly merged GPS and Survey data were then overlaid on a livelihood zone map for Burkina Faso in ArcGIS (see Figure 14).

The spatial component to the survey data allows for location specific analysis of the results. This advantage allows for a more robust analysis and provides useful information regarding the spatial distribution of child malnutrition rates throughout the country. By utilizing a method that focuses on the lower extreme of a distribution coupled with spatial data, we create a detailed explanation for specific phenomena occurring in specific places.

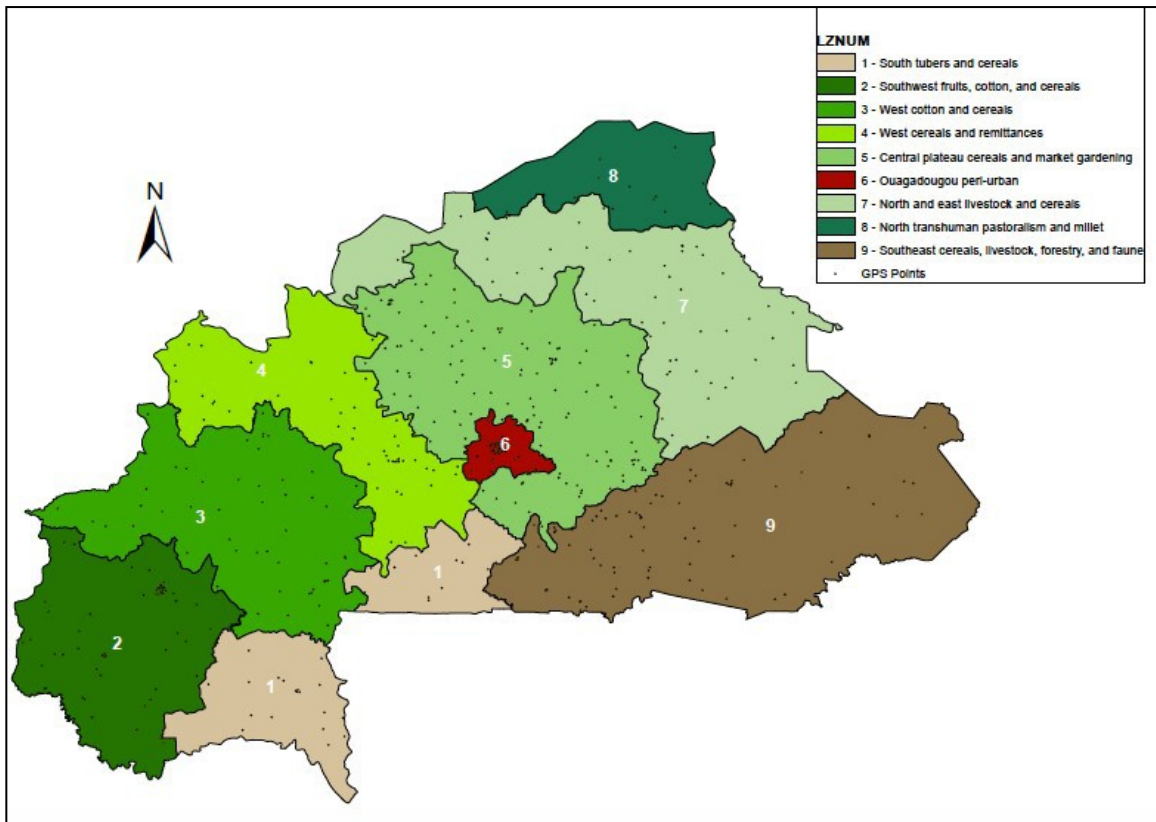


Figure 14. *Livelihood zones merged with survey data GPS points.*

6. RESULTS

Both exploratory analysis and quantile regression was performed using the household 2010 data from Burkina Faso. The exploratory analysis provided a general idea of the distribution of the data and child malnutrition rates throughout the country. Independent variables were selected based on the results of a standard linear regression. Residency, mother's education, and sex of child had the most significant results in a standard regression using child height-for-age, weight-for-height, and weight-for-age z scores as the dependent variable. These significant independent variables were then used to assess the prevalence of malnourished children under 5 for each category. At least 10% of children under 5 with -2 standard deviations (SD) below the mean for height-for-age, weight-for-height, and weight-for-age z scores are evident in each of the selected indicator variables (see Figure 15).

Both urban and rural areas have 10% or more of children under 5 stunted, wasted, and underweight. Rural residency has higher rates for all three anthropometric measures compared to those living in an urban region. As mother's education attainment increased the prevalence of stunting, wasting, and underweight decreased. The sex of the child varied by a few percentages for each measure with males having higher rates of malnutrition compared to female children under 5. Weight-for-height z scores or wasting tends to be relatively low in all categories and height-for-age or stunting is the highest rate for all independent variables. In addition to the standard linear regression, a

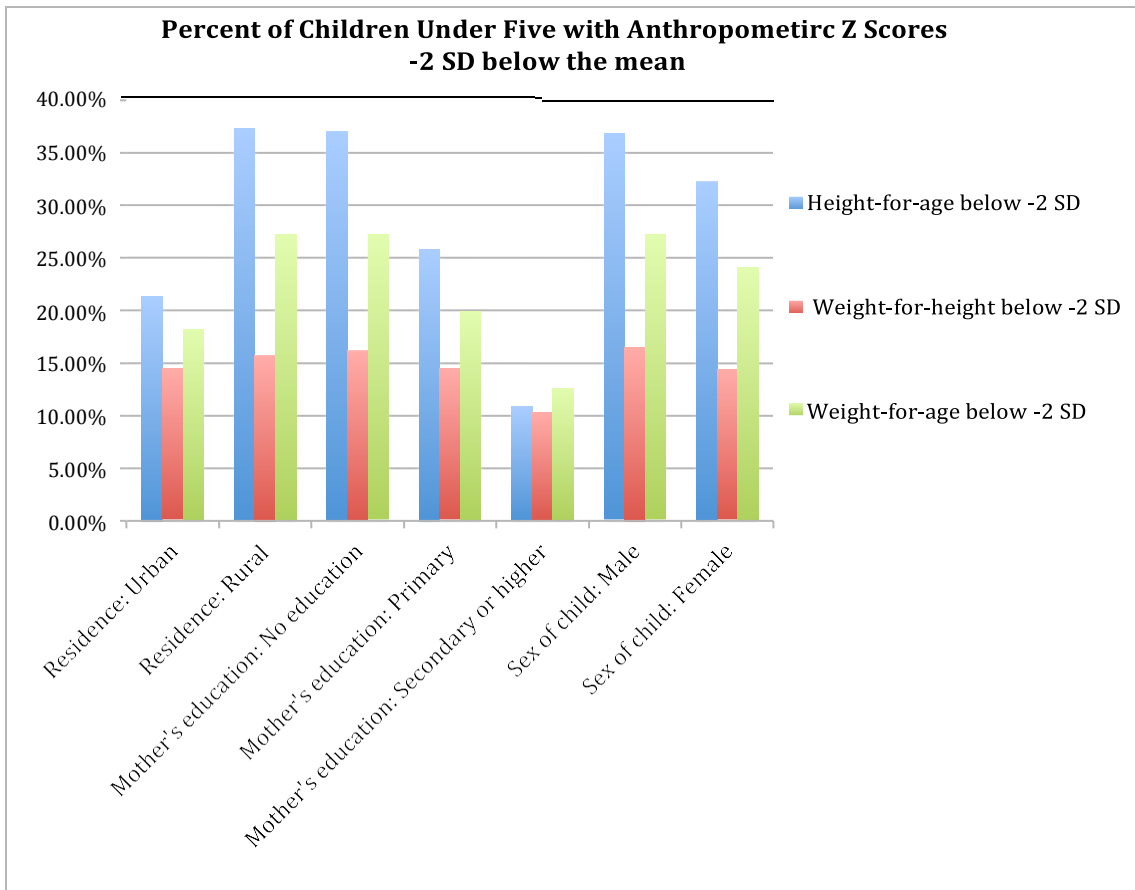
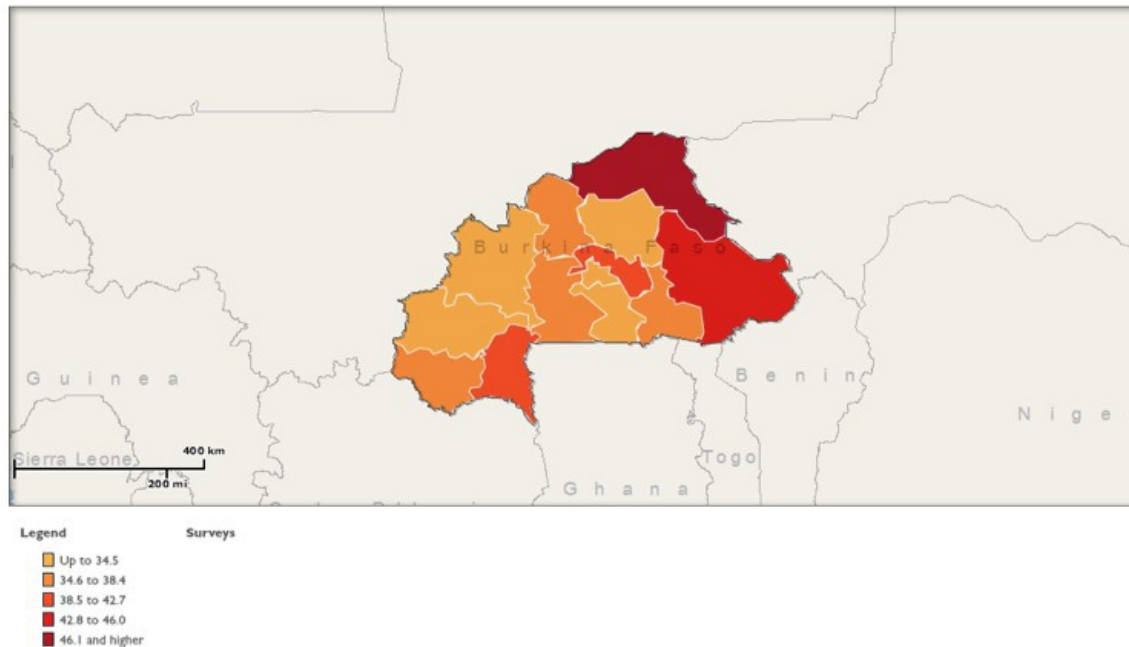


Figure 15: Percent of children under 5 with anthropometric Z scores -2 SD

spatial exploratory analysis was performed using the geo referenced anthropometric z scores. The z scores that fell -2 SD below the mean were mapped using the DHS STAT compiler. This analysis allowed for a spatial assessment of the distribution of child malnutrition rates throughout the country. Figure 16 depicts the percentage of geo-referenced height-for-age z scores that are -2 SD below the mean for children under 5. The five quantile breaks for the mapped height-for-age z scores are 0% - 34.5%, 34.6% - 38.4%, 38.5% - 42.7%, 42.8% - 46%, and 46.1% and higher. The highest rates (46.1% or higher) of height-for-age z scores below -2 SD or stunting occurs in the northern and

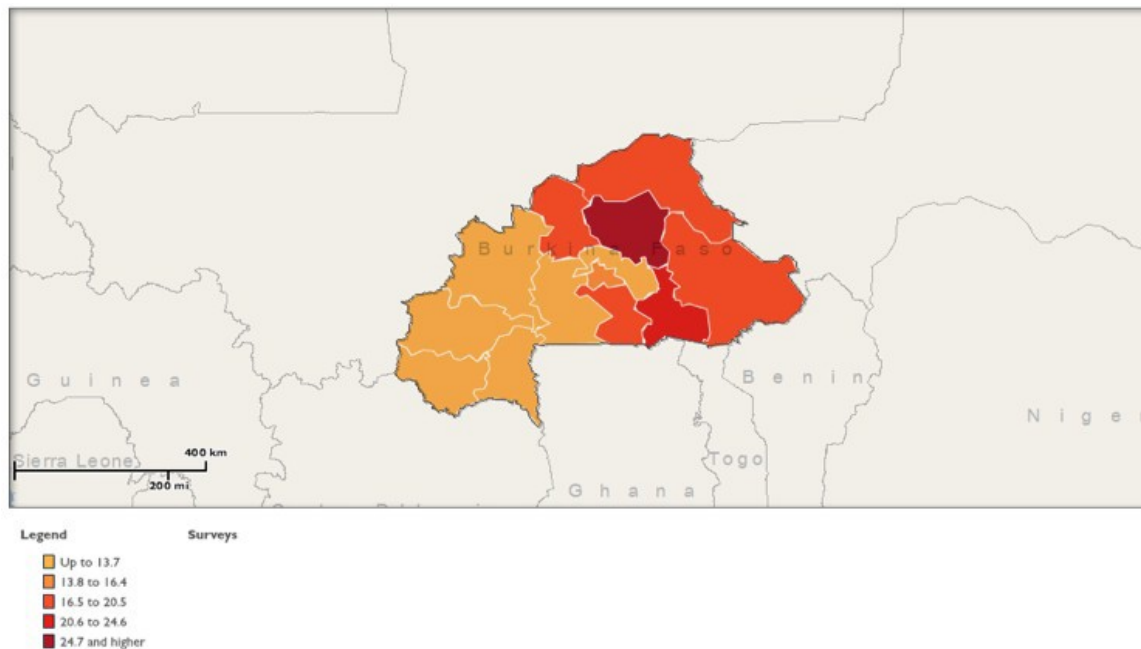


ICF International, 2012. The DHS Program STATcompiler - <http://www.statcompiler.com> - February 7 2015.

Figure 16: *Children under 5 with -2 SD below the mean for height-for-age Z scores*

eastern most regions of Burkina Faso.

These areas correlate with the north transhuman pastoralism and millet livelihood zone and the north and east livestock and cereals livelihood zone. In the southeast cereals, livestock, forestry, and fauna livelihood zone there is 42.8% - 46% prevalence of stunted children under 5. Figure 17 is the percentage of geo-referenced weight-for-height z scores that are -2 SD below the mean for children under 5. The five quantile breaks for weight-for-height z scores are 0% - 13.7%, 13.8% - 16.4%, 16.5% - 20.5%, 20.6% - 24.6%, and 24.7% and higher. The highest rates (24.7% or higher) of weight-for-height z scores -2 SD below the mean or wasting occur in the central, northern, and eastern parts of Burkina Faso. This area correlates to the central plateau cereals and market gardening livelihood zone and southeast cereals, livestock, forestry, and fauna. Areas with at least 16.5% - 24.6% of wasting occur in the north and east livestock and cereals livelihood zone and



ICF International, 2012. The DHS Program STATcompiler - <http://www.statcompiler.com> - February 7 2015.

Figure 17: Children under 5 with -2 SD below the mean for weight-for-height Z scores.

the north transhuman pastoralism and millet livelihood zone.

Figure 18 is the percentage of geo-referenced weight-for-age z scores that are -2 SD below the mean for children under 5. The five quantile breaks for weight-for-age z scores are 0% - 23.5%, 23.4% - 25.6%, 25.7% - 33.1%, 31.2% - 38.2%, and 38.3% and higher. The highest rates (33.2%-38.2%) of children under 5 with weight-for-age z scores -2 SD below mean or underweight occur in the northern and eastern regions of the country. These areas are also known as the north and east livestock and cereals livelihood zone, the north transhuman pastoralism and millet livelihood, and the southeast cereals livestock, forestry, and fauna livelihood zone. All three anthropometric measures have the highest prevalence rates in the same general north, northeastern part of the country. This spatial pattern indicates the north and

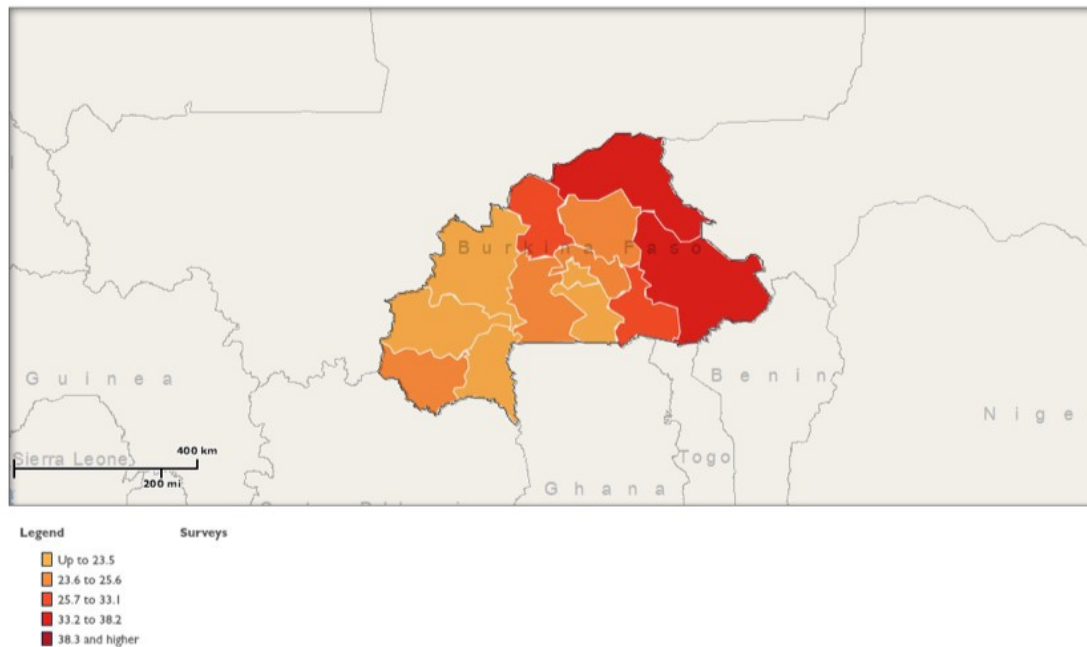


Figure 18: *Children under 5 with -2 SD below the mean for weight-for-age Z scores*

northeastern part of Burkina Faso is experiencing higher rates of malnutrition in children under 5.

6.1 Results From Height-for-Age Z Scores

The results from the quantile regression varied across the different anthropometric measures and quantiles. The 25th, 50th, and 90th quantile were analyzed for the height-for-age, weight-for-height, and weight-for-age z scores. The 25th quantile was our area of interest because this is the lower tail of the distribution for all anthropometric z scores, but other quantiles were analyzed for comparison. The variables with the most significance are indicated by *p*-value of less than 0.05 and are marked with an asterisk in the results table. For the height-for-age z score at the 25th quantile, the most significant variables are mothers higher education, child sex as female, surface water as source for

drinking water, and rural residency (see Table 4). Mother's higher education had a large, positive value, indicating a positive effect on the dependent variable. Child sex as female also had a positive effect on the height-for-age z score. Surface water and rural residency had negative effects on the dependent variable.

The significant variables for the height-for-age z score at the 50th quantile are mothers primary and secondary education, child sex as female, source for drinking water as other, and rural residency (see Table 5). Mother's primary and secondary education attainment was significant in the quantile regression with positive value indicating a positive effect on the dependent variable. Child sex as female also had a positive effect on the height-for-age z score at the 50th quantile. Additionally, drinking water as other also indicated a positive significance on the dependent variable. Rural residency was the only significant variable with a negative effect on the height-for-age z score at the 50th quantile.

The most significant variables for the height-for-age z score at the 90th quantile are mother's secondary education, livelihood zone #5, source for drinking water as surface water, and marital status of not living together (see Table 6). Mother's secondary education attainment was significant in the quantile regression at the 90th quantile with a positive value indicating a positive effect on the dependent variable. Livelihood zone #5 also had a positive effect on the height-for-age z score at the 90th quantile. Additionally, marital status as not living together indicated a positive effect on the dependent variable. Drinking water as surface water is the only significant variable with a negative effect on the height-for-age z score at the 90th quantile. Table 7 has a summary of all the significant variables.

Table 4. *Quantile regression results for HAZ at the 25th quantile, * indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>*Mother's education: Primary</i>	3.97	8.04	0.00
<i>*Mother's education: Secondary</i>	5.24	12.97	0.00
<i>*Mother's education: Higher</i>	2.45	61.00	0.013
<i>*Child sex: Female</i>	3.42	5.541	0.00
<i>Livelihood Zone #1</i>	-1.78	11.73	0.298
<i>Livelihood Zone #2</i>	-1.56	12.12	0.11
<i>Livelihood Zone #3</i>	-1.32	11.80	0.17
<i>Livelihood Zone #4</i>	0.16	11.88	0.86
<i>Livelihood Zone #5</i>	0.53	11.27	0.59
<i>Livelihood Zone #6</i>	0.97	16.32	0.32
<i>Livelihood Zone #7</i>	-1.14	12.27	0.25
<i>Livelihood Zone #8</i>	0.88	14.74	0.37
<i>Livelihood Zone #9</i>	-0.80	12.40	0.42
<i>Drinking water source: Tube Well Water</i>	-1.52	9.152	0.12
<i>Drinking water source: Dug Well</i>	-0.74	9.45	0.45
<i>*Drinking water source: Surface Water</i>	-3.67	14.41	0.00
<i>Drinking water source: Other</i>	0.19	46.03	0.84
<i>*Residency: Rural</i>	-3.08	8.47	0.00
<i>Marital Status: Married</i>	0.21	37.74	0.83
<i>Marital Status: Living Together</i>	0.00	41.21	1.00
<i>Marital Status: Widowed</i>	0.61	47.30	0.53
<i>Marital Status: Divorced</i>	1.62	42.48	0.10
<i>Marital Status: Not living together</i>	0.60	37.80	0.54
<i>Sex of head of household: Female</i>	0.00	9.50	1.00

Table 5. *Quantile regression results for HAZ at the 50th quantile, * indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>*Mother's education: Primary</i>	2.85	7.86	0.00
<i>Mother's education: Secondary</i>	5.48	11.58	0.00
<i>Mother's education: Higher</i>	1.18	56.66	0.23
<i>Child sex: Female</i>	2.89	5.34	0.00
<i>Livelihood Zone #1</i>	-0.03	13.20	0.87
<i>Livelihood Zone #2</i>	-0.10	13.75	0.91
<i>Livelihood Zone #3</i>	-0.33	13.36	0.73
<i>Livelihood Zone #4</i>	-0.03	12.57	0.96
<i>Livelihood Zone #5</i>	0.16	12.23	0.87
<i>*Livelihood Zone #6</i>	2.17	14.47	0.02
<i>Livelihood Zone #7</i>	-1.06	13.83	0.28
<i>Livelihood Zone #8</i>	-0.16	27.23	0.86
<i>Livelihood Zone #9</i>	0.15	13.03	0.87
<i>Drinking water source: Tube Well Water</i>	-0.74	9.79	0.45
<i>Drinking water source: Dug Well</i>	-0.90	10.19	0.36
<i>*Drinking water source: Surface Water</i>	-2.23	15.34	0.02
<i>*Drinking water source: Other</i>	3.40	21.34	0.00
<i>*Residency: Rural</i>	-3.89	8.14	0.00
<i>Marital Status: Married</i>	-0.61	24.74	0.53
<i>Marital Status: Living Together</i>	-1.51	28.27	0.13
<i>Marital Status: Widowed</i>	-0.06	34.84	0.94
<i>Marital Status: Divorced</i>	0.50	263.65	0.61
<i>Marital Status: Not living together</i>	-0.67	36.55	0.49
<i>Sex of head of household: Female</i>	-0.29	9.35	0.76

Table 6. *Quantile regression results for HAZ at the 90th quantile, * indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	-0.21	7.83	0.83
<i>*Mother's education: Secondary</i>	2.71	17.79	0.00
<i>Mother's education: Higher</i>	0.61	84.14	0.54
<i>Child sex: Female</i>	0.47	6.98	0.63
<i>Livelihood Zone #1</i>	0.42	12.89	0.91
<i>Livelihood Zone #2</i>	1.23	12.46	0.21
<i>Livelihood Zone #3</i>	-0.27	13.51	0.78
<i>Livelihood Zone #4</i>	-0.42	16.28	0.66
<i>*Livelihood Zone #5</i>	3.66	11.36	0.00
<i>Livelihood Zone #6</i>	1.340	17.40	0.18
<i>Livelihood Zone #7</i>	1.88	14.53	0.06
<i>Livelihood Zone #8</i>	-0.37	16.71	0.70
<i>*Livelihood Zone #9</i>	4.89	14.28	0.00
<i>*Drinking water source: Tube Well Water</i>	-2.18	12.19	0.02
<i>*Drinking water source: Dug Well</i>	-2.02	11.87	0.04
<i>*Drinking water source: Surface Water</i>	-2.79	18.00	0.00
<i>*Drinking water source: Other</i>	2.12	16.49	0.03
<i>Residency: Rural</i>	-1.71	8.94	0.08
<i>Marital Status: Married</i>	1.32	21.30	0.18
<i>Marital Status: Living Together</i>	0.55	25.99	0.58
<i>Marital Status: Widowed</i>	0.55	23.01	0.58
<i>Marital Status: Divorced</i>	0.64	651.44	0.51
<i>*Marital Status: Not living together</i>	4.60	21.76	0.00
<i>Sex of head of household: Female</i>	-1.51	10.57	0.13

Table 7. Summary of significant results from height-for-age Z score quantile regression

	Positive Significant Variables	Negative Significant Variables
25th Quantile	<ul style="list-style-type: none"> • Mother's higher education • Child sex: female 	<ul style="list-style-type: none"> • Rural residency • Drinking water source: surface water
50th Quantile	<ul style="list-style-type: none"> • Mothers primary education • Mother's secondary education • Child sex as female • Drinking water source: other 	<ul style="list-style-type: none"> • Rural residency
90th Quantile	<ul style="list-style-type: none"> • Mother's secondary education • Livelihood zone #5 • Marital status: not living together 	<ul style="list-style-type: none"> • Drinking water source: surface water

6.2 Results From Weight-for-Height Z Scores

The weight-for-height z score has five significant variables at the 25th quantile: sex of head of household as female, marital status as not living together, water source as other, livelihood zone #9 (Southeast cereals, livestock, forestry, and fauna), and child sex as female (see Table 8). Child sex as female is the only positive effect on weight-for-height z score and the rest of the independent variables have a negative effect. The weight-for-height z score has three significant variables at the 50th quantile: mothers

Table 8. *Quantile regression results for WHZ at the 25th quantile, * indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	0.53	7.47	0.59
<i>Mother's education: Secondary</i>	0.87	9.13	0.38
<i>Mother's education: Higher</i>	0.73	133.85	0.46
<i>*Child sex: Female</i>	2.47	4.85	0.01
<i>Livelihood Zone: #1</i>	1.56	11.86	0.47
<i>*Livelihood Zone: #2</i>	1.91	12.53	0.05
<i>Livelihood Zone: #3</i>	0.50	11.91	0.61
<i>Livelihood Zone: #4</i>	-1.31	12.97	0.19
<i>Livelihood Zone: #5</i>	-0.92	11.84	0.35
<i>Livelihood Zone: #6</i>	-0.30	16.59	0.76
<i>*Livelihood Zone: #7</i>	-2.27	13.15	0.02
<i>Livelihood Zone: #8</i>	-1.75	19.41	0.08
<i>*Livelihood Zone: #9</i>	-1.99	13.53	0.04
<i>*Drinking water source: Tube Well Water</i>	-1.94	7.71	0.05
<i>Drinking water source: Dug Well</i>	-0.40	7.41	0.68
<i>Drinking water source: Surface Water</i>	-1.43	11.18	0.15
<i>*Drinking water source: Other</i>	-3.12	23.65	0.00
<i>Residency: Rural</i>	-0.68	5.81	0.49
<i>*Marital status: Married</i>	-4.72	7.19	0.00
<i>*Marital status: Living Together</i>	-1.92	14.00	0.05
<i>*Marital status: Widowed</i>	-4.13	9.91	0.00
<i>Marital status: Divorced</i>	-0.10	267.79	0.91
<i>*Marital status: Not living together</i>	-3.00	22.29	0.00
<i>Sex of head of household: Female</i>	-1.78	7.72	0.07

higher education, livelihood zone #5, and livelihood zone #8 (see Table 9). Mother's higher education is the only positive effect on weight-for-height z score. Both livelihood zone #5 and #8 have negative effects on the weight-for-height z score at the 50th quantile. The significant dependent variables at the 90th quantile for weight-for-height z scores are livelihood zone #8, drinking water source as surface water, and drinking water source as other (see Table 10). All three significant dependent variables have negative effects on the weight-for-height z scores at the 90th quantile. A summary of all the significant variables from each quantile in the weight-for-height z score quantile regression can be found in Table 11.

6.3 Results From Weight-for-Age Z Scores

There are four significant variables in the quantile regression for the weight-for-age z score at the 25th quantile: sex of head of household as female, marital status as divorced and married, and rural residency (see Table 12). Marital status as divorced was the only coefficient with a positive effect on the dependent variable. There are two significant variables in the quantile regression for the weight-for-age z score at the 50th quantile that have a positive effect on the dependent variable. Mother's secondary and higher education are the only variables with a positive significance (see Table 13). Livelihood zone #8, drinking water source as surface water, and rural residency all have significant negative effects on the weight-for-age z scores. There are five significant variables in the quantile regression for the weight-for-age z score at the 90th quantile: mothers secondary education, livelihood zone #2, drinking water source as tube well water, drinking water source as surface water, and rural residency (see Table

Table 9: *Quantile results for WHZ at the 50th quantile, *indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	-0.78	8.29	0.43
<i>Mother's education: Secondary</i>	-0.75	8.63	0.45
<i>*Mother's education: Higher</i>	2.32	22.37	0.02
<i>Child sex: Female</i>	0.42	4.69	0.66
<i>Livelihood Zone: #1</i>	1.61	12.62	0.21
<i>Livelihood Zone: #2</i>	1.33	12.37	0.18
<i>Livelihood Zone: #3</i>	-1.47	11.49	0.13
<i>Livelihood Zone: #4</i>	-0.94	13.80	0.34
<i>*Livelihood Zone: #5</i>	-1.93	10.61	0.05
<i>Livelihood Zone: #6</i>	-0.91	13.10	0.35
<i>*Livelihood Zone: #7</i>	-2.39	11.90	0.01
<i>*Livelihood Zone: #8</i>	-3.19	18.45	0.00
<i>Livelihood Zone: #9</i>	-1.80	11.63	0.07
<i>Drinking water source: Tube Well Water</i>	-1.83	8.69	0.06
<i>Drinking water source: Dug Well</i>	-1.48	9.06	0.13
<i>Drinking water source: Surface Water</i>	-1.64	10.97	0.10
<i>Drinking water source: Other</i>	-1.36	28.82	0.17
<i>Residency: Rural</i>	0.00	8.15	1.00
<i>Marital status: Married</i>	0.03	16.06	0.97
<i>Marital status: Living Together</i>	0.63	20.56	0.52
<i>Marital status: Widowed</i>	0.55	23.55	0.58
<i>Marital status: Divorced</i>	0.50	60.30	0.61
<i>Marital status: Not living together</i>	-0.24	36.26	0.80
<i>Sex of head of household: Female</i>	-1.29	8.85	0.19

Table 10. *Quantile regression results for WHZ at the 90th quantile, * indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	0.07	13.45	0.94
<i>Mother's education: Secondary</i>	-1.05	10.47	0.29
<i>Mother's education: Higher</i>	-0.25	34.91	0.79
<i>Child sex: Female</i>	1.05	6.61	0.29
<i>Livelihood Zone: #1</i>	1.11	20.24	0.18
<i>Livelihood Zone: #2</i>	1.38	21.61	0.16
<i>Livelihood Zone: #3</i>	-1.10	18.12	0.26
<i>Livelihood Zone: #4</i>	-0.75	18.60	0.45
<i>Livelihood Zone: #5</i>	-0.11	17.76	0.91
<i>Livelihood Zone: #6</i>	0.12	24.69	0.90
<i>Livelihood Zone: #7</i>	-0.67	19.32	0.50
<i>*Livelihood Zone: #8</i>	-2.66	23.28	0.00
<i>Livelihood Zone: #9</i>	0.05	18.85	0.95
<i>Drinking water source: Tube Well Water</i>	-1.04	10.54	0.29
<i>Drinking water source: Dug Well</i>	-1.62	9.82	0.10
<i>*Drinking water source: Surface Water</i>	-2.05	16.07	0.04
<i>*Drinking water source: Other</i>	-3.22	20.80	0.00
<i>Residency: Rural</i>	1.50	9.98	0.13
<i>Marital status: Married</i>	-0.14	34.89	0.88
<i>Marital status: Living Together</i>	-0.74	39.13	0.45
<i>Marital status: Widowed</i>	-0.13	74.64	0.89
<i>Marital status: Divorced</i>	0.34	537.52	0.73
<i>Marital status: Not living together</i>	0.25	39.13	0.79
<i>Sex of head of household: Female</i>	-1.33	7.50	0.18

Table 11. *Summary of results from weight-for-height Z scores quantile regression*

	Positive Significant Variables	Negative Significant Variables
25th Quantile	<ul style="list-style-type: none"> • Child sex as female 	<ul style="list-style-type: none"> • Sex of head of household: female • Marital status: not living together • Drinking water source: other • Livelihood zone #9
50th Quantile	<ul style="list-style-type: none"> • Mother's higher education 	<ul style="list-style-type: none"> • Livelihood zone #5 (Central Plateau Cereals and Market Gardening) • Livelihood zone #8 (North Transhumant Livestock)
90th Quantile		<ul style="list-style-type: none"> • Livelihood zone #8 (North Transhumant Livestock Rearing and Millet) • Drinking water source: surface water • Drinking water source: other

14). Mother's secondary education and livelihood zone #2 are the only two significant variables with a positive effect on the weight-for-age z scores at the 90th quantile. Drinking water sources as tube well water and surface water both have a negative effect on the dependent variable. Rural residency is also a significant negative independent variable in the weight-for-age z score at the 90th quantile.

A summary of all the significant variables from each quantile in the weight-for-age z score quantile regression can be found in Table 15. The results from the quantile regression revealed several significant independent variables that were not present in the standard linear regression analysis. The independent variables for drinking water

Table 12: *Quantile regression results for WAZ at the 25th quantile, *indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>*Mother's education: Primary</i>	2.82	6.71	0.00
<i>*Mother's education: Secondary</i>	5.68	8.26	0.00
<i>*Mother's education: Higher</i>	3.78	31.17	0.00
<i>*Child sex: Female</i>	2.93	4.43	0.00
<i>Livelihood Zone: #1</i>	-0.57	11.27	0.49
<i>Livelihood Zone: #2</i>	-0.49	12.22	0.62
<i>*Livelihood Zone: #3</i>	-2.11	12.29	0.03
<i>*Livelihood Zone: #4</i>	-2.14	11.17	0.03
<i>Livelihood Zone: #5</i>	-0.99	11.01	0.31
<i>Livelihood Zone: #6</i>	-0.49	16.27	0.62
<i>*Livelihood Zone: #7</i>	-3.33	13.77	0.00
<i>*Livelihood Zone: #8</i>	-2.49	24.40	0.01
<i>*Livelihood Zone: #9</i>	-1.94	11.83	0.05
<i>*Drinking water source: Tube Well Water</i>	-1.92	7.79	0.05
<i>Drinking water source: Dug Well</i>	-1.34	8.15	0.17
<i>*Drinking water source: Surface Water</i>	-3.33	11.69	0.00
<i>Drinking water source: Other</i>	-0.39	43.55	0.69
<i>*Residency: Rural</i>	-2.20	6.81	0.02
<i>*Marital status: Married</i>	-3.37	6.51	0.00
<i>Marital status: Living Together</i>	-1.80	8.29	0.07
<i>Marital status: Widowed</i>	0.26	19.09	0.79
<i>*Marital status: Divorced</i>	3.29	23.08	0.00
<i>Marital status: Not living together</i>	-1.35	28.67	0.17
<i>*Sex of head of household: Female</i>	-2.44	9.39	0.01

Table 13: *Quantile regression results for WAZ at the 50th quantile, *indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	1.40	5.44	0.15
<i>*Mother's education: Secondary</i>	2.68	9.20	0.00
<i>*Mother's education: Higher</i>	2.45	26.88	0.01
<i>*Child sex: Female</i>	2.13	4.20	0.03
<i>Livelihood Zone: #1</i>	1.43	9.23	0.71
<i>Livelihood Zone: #2</i>	1.68	9.71	0.09
<i>Livelihood Zone: #3</i>	-0.24	9.55	0.80
<i>Livelihood Zone: #4</i>	-0.28	11.85	0.73
<i>Livelihood Zone: #5</i>	-0.08	8.10	0.93
<i>*Livelihood Zone: #6</i>	1.90	9.27	0.05
<i>Livelihood Zone: #7</i>	-1.73	10.93	0.08
<i>*Livelihood Zone: #8</i>	-2.65	18.06	0.00
<i>Livelihood Zone: #9</i>	-1.16	9.40	0.24
<i>Drinking water source: Tube Well Water</i>	-1.96	7.11	0.04
<i>Drinking water source: Dug Well</i>	-1.52	7.66	0.12
<i>*Drinking water source: Surface Water</i>	-2.84	11.58	0.00
<i>Drinking water source: Other</i>	0.27	24.63	0.78
<i>*Residency: Rural</i>	-3.38	6.39	0.00
<i>Marital status: Married</i>	0.14	11.42	0.88
<i>Marital status: Living Together</i>	0.09	13.86	0.92
<i>Marital status: Widowed</i>	-0.26	16.46	0.79
<i>Marital status: Divorced</i>	0.45	118.66	0.64
<i>Marital status: Not living together</i>	-0.16	17.80	0.86
<i>Sex of head of household: Female</i>	-0.04	7.69	0.96

Table 14: *Quantile regression results for WAZ at the 90th quantile, *indicates p-value of .05 or less*

Variable	Coefficients	Std. Error	P value
<i>Mother's education: Primary</i>	1.23	5.66	0.21
<i>*Mother's education: Secondary</i>	2.77	5.76	0.00
<i>Mother's education: Higher</i>	0.68	32.30	0.49
<i>Child sex: Female</i>	1.75	4.56	0.07
<i>Livelihood Zone: #1</i>	1.44	11.87	0.31
<i>*Livelihood Zone: #2</i>	2.25	13.27	0.02
<i>Livelihood Zone: #3</i>	-1.48	10.74	0.13
<i>Livelihood Zone: #4</i>	-1.14	18.93	0.25
<i>Livelihood Zone: #5</i>	0.00	11.50	1.00
<i>Livelihood Zone: #6</i>	1.49	14.07	0.13
<i>Livelihood Zone: #7</i>	-1.35	14.02	0.17
<i>Livelihood Zone: #8</i>	-0.57	12.12	0.56
<i>Livelihood Zone: #9</i>	-0.28	13.91	0.77
<i>*Drinking water source: Tube Well Water</i>	-2.36	6.76	0.01
<i>Drinking water source: Dug Well</i>	-1.81	6.06	0.06
<i>*Drinking water source: Surface Water</i>	-6.39	5.63	0.00
<i>Drinking water source: Other</i>	0.96	23.81	0.33
<i>*Residency: Rural</i>	-3.78	4.48	0.00
<i>Marital status: Married</i>	0.25	31.79	0.80
<i>Marital status: Living Together</i>	-0.40	37.46	0.68
<i>Marital status: Widowed</i>	0.30	52.94	0.76
<i>Marital status: Divorced</i>	0.50	493.65	0.61
<i>Marital status: Not living together</i>	1.02	71.13	0.30
<i>Sex of head of household: Female</i>	-0.36	8.19	0.71

Table 15. *Summary of results from weight-for-age Z scores quantile regression*

	Positive Significant Variables	Negative Significant Variables
25th Quantile	<ul style="list-style-type: none"> • Marital status: divorced 	<ul style="list-style-type: none"> • Sex of head of household as female • Marital status: married • Rural residency
50th Quantile	<ul style="list-style-type: none"> • Mother's secondary education • Mother's higher education 	<ul style="list-style-type: none"> • Livelihood zone #8 (North Transhumant Livestock Rearing And Millet) • Drinking water source: surface water • Rural residency
90th Quantile	<ul style="list-style-type: none"> • Mother's secondary education • Livelihood zone #2 (South-west Fruits, Cotton, And Cereals) 	<ul style="list-style-type: none"> • Drinking water source: tube well water • Drinking water source: surface water • Rural residency

source, marital status, livelihood zone, and sex of head of household were found to be significant in the 25th quantile for z scores $-2 SD$ below the mean. Each z score had different independent variables that were significant in the quantile regression. This indicates that different variables may be driving the different types of malnutrition: stunting, wasting, and underweight. The quantile regression provided a more specific analysis for each dependent variable at the 25th quantile as compared with the average of the distribution in a standard linear regression. The combination of exploratory analysis,

linear regression, and quantile regression delivers a thorough and robust measure of the data. These results will aid in identifying areas of influence in child malnutrition and food insecurity in Burkina Faso.

7. DISCUSSION

The goal of this research was to determine areas of resiliency to food insecurity in Burkina Faso to identify and develop better food aid allocation practices and food policy. I accomplished this goal by applying quantile regression to geo-referenced Demographic Health Survey data to examine relationships among variables that shed light on factors driving child undernutrition. Understanding which variables contribute to severe malnutrition in children under 5 will aid in combatting food insecurity in this impoverished and food insecure region. Using the livelihood zones in our approach helps to identify the spatial distribution of food insecurity and distinguish specific livelihoods that may be more resilient in food insecure regions.

7.1 Height-for-Age Z Score 25th Quantile

Three significant independent variables from the 25th quantile for the height-for-age z score quantile regression are mother's primary and secondary education level and child sex as female. These variables have a positive relationship with height-for-age z score, meaning they result in higher z scores or more nutritionally healthy children under 5. As education level increases for mothers, children under 5 have better health outcomes (Silva, 2005). This result is an anticipated outcome because mothers with higher education tend to have more resources available to them. Mother's with a higher education level are more likely to influence children health outcomes in several positive

ways. (1) Formal education provides health knowledge for future mothers; (2) Skills like literacy and numeracy acquired in school help mothers diagnose and treat child health issues; (3) Higher education exposes mothers to modern society and makes them more receptive to medical treatments and vaccinations; (4) Mothers with formal education are more likely to raise household income, either through higher wages or increased work productivity; and (5) Educated women tend to opt for fewer children, which will allow for less competition and more allocation of resources, resulting in healthier children (Glewwe, 1999; Schultz, 1984). Mothers with higher education have more potential to have better jobs, more income, resources, and knowledge to combat child health issues. Policies that focus on increasing mother's education in Burkina Faso may be an effective strategy in reducing child malnutrition. Maternal education has a accumulative effect on children nutrition outcomes throughout their first 5 years of development, so it is expected that height-for-age z scores, which are indicative of chronic nutrition status, is more likely to be influenced by the long-term beneficial effects of mother's educational attainment (Smith, Ruel, & Ndiaye, 2005). Policies that focus on increasing mother's education in Burkina Faso may be an effective strategy in terminating child malnutrition.

There is a significant, positive result at the 25th quantile for children under 5 with sex as female and height-for-age z scores. This outcome was not anticipated because male children tend to be prioritized in a household due to the fact that they will be able to contribute more labor-intensive work for their family. Other research suggest that this finding is typical in SSA and may be biologically driven rather than behaviorally. In a study by Gareene (2003), it was discovered that child malnutrition is more prevalent among boys on average of +5% with no difference in behavioral actions between the two

sexes, suggesting that a biological causality may be in place. This research specifically studied three behavioral indicators (1) preventive health actions: vaccinations, (2) curative medicine: oral rehydration therapy and (3) feeding practices: breastfeeding in SSA. The study revealed equal treatments of all three indicators between the two sexes. With no apparent favoring between the sexes, male children naturally tend to be more sensitive or prone to shorter heights for age in SSA and specifically in Burkina Faso. Furthermore, male children displayed a slight disadvantage in neonatal mortality, postneonatal mortality, child mortality, and prevalence of malnutrition throughout SSA (Gareene, 2003). This finding sheds light on perhaps a biological driver for malnutrition specific to male children under 5. Further research in sex differences of health outcomes should be pursued in order to eliminate any discriminatory behavior that is not captured by the DHS data. If a biological factor is driving male children malnutrition rates in SSA, more research should be done that focuses on understanding what specifically causes the predominant low height-for-age z scores in male children at a biological level, which is beyond the scope of this analysis.

Two variables that have negative effects with height-for-age z scores at the 25th quantile are drinking water source as surface water and rural residency. Both of these variables are expected outcomes when analyzing stunting. Children's access to safe, clean drinking water has a major effect on health outcomes. Surface water may contain contaminants and disease that influence a child's health outcome. Common contracted water-borne illnesses are diarrhea, ascariasis (roundworm), dracunculiasis (guinea-worm), schistosomiasis, and trachoma (Hoddinott, 1997). These diseases can cause both temporary and long-term effects that can prevent someone from absorbing and retaining

the nutrients from food necessary for adequate nutrition. Water-borne illnesses can have a huge impact on children's health outcomes, especially those who are under 5 years old, because they are more vulnerable and have weaker immune systems. The drinking water source is also used as a proxy for a more broad determination of the overall health environment of a particular country. Water sources can be used as a proxy for both the health environment and health services because the measure is highly correlated with other measures of the quality of a country's health environment and over-development (Smith & Haddad, 2000). Access to safe drinking water is extremely important to the health of the population and indicates an overall healthier environment and better services.

A negative result from the quantile regression for height-for-age z scores at the 25th quantile is rural residency. Many rural areas have limited food markets and lack the availability and accessibility to food. Fotso (2007) study also revealed higher rates of malnutrition in rural areas as compared to urban areas. Several factors may be the driver for higher rates of child malnutrition in rural areas. Children under 5 that live in rural areas in developing countries see a lack of dietary diversity and insufficient amounts and infrequency of feedings lead to deteriorated growth (Smith, Ruel, & Ndiaye, 2005). Urban areas also have more access to resources, food, and services. Women have increased access to food, formal education, adequate childcare, and health services in urban areas (Smith, Ruel, & Ndiaye, 2005). The stunting, long-term malnutrition in Burkina Faso for children under 5 at the 25th quantile is negatively influenced by surface water and rural residency.

7.2 Height-for-Age Z Score 50th Quantile

The variables with a positive significance for the height-for-age z score at the 50th quantile are mothers primary and secondary education, child sex as female, and source for drinking water as other. Mother's primary and secondary education and child sex as female correspond to the results from the 25th quantile. Additionally, rural residency was the only significant variable with a negative effect on the height-for-age z score at the 50th quantile, which is also the case at the 25th quantile. The only variable that was not present at the 25th quantile and significant at the 50th quantile is drinking water source as other. Drinking water source as other has a positive relationship with height-for-age z scores at the 50th quantile. Since this variable is essentially unknown, further research is needed to identify the actual source of "other." It would be worth identifying because it has a positive effect of children under 5 stunting and can be implemented in areas where the water source has a negative impact on height-for-age z scores.

7.3 Height-for-Age Z Score 90th Quantile

The most significant variables for the height-for-age z score at the 90th quantile with a positive relationship are mother's secondary education, livelihood zone #5, and marital status of not living together. Mother's secondary education attainment is an anticipated significant result in the quantile regression at the 90th quantile and is also seen at both the 25th and 50th quantiles. Livelihood zone #5: Central plateau cereals and market gardening, has a positive effect on the height-for-age z score at the 90th quantile (see Figure 19).

This is one of the most food insecure livelihood zones in the country and the

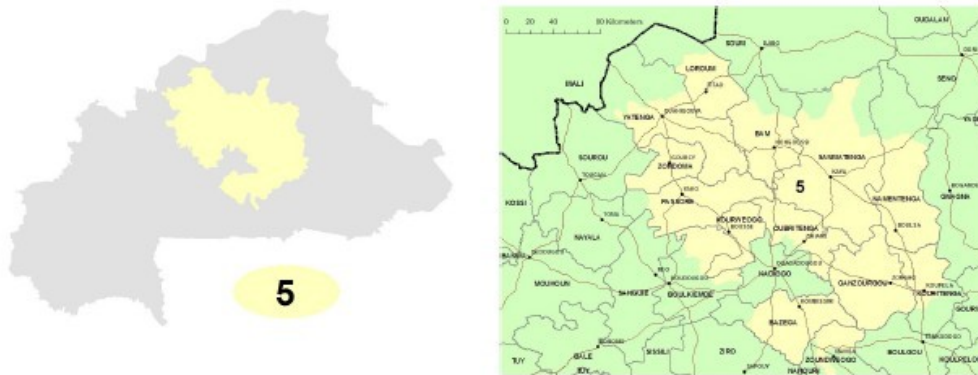


Figure 19. Map of livelihood zone #5: Central plateau cereals and market gardening (FEWS, 2010)

positive relationship with height-for-age z scores is only present in the top tier of the population distribution (FEWS, 2010). The positive relationship with livelihood zone #5 is only present in children under 5 with the greatest height-for-age z scores. The 90th quantile does not represent malnourished or stunted children, these children have above average height-for-age z scores. One reason we may expect a positive relationship in this upper quantile is that although this region is food insecure, there is a large wealth disparity and wealthy households may be more resilient to rises in market prices for food (FEWS, 2010). Additionally, marital status as not living together indicated a positive effect on the dependent variable. This result is particularly interesting because marital status of not living together has a negative relationship at the 25th quantile. Possible explanations for this unexpected result is that children in the upper quantile have more resources available to them and single parent households may take advantage of communal childcare and resources.

Drinking water as surface water is the only significant variable with a negative effect on the height-for-age z score at the 90th quantile. Surface water is expected to produce a negative relationship due to the impacts from water-borne illnesses. This result

coincides with the results at the 25th quantile for height-for-age z scores. With all of these results, policy makers and outreach programs can improve drinking water sources especially to those living in a rural regions to help eradicate child stunting. Knowing that mother's education has a positive relationship to stunting, this can influence programs that promote women equality and access to education.

7.4 Weight-for-Height Z Score 25th Quantile

Several variables resulted in a negative relationship with weight-for-height z scores from the quantile regression analysis at the 25th Quantile. The most significant independent variables with a negative relationship are drinking water source as "other," marital status as not living together, and livelihood zone #9 or southeast cereals, livestock, forestry, and fauna livelihood zone. Water source as "other" indicates there is no access to water from piped water, tube well water, dug well water, or surface water. Considering that this result was so significant, it would be crucial for future research to consider determining the other sources of water. The source of water is an important indicator for health outcomes in children and can have a negative effect when the source is not clean or safe.

The marital status of not living together is an anticipated negative relationship for weight-for-height z scores. Parents who are not living together may be an indication of a single-lead household, which means it is more likely to have less resources and food available. The welfare of children is dependent upon adults and access to parent's care, resources, economic support, and socialization (Lloyd & Desai, 1992). Only having access to a single-parent in a household will limit a child's available resources and

overall affect their weight-for-height z scores.

Livelihood zone #9: Southeast cereals, livestock, forestry, and fauna, has a negative relationship with weight-for-height z scores in children under 5 (see Figure 20). This particular livelihood zone is expected to have better health outcomes due to its diversified agriculture, favorable rainfall, and access to markets. This result was not an expected relationship because this area tends to have better overall food security and nutritional outcomes. Livelihood zone #9 is a generally a wealthier area that often produces surplus of food and goods, there is good access to markets, as well as cross-border trade with Ghana, Niger, Togo, and Benin; see Figure 20 (FEWS, 2010).

Due to the proximity to local and border markets, households from all wealth groups' benefit from access to trade and better road networks compared to the rest of the country. Additionally, this region is somewhat of a transit area where it is host to many migrant and seasonal workers (FEWA, 2010). The dependent variable, weight-for-age z

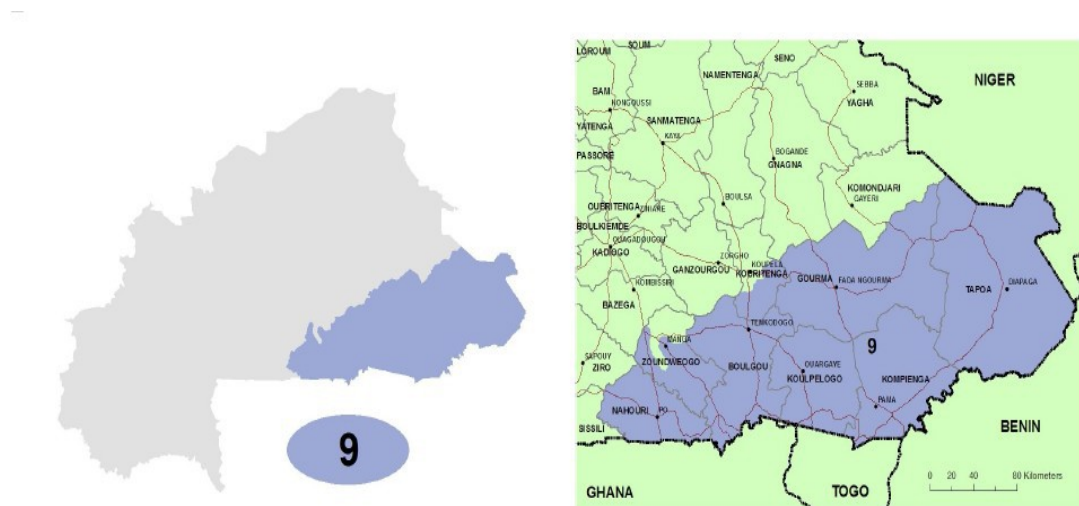


Figure 20: Map of livelihood zone #9: Southeast cereals, livestock, forestry and fauna zone (FEWS, 2010)

scores, is indicative of acute malnutrition; we can assume this result is a reflection of a temporary food shortage or raise in market prices. We can look at previous years to see the pattern of food security and causes that may be influencing weight-for-height z scores in children under 5 living in livelihood zone #9 (see Figure 21).

There may be a negative correlation present in this livelihood zone due to previous years of very poor food security from 2006-2007 and poor food security during 2007-2008. Being that weight-for-height is an indication of wasting, or acute malnutrition, this zone may be experiencing a temporary loss in food availability or accessibility. Even in times of recovery, children may be more vulnerable to even short-term loss of food and nutrients. Typically, we would expect to find this zone to have higher nutrition levels in the long run because of the diversity of its livelihood making it more resilient to hazards and food shocks.

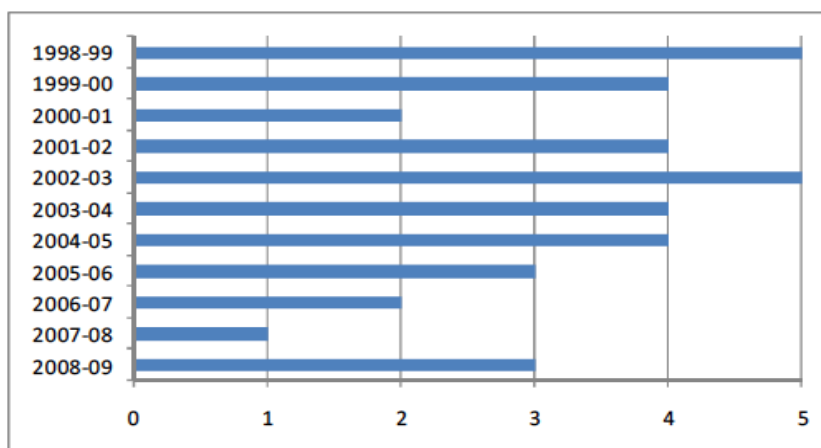


Figure 21: *Food Security Pattern 1988-2009 (1) Represents a very poor year for food security; (2) poor year; (3) an acceptable year; (4) a good year; and (5) an excellent year. This graph helps demonstrate the food security in this particular zone. The most recent below average years 2006-2008 were caused by poor distribution of rainfall and resulted in flooding and crop damage (FEWS, 2010).*

Another variable that was negatively associated with weight-for-height z scores at the 25th quantile is the sex of head of household being female. In many developing countries, a female-headed household is on average worse off than those of male-headed households (Lloyd & Desai, 1992). This result is what we would anticipate considering that female head of households may not have additional resources or time to work if they are the main caretakers for their children. Having a female-headed household can limit the amount of food available for a family, which negatively impacts the health of children under 5 and their access to resources (Lloyd & Desai, 1992).

A positive significant variable in the weight-for-height z score 25th quantile regression is child sex as female. This was the same positive relationship as in the height-for-age z score quantile regression. We can attribute this result to a potential biological phenomenon that the DHS data are not capturing. The acute malnutrition of children under 5 in Burkina Faso appears to be mostly influenced by drinking water sources and the characteristics of the household. A household with parents not living together and female-headed may limit resources for food, which is why we see acute malnutrition. Often times these household scenarios may be temporary or occur periodically. To improve acute malnutrition in Burkina Faso, efforts to maintain a two-person household could be beneficial for the health outcome of the children.

7.5 Weight-for-Height Z Score 50th Quantile

The only positive, significant relationship with weight-for-height z scores at the 50th quantile is mother's higher education. Mother's higher education is an expected result because as education level increases for mothers, children under 5 have better

health outcomes (Silva, 2005). Two negative, significant variables for weight-for-height z scores at the 50th quantile are livelihood zone #5: Central plateau cereals and market gardening and livelihood zone #8: North transhumant livestock rearing and millet (see Figure 22). These are the two most food insecure regions in Burkina Faso and is anticipated to have a negative impact of weight-for-height z scores in children under 5. Livelihood zone #5 has high population density and poor crop yields, making this region very vulnerable to food insecurity (FEWS, 2010).

Livelihood zone #8 is one of the most food insecure in the nation and has the least amount of rainfall. It is generally characterized by livestock rearing and some cultivated agriculture, mainly millet; however, lack of pasture and water makes livestock rearing difficult. Access to water for humans is also difficult in this dry region where mild drought occurs frequently.

7.6 Weight-for-Height Z Score 90th Quantile

There are three significant independent variables at the 90th quantile for weight-for-height z scores. In livelihood zone #8: North transhumant livestock rearing and millet, drinking water source as surface water and drinking water source as other all have negative effects on the weight-for-height z scores. There are no significant positive variables in the upper quantile. All three of the negative significant variables are anticipated due to the vulnerability of livelihood zone #8 and potential illnesses from drinking water sources. Livelihood zone #8 has negative impacts on weight-for-height z scores at both the 50th and 90th quantile, which indicates there may be short-term food deprivation happening in this region. Livelihood zone #5 and #9 also have negative

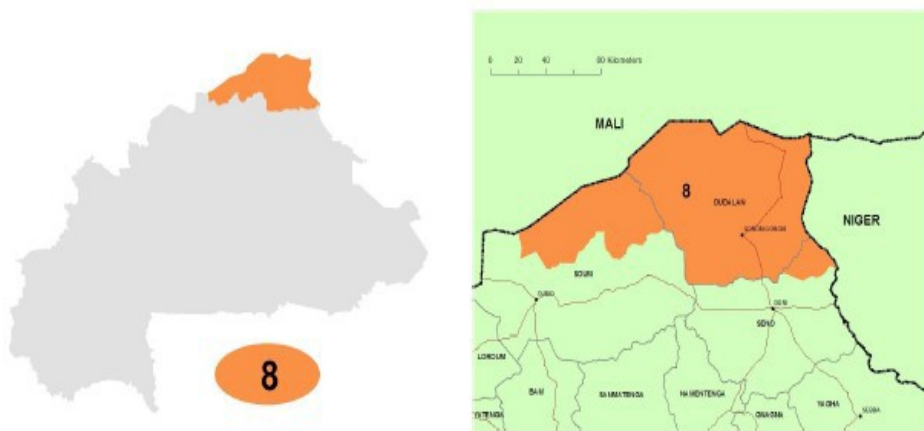


Figure 22: *Livelihood zone #8: North transhumant livestock rearing and millet (FEWS, 2010).*

impacts on weight-for-height z scores in children under five at the 50th and 25th quantile, respectively. These livelihood zones are indicating short-term food insecurity.

7.7 Weight-for-Age Z Score 25th Quantile

The weight-for-age z score quantile regression at the 25th quantile resulted in three negative variables that include sex of head of household as female, marital status as married, and residency as rural. Sex of head of household as female and rural residency is expected to have negative correlations to child anthropometric measures. The marital status as married having a negative outcome was an unanticipated results for this analysis. In addition, marital status as divorced showed a positive correlation to weight-for-age z scores, which again was an unexpected result. There is no obvious justification for these results, but it may be an indication of problems with the data. In Burkina Faso, polygamy is practiced and therefore may limit the father's contribution to his married wife since he could be providing for multiple children or families. A divorced household

may have less children to care for and therefore more available resource for their family.

7.8 Weight-for-Age Z Score 50th Quantile

There are two significant variables in the quantile regression for the weight-for-age z score at the 50th quantile that have a positive effect on weight-for-age z scores. Mother's secondary and higher education are the only variables with a positive significance. Mother's education is an expected positive relationship with all anthropometric measures. Livelihood zone #8: North transhumant livestock rearing and millet, drinking water source as surface water, and rural residency all have significant negative effects on the weight-for-age z scores. Rural residency has a negative impact across all quantiles in children under 5 weight-for-age z scores. Livelihood zone #8 is expected to have a negative impact and coincides with the results from the weight-for-height z scores. Drinking water source as surface water is another reoccurring negative variable that appears in all three anthropometric measures.

7.9 Weight-for-Age Z Score 90th Quantile

There are five significant variables in the quantile regression for the weight-for-age z score at the 90th quantile: mothers secondary education, livelihood zone #2: South-west fruits, cotton, and cereals (see Figure 23), drinking water source as tube well water, drinking water source as surface water, and rural residency. Mother's secondary education and livelihood zone #2 are the only two significant variables with a positive effect on the weight-for-age z scores at the 90th quantile. Livelihood zone #2 is dependent upon rain-fed cultivation but maintains a general food secure population, so it can be

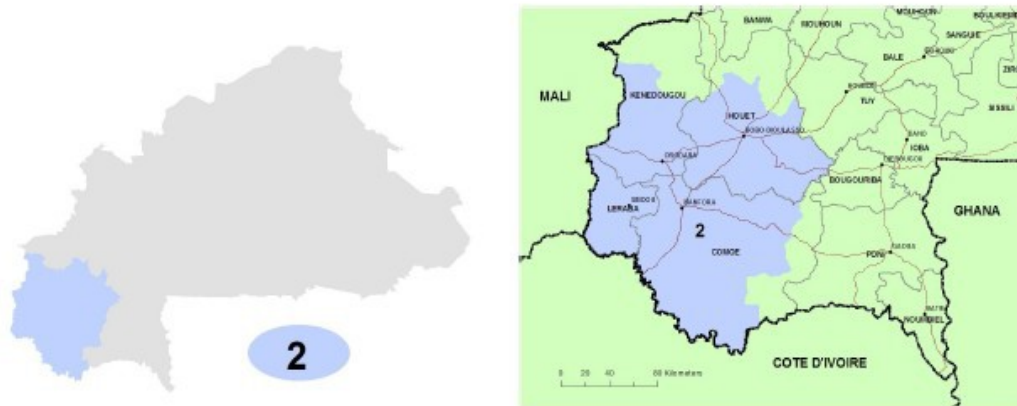


Figure 23: *Livelihood zone #2: South-west fruits, cotton, and cereals (FEWS, 2010)*

expected that it has a positive relationship with the upper quantile of weight-for-age z scores (FEWS, 2010). Drinking water sources as tube well water and surface water both have a negative effect on the dependent variable. Rural residency is also a significant negative independent variable in the weight-for-age z score at the 90th quantile.

The results for the quantile regression shed light on both the driving factors leading to acute and chronic child malnutrition and the factors that can reduce negative health outcomes in Burkina Faso. We can use the results to make better-informed decisions on how to reduce food insecurity and child malnutrition. Policy that focuses on increasing formal education for mothers in Burkina Faso can greatly affect the health outcomes for children under 5. Mothers that acquire higher education tend to have healthier children, increase access to resources, and are more knowledgeable when it comes to making health care decisions. Other ways to make a positive contribution to child malnutrition in Burkina Faso is to increase access to safe and sanitary drinking water. Many water-borne illnesses have a significant impact on vulnerable children under 5 health outcomes. Additionally, policy and projects promoting two-parent

households can help increase children's access to resources and make them more resilient to food insecurity. Single-parent, female-headed households tend to have a negative impact on child health outcomes.

Further research is needed in order to understand and better explain the sex difference in children under 5 health outcomes. Male children under 5 have a slight disadvantage in height-for-age z scores and weight-for-height z scores in Burkina Faso. Other studies have also concluded this same result when all behavioral variables indicate no difference between male and female children indicating a probable biological causality. The scope of this study does not cover investigating the health differences between male and female children, but it is something that should be addressed and investigated in future research involving child malnutrition. We can conclude that female children under 5 in Burkina Faso tend to be more resilient to negative health impacts and show better growth rates compared to their male counterparts.

8. CONCLUSION

In this study, resilience to food insecurity in Burkina Faso was analyzed through child anthropometric measures using a livelihood framework. By assessing child malnutrition rates in a food insecure region, we can isolate the livelihood zones that are more resilient and identify variables that are most significant in those areas.

Understanding what makes one livelihood zone more resilient to food insecurity compared to others, we can apply more effective means of reducing food security and child malnutrition. A mitigation effort designed around creating more resilient households has the potential of reducing food insecurity in both the short and long term. Mother's education frequently appeared as a positive result across the height-for-age, weight-for-height, and weight-for-age z score quantile regressions. This finding is significant among all anthropometric measures and throughout the varying quantile levels (25th, 50th, and 90th). Policy focusing on increasing women's access to higher education may have a large impact on improving child malnutrition and household food insecurity in Burkina Faso. Education provides not only useful knowledge about vaccines and nutrition, but it is also a way to increase potential resources and job opportunities. Households with educated mothers will be more resilient than those without any education. Other findings from the quantile regression include impacts from different livelihood zones.

The livelihood zones that positively effect height-for-age, weight-for-height, and

weight-for-age z scores are livelihood zone #2: South-west fruits, cotton, and cereals and livelihood zone #5: Central plateau cereals and market gardening. The positive relationship with livelihood zone #5 is only present in children under 5 with the greatest height-for-age z scores, at the 90th quantile. This may be indicating a large health disparity because this livelihood zone also shares a negative relationship at the 50th quantile for weight-for-height z scores. Livelihood zone #5 may be facing acute food insecurity, leaving only a small portion of the population, the 90th quantile, resilient. Adopting practices from these livelihoods may help increase resiliency in other zones across Burkina Faso. By diversifying practices, the chances of sustaining and building resiliency increases. The livelihood zones that have a negative impact on children under 5 anthropometric measures are zone #8: North transhumant livestock rearing and millet, zone #5: Central plateau cereals and market gardening, and zone #9: Southeast cereals, livestock, forestry, and fauna. These zones may face more severe food insecurity and should be the focus for mitigation efforts and policy aimed at decreasing child malnutrition rates and food insecurity.

Source of drinking water is another significant finding in this study and has both positive and negative relationships with children under 5 height-for-age, weight-for-height, and weight-for-age z scores. Policy that aims at improving drinking water can have a significant impact on increasing the resiliency of households in Burkina Faso. Projects that provide safe and clean drinking water can have a large impact on child malnutrition. Identifying the healthy sources of drinking water is essential and future research should focus on classifying specific water sources. Another result that needs further research would be the child sex as female. This is a confounding result and

suggests a biological response rather than a behavioral one. Research that focuses on the role of sex in child malnutrition could help explain why female children are less likely to have low height-for-age, weight-for-height, or weight-for-age z scores. Burkina Faso is a country facing many challenges, but as it continues to develop, and grow in population, eradicating hunger and poverty will be an important issue to tackle. This study is just the first step in analyzing the dynamics of food insecurity in developing countries. Every country faces unique circumstances, so this study should only be conclusive for this particular country. However, applying the method of quantile regression may be a useful tool in research surrounding food insecurity in developing nations. This method is more definitive in its analysis on particular portions of the population as compared to a standard linear regression that focuses solely on the mean of the distribution. By looking at a subset of the population, we can better direct and allocate resources to the most vulnerable. As we develop a better understanding of resiliency, it will become an important factor in helping communities facing food insecurity.

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