Geographic Targeting of Risk Zones for Childhood Stunting and Related Health Outcomes in Burkina Faso

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Abstract

Several studies seeking alternative intervention strategies for chronic food insecurity in food-poor nations now advocate the simultaneous evaluation of multiple causative agents to identify and monitor at-risk populations. This study attempted to do so using a three-tiered conceptual framework that expressed childhood nutritional health outcomes as a function of basic, underlying and immediate causes that are manifested at the regional/community level, the household level and the personal level. Focusing on stunting (short stature) as a direct cumulative indicator of food insecurity, the geographic patterns of this nutritional health outcome were mapped using empirical data from Burkina Faso. The spatial analysis revealed several isolated pockets of at-risk populations. Further analysis using logistic regression methods revealed significant disparities in childhood vulnerability based on factors such as urbanization, geographic accessibility, poverty, maternal education and occupation, environmental health, and age, gender and dietary intake of the child. Contrary to research expectations, there were no observed relationships between childhood nutritional health outcomes and the biophysical characteristics of the communities. The odds ratios of stunting in the marginal areas with harsh environmental conditions were comparable to those observed in the wetter, crop-intensive regions. Overall, the findings underscore the need for broadening the scope of research beyond physical environmental conditions to include more socio-economic and anthropogenic factors that result in long-term effects of food insecurity, particularly among young children.

Introduction

The dramatic transformation in agricultural practices over the last four decades, coupled with increasing restructuring of agricultural systems worldwide, has resulted in higher food produc-

tivity and greater self-sufficiency among residents in several countries. Despite these developments, roughly 15% of the world's population still suffers from persistent hunger and malnutrition (Food and Agricultural Organization of the United Nations [FAO] 2002). These conditions are particularly disturbing in sub-Saharan Africa, where about a third of the population is believed to be malnourished, including 31 million children under the age of five (Rukuni 2002). This region has shown the smallest improvement in the average daily per capita calorie consumption and statistical forecasts now point toward a grim outlook with a projected 44% rise in nutritional deficiencies within the next decade (Shapouri and Rosen 1999).

Chronic food insecurity conditions compromise the well-being of the population, and those at greatest risk of suffering irreparable health consequences are the young children. Nutritionally deprived children are vulnerable to cognitive and developmental impairments including lower intelligence, poor academic functioning, stunting (short stature), wasting and a diminished capacity for work in adulthood (Frongillo et al. 1997; Olson 1999; Weinreb et al. 2002).

In the quest for new approaches to deal with these concerns, researchers and policy makers alike are now exploring alternative strategies to expand the role of preventive and early warning mechanisms to help identify at-risk populations and regions. For example, in a recently published article on world hunger and food insecurity, Struble and Aomari (2003) argued that simplistic solutions such as short-term food aid, limiting population growth or increasing agricultural productivity are no longer adequate measures for dealing with these conditions. Rather, they called for broader, more integrative, approaches that embrace many issues, including food access, promoting healthy diets and lifestyles, improving environmental health, incorporating nutritional objectives into development policies, and assessing, analyzing and monitoring at-risk populations. Similar suggestions have underscored the need for the simultaneous assessment of multiple causes so that synergies between these factors can be obtained and new approaches developed to assist the vulnerable groups (Frankenberger 1996; Frongillo et al. 1997).

A variety of analytical tools and information systems are also now emerging to assist in data integration, analysis and surveillance of food insecurity conditions at different spatial scales. Measures of food productivity and stock levels, food prices, accessibility, biophysical attributes of communities and the socio-economic, health and nutritional status of individuals and households are now being collected and analyzed systematically using geo-statistical methods (Parris et al. 2002; Wiebe et al.1998; Curtis and Hossain 1998). Poverty maps using small-area estimation techniques are also being developed based on the integration of multiple data sources (FAO 2003). All of these applications allow for the spatial characterization of vulnerable population groups and the joint evaluation of several risk factors that account for these conditions. In concert with these efforts, this paper will discuss the multi-dimensional causes of food insecurity conditions, analyze the relationships between food insufficiency and nutritional health outcomes among children, and identify the demographic, socio-economic and environmental correlates of these conditions. Emphasis is placed on the proximate and immediate causes of childhood malnutrition. Empirical evidence is drawn from data generated in Burkina Faso, West Africa. Three questions, posed at the beginning of the study, are addressed: (1) How is food insecurity manifested at different spatial scales in Burkina Faso? Does it follow a rural-urban dichotomy, an agro-ecological dimension or political subdivision of the country? (2) What are the long-term nutritional health consequences of food-insecure conditions on young children, and can these health outcomes be analyzed spatially to identify and monitor the high-risk areas? (3) What are the linkages between the childhood health outcomes and the bio-physical characteristics of the communities, transportation infrastructure, the socio-economic attributes of the households, maternal characteristics and access to health services?

The paper is organized into five sections. The first provides an overview of food insecurity conditions and health implications for young children, based on documented evidence from food-poor as well as food-rich nations. The causative factors of food insecurity and nutritional outcomes are also discussed within the context of a causal framework. The second section describes the study area, Burkina Faso, highlighting the regional characteristics and the specific challenges facing residents in

the country. The research design and analytical methods are then described, followed by a presentation of the results. The paper concludes with a summary of pertinent findings and research implications.

Food Insecurity Conditions and Childhood Vulnerability: An Overview

Following the initial definition proposed by the World Bank (1986), multiple characterizations of food security/insecurity have emerged over the last two decades, several of which focus on key dimensions such as food availability, entitlement, access, safety and security. Food insecurity conditions are said to exist when individuals or households lack access to nutritionally adequate foods (in terms of quality, quantity, safety and culturally acceptability), or their ability to obtain these foods is limited, at risk or uncertain (Saad 1999; Frongillo 1999; Smith et al. 2000; Nnakwe and Yegammia 2002). More recently, others have suggested a more comprehensive operationalization of food insecurity that extends beyond the nutritional needs of individuals to include additional items such as (i) the livelihoods of various population groups, (ii) their perceptions, coping mechanisms and responses to recurrent hazards, as well as the trade-offs made between acquiring food versus other basic necessities such as healthcare, education, housing, or selling off livestock and other productive assets and (iii) the degree of vulnerability associated with those conditions (Maxwell et al. 1999; Goldberg and Frongillo 2001).

For studies evaluating differential levels of vulnerability, the consensus has been that children are among the most susceptible population group, as well as older adults, and pregnant and lactating women. This conclusion has been noted in both food-rich nations such as the United States and in developing countries undergoing chronic conditions of food insecurity (Nnakwe and Yegammia 2002; Olson 1999). Among children in developing countries, anthropometric indicators such as stunting and wasting have been identified as the most direct nutritional consequences of food insecurity (Campbell 1991, WHO 1995). Children undergoing long-term nutritional deficiencies are vulnerable to growth retardation, stunting and impaired physical development. While these indicators reflect the visible outcomes of childhood malnutrition, there are other less discernible yet deleterious effects of undernutrition on children. Specifically, inadequate nutrition and poor feeding patterns affect the cognitive functioning of children, limiting their ability to concentrate and perform complex tasks. The most direct link between undernutrition and childhood cognition has been established through iron-deficiency anemia, a prevalent nutritional disorder that influences the child's attention span, memory and overall ability to learn (Skalicky et al. 2000).

Nutritionally deprived children are also more likely to suffer from chronic illnesses. Weinreb et al. (2002) investigated the independent contribution of hunger on the health of preschool and school-aged children. Their results confirmed that severe hunger was indeed a significant predictor of chronic illnesses even after controlling for low birth weight, the life events of the child and other extraneous factors. Malnutrition is now considered the leading indicator of childhood mortality in food-poor countries and explains why one in seven children in these countries is likely to die before reaching the age of five (FAO 2002).

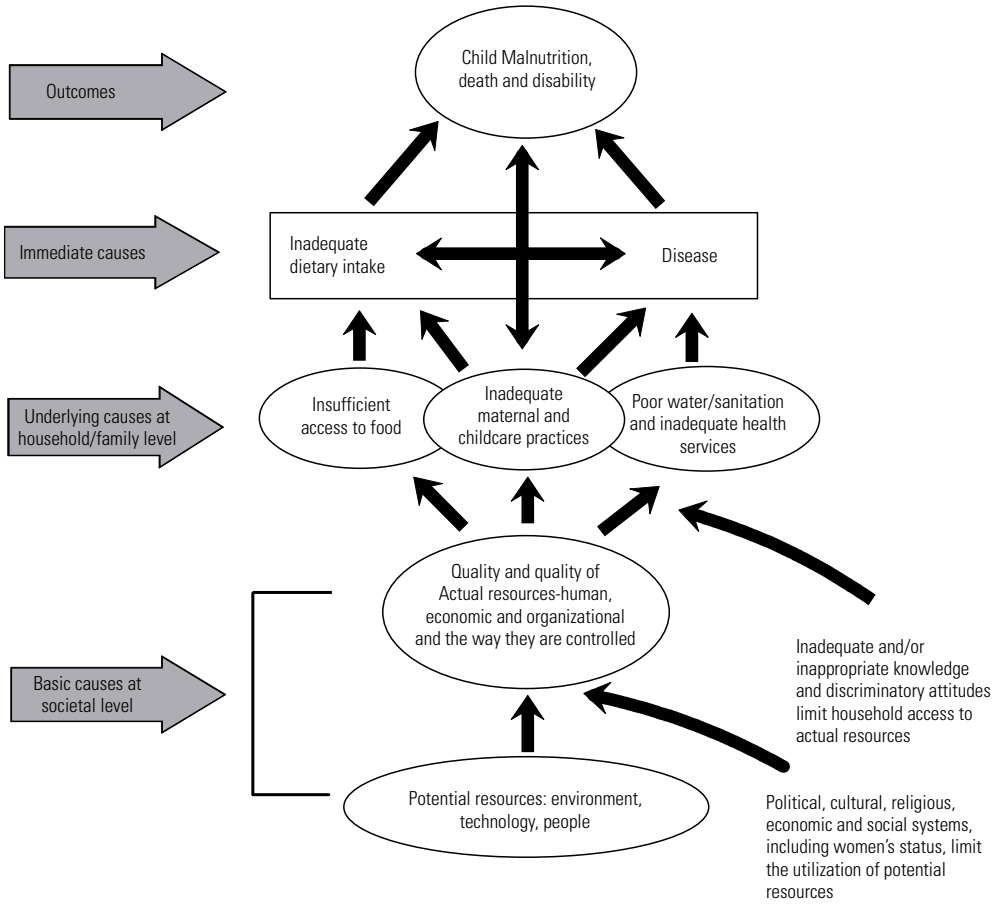
Additional evidence from international agencies points toward the increased susceptibility of nutritionally deprived children to common infectious and potentially fatal diseases such as malaria, acute respiratory illness and measles. These conditions are further complicated by the fact that sick children are more likely to have poor appetites and therefore consume less food, leaving them with fewer nutrients required for their cognitive and physical development (Smith et al. 2000).

Multiple Causes of Childhood Malnutrition

Extensive research on food insecurity confirms the multifactorial nature of the problem, particularly in sub-Saharan Africa (Curtis and Hossain 1998; Goldberg and Frongillo 2001; Girma and Genebo 2002; FAO 2002, 2003). Food insecurity conditions are triggered, and in some instances exacerbated, by events at different spatial scales including the household, community, regional, national and international levels (Smith et al. 2000). Figure 1 provides a conceptual framework that illustrates the causative linkages and contributory role of these factors in explaining the nutritional

status and health of children. This framework is based on the original proposition by the United Nations Children's Fund (UNICEF 1990) and subsequent modification by others (Jonsson 1995; Frongillo et al. 1997). The framework integrates several components of childhood malnutrition that range from large-scale factors such as the physical/environmental characteristics of a region and the economic/political systems to more specific characteristics of the child. Childhood food insecurity and the corresponding health outcomes are presented as endpoints resulting from the complex interplay between three types of determinants that are immediate, underlying or basic in nature. The immediate causes are associated with the individual child's nutrition and health which, as discussed in the preceding section, are the direct determinants of stunting, wasting, cognitive impairments and possibly death. Additional risk factors associated with the individual child include the birth weight, age, birth order and birth interval, all shown to be positively associated with malnutrition and related health outcomes (Girma and Genebo 2002; Garret and Ruel 1999).

Figure 1. Determinants of childhood malnutrition and associated health outcomes



Source: UNICEF, 1990

The immediate causes of childhood malnutrition result from three major underlying causes manifested at the household level: insufficient access to food, unsanitary household environments and poor caregiving practices. The latter, including the various ways in which the children are fed,

nurtured and raised in households, are particularly vital for their nutritional well-being. Further, the role of caregiving extends well beyond the mother to include the entire family, household and community within which the children reside. As documented by UNICEF (1990), both mothers and children require the care and support from their families, households and communities such that communities where mothers are well supported, educated and cared for often translate into better caregiving environments for the children. The health status of the mother, using a basic anthropometric measure such as the body mass index (BMI), is therefore a useful proxy of a child's nutritional status. Surveys conducted in developing countries have shown that undernourished mothers with a BMI below 18.5 are more likely to earn lower wages in jobs involving physical labour and consequently face greater threats to household food insecurity (FAO 2002). Other studies have found a consistently positive relationship between the mother's BMI and household food insecurity, even after controlling for variables such as employment status and income levels (Olson 1999). Additional attributes of the mother that are useful in evaluating childhood malnutrition include educational attainment, age, employment and marital status. Specifically, healthy mothers with moderate to high educational attainment, good occupational status and with equal or greater control over the household income and decision making are more likely to have nutritionally healthy children. With respect to age, some researchers have found that mothers in the youngest age group (15–19 years) and oldest age category (45–49 years) are more likely to be food insecure. Marital status has also been shown to influence household food insecurity, with more vulnerable conditions found among unmarried rural and divorced/separated urban women (Girma and Genebo 2002).

Other characteristics of the household that influence the nutritional and physical well-being of the child include access to health services and the hygienic state of the household in which the child resides. Limited access to healthcare facilities, the failure to immunize the child and the presence of unsanitary household conditions elevate childhood susceptibility to infectious diseases and indirectly influence children's nutritional and physical well-being (Girma and Genebo 2002).

Finally, at a broader level of conceptualization, the underlying factors are a function of several basic causes of food insecurity (Figure 1). These basic causes are manifested at larger spatial scales with variability at the community, regional or national levels. The regional or political subdivision of communities, the presence of environmental hazards (droughts, land degradation, floods, pests), economic/developmental challenges (trade imbalances, currency devaluations, market failures), structural adjustment policies, poor transportation networks, and armed conflicts (rebel incursions, civil strife, wars) have all been identified as the basic causes of food insecurity in different parts of sub-Saharan Africa. These conditions have been compounded recently by the HIV/AIDS epidemic that has devastated the workforce, leaving behind a less productive population of old adults and orphaned children.

To summarize, Figure 1 provides a comprehensive three-tiered framework for understanding food insecurity and the nutritional health outcomes among children. A crucial step toward evaluating these conditions requires an appropriate mix of geospatial data, analytical tools and strategies that will enable the simultaneous assessment of these variable sets to identify areas with vulnerable population groups. The rest of the paper attempts to do so using data from Burkina Faso. Emphasis is placed on evaluating the underlying and basic circumstances leading to food insecurity, including the maternal and household characteristics, the physical and infrastructural characteristics of the communities, and how these conditions affect the nutritional and physical state of young children, the most susceptible population group.

The Study Area

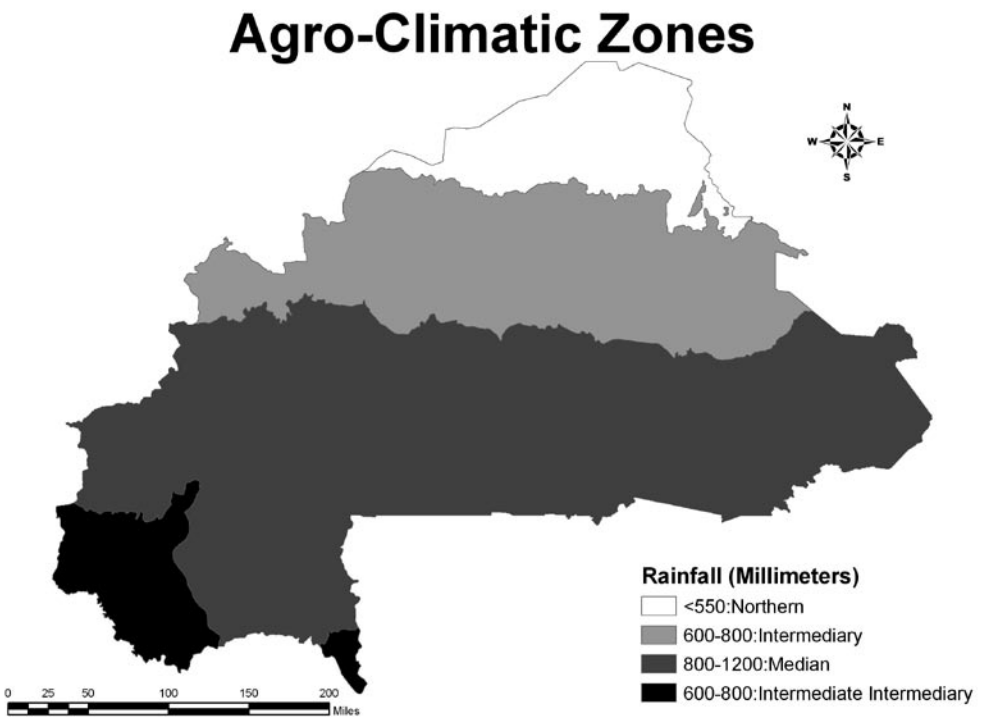
Burkina Faso, West Africa, is a classic example of a country where food insecurity conditions are multifactorial and must therefore be understood within these varied contexts, including: (i) its landlocked location with limited infrastructure and accessibility to external markets, (ii) a multi-ethnic society characterized by diverse groups, with distinct livelihood strategies and behavioral adaptations in different ecological zones, (iii) the prevalence of recurring hazards in a marginal environment and

(iv) a turbulent political past and ongoing struggle to establish a democratic state.

Burkina Faso gained independence in 1960, along with a political economy that never fully recovered from the deliberate colonial policies of underdevelopment. The country has since struggled to establish a democratic state as it flip-flops continually between military and civilian governments. Its economy has been regarded as one of the world's poorest, suffering from currency devaluation, market failures and other destabilizing forces. In 2003, the country was ranked 173rd of 175 countries in the Human Development report (United Nations Development Program 2003). More than 45% of the population live below the poverty line and most residents are highly food insecure. These conditions have worsened in recent years due to the political conflict in Cote D'Ivoire, forcing migrant workers to return home as well as limiting the export of livestock, the second major source of external revenue for residents.

Beyond the economic and political challenges, Burkina Faso is also known for its myriad environmental hazards, exacerbated by its proximity to the Sahara Desert. There are four agro-climatic zones with varying amounts of rainfall and soil quality, particularly in the northern and eastern regions (Figure 2). The most recurring hazards are drought conditions and locust attacks, both of which limit agricultural productivity. Burkinabes, though, have found ways to adjust to these environmental conditions and the challenges they present. Goldberg and Frongillo's (2001) study confirmed a significant diversification of labour and resources within the various productive zones. Residents are pastoralists (raising and herding livestock) and farmers, but most are also involved in a number of off-farm activities to supplement their income. These include seasonal employment in urban areas, small-scale fishing, petty trading, craft making and tanneries using leather and animal skins.

Figure 2. Agro-climatic zones in Burkina Faso



Source:Office de la Recherche Scientifique et Technique Outmer et Ministere de la Cooperation, 1976; Rebublique de Haute-Volta Ressources en Sols

Demographic indicators reflect a population growing rapidly, at a rate of about 3%. With a total population of about 12.3 million, about 50% of the people belong to the Mossi group and the rest are members of less dominant groups such as the Gurunsi, Senufo, Lobi, Bobo, Mande and Fulani. Of notable significance to this research is the fact that roughly half of the country's residents (49%) are children below 15 years of age. A nutritional profile of the country recently submitted by the FAO (2004) showed a persistent trend with childhood malnutrition rates still higher than the maximum acceptable standards set by the World Health Organization (WHO). Childhood food insecurity is threatened further by the increasing prevalence of HIV/AIDS, which has resulted in about 260,000 orphans (0–17 years). A recent report by the United Nations concluded that HIV/AIDS has impacted Burkina Faso more than any other country in West Africa with the exception of Cote D'Ivoire. About 300,000 adults and children are now living with the disease, with an adult prevalence rate of 4.2% (UNAIDS 2004). These conditions are expected to have severe long-term consequences on the children and the economic viability of the nation as a whole.

Data Sources and Methods

Three major sources of data were used in this study. First, the food balance sheets including per capita food production, non-food crop production, and general population statistics were derived from the United Nations Food and Agricultural Organization's database. Second, digital–spatial data layers at different scales were secured from the African Data Dissemination Service, which had earlier compiled this information from four sources: United States Geological Service (USGS), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and Chemonics International Inc. The data included transportation infrastructure, cropland use intensity, agro-climatic conditions and administrative boundary files at four levels. Figure 3 illustrates the administrative subdivisions at the provincial level. All metadata for these layers were secured from their original sources.

The third data set was generated from the Demographic and Housing Survey III (DHS). DHS is a nationally representative survey administered to residents in several countries worldwide. The program has been in operation since 1984 and is carried out by Macro International with funding from USAID (U.S. Agency for International Development). A two-stage random sampling approach is used in these surveys. Initial sampling is based on a cluster design in which homogeneous geographical areas (clusters) are first selected within administrative subdivisions (Figure 3). Households or individuals are then selected within the clusters as the ultimate sampling units. Surveys are administered using two instruments: a household questionnaire and an individual questionnaire for women of reproductive age (15–49 years).

Data used in this study were from the childhood-based file generated from the individual questionnaire administered to women of reproductive age in 1999. The data consisted of nearly 6000 records of children, their health and nutritional status, the maternal characteristics including reproductive histories, and the socio-economic and hygienic characteristics of the households. The data were preprocessed extensively, including the reclassification and creation of new variables for use in subsequent analysis. Following is a brief description of the preliminary steps taken to process the data.

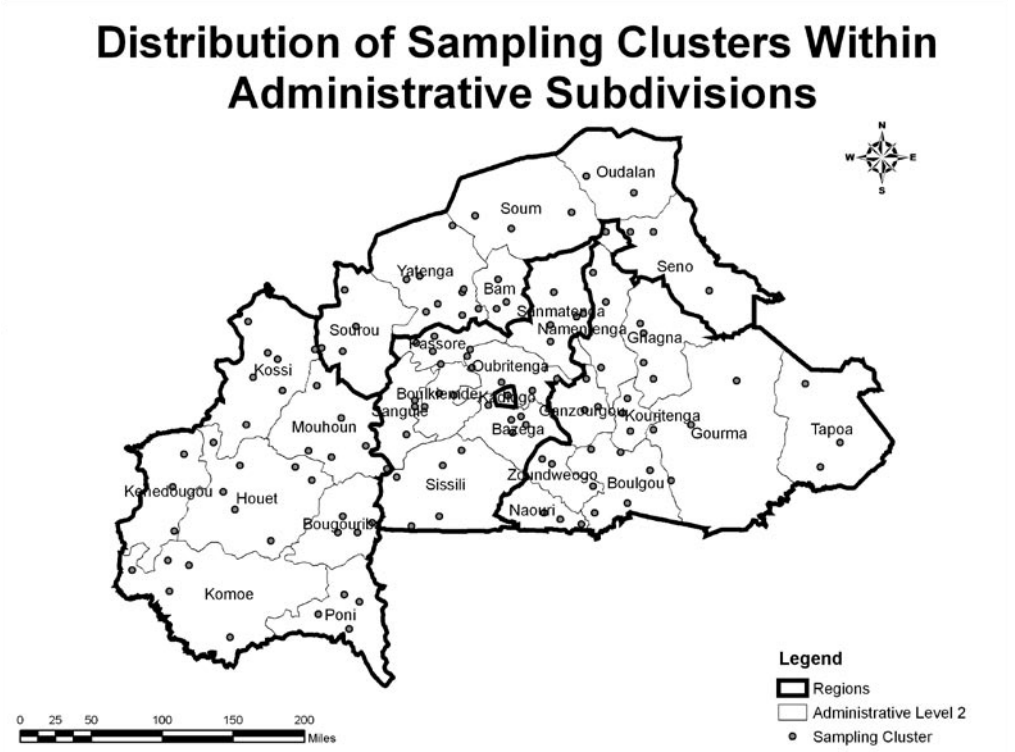
Preprocessing and Integration of Data

The major analytical objective, as indicated earlier, was to embark on a simultaneous evaluation of the proximal factors that best explain the spatial distribution of childhood nutritional health outcomes. To accomplish this, DHS data were first queried to remove all children under three months of age, since the weight and other anthropometric measures of these children are influenced largely by prenatal conditions and maternal risk factors. The remaining childhood data file, consisting of 4673 records, was used to evaluate the nutritional outcomes.

Earlier studies had identified stunting, wasting and underweight characteristics of children as three anthropometric indicators that reflect the direct consequences of food insecurity (Campbell 1991). This study focused on stunting, an indicator of the long-term cumulative effects of food

insecurity in which the child's height-for-age is below two standard deviations of the median height-for-age of the standard reference population (WHO 1995). Using this classification, a binary variable was created for stunting by assigning a value of 1 to all cases in which the nutritional health outcome of stunting was evident and a value of zero to those in which the outcome was absent.

Figure 3. Data sampling clusters

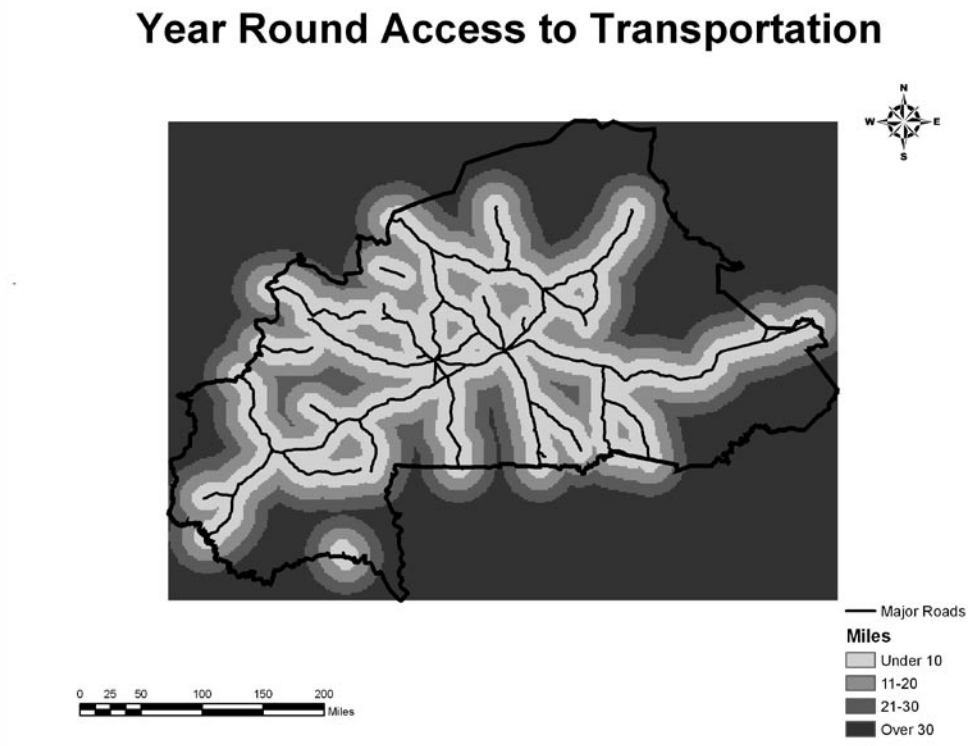


Additional variables deemed relevant to the analysis were also secured from the DHS survey. The age, gender and current nutritional and health status of each child were garnered. Maternal attributes including educational achievement, age, marital status, occupation and BMI were also secured. Among the household and community characteristics, the regional location (administrative subdivision), type of residence (rural/urban) and the total number of kids under five years were integrated into the data file. Using an approach previously proposed by Curtis and Hossain (1998), a proxy index of socio-economic status was calculated based on whether the child's residence was equipped with eight different amenities (electricity, radio, refrigerator, bike, motor bike, car and a modern floor). The index, ranging from 0 to 8, was used to categorize the households into three socio-economic groups: low income with 0–2 amenities, middle income with 3–5 amenities, and high income households with 6–8 amenities. The environmental health attributes were based on two proxies: household access to drinking water and the type of toilet facilities.

Finally, three spatially referenced files representing transportation infrastructure, agro-climatic conditions and cropland use patterns were integrated into the analysis. Using the transportation infrastructure, geographic accessibility of each household within a cluster sampling unit was assessed. First, a query was performed to identify all the primary and secondary roads with year-round access. Seasonal roads were excluded from the analysis. Next, the distance analysis function in ArcGIS

(a Geographic Information Systems software) was performed and the results categorized based on proximity to these major roads. As shown in Figure 4, the least accessible areas are in the far north and east of the country where some communities are 40 to 60 miles away from major road networks. As expected, Ouagadougou and the surrounding central region are the most connected areas. There also appears to be a slight western orientation in the transportation network, which is not surprising given the historical legacy of the colonial era. Year round access to these transportation lines is deemed relevant for the swift and efficient delivery of resources to various parts of the country. More importantly, the major roads increase the range of access to various food sources, thereby decreasing group vulnerability to food insecurity. Therefore, communities or households within a proximal distance to these major transportation lines are more likely to be food secure than others. The distance of each household from the major roads was computed and integrated into the childhood-based file for subsequent analysis.

Figure 4. Year round transportation access



The staple diet in Burkina Faso is cereal based, so household food security must be evaluated using factors that influence the production of cereals, notably millet, sorghum, maize and rice (FAO 2004). In this study, a decision was made to use the agro-climatic conditions, identified earlier in Figure 2, with each zone reflecting the biophysical conditions conducive to cereal production in varying parts of the country. The intensity of cropland use was also integrated into the statistical analysis. There is limited crop productivity in the drier northern parts of the country where residents have far less favourable conditions for growing cereals than those in the wetter regions in the central and western parts of the country. The eastern region also has constraints for crop productivity due to poor soil conditions. Children residing in these areas are expected to be more susceptible to food insecurity than their counterparts in the central and western regions. Data values from these files

were added to the childhood-based file by first performing spatial queries using the cluster-based identification number of each childhood residence. The final comprehensive database consisted of several data layers for use in mapping and statistical validation to discern the spatial characteristics of childhood nutritional heath outcomes in Burkina Faso.

Investigating the Geographical Distribution of Childhood Stunting

Based on the sample data and the WHO guidelines mentioned earlier, the prevalence rate of stunting at the national level in Burkina Faso is approximately 28% for children under five years. However, this national rate camouflages the significant disparities in stunting levels observed across the country. These patterns are best seen in Figure 5, which portrays the regional variability in childhood stunting, with several isolated pockets of high-risk areas. The map was derived using the ordinary kriging algorithm in the Geostatistical Analyst extension of ArcGIS. Kriging was used to evaluate the spatial prevalence of stunting, based on local weighted averaging (Kleinschmidt et al. 2000). Specifically, using the sample data gathered across the country, the estimated prevalence rate of stunting denoted as $\hat{Z}$, at any given location with coordinates (X_o and Y_o), was calculated as follows:

$$\hat{Z}(X_o, Y_o) = \sum_{i=1}^{n} \lambda i \, Z_{obs}(X_i, Y_i)$$

where, Z_{obs} refers to sampled data values obtained at *n* nearest locations (X_1, Y_1), (X_2, Y_2), and … (X_n, Y_n). The associated weights (λi) in the analysis were based on a variogram that captures the degree of spatial dependence or autocorrelation between the observed measurements. Kriging was selected because of its notable strength in producing the best linear unbiased estimates with known minimum variances. It is beyond the scope of this paper to provide a full description of this technique and its advantages in the geospatial modelling of disease risks. More detailed descriptions of the technique can be found in Cressie (1993), Oliver and Webster (1990), Goovaerts (1997) and several other applications.

Figure 5. Kriged risk zones for childhood stunting

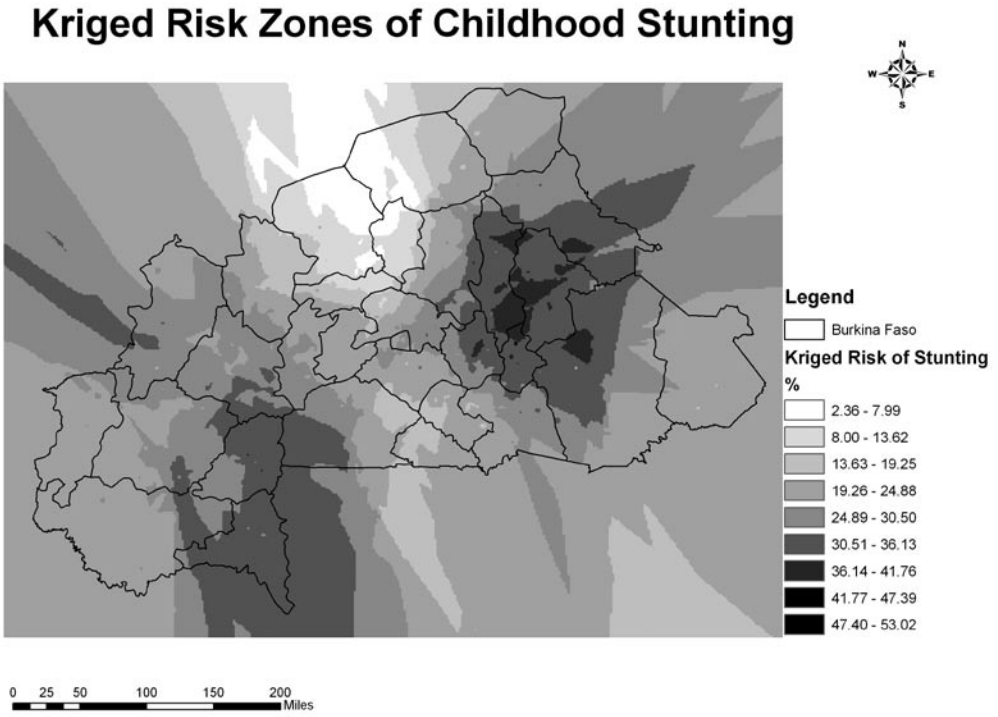


Figure 5 shows the kriged risk zones that reflect spatial variability in childhood stunting. Generally, the highest incidences are found in the eastern quadrant, especially in communities in Gnagna, Nametenga, Seno and Kouritenga where the levels of stunting appear to exceed 40%. High-risk groups are also observed in the south in the provinces of Poni and Bougouriba and in the western province of Kossi. Stunting levels found in the capital city region, Ouagadougou, in the centre north around Bam, and in some western provinces such as Kenedougou are below the observed national rates.

The final analytical step in this study involved the use of two complementary statistical methods to help explain the observed spatial differences in stunting levels as a function of the three groups of determinants cited earlier. First, a chi-square test was performed to evaluate the bivariate relationships between stunting and the basic, underlying and immediate factors (Tables 1 to 3). Next, a logistic regression analysis was performed to determine the differential levels of risks of stunting among the children. The statistical results based on the odds ratios [*EXP(B)*], the 95% lower and upper confidence bands, and the level of significance of the Wald Statistic are summarized in Table 4. For variables that are statistically significant ($p < .05$), the children in categories with odds ratios greater than 1 are considered to be at significantly greater risk of stunting than those children within the reference category. Following is a more detailed discussion of the statistical results.

Table 1. Basic causes of stunting: Unweighted percent distribution among categorical independent variables

Community Characteristics	n (%)	%Stunted Observed	X^2	Sig.
Major Administrative Regions			26.15	.001***
North	326 (7.0)	26.1%		
East	968 (20.7)	33.5%		
Central/South	1086 (23.3)	28.9%		
West	1568 (33.6)	27.0%		
Ouagadougou	722 (15.5)	22.7%		
Place of Residence			20.67	.001***
Rural	3900 (83.5)	29.4%		
Urban	773 (16.5)	21.3%		
Crop Land Use Intensity			.886	.829
50-70%	206 (4.4)	28.2%		
30-50%	2020 (43.2)	28.0%		
5-20%	567 (12.1)	29.6%		
0-5%	1880 (40.2)	27.6%		
Agro-Climatic Regions			5.19	.158
Northern	107 (2.3)	29.0%		
Intermediary	929 (19.9)	29.1%		
Median	3114 (66.6)	28.4%		
Inter-Intermediary	523 (11.2)	23.9%		
Proximity to Roads with Year-round Access			25.95	.001***
Within 10 miles	3549 (75.9)	27.2%		
11 to 20 miles	650 (13.9)	30.8%		
21 to 30 miles	304 (6.5)	28.9%		
31 to 40 miles	70 (1.5)	41.4%		
41 to 50 miles	74 (1.6)	40.5%		
51 to 60 miles	26 (0.6)			

*** Highly Significant at 0.001; ** Significant at 0.05; * Marginally Significant at 0.1; Unmarked Not Significant

Table 2. Underlying causes of stunting: Unweighted percent distribution among categorical independent variables

	n (%)	%Stunted Observed	X^2	Sig.
Household Characteristics				
Socioeconomic Status			26.25	.001***
Low	3066 (65.6)	29.2%		
Middle	1436 (30.3)	27.7%		
High	171 (3.7)	11.1%		
Children under 5 years in Household			4.93	0.085*
1-5 children	2675 (57.2)	27.3%		
6-10 children	1750 (37.4)	28.3%		
More than 10 children	248 (5.3)	33.9%		
Environmental Health Status				
Source of Drinking Water				
Piped or Bottled	643 (13.8)	20.5%	20.92	.001***
Other	4030 (86.4)	29.3%		
Type of Sewage facility			9.338	.009***
Toilet	25 (0.5)	12%		
Latrine	1062 (22.7)	25.4%		
No Facility	3425 (73.3)	29.3%		
Maternal Characteristics				
Education			26.29	.001***
None	4146 (88.7)	29.0%		
Some	393 (8.4)	24.7%		
High School and higher	134 (2.9)	9.7%		
Body Mass Index			3.862	0.145
Underweight (Under 18.5)	656 (14.0)	26.7%		
Normal (18.5 to 29.5)	3666 (78.5)	28.7%		
Overweight(Over 29.5)	351 (7.5)	24.2%		
Marital Status			7.549	.001***
Married	4275 (91.5)	28.4%		
Living Together	273 (5.8)	25.3%		
Widowed	51 (1.1)	17.6%		
Divorced/Not Living Together	36 (0.8)	13.9%		
Never Married	38 (0.8)	31.6%		
Occupation			28.06	.001***
Not Working	883 (18.9)	25.3%		
Prof., Tech., Manag.,	32 (0.7)	3.1%		
Sales	1496 (32.0)	28.5%		
Agri-Self employed	1822 (39.1)	30.4%		
Services	36 (0.8)	11.1%		
Manual	293 (8.4)	25.4%		

*** Highly Significant at 0.001; ** Significant at 0.05; * Marginally Significant at 0.1; Unmarked Not Significant

Basic Causes of Childhood Stunting

Table 1 summarizes the statistical results for the five variables used to assess the basic causes of stunting. Starting with the major administrative subdivisions, the results confirmed significant regional differences in stunting levels. Highest levels were in the eastern region where, on average, 33.5% of the children were stunted. The lowest level was observed in the capital city, Ouagadougou. Using the latter as the reference category in the logistic regression analysis that was performed later, the risk of stunting was highest in the east followed by the central/south region (Table 4). Children in the north and west of the country had similar, though slightly elevated, risks compared with the children in Ouagadougou. These findings were generally consistent with the spatial patterns observed in Figure 5.

Table 3. Immediate causes of stunting: Unweighted percent distribution among categorical independent variables

	n (%)	%Stunted Observed	X^2	Sig.
Child Characteristics				
Age (months)			155.9	.001***
4-12	852 (18.2)	12.3%		
13-24	966 (20.7)	36.9%		
25-36	936 (31.7)	31.7%		
37-48	1048 (31.4)	31.4%		
49-60	871 (25.7)	25.7%		
Gender			5.58	.018**
Male	2405 (51.5)	29.6%		
Female	2268 (48.5)	26.5%		
Nutritional Status				
Breastfed			1.785	0.185
No	2615 (56.0)	28.8%		
Yes	2058 (44.1)	27.1%		
Milk			5.53	0.019**
No	4580 (98.0)	28.3%		
Yes	93 (2.0)	17.2%		
Formula			2.24	0.134
No	4656 (99.6)	28.1%		
Yes	17 (0.4)	11.8%		
Table Food			19.43	.001***
No	3459 (74.0)	26.3%		
Yes	1214 (26.0)	32.9%		

*** Highly Significant at 0.001; ** Significant at 0.05; * Marginally Significant at 0.1; Unmarked Not Significant

The residential location of the children (urban/rural) was also useful in pinpointing the high-risk areas. As expected, higher incidences of stunting were found among rural children than those residing in urban areas. Further analysis using logistic regression confirmed that rural children were one and a half times more likely to be stunted than urban children (Table 4).

Another major predictor of childhood nutritional insecurity was access to year-round transportation lines. For communities within 10 miles of major thoroughfares, the prevalence of stunting among children was about 27%, almost the same as the observed national rate. With increasing distance, the odds of stunting increased, particularly among children residing in communities that were 30 miles or more from these roads.

Assessment of childhood variability in stunting was also based assessed on the agro-climatic conditions and cropland use intensity. Contrary to expectations, however, there were no statistical differences in nutritional health outcomes across these areas. The levels of stunting cases observed in the marginal environments were statistically comparable to the levels observed in all other climatic regions. Similarly, the levels of childhood stunting were similar across the varying levels of cropland productivity. Children residing in northern communities with limited precipitation and land use were at no greater risk of stunting than those residing in more productive areas in the south and west.

Findings generated at the basic level suggest that variability in childhood stunting is primarily a function of socio-economic/political factors rather than the physical/environmental characteristics of these communities. The political/regional subdivision of the country, the degree of urbanization and transportation infrastructure were more relevant at this level. Even though the northern reaches of the country faced more physical constraints, the odds ratios indicated little change in the likelihood of developing long-term nutritional health outcomes of food insecurity. One explanation for this may relate to the low levels of population density in these marginal areas when compared with the southern areas with greater crop intensity but denser populations and therefore greater competi-

tion for food and other resources. Another potential explanation for this observed pattern may be due to the interventions in recent years by donor agencies. Given the intense media coverage on desert encroachment and famine in the Sahelian regions in previous years, most agencies made a conscious decision to focus their efforts in these areas. Specifically, most of the provinces targeted for food assistance in recent years have been in the north, including Oudalan, Soum, Seno, Yatenga, Bam and Passore. These programs have helped minimize the cumulative effects of food insecurity in these marginal environments. Finally, a third explanation may have to do with the livelihood of

Table 4. Odds ratios for logistic model of childhood stunting

	Odds Ratios [Exp(∃)]	95% CI Exp(∃)	Wald Statistic Sig.
Basic Causes			
DHS Administrative Regions			.001***
North	1.20	0.88, 1.62	
East	1.71	1.73, 2.13	
Central/South	1.36	1.11, 1.72	
West	1.25	1.02, 1.55	
Ouagadougou(Ref.)	1.00		
Place of Residence			.001***
Rural	1.53	1.27, 1.84	
Urban (Ref.)	1.00		
Crop Land Use Intensity			0.828
50-70%(Ref.)	1.00		
30-50%	0.99	0.72, 1.37	
5-20%	1.07	0.75, 1.52	
0-5%	0.97	0.71, 1.34	
Agro-Climatic Regions			
Northern	1.29	0.82, 2.06	0.159
Intermediary	1.30	1.02, 1.66	
Median	1.26	1.09, 1.56	
Inter-Intermediary(Ref.)	1.00		
Proximity to Roads with Year-round Access			.003***
Within 10 miles (Ref.)	1.00		
11 to 20 miles	1.19	0.99, 1.43	
21 to 30 miles	1.09	0.84,1.41	
31 to 40 miles	1.89	1.17, 3.06	
41 to 50 miles	1.82	1.14, 2.92	
51 to 60 miles	0.01	0.00,2.66	
Underlying Causes			
Household Characteristics			
Socioeconomic Status			.001***
Low	3.28	2.02,5.32	
Middle	3.05	1.87,4.99	
High (Ref.)	1.00		
Children under 5 years in Household			.086*
1-5 children(Ref.)	1.00		
6-10 children	1.05	0.92, 1.20	
More than 10 children	1.36	1.03, 1.79	
Environmental Health Status			
Source of Drinking Water			.001***
Piped or Bottled(Ref.)	1.00		
Other	1.60	1.31, 1.96	
Type of Sewage facility			.011**
Toilet (Ref.)	1.00		
Latrine	2.49	0.74, 8.39	
No Facility	3.04	0.91, 10.16	

Table 4. Continued

	Odds Ratios [Exp(∃)]	95% CI Exp(∃)	Wald Statistic Sig.
Underlying Causes			
Maternal Characteristics			
Education			.001***
None	3.77	2.12, 6.71	
Some	3.03	1.64, 5.62	
High School and higher(Ref.)	1.00		
Body Mass Index			0.146
Underweight (Under 18.5)(Ref.)	1.00		
Normal (18.5 to 29.5)	1.10	0.92, 1.33	
Overweight(Over 29.5)	0.87	0.65, 1.18	
Marital Status			.1074
Married (Ref.)	1.00		
Living Together	0.85	0.64, 1.13	
Widowed	0.54	0.26, 1.11	
Divorced/Not Living Together	0.40	0.15, 1.09	
Never Married	1.16	0.58, 2.30	
Occupation			.001***
Not Working (Ref.)	1.00		
Prof., Tech., Manag.,	0.11	0.01, 0.72	
Sales	1.17	0.97, 1.42	
Agri-Self employed	1.29	1.08, 1.55	
Services	0.37	0.12, 1.05	
Manual	1.02	0.77, 1.33	
Immediate Causes			
Child Characteristics			
Age (months)			.001***
4-12 (Ref.)	1.00		
13-24	4.41	3.25, 5.28	
25-36	3.30	2.58, 4.22	
37-48	3.25	2.55, 4.14	
49-60	2.45	1.91, 3.17	
Gender			.018**
Male	1.17	1.02, 1.33	
Female(Ref.)	1.00		
Nutritional Status			
Breastfed			0.18
No	1.09	0.96, 1.24	
Yes (Ref.)	1.00		
Milk			0.021**
No	1.89	1.10, 3.26	
Yes (Ref.)	1.00		
Formula			0.153
No	2.93	.066, 12.80	
Yes (Ref.)	1.00		
Table Food			.001***
No	0.35	0.33, 0.39	
Yes (Ref.)	1.00		

*** Highly Significant at 0.001; ** Significant at 0.05; * Marginally Significant at 0.1; Unmarked Not Significant

residents, especially in the northern reaches of the country. Specifically, raising cattle, not farming, is the dominant economic activity in these areas. Children in the areas therefore have greater access to milk in this region than their counterparts in other regions, thus concealing the nutritional deprivation that is captured by stunting. All of these factors may be at work in determining the relatively low levels of stunting in spite of the varying levels of crop productivity.

Underlying Causes of Childhood Stunting

Among the underlying causes of stunting, three sets of variables were evaluated: (i) household attributes, (ii) maternal characteristics and (iii) the environmental health status of the household (Table 2). In assessing the socio-economic status of the household, almost two thirds were classified as low-income, 30% as middle-income and 3.7% as high-income families. Subsequent analysis using logistic regression confirmed that the risk of childhood stunting was very high in both the low-income and middle-income households, where children were three times more likely to be stunted than the children from high-income households (Table 4). These findings were basically consistent with several other studies documenting poverty and the socio-economic status of households as key predictors of childhood vulnerability to malnutrition (Frongillo et al. 1997; Olson 1999; Weinreb et al. 2002, Girma and Genebo 2002).

The second household attribute selected for analysis was the number of children under five years residing in the household. The sample data showed that 57.2% of the households had one to five children, 37.4% had 6 to 10 children, and 5% had more than 10 children. It is not uncommon to find such large families in Burkina Faso and other African countries, particularly in rural communities. Goldberg and Frongillo (2001) alluded to this in their research, describing the typical Mossi household as essentially an extended family system or boodoo consisting of the husband and several wives, their children and their married sons' families. Access to food in such households, they argued, was based on one's ranking, with younger lineage members, females and lower status co-wives and their children facing the greatest threat to food insecurity (Goldberg and Frongillo, 2001). Children in such households are also less likely to receive the same amount of attention, time and care as children from smaller households. In this study, the statistical analysis produced a marginally significant variable, with the risk of stunting high only among households with more than 10 children (Table 4).

Two other attributes, both reflecting the environmental health status of the household, were statistically related to the prevalence of stunting. Children residing in households without access to piped or bottled water faced a greater risk of stunting than their counterparts. Also significant was the type of sewage facility used in the household. Based on the sample data, nearly three quarters of the households did not have access to a toilet facility. Some of these families relied on pit latrines, and others did not have any facility at all. The risk of stunting was significantly greater (over three times) among children residing in those households. Both measures point to the relevance of environmental quality in minimizing childhood illnesses. Children residing in unsanitary conditions face frequent bouts of illness that in turn affect their dietary intake and result in long-term nutritional outcomes.

Among the maternal characteristics, education and occupational status emerged as key determinants of childhood nutritional security. Mothers without any formal education were nearly four times more likely to have stunted children when compared with those with at least 12 years of education ($p < .01$). Based on the occupational status of the mother, the highest levels of stunting were observed among mothers who were self-employed in agriculture and sales. Children whose mothers were gainfully employed in professional, technical, managerial or service sectors were better off, with lower risks of stunting ($p < .01$).

The overall nutritional status of the mothers was encouraging when compared with the children's. About 78% of mothers had normal a BMI between 18.5 and 24. Only about 14% had a BMI below 18.5. Contrary to previous studies however, BMI was not a statistically significant predictor of childhood stunting.

The marital status of the mothers was also evaluated. Based on the chi-square analysis, the prevalence rate of stunting was highest among mothers who had never married (31%). However, logistic regression results showed that even though the risk was slightly elevated among unmarried mothers, it was statistically insignificant. In this study, nearly all mothers (91%) interviewed were married, and that may have led to the difficulty in isolating the unique effects of this variable on childhood

malnutrition. Further analysis would require a more equitable representation of mothers in all five categories used to calibrate this variable.

Immediate Causes of Childhood Stunting

The immediate causes of childhood nutritional outcomes were all based on the personal characteristics of the children (Table 3). The age of the child was significantly related to childhood stunting. The incidence of stunting was highest among one- and two-year-old children, with risks four to five times greater than the reference group (Table 4). The risk was also higher among two- to four-year-olds but declined by the age of five. Among the nutritional indicators, results showed that, surprisingly, breastfeeding recipients did not have any notable advantage over others. However, the risk of stunting was slightly elevated among children whose diet was based primarily on table foods. Also, a significant relationship was found between stunting and milk consumption. Specifically, those who did not consume milk on a daily basis were nearly twice as likely to be stunted as those receiving milk as part of their daily diet. Gender disparities in stunting also emerged among the children. Boys were found to be at slightly higher risk for stunting than girls. This pattern has been documented by other studies as well, even though no plausible explanation has been offered for the observed disparity in childhood vulnerability (Garrett and Ruel 1999).

Research Summary and Implications

The upward trend in chronic food insecurity conditions in sub-Saharan Africa does not bode well for the young children who are likely to suffer irreparable health consequences. In Burkina Faso, where nearly half the population is under the age of 15, this study examined the various dimensions of this problem in an attempt to identify and explain the distribution of at-risk areas. The findings support several implications. First, they underscore the need for continued emphasis on a multifactorial approach to address the problem. In this study, the successful integration of the DHS survey data along with spatial–digital coverages allowed for the joint evaluation of the various risk factors.

Second, the emergent patterns observed in this study revealed several risk areas for childhood malnutrition in Burkina Faso, with the likely causes extending beyond physical/environmental conditions. Factors such as the regional subdivision of the country, urbanization and access to reliable transportation services were clearly more influential in explaining the geographic distribution of childhood malnutrition in these areas. Thus, reactive approaches once used by donor agencies, focusing on food emergencies caused by biophysical conditions, must incorporate these additional risk factors.

This research also supports the need for geographic targeting of at-risk populations beyond the broad regional and community levels to include more detailed assessment at the household and individual levels. For example, at the household level, the study illustrated that the most significant means of ensuring nutritional security of young children included better incomes and access to amenities and other resources that improve the quality of life of household members, good sanitary conditions, better education and occupational opportunities for the mothers who are the primary caregivers. At the individual level, results confirmed the existence of differential susceptibility among the children, implying that intervention efforts must also target children with poor diets, one- and two-year-olds, and boys.

One drawback in this study was the failure to incorporate data on HIV/AIDs prevalence, which, as noted earlier, has emerged as a major risk factor in childhood nutritional insecurity. As more reliable indicators of this pandemic become available, the integration of the data into the comprehensive analytical framework would contribute toward an even better understanding of childhood food insecurity in this region.

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