Anna Carla Lopez
Doctoral Candidate
Departments of Geography
San Diego State University/UC Santa Barbara

and

John R. Weeks, PhD
International Population Center/
Department of Geography
San Diego State University

The urban and nutrition transition: using GIScience and remote sensing to map predictors of urban household food security in Accra, Ghana

For Presentation at the Population Association of America Annual Meeting
Detroit, 2009

Abstract

As cities continue to grow rapidly in the developing world and become home to higher concentrations of people, the need to improve our spatially explicit knowledge of population, health and environment issues has become a priority. The past twenty years of urban development have yielded higher numbers of undernourished urban households. With the use of both GIS and RS technologies in combination with census and survey data, I used geographic methods for mapping urban socio-economic and environmental data, as well as for providing insights into the state of food security among urban populations in developing countries and its underlying socio-economic, environmental and spatial predictors. Results from the analysis show that remote sensing data are significant in understanding the spatial and environmental dynamics of household nutrition. Additionally, neighborhood vegetation cover, breastfeeding and access to sanitation services are positively related to better nutritional health and household food security. I conclude that data derived from satellite imagery can contribute important information for urban social science and health research. Additionally, in terms of local health policy, improving neighborhood environments and child and maternal nutrition programs may promote better nutritional health outcomes among households in Accra.

1. Introduction

Today, cities are home to 3.5 billion people (UN POPIN, 2007), most of whom reside in developing countries. Throughout the world, urban inhabitants have a better quality of life than their rural counterparts. However, cities in poverty-stricken countries run counter to this global paradigm. In sub-Saharan Africa alone, over 40% of the population lives in cities, with 72% of urban dwellers living in slums (UN HABITAT 2001). As cities continue to grow rapidly and become home to higher concentrations of people, the need to improve our spatially explicit knowledge of population, health and environment issues has become a priority.

The focus of this study is urban food security[1] and nutritional health. I explored geographic methods, including remote sensing (RS) and Geographic Information Systems (GIS), in their application towards food security assessment in urban areas of developing countries. Rapid rates of urban population growth over the past twenty years have yielded higher numbers of undernourished urban households (Popkin, 2002). Because of the preponderance of research, urban hunger may be routinely underestimated (Amoah, 2003; Biritwun et al, 2005). In particular, I ask the question:

---

[1] Defined as access, at all times, to adequate safe, nutrition and culturally appropriate foods.

What are the underlying socio-economic, environmental and spatial predictors of urban food insecurity?

Urban food security studies have failed to adequately and extensively disaggregate figures *within* urban areas, resorting to cross-urban comparative studies, or rural-urban studies. I contend that food security occurs heterogeneously across the urban landscape and that certain neighborhoods within cities experience earlier rises in food security, while others see a lag in the eradication of under-nutrition deficiencies. Similarly, studies have also failed to assess the role of the built environment and spatial organization in the ability of households to access sufficient quantities of healthy food.

With cutting edge integration of methods and applied technology in geography, this study broadens as well as deepens the understanding of nutritional health in urban populations of developing countries, especially in sub-Saharan Africa. By identifying intra-urban differentials in nutritional health, I advance local scale applications of poverty mapping. With the use of both GIS and RS technologies in combination with census and survey data, I tested the usefulness of geographic methods for mapping urban socio-economic and environmental data, as well as for providing insights into the state of food security among urban populations in developing countries and its underlying socio-economic, environmental and spatial predictors.

Urban food security and poverty mapping

Urban lifestyles in developing countries have translated into shifts away from high intakes of carbohydrates and fibers towards high intakes of saturated fats. Because the *nutrition transition* in developing countries is compounded by the persistence of undernourishment and micronutrient deficiencies, poverty, continued high fertility and mortality, and a highly significant infectious disease burden (Popkin, 2002), it has exacerbated an increase in nutrition related non-communicable disease (NR-NCD).

Broader nutrition studies in developing countries have shown that women are more prone than men to higher rates of obesity *and* underweight (Amoah, 2003; Galal, 2002), implying that food insecure households may exhibit either signs of malnourishment. Women's greater economic vulnerability may contribute to a less consistent and highly caloric diet for the household (Lopez, 2008a forthcoming). Similarly, children (often within the same household) are more likely to show signs of under-nutrition and micronutrient deficiencies than adults (Haddad et al, 1999; Doak et al 2002; Ghassemi et al, 2002; Montiero et al, 2002; Galal 2002; Amoah, 2003).

Food security is considered a complex situation involving economic, social, political and environmental factors, and therefore good information is key to meeting the needs of hungry populations and for effectively implementing strategies to reduce hunger. Geographic research is particularly useful in collecting food security information and can be summed into the following three areas:

- Identification of food insecure populations;
- Monitoring of food security situations; and
- Understanding of the socio-economic, political, environmental and demographic processes which result in food insecurity.

Monitoring food insecurity over time is beyond the scope of this study, while examining the underlying factors affecting household food security will be undertaken in the following chapter. This paper will focus on the identification of food insecure households within the city.

The use of geo-referenced in depth surveys or censuses are critical for identifying locations of food insecure populations or "hunger hotspots." These surveys can be used to calculate both daily food intake and inequality in access to food. The former can be used as a biological measure of food insecurity, while the latter can be used as measure of the food *access* problem. Furthermore, information on the demographic composition of households, the quality of their diets and the extent of their food deprivation can be obtained from these datasets. Because the data contain locational information, geographers can use a GIS environment to apply spatial algorithms to identify non-random spatial patterns and identify where the most afflicted areas are located. The use of GIS allows for the inclusion of ancillary data that map transportation networks, elevation, climate and other environmental information. With this type of spatially explicit information, resources can be deployed more efficiently in terms of both time and monetary resources, reducing the extent of human suffering.

Hunger is a function of unequal *distribution* of social and economic resources across space and time. A geographer might ask*, why do some places/communities have an abundance of food resources and others not? And how is the access to those resources spatially and temporally distributed?* In particular, a geographic analysis would take into account the existing human/environment relationships which result in food insecurity. The environment, as an actor, becomes a prominent variable in the equation. It is scene as a source of obstacles or opportunities. This is not to say that the role of demographic factors is diminished. On the contrary, population issues are present in both the cause and affect of hunger situations. Dialectical relationships existing between people and their environments are critical to the understanding of food security whether it occur in rural or urban places. For geographers, *space matters* and must be acknowledged as an prime factor in poverty and hunger studies, but what occurs in that space and why is of equal importance.

Thus I argue that if hunger is to be addressed by researchers, then so must the socio-economic and physical variability present within the various landscapes. It is important to study food security within the ecology and geography which surrounds a household or community, because those households are also embedded in social, economic and political process that are present at different scales. Put together, these elements create the environment in which a household pools its resources for survival, including those related to food and nutrition. By understand these *processes* that result in urban hunger we can put forth better policies that can better the livelihoods of the urban poor and marginalized.

Remote Sensing Land Cover Analysis using VIS

Social scientists have tended to focus on the population and social organizational parts of the urban system, and are often vague, if not dismissive, of the built environment--of the buildings, parks, roads, bridges, and the associated infrastructure that humans create out of the natural environment and which become the places where everyday life takes place. Micklin and Sly (1998) put the built environment under technology, representing one set of "tools" available to human society. Yet, the built environment is more than that--it is the actual environment in which a large fraction of humans spend their entire lives. The natural environment is so transformed by urbanization that the majority of urban residents spend little time touching soil and interacting with flora and fauna. Even more importantly, the built environment is not just a product of human activity; it is also a very important element of what Namboodiri (1988) has called the goal of human ecology, which is "to identify the linkage between the dynamics of human interdependence and the pursuit of the art of living." Local context is emerging as an important way of conceptualizing inequalities in the social world (Tickamyer 2000), and this approach is exemplified by the work of Gatrell (2003) and Sampson (2003), among others.

Neighborhood context thus provides a conceptual framework for using landscape metrics to aid in our categorization of data from remotely sensed imagery. It suggests that different kinds of built environments may well be associated with different kinds of human behavior. Among these behaviors are almost certainly aspects of life that influence health levels. The landscape metric algorithms allow me to produce several indices of the way in which each land cover class is organized spatially. These include, in particular, shape complexity and isolation/contiguity of class types, based on concepts of fractal geometry. Work is only now beginning on the creation of what might be thought of as a "reference library" of landscape metrics that are consistently related to particular kinds of urban places. Indeed, the study by Herold, Scepan and Clark (2002) is one of the very first of its kind. This is, of course, one of the ways in which the proposed research is moving into quite literally uncharted territory, but the potential is very high that these measures will allow us to create much more meaningful quantifiable indices of the built and natural environmental contexts which I believe to be importantly related to inequalities in health. For example, it is widely argued that the health of children is enhanced by an urban environment that incorporates green spaces where children can safely play (Hardoy, Mitlin and Satterthwaite 2001). The proportional abundance of vegetation, as classified from the imagery, tells me whether there is a measurable portion of vegetation cover within a given urban area. The contagion index of landscape metrics can then tell us how clumped together the patches of vegetation are. If this index is high, I can expect that the vegetation represents a true green space—perhaps a park--rather than randomly placed plants.

Previous studies (Weeks et al, 2005) have tested this hypothesis in areas of moderate climate with moderate amounts of vegetation cover. The hypothesis has not been tested in tropical climates where heavy amounts of vegetation cover are expected, even in urban areas. I tested this hypothesis by integrating remote sensing data into my analysis of other health and socio-economic variables.

This food security study implemented the pioneering use of remote sensing to quantify compositional aspects of the urban environment. Imagery provided information on land-cover such as vegetation, bare soil, impervious surface etc, and land-use (industrial, residential, public space etc). High resolution imagery was employed to break down the variability in land-cover of urban residential neighborhoods.

Land cover represents the physical materials found on the earth's surface (or the types of features which are present) such as water, vegetation, impervious surface, shade, bare soil, etc. The principle objective of remote sensing is to identify these feature and quantify the extent of their presence in the research area, or to "estimate land cover fractions." The results are used for a wide range of analysis from forest monitoring to urban change detection. However, the quantification of land cover fractions is also determined by the scene model used. According to Strahler *et al.* (1989) there are two: H-resolution (H) models and L-resolution (L) models. H-resolution models occur when objects of interest in the imagery are larger than the pixel size and therefore can be resolved. These types of models are particularly appropriate for urban areas because of their high levels of heterogeneity. L-resolution models, on the other hand, occur when objects of interest are smaller than the pixel size and therefore cannot be resolved. Forestry mapping, for example, is conducted most efficiently using an L-resolution model since each individual tree does not have to be clearly identified. To this I might add the possibility of an M-resolution (M) model where some features of interest are larger than the pixel size and can be individually resolved and other are smaller and thus compromised in detail.

In classifying the data by land cover I will use Ridd's (1995) V-I-S (vegetation, impervious surface, soil) model to the high resolution imagery available for Accra. Ridd (1995) devised this method for land cover fraction mapping for urban areas. His work was based on research that explained that the dominant "building blocks" or materials of urban areas are vegetation, impervious surface, and soil. By extracting the proportional presence of each of these types of surface materials, he could basically estimate the different types of land-*use* occurring within a city. An area comprised entirely of soil, for example, may be considered a desert area or non-inhabited. However, if an area were to be composed of mostly soil *and* impervious surface, it could indicate an industrial park in a developed country or a low-income housing neighborhood in a developing country.

Based on the previous work of Phinn and Murray *et al* (2002), Rashed et all (2003, 2005) included water/shade as an extra dimension to Ridd's model since it improved the land – cover estimation of non-U.S. urban areas. Their work used an M-resolution scene model (Landsat TM) where some of the objects were smaller than the pixels and thus pixels could not be entirely classified with a single property. Thus spectral-mix analysis techniques were applied to extract land cover fractions from a scene in Cairo, Egypt. These results were later used for estimating socio-economic and demographic characteristics of the population.

In this research, I will explore, test, validate, and implement a land-cover V-I-S model using software supported by Erdas Imagine 8.3.1 (2001).

2.0 Research Area – Accra, Ghana

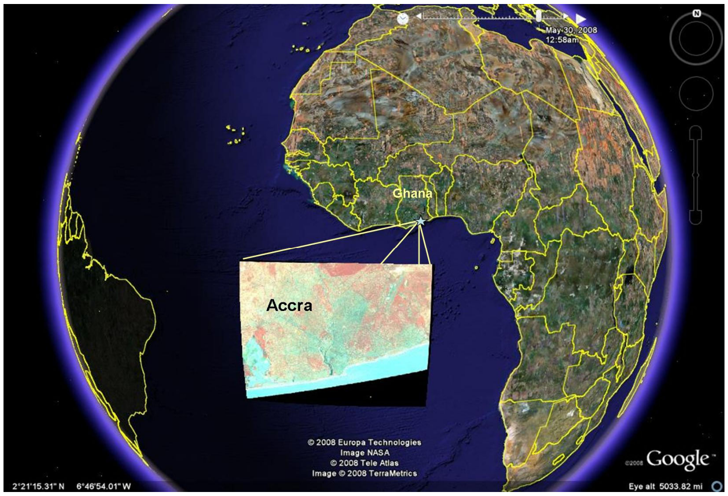


Figure 1: Accra, Ghana
(Sources, Google Earth, 2008; and Digital Globe, 2002),

The study is focused on the urban area known as the Accra Metropolitan Area (AMA) (Figure 1) the most densely populated and urbanized area of the Greater Accra Region. AMA is the capital city of Ghana, a West African country located on the Gulf of Guinea. Accra is often referred to as the "center of the earth" located 5°30' North, 0°10' West, nearly at the intersection between the equator and Prime Meridian. The city area is measured at 185km^2, while the entire metro area takes up 200 km^2. According to the Ghana 2000 Census, AMA is currently is home to circa two million people, with a growth rate of 3%. Therefore, the population density is close to 10,000 people per square kilometer. By the year 2020, over 3 million people are expected to live in Accra (UN Population Division, 2008). Though Accra is the heart of economic and political activity in Ghana, nearly 70 % of the city's population survives in slum-like conditions lacking access to basic services such as water, sanitation, and health care (Weeks et al, 2007).

Ghana was the first country in Africa to gain independence from colonial powers. In the summer of 1957, Ghana declared its freedom from the United Kingdom. Accra, now the capital of a free state, steadily attracted a flow of population from all parts of the country. The relaxation of urban zoning laws after independence spurred the city into the busy sprawl that defines it today (Pellow, 2002; Grant and Yankson, 2003). While the central area of the city is characterized by well known neighborhoods, Accra's boundaries continue to expand toward the northern inland area beyond the University of Ghana where housing is more affordable and land is abundant. New transportation networks that connect suburban areas to the center of the city have generated greater sprawl. High-rise commercial buildings are in continuous expansion, especially near the international airport, a hub for corporate growth.

The Demographic and Health Survey of 2003 was used to calculate basic population data. Total fertility rates (TFR) remain high in Ghana. The TFR in rural areas remains at 5.6 children per women compared to 3.1 in the cities (both well beyond replacement). When rural economies were being heavily targeted by structural adjustment policies (SAPs) during the 1980s and 1990s, shifting economic diversity to urban centers, the "excess" rural population migrated to urban centers, especially Accra (Grant and Yankson, 2003). Though cities remained susceptible to the harsh economic reforms of SAPs and consequently experienced high rates of unemployment, they had the advantage of fostering a lively *informal* economy which nevertheless continued to attract people from the countryside.

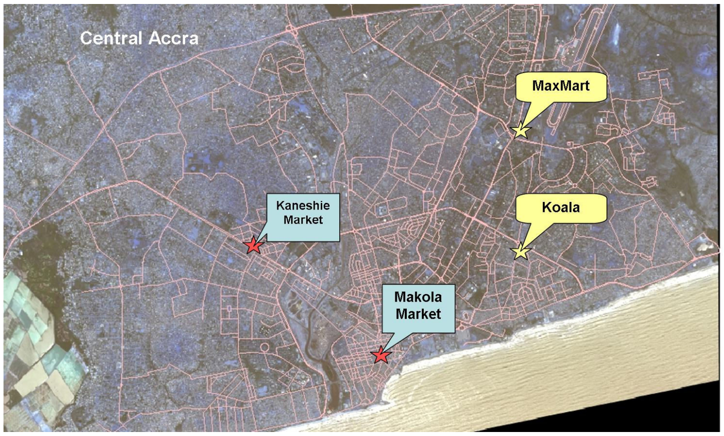


Figure 2: Major food markets in Accra

Twenty-five major markets are located within AMA of which ten supply approximately 80 percent of the city's food needs (Lardemelle, 1996). Outside of the formal market setting, countless food traders roam the streets of Accra selling fresh fruits and vegetables, processed foods (or *provisions*), or small snacks prepared at home for the retail market. Relative ease of entry into the informal food market makes food vending a popular trade for Ghanaians living in Accra. Woman account for over 90 percent of food traders in the city and are heavily involved in the urban food system from the farming and wholesaling of products to retailing to the urban consumer (Lardemelle, 1996). Two major supermarkets, MaxMart and Koala, function in AMA and cater primarily to wealthy Ghanaian families or the expatriate community due to their high retail prices. More recently in November 2007, the African retailer giant Shoprite has opened the doors of one its large supermarkets in the new Accra Mall just north of the Airport area. The majority of people in Accra buy their food from local open-stall markets such as Makola Market and Kaneshie Market, or from small retailers of dry goods and street vendors (Figure 2). While food is relatively abundant in Accra, price increases on basic staples have made it harder for low-income families to meet their food needs in terms of both quantity and quality of diet. This is compounded by the fact that more than 50 percent of Ghana's population is under the age of 20 (US Census Bureau, 2008). In the next 25 to 50 years, this pattern is expected to change, reflecting an expected (but by no means certain) decrease in mortality rates and a slowly aging population as Ghana enters an epidemiological transition. The transition portends a decreasing incidence of infectious disease, but a increasing rate of chronic and degenerative age-related diseases.

No health and nutrition data are available in the census, which covers 100 percent of the population in Accra. However, survey data have shown that nearly 4% of the population in the Greater Accra region is underweight, and that 11.5%, 7.5%, and 11.4% of children in the same area are underweight, stunted and wasted respectively (DHS, 2003). Nearly 65% percent of children consume inadequate intakes of Vitamin A, and another 60% percent are lacking sufficient quantities of iodine in their diets. The average life expectancy for Ghanaians at birth is 59 years (UNICEF, 2008).

Over 50 percent of Ghana's population is under the age of 20 (US Census Bureau 2008). In the next 25 and 50 years, this pattern is expected to change, reflecting decreasing mortality rates and an aging population as Ghana enters an epidemiological transition. The transition indicates a decreasing incidence of infectious disease, and an increasing rate of chronic and degenerative age-related diseases.

3.0 Data

Data for this analysis come from three disparate sources which are combined into a geodatabase: (1) GIS data; (2) Population data; and (3) Remote Sensing data. These data sets are briefly introduced in the table below and described in detail immediately following.

GIS Data	Population Data	Remote Sensing Data
Accra boundary file including all 1724 enumeration areas (EAs).	2003 Women's Health Study of Accra - individual/household and EA level data.	2002 Digital Globe Quickbird Satellite Imagery. 2.4m resolution.
	Ghana 2000 Census – 10% sample	
	Ghana 2003 Demographic and Health Survey	

3.1 GIS Data

A shapefile (Figure 3) representing the urban boundaries of Accra and compatible with GIS software programs was developed at San Diego State University in 2004 as part of a pilot project funded by the National Institute of Child Health and Human Development (NICHD) under the R21 experimental grant mechanism (grant number R21 HD046612-01). All 1724 EAs of the Greater Accra Metropolitan Area that are present in the Ghana 2000 Census are represented, georeferenced, and available in digitized format in preparation for GIS analysis.

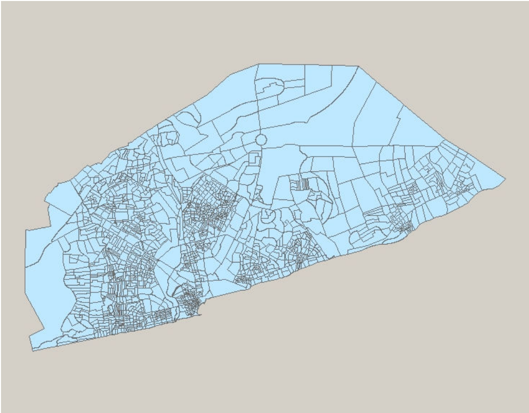


Figure 3: GIS Shapefile of Accra, Ghana.

3.2 Women's Health Study of Accra

The richest source of health data for Accra comes from Harvard University's 2003 Women's Health Study of Accra (WHSA), (Duda et al, 2007) and generously made available by co-principal investigator John R. Weeks at San Diego State University. Data were collected from 3,200 women aged 18 and older between April and July 2003 and provide self-report health data, data from a clinical examination and laboratory work as well as data on the household's facilities matched to the census of 2000. To obtain a representative sample for the Women's Health Survey in Accra, EAs were first stratified into four quartiles representing different levels of socio-economic status. Household facility indicators and education were used to measures Socio-economic (SES) levels.

The result was a representative sample of 200 (out of 1731) non-contiguous, occupied Enumeration Areas (EAs) with an average of 959 people residing in each. Study women ages 18 and older, were selected with probabilities fixed according to the socio-economic status (SES) of the EA and the age group of the women. Older women were progressively over-sampled (Hill et al, 2007). Women were selected with probabilities fixed according to the SES status of the EA and the age group of the women. Older women were progressively over-sampled. Overall, a total of 3175 Ghanaian women, age 18 years and older, were interviewed with a privately conducted household survey (HHS) that included questions for self-reported illnesses, reproductive history, health practices, The survey included a short form to measure health morbidity, risks for illnesses and social history (Duda et al, 2007).

The survey includes a section which is dedicated specifically to food security and the food consumption patterns of the women surveyed. While limited, information derived from this portion of the survey was used to describe both the quantity and quality of diets, and made possible the extraction of a “food security” dependent variable. To maintain privacy the location of each household in the survey is georeferenced to the census EA-level.

3.3 Ghana 2000 Census

Census data come from a ten percent anonymized sample from the Ghana 2000 Census, provided to us by Ghana Statistical Services. Like the WHS data, these data are georeferenced to the enumeration area (EA) of the respondent. While the census data do not include information about food security or nutrition, they remain a rich source of information in regards to living standards. The census contains numerous questions which describe housing conditions, access to basic services and general material possessions of a household. The Census does not contain any questions directly related to income, but through related variables I derived a proxy for household economic wellbeing. All 1700 EAs which are present in the Ghana 2000 Census are available in digitized format as a shapefile to be used for GIS analysis (Weeks et al, 2007

3.4 Ghana 2003 Demographic and Health Survey

The Demographic and Health Survey of 2004 was used to calculate basic population data. Total fertility rates (TFR) remain high in Ghana. The TFR in rural areas remains at 5.6 children per women compared to 3.1 in the cities (both well beyond replacement). When rural economies were being heavily targeted by structural adjustment policies (SAPs) during the 1980s and 1990s, shifting economic diversity to urban centers, the “excess” rural population migrated to urban centers, especially Accra (Grant and Yankson, 2003). Though cities remained susceptible to the harsh economic reforms of SAPs and consequently experienced high rates of unemployment, they had the advantage of fostering a lively *informal* economy which nevertheless continued to attract people from the countryside.

3.5 Satellite Imagery

One particularly important aspect of this research will be the use of urban remote sensing to quantify compositional aspects of the urban environment. Imagery can be particularly useful in providing information on land-cover (basic components on the ground) and land-use (industrial, residential, public space etc). A high spatial resolution (2.4 meter) multi-spectral (four bands—blue, green, red, and near infra-red) Digital Globe Quickbird satellite image (Figures 4 and 5) of the Accra metropolitan area (acquired on 12 April 2002 on a cloudless day), was used for the remote sensing analysis along with a 0.6 meter resolution panchromatic image taken at the same time. The multispectral image is of sufficiently high resolution that I may obtain a high degree of accuracy with a “hard” land cover classification. The imagery covers 86% of the 1724 enumeration areas. Coverage encompasses the western portion of the city, thus limiting the remote sensing analysis for the eastern part of the city. Results for the remote sensing analysis are not representative of all Accra.

In classifying the data by land cover I will use Ridd's (1995) V-I-S (vegetation, impervious surface, soil) model to the high resolution imagery available for Accra. Ridd (1995) devised this method for land cover fraction mapping for urban areas. His work was based on research that explained that the dominant "building blocks" or materials of urban areas are vegetation, impervious surface, and soil. By extracting the proportional presence of each of these types of surface materials, he could estimate the different types of land-*use* occurring within a city. An area comprised entirely of soil, for example, may be considered a desert area or non-inhabited. However, if an area were to be composed of mostly soil *and* impervious surface, it could indicate an industrial park in a developed country or a low-income housing neighborhood in a developing country.

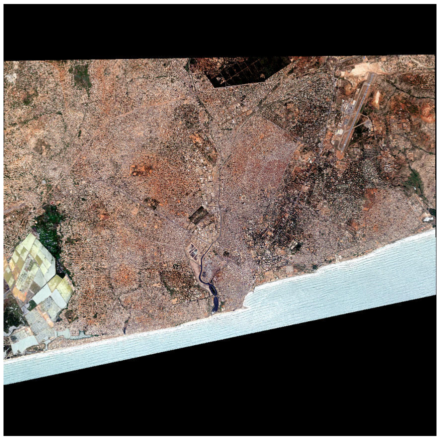


Fig.4 2002 Quickbird Imagery, true color.

Fig.5 2002 Quickbird Imagery, multispectral.

Vegetation, impervious surface, and bare soil will also be used as independent variables in this study. These remote sensing variables will be tested under the Neighborhood Environment category of my conceptual model. The V-I-S components will be aggregated at the EA level and also tested for significance in the multi-level model.

4.0 Methods

4.1 The Dependent Variable

The Women's Health Survey in Accra contains two distinct modules on Nutrition and Food Security, respectively. While the data were limited, the Food Security module provided the independent variable for this study: *food security*. Food security is defined as access at all times to sufficient quantities of nutritious and culturally appropriate foods. All individuals were asked to describe their household food security in the last year. Individuals could select their response from the following five answers:

1. WE ALWAYS HAVE ENOUGH TO EAT AND THE KINDS OF FOOD WE WANT
2. ENOUGH TO EAT BUT NOT THE KINDS WE WANT
3. SOMETIMES WE DON'T HAVE ENOUGH or ANYTHING TO EAT
4. OFTEN WE DON'T HAVE ENOUGH or ANYTHING TO EAT
5. DK or REFUSED

To simplify the data, answers were recoded in two different groups based on the definition of food security used in this study. Households were considered food secure if they responded with answer number 1. Answers 2, 3 and 4 were classified as food insecure; and answer 5 was eliminated from the data set. Recoding of the data was established where 1 was equal to food secure households and 0 was equal to food insecure households. Basic descriptive statistics were undertaken on the dependent variable.

4.2 Spatial Analysis

The null hypothesis for spatial distribution of food security was distributive randomness at the household level. While there are distinct neighborhoods of high and low socio-economic status within the city, well -to -do landowners may live in slum areas just as low-income households may settle in the same neighborhood as the households they depend on for their livelihood.

Data were mapped in ArcGIS to determine statistically significant spatial patterns at the household level. First, binary data (food secure and food insecure) were measured in proportional abundance at the EA level. Global levels of auto-correlation were applied to identify similar values of proportional abundance across sampled EAs. The Getis-Ord General G statistic was used to measure whether low or high values were clustered together over the entire urban area. A weights matrix for discrete (non-contiguous) features was created using inverse-Euclidean distance (distance decay) so that each pair of EA centroids was given a unique value.

Moran's I (1950) and Local Indicators of Spatial Autocorrelation (LISA) were also used to examine patterns of spatial autocorrelation of food security. Moran's I is a measure of spatial autocorrelation. Like autocorrelation (or correlation in time), *spatial* autocorrelation means that adjacent observations of the same phenomenon are correlated in (two-dimensional) space. Spatial autocorrelation gains complexity over autocorrelation because the correlation is both two-dimensional and bi-directional.

These calculations require a weights matrix in order to provide Global Moran's *I* and LISA values in their commonly used form. It is usual to standardize the row totals in the weights matrix to sum to 1. One advantage of row standardization is that for each row (location) the set of weights corresponds to a form of weighted average of the neighbors that are included. Row standardization may also provide a computationally more stable weights matrix. This procedure alters the Global Moran *I* value when rows have differing totals, which is the typical situation.

The Local Moran statistic decomposes Moran's *I* into contributions for each location, I_i. The sum of I_i for all observations is proportional to Moran's *I*, an indicator of global pattern. Thus, there can be two interpretations of Local Moran statistics, as indicators of local spatial clusters and as a diagnostic for outliers in global spatial patterns.

The local Moran test (Anselin, 1995), detects local spatial autocorrelation. It can be used to identify local clusters (regions where adjacent areas have similar values) or spatial outliers (areas distinct from their neighbors). A large positive value for Moran's I indicates that the feature is surrounded by features with similar values, either high or low. A negative value for I, indicates that the feature is surrounded by features with dissimilar values.

The local Gi*-statistic (Getis-Ord,) was also used to identify clusters of high or low values. For each target feature in the dataset, the statistic compares neighboring features within a specified distance. The result is a map which shows the extent to which each feature is surrounded by similarly high or low values.

4.3 Remote sensing analysis

The imagery used in this study was of sufficiently high resolution to apply a supervised, hard-classification of land-cover type for each pixel using Erdas Imagine version 8.3.1. In a supervised classification, information about the scene is known *a priori* to the classification process such as land-use type: urban, agricultural, forest, etc. In this case I examined Accra's urban scene where some areas of each land-cover type (impervious surface, vegetation or bare soil) were specifically known before classification and were thus used to collect supervised training sights for each class. In classifying the data by land cover I used Ridd's (1995) V-I-S (vegetation, impervious surface, soil) model to the high resolution imagery available for Accra. Ridd (1995) devised this method for land cover fraction mapping for urban areas.

Training sights are considered pure representatives for each class and therefore their spectral characteristics are used as a basis for classifying the rest of the image. To reduce errors, several representative training sights were collected for each individual class. In the case of impervious surface for example, paved roads, metal rooftops and concrete rooftops were all collected and aggregated to represent a single class. Training areas were also distributed across the whole scene as evenly as possible. Twenty training samples were used for each land cover class. Areas representing water were masked from the analysis as they are also non-inhabited areas

The Gaussian maximum likelihood classifier was used to examine the probability function of a pixel for each of the three built environment classes. The classifier assumes that the training statistics for each class have a normal distribution. The classifier then uses the training statistics to compute a probability value of its membership one of the three land cover category classes. This allows for within-class spectral variance. Using this framework, Erdas Imagine assigned every pixel to a single class within the classification scheme. Confusion among class membership resulted in some pixels left unclassified. Unclassified pixels represented less than one percent of total pixels. They were included as a fourth category and removed in the final product to reduce error amongst known classes. Proportional abundance of each class was aggregated to the EA level. Vegetation, impervious surface and bare soil were used as independent variables under the Neighborhood Environment conceptual framework category.

4.4 Reduction of Variables

The next step was to reduce the determinants of the dependent variable *food security* from the socio-economic, health and environmental data in the census and surveys. While several hundred variables were representative in the data sets, I selected only those consistent with the food security literature (FAO 1996, FAO 1997, FAO 2001, Garrett 2000, Haddad et al 1999, Maxwell 1999, Maxwell et al 1999, Maxwell et al 2000) and with the environmental health literature (Akash and Mousa, 1999; Chambers 1995, Grant and Yankson 2003, Pelling 2003, Robbins 2004, Satterthwaite 1995, Songsore and Goldstein 1995, Songsore and McGranahan 1993, Songsore and McGranahan 1998, Weeks 2003, Zimmerer 2003). These variables were categorized within one of the following groups representative of my conceptual model: socio-economic status, home environment, neighborhood environment, and health and wellness. Statistical Analysis was performed using SPSS 14.0 for Windows (SPSS, Inc. Chicago, IL, USA).

Histograms of all variables were analyzed to determine their frequency distribution in relation to a normal curve. Variables which showed deviation from the norm, (i.e. where a taller primary peak as well one or more shorter secondary peaks were present), were recoded to appreciate the natural tendencies in the data.

Taking these criteria into account, nearly one-hundred relevant independent variables were available from the composite of data initially considered. Through a Pearson's chi-square test of independence, these variables were in turn reduced to twenty-nine variables distributed among the four conceptual categories.

4.5 Selection of Variables: Principle Components Analysis (PCA)

PCA was used for dimensionality reduction in the data set by retaining those characteristics of the data set that contribute most to its variance, by keeping lower-order principal components and by ignoring higher-order ones. Remaining variables were grouped into the four conceptual categories: Socio-economic status, Home Environment, Neighborhood Environment and Health. PCA was undertaken within each of those categories in order to group condense multiple variables into individual components. Components were then evaluated for theoretical coherence. Where theory supported the separation of components, individual variables were retained, and similarly where theory supported the grouping of variables, new component variables were given precedence.

4.6 Binary Logistic Regression

Because the dependent variable is binary in nature (households are either food secure or food insecure) a logistic regression model was used to predict the probability of household food security, using the independent variables selected above.

$$f(z) = \frac{1}{1 + e^{-z}}$$

Figure 6: Binary logistic function

A model of the function is shown in Figure 6. The "input" is *z* and the "output" is *f*(*z*). The output is confined to values between 0 (food insecure) and 1 (food secure). The vector *z* represents the exposure to some set of risk factors, while *f*(*z*) represents the probability of a particular outcome, given that set of risk factors. The vector *z* is a combined measure of the contribution of all the risk factors used in the model.

The vector *z* is defined as

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k,$$

where β_0 is the "intercept" and β_1, β_2, β_3, etc, are the regression coefficients of independent variables x_1, x_2, x_3 respectively. Each regression coefficient describes the influence of each risk factor on the dependent variable, taking all other predictor variables into account. A positive regression coefficient means that that risk factor increases the probability of the outcome (food security), while a negative regression coefficient means that that risk factor decreases the probability of that outcome (e.g. less food security). Logistic regression is a useful way of describing the relationship between one or more risk factors (e.g., age, education, etc.) and an outcome such as food security (which only takes two possible values: food secure or not food secure).

Results from the analysis were compared to the multi-level regression model explained below.

4.7 Multi-level Analysis

A two-level random intercept logistic multi-level model was developed in MLWin 2.01. The random intercept model allowed the overall probability of food security to vary across EAs. The binary response was y_{ij} which equaled 1 if a household *i* in EA *j* was food secure, and 0 if it was not. Similarly, a *j* subscript was added to the proportion so that π_{ij} = Pr(y_{ij} = 1). If there is a single explanatory variable, x_{ij}, measured at the household level, then a two-level random intercept model will resemble the following:

$$\text{logit}(\pi_{ij}) = \beta_{0j} + \beta_1 x_{ij}$$
$$\beta_{0j} = \beta_0 + u_{0j}$$

Here, the intercept consists of two terms: a fixed component β_0 and an EA-specific component, the random effect u_{0j}. It is assumed that the u_{0j} follow a Normal distribution with mean zero and variance σ^2_{u0}.

$$\text{logit}(\pi_i) = \log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 x_i$$

All variables from the previous binary logistic model were entered. All variables except for *vegetation* were entered at the household level. *Vegetation* was entered at the EA level.

Quasi-likelihood methods we implemented in *MLwiN*. These procedures use a linearization method, based on a Taylor series expansion, which transforms a discrete response model to a continuous response model. After applying the linearization, the model is then estimated using iterative generalized least squares (IGLS) or re-weighted IGLS (RIGLS). The transformation to a linear model requires an approximation to be used. I began with a 1st order marginal quasi-likelihood (MQL) which offers the crudest approximation but may lead to estimates that are biased downwards. Therefore, the 1st order MQL was used to obtain starting values for a 2nd level predictive (or penalized) quasi-likelihood (PQL) which is useful for improving the estimation procedure (Rasbash et al, 2005).

5.0 Results

5.1 Descriptive analysis

Over half, or 57% of the respondents in the WHS in Accra were food insecure, while 43% were food secure, meaning that the majority of women surveyed do not have access to the quantity and quality of foods they desire at all times. To further explore diet related factors, the following variables were explored: *servings of fruit per day, serving of vegetables per day, whether or not meals were skipped in the past 12 months, and frequencies of skipped meals over the past 12 months.*

Food Security in Accra:

	Frequency	Valid Percent
0	1738	57.2
1	1303	42.8
Total	3041	100

Nearly three-quarters of women surveyed consumed four or less servings of fruit per day. And nearly half of women had four or less servings of vegetables per day. This variable, however, is problematic because "serving" is undefined in the survey. The USDA Food Guide Pyramid recommends 5-9 servings of fruits and vegetables every day, where a serving is defined as:

- One medium-size fruit
- 1/2 cup raw, cooked, frozen or canned fruits (in 100% juice) or vegetables
- 3/4 cup (6 oz.) 100% fruit or vegetable juice
- 1/2 cup cooked, canned or frozen legumes (beans and peas)
- 1 cup raw, leafy vegetables
- 1/4 cup dried fruit

Older children, teen girls, active women, and most men who typically need about 2,200 calories to reach or maintain a healthy weight are recommended to consume at least 7 servings – 3 fruits, 4 vegetables – a day. "Serving" size, however, may have been lost in translation when administering the survey and therefore it is unclear whether women were measuring their own consumption with reference to the USDA guidelines.

A large majority, nearly 83% of respondents, said that they had involuntarily skipped meals in the twelve month preceding the survey. A further look showed that nearly 70% of respondents skipped meals almost every month of the year (Figure 7). Only a small minority (12.5) skipped meals only one or two months out of twelve.

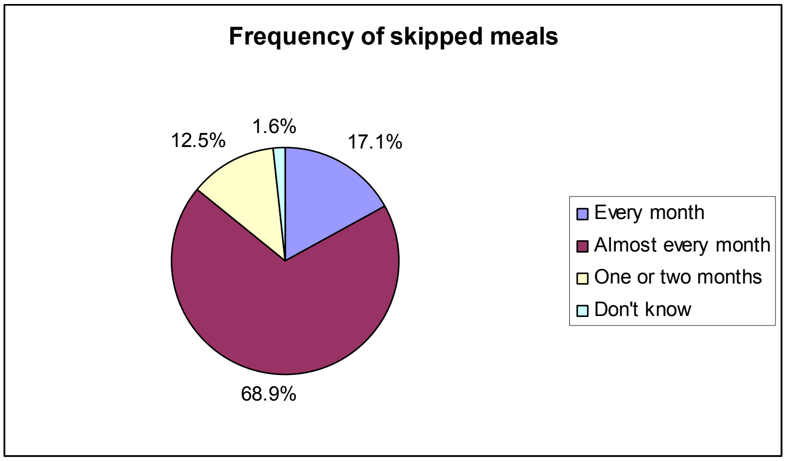


Fig 7.

The descriptive statistics point toward a pattern of significant urban food insecurity. The majority of correspondents were food insecure, as defined by this study, and had a high frequency of skipping meals on an involuntary basis. However, the depth of food and nutrition insecurity is unclear from the variables representing fruit and vegetable consumption, Therefore, it is impossible to discern from this data whether the households that are food insecure are also nutritionally insecure in the long-term.

5.2 Spatial Analysis

First, the General G statistic was employed to determine global spatial patterns in the data. A general G index of 25.75 was derived using ArcGIS 9.1. The index was converted to a z-score of 0.91 which classified the distribution of food security as spatially random. Figure 8 shows food secure areas in red (greater proportion of high values) and food insecure areas in blue (greater proportion of low values). Similar values are not spatially clustered in space. We can infer from this diagnosis that there are equal chances of finding food secure or food insecure households in all areas of the city.

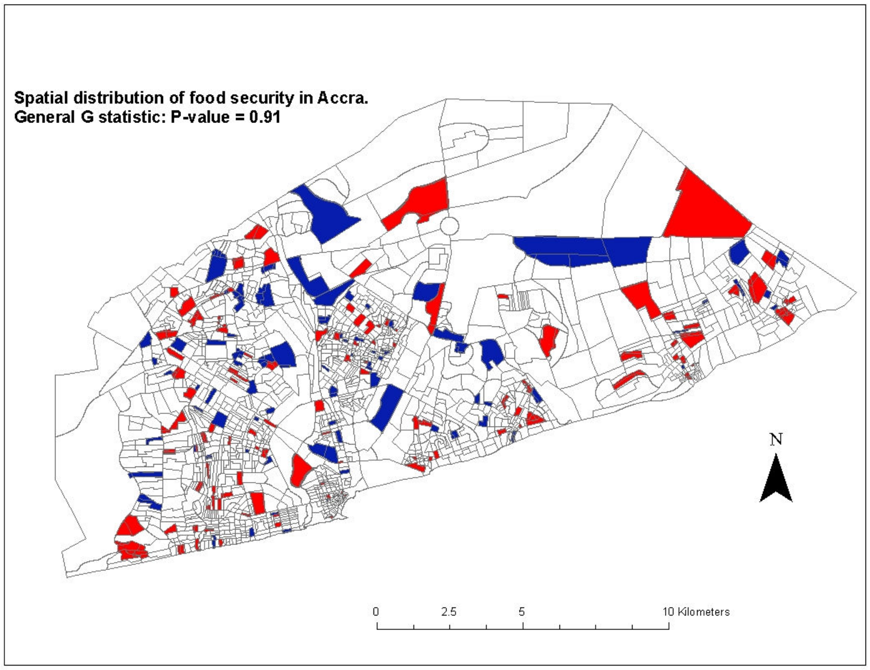


Fig 8.

To further investigate global patterns, Moran's I was used (Figure 9). Moran's I spatial autocorrelation statistic is visualized as the slope in the scatter plot with the spatially lagged variable on the vertical axis and the original variable on the horizontal axis. The variables are standardized to facilitate interpretation and categorization of the type of spatial autocorrelation (cluster or outlier). The slope of the regression line is Moran's I statistic, indicated at the top of the window. The four quadrants in the scatter plot correspond to different types of spatial correlation. Spatial clusters in the upper right (high-high) and lower left (low-low) quadrants, and spatial outliers in the lower right (high-low) and upper left (low-high) quadrants. Note that the magnitude of Moran's I as such does not indicate significance, nor are the statistics directly comparable across weights and variables.

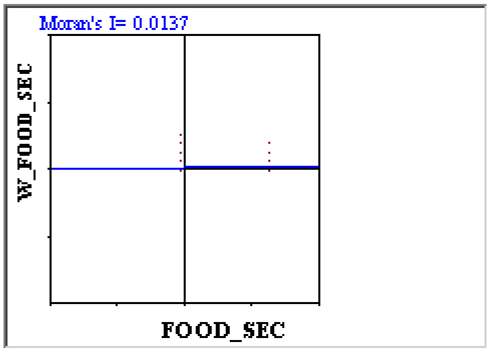


Fig 9.

In this case the box plot shows data in the upper-right quadrant indicating cluster of high-high values. The value for Moran's I, however, is 0.0137 indicating a near random distribution (Mitchell, 2005), thus reiterating the results from the general G statistic.

Local Moran's I for food security was calculated and mapped in GeoDa (Figures 10 and 11). Figure 10 is a choropleth map showing those locations with significant Local Moran statistics as different shades of green, depending on the significance level. The darker the shade of green, the more significant is the cluster. Numerous dark green areas are visible on the map across the entire landscape.

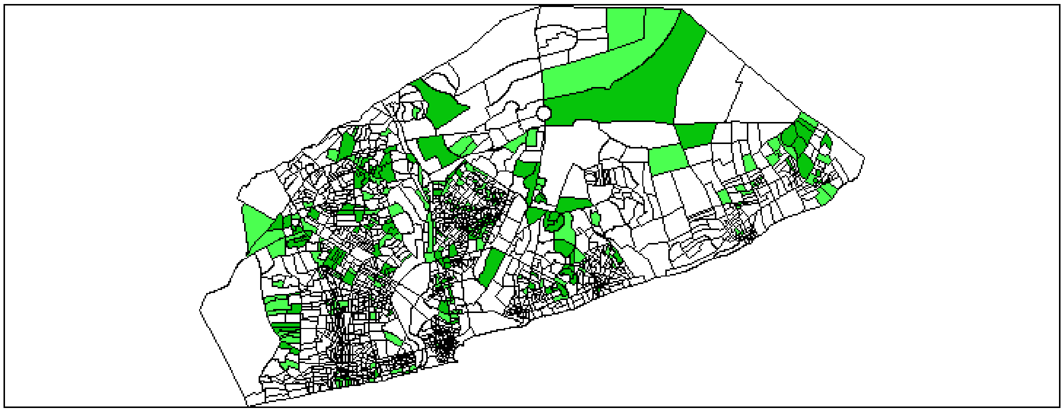


Fig 10.

Figure 11 is a choropleth map (also generated in GeoDa) showing those locations with a significant Local Moran statistic classified by type of spatial correlation: bright red for high-high association, bright blue for low-low, light blue for low-high, and light red for high-low. The high-high and low-low locations suggest clustering of similar values ("high" indicating food secure households, and "low" indicating food insecure), whereas the high-low and low-high locations indicate spatial outliers. These latter areas are most notable on the map as would be expected when data is spatially distributed randomly. A few high-high (red) areas are visible around the central parts of the map, while no areas of low-low are clearly visible. Again, because of the spatial randomness of the data, few high-high or low-low areas were expected.

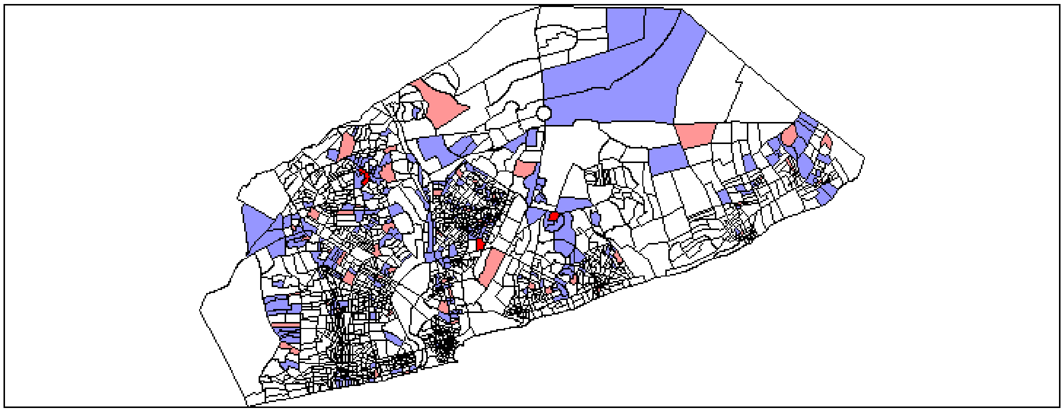


Fig. 11.

To verify the local spatial pattern in the data G_i^* was employed, where the value of the target feature was included. Z-scores for the statistic were mapped (Figure 12). Statistically significant polygons (greater than 1.96 or less than -1.96) indicated clusters of high and low values respectively. In this instance, only high valued clusters (food secure) are manifest in the data and are shaded red on the map. Values between -1.96

and 1.96, or non-significant areas, show no apparent concentration of similar values and are not shaded on the map

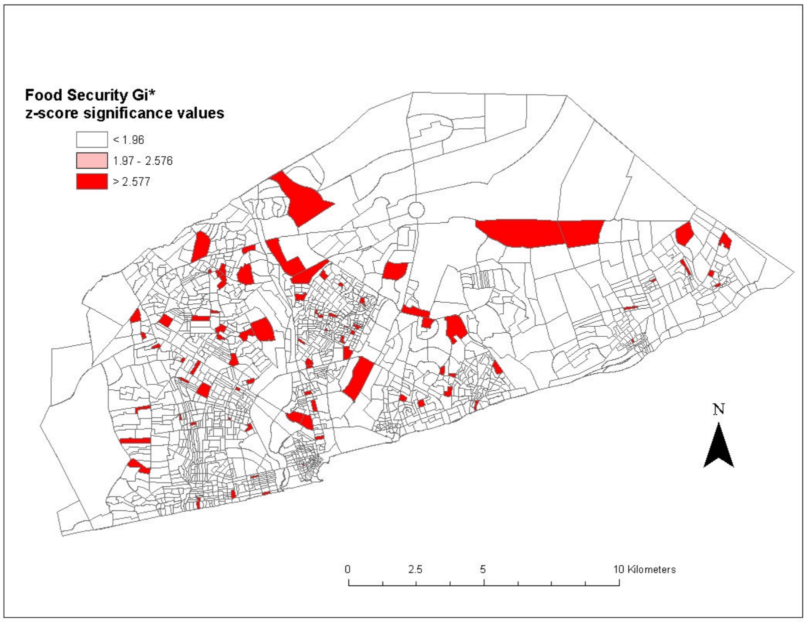
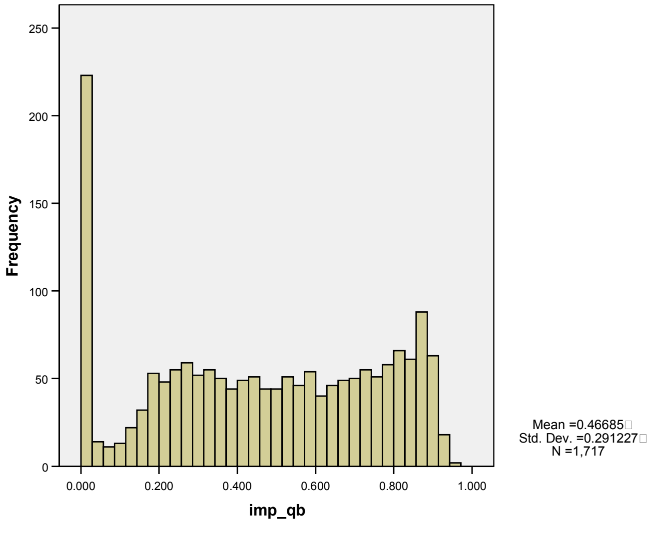


Fig 12..

5.3 Remote Sensing Analysis

A Kappa coefficient was estimated for classification accuracy. Correctly assigned pixels may have been assigned by chance and not based on the classification decision rule. The kappa value $\hat{K}$ indicates how accurate the classification output is after this chance, or random, portion has been accounted for. Therefore, Kappa is a measure of observed accuracy against expected accuracy. Kappa is always equal to or less than 1, with measures between 0.80 and 1 considered representative of strong agreement between the observed classification result and the expected classification result. A Kappa coefficient of 0.9057 was calculated for this study. The coefficient confirms a high level of accuracy attributed to a simple classification scheme applied to high-resolution imagery.

Fig 13.



Histograms were created for each class (i.e. impervious surface, bare soil, and vegetation) as seen in Figures 13, 14 and 15, respectively. The histograms represent proportional abundance of each class within every EA covered by the imagery. We see that proportions of bare soil and impervious surface are evenly distributed across EAs without a significant pattern in the data. Vegetation, on the other hand, shows a noticeable majority of EAs with very little vegetation and a small minority of EAs that contain large proportions of vegetation cover.

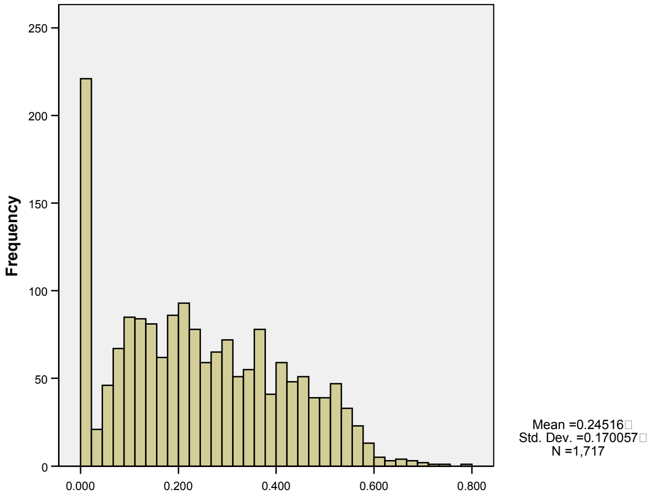


Fig 14.

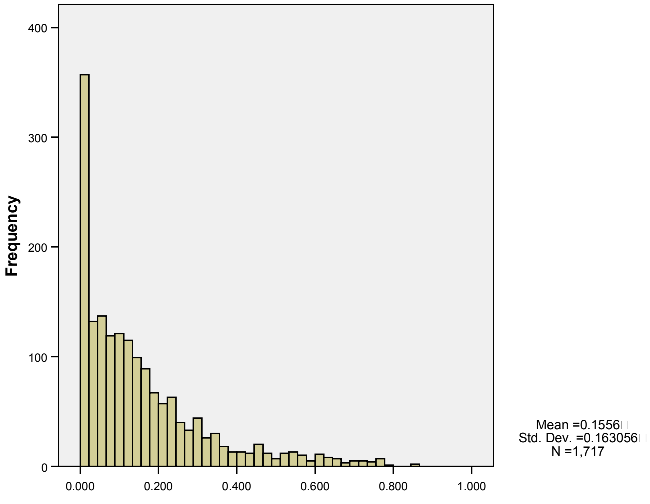
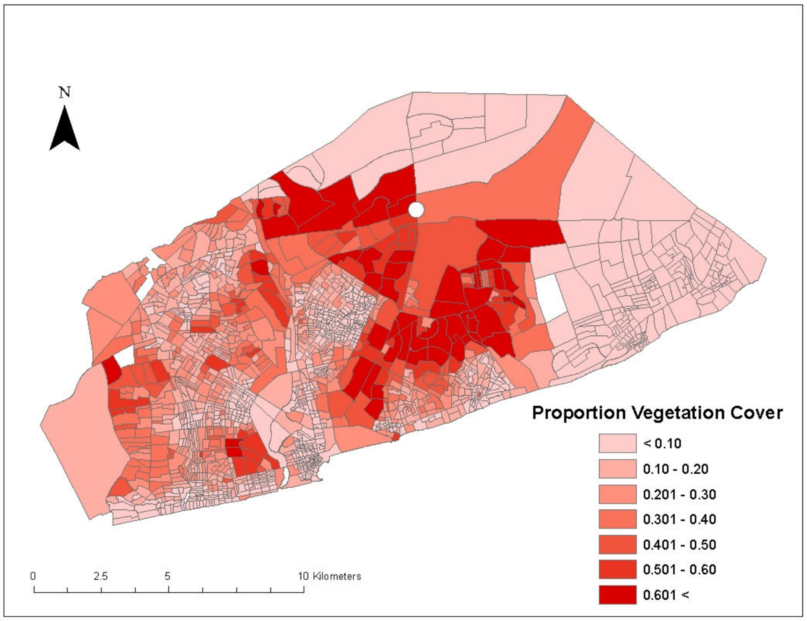


Fig 15.

Vegetation was mapped in ArcGIS to discern spatial patterns in its distribution. We see in Figure16 that higher proportions of vegetation are concentrated vertically around the central part of the map (equivalent to the eastern fringe of the imagery) and in a few areas west of the Korle Lagoon. Clusters of similar (high or low) values were identified using Local Moran's I in ArcGIS Cluster and Outlier Analysis. Figure 17 represents a map of these clusters. The most significant high value clusters are visible in dark red and low value clusters in dark blue. We see that across Accra, vegetation is highly clustered in multiple areas including along the Korle Lagoon (vertically in the center of the map), in the Cantonments area to the East, and in several patches in the western part of the city.

Though Accra is located close to the equator in a tropical environment, we can conclude that vegetation is not randomly distributed across the city but significantly clustered in specific areas. Given its important spatial pattern, vegetation was tested in the analytical model as a predictor of household food security.

Fig 16.



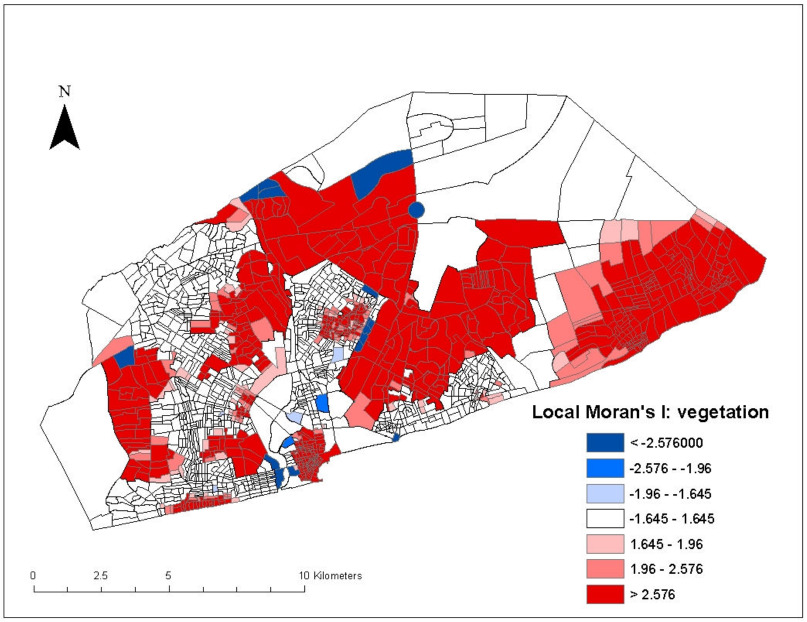


Fig 17.

5.4 Principle Components Analysis

Principle Components were extracted from three of the four conceptual categories. The category Neighborhood Environment did not undergo PCA because it only held three remote sensing variables, and all those variables were important for testing on an individual basis. The following table shows the initial set of variables within each category:

Socio Economic Status	Home Environment	Neighborhood Environment	Health
Tenure	Dwelling type	Impervious surface	Overall health
Cooking Fuel	Roof material	Bare soil	Diabetes
Fridge	Electricity (light)	Vegetation	Heart attack
Phone	Kitchen facility		Stroke
TV	Bathing facility		Malaria
Radio	Toilet facility		TB
Car	Water source		Obesity
Education	Liquid waste collection		Anemia
	Solid waste collection		Breastfed children

SPSS keeps any factor with an eigenvalue larger than 1.0. If a factor has an eigenvalue less than 1.0, then it explains less variance than an original variable and is usually rejected. Several iterations were completed for each category until finding the set of variables and components which explained the greatest amount of total variance.

For socio-economic status, *education, income, tenure, and cooking fuel,* were removed from the process since they significantly reduced the explained variance. Thus, *radio, tv, fridge, car, and phone* were retained (with a 78% explanation of the variance) and sorted into the following components:

Rotated Component Matrix(a)

	Component	
	1	2
radio	.969	.123
tv	.969	.123
fridge	.696	.367
car	.068	.850
phone	.264	.765

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
(a)Rotation converged in 3 iterations.

where the first component called “home appliances” consisted of *fridge, tv,* and *radio;* and the second component called “communication” included *car* and *phone.* However, because of the theoretical importance of refrigerators for food storage in the household, the first component was unraveled and all three variables were maintained separate. “Communication” was kept as a new variable, since neither television nor phone have significant theoretical importance on their own, but access to modes of transport and communication can benefit households socially and economically.

The next set of variables was one describing the Home Environment. *Roof material* was removed which increased the total explained variance from 47% to 52%. All other variables were retained and the following components were generated:

Rotated Component Matrix(a)

	Component	
	1	2
bath	.789	.096
toilet	.788	.150
liqwaste	.724	-.108
dwelling	.718	.133
kitchen	.688	.027
solidwas	.455	-.011
water	.004	.791
light	.080	.743

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
(a) Rotation converged in 3 iterations.

where *bath, toilet, liquid waste, dwelling, kitchen and solid waste* comprise the first component; and *water* and *light (electricity)* make up the second. In this case, neither component was retained. The first component contained several variables of theoretical importance to food security studies including type of kitchen facility, access to liquid and solid waste services, and access to toilet facilities. The second component contained *water* which is also an important theoretical variable and should stand alone. Therefore, the second component was also eliminated leaving *water* and *light* separate.

The third and last set of variables comprising Health generated the following components:

Rotated Component Matrix(a)

	Component		
	1	2	3
diabetes	.761	.074	-.184
stroke	.702	-.037	.200
malaria	-.137	.759	-.021
obesity	.170	.703	.034
tb	.013	.018	.967

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
(a) Rotation converged in 4 iterations.

Where *diabetes and stroke* comprise the first component; *malaria* and *obesity* comprise the second; and *tuberculosis* stands alone as a third component. *Overall health, breastfeeding,* and *heart attack,* and *anemia* were removed as they debilitated the strength of the variance. The first component was kept as a new independent variable and called *diet related disease.* The second component was not logically combined (where *obesity* should theoretically be in the first component), and therefore it was dissolved in order to examine variables individually.

5.5. Binary Logistic Model

The final independent variables therefore selected for the binary logistic model were the following:

Socio-economic	Home Env.	Neighborhood Env	Health
TV	Bath	Impervious Surface	Diet disease
Fridge	Liquid waste	Bare Soil	Malaria
Communication	Solid waste	Vegetation	Obesity
Tenure	Dwelling		TB
	Water		Breastfeeding
	Light		Overall health
	Kitchen		
	Toilet		

where all variables were measured at the individual level, except for the Neighborhood Environment (remote sensing) variables which were measured at the EA level.

In the first category, Socio-Economic Status, all variables from the factor analysis were retained, including the new variable labeled *communication.* Similarly, all variables in the second category, Home Environment, were also included, although no new variables from the factor analysis were introduced.

All three remote sensing variables in the Neighborhood Environment category were tested in the binary logistic equation. In accordance with one of the research objectives of this study, all remote sensing variables were used in order to extensively explore their usefulness for deriving food security related information.

In the Health category, all variables from the PCA exercise were included. *Breast feeding* and *overall health* were reintroduced into the equation for theoretical importance. As discussed above, breastfed children tend to be better nourished and protected from disease, both fundamental factors in the biological utilization of food. Similarly, better overall health, as described by the subject herself, allows for more work days where income can be earned or more school days for education. As stated by Maxwell (1999) both income and education play a fundamental role in achieving food security.

SPSS 14.0 was used to test the binary logistic model using *food security* as the dependent variables. Independent variables were entered in “blocks” according to each theoretical category where Block 1 = Socio-economic variables, Block 2 = Home Environment variables, Block 3 = Neighborhood Environment remote sensing variables, and Block 4 = Health variables.

Variables without a significant impact on the equation were systematically removed by SPSS as additional blocks were entered. At the end of the iteration process, only the following statistically significant variables were left in the equation:

x_1 = fridge
x_2 = tenure
x_3 = bathing facility
x_4 = solid waste collection
x_5 = vegetation cover
x_6 = breastfeeding

x_7 = overall health

Therefore the model can be expressed as:

$$food\ security = \frac{1}{1+e^{-z}},\ where\ z = \beta_0 + \beta_1 fridge + \beta_2 tenure + \beta_3 bath + \ldots + \beta_7 overhealth$$

The final Nagelkerke R square was 0.134, suggesting a weak association between the independent variables and the dependent variable. Several explanations are possible. The first is that the quantitative data sets used in this analysis were not adequate in terms of food security and nutrition data despite the fact that they were the best standardized data sets available for exploring nutritional health in Accra. Most demographic and health data sets do not sufficiently sample the population in terms of nutritional health issues and are geared for detecting only situations of long-term famine rather than shorter term but reoccurring food insecurity. Second, the spatial variation of different food secure groups may be causing a "cloudy" pattern within the data set rather than a more clearly defined trend line. In other words, food secure and food *in*secure households may be situated within similar geographical regions (EAs) and therefore neighborhood level variables may not be clearly influencing the outcome.

The table below shows the model summary for the binary logistic regression. The top three variables with the highest explanatory β coefficient were, in order from highest to lowest: *vegetation, solid waste, and bathing facility*. The lowest scoring variables were, in order from lowest to highest: *tenure, overall health and breast feeding*.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	fridge	.517	.103	24.982	1	.000	1.677
	tenure	-.217	.063	11.782	1	.001	.805
	bath	.649	.118	30.242	1	.000	1.914
	solidwas	.926	.148	38.911	1	.000	2.525
	veg	1.066	.360	8.775	1	.003	2.905
	breastfeed	.465	.161	8.335	1	.004	1.592
	over_healt	.429	.113	14.335	1	.000	1.535
	Constant	-1.429	.237	36.459	1	.000	.239

a Variable(s) entered on step 1: breastfeed, over_healt.

Food security is positively related to *fridge, bathing facility, solid waste, vegetation, breast feeding, and overall health. .* It is negatively associated with *housing tenure,* again due to the direction of the data. At 2.905 the expβ coefficient for *vegetation* was significantly larger than coefficients for all other variables. The implications are important and support studies by Weeks (2003) that show that remote sensing can be used to trace patterns of social processes on the ground. While more research is needed to understand how vegetation patterns are related to household nutrition security, this result indicates a first step in recognizing the validity of remote sensing data in social studies research.

5. 6 Multi-level Model

The multi-level model results (below) clearly mirror the logistic regression, but this time accounting appropriately for vegetation, a neighborhood level variable. We see that the intercept for EA *j* is -1.72 + *u*0 *j,* where the variance of *u*0 *j* is estimated as 0.382 (SE = 0.151).

$$\text{foodsec}_{ij} \sim \text{Binomial}(\text{denom}_{ij}, \pi_{ij})$$

$$\begin{aligned}\text{logit}(\pi_{ij}) = \beta_{0j}\text{cons} &+ 0.581(0.116)\text{fridge}_{ij} + -0.205(0.072)\text{tenure}_{ij} + \\ &0.626(0.133)\text{bath}_{ij} + 0.918(0.158)\text{solid}_{ij} + 0.607(0.437)\text{veg}_{j} + \\ &0.408(0.187)\text{brstfd}_{ij} + 0.497(0.125)\text{overhlth}_{ij}\end{aligned}$$

$$\beta_{0j} = -1.372(0.276) + u_{0j}$$

$$\left[u_{0j}\right] \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \left[0.382(0.151)\right]$$

$$\text{var}(\text{foodsec}_{ij} | \pi_{ij}) = \pi_{ij}(1 - \pi_{ij})/\text{denom}_{ij}$$

In the multi-level model, chances of household food security increase with ownership of a fridge, adequate bathing facilities, access to better solid waste collection services, better overall health, and infant breast feeding practices. Again, the variable *tenure,* is ordered so the least secure situations have a higher ranking, resulting in a negative output in the model. Therefore, chances of being food secure increase with better housing tenure. Vegetation resulted in a positive outcome, indicating that chances of a household being food secure increase with greater proportions of vegetation at the EA level.

The table below shows Z-ratios, which can be compared with a standard Normal distribution to carry out pair-wise tests of differences for each independent variable. A two-tailed z-test of significance was carried out and returned significant p-values as shown. From this test, it is possible to see that all variables are significant at the .05 level except for vegetation which was nevertheless significant at the .10 level.

Odds ratios of coefficients:

Variable	β	S.E.	z = β/S.E.	p-value
fridge	0.581	0.116	5.009	0.000
tenure	-0.205	0.072	-2.847	0.002
bath	0.626	0.133	4.707	0.000
solid	0.918	0.158	5.810	0.000
veg	0.607	0.437	1.389	0.082
breastfeed	0.408	0.187	2.182	0.015
overall health	0.497	0.125	3.976	0.000

For discrete response models, the likelihood ratio test is unavailable and a Wald test is a viable alternative. A Wald test was therefore carried out in MLWin although this test is approximate, as variance parameters are not normally distributed. The test statistic was 24.775, which we compare to a chi-squared distribution on (n-1) or 6 d.f. The returned p-value was 0.0003 or a value of high statistical significance. Therefore we can conclude that there are significant differences between EAs in terms of food security, and that a multi-level approach to analysis was both useful in term of extracting data and providing information for policy.

6.0 Conceptual Model Agreement

The first category, *Socio-Economic Status*, was composed of all variables representing demographic, income, education and gender based factors. Two variables, *housing tenure*, and *ownership of a refrigerator* were significant in this study. The former holds a positive relationship with food security. This variable represented four different holding possibilities from least secure to most secure: perching (or squatting), rent-free living, renting, or owning. Perching and rent-free living were considered insecure arrangements where household dwellers could not legally prove their right to occupy their home. Conversely, renters and owners were in the most tenure-secure property holding. *Ownership of a refrigerator* was also positively related to food security leading me to make several inferences. First, a household must be able to save considerable income to buy a large household appliance such as a refrigerator. Second, the household must be regularly serviced by electricity. In a city where large electrical appliances are luxuries, households that own a refrigerator are generally middle to upper class, with sufficient income to buy adequate amounts of food. Third, and in tandem with the food utilization literature, refrigerators allow households to store their food properly and reduce the chances of food borne illness. The latter is especially significant considering Accra's hot tropical climate, where food, if left out, can easily rot within hours.

The next category, *Home Environment*, is represented by *solid waste disposal and type of bathing facility. Solid waste disposal* represents a number of options used by people in the capital city. These range from proper and regular garbage collection by city maintenance crews, to the tossing or burning of waste in the street or gutter. Again, the literature indicates a positive relationship between better systems of solid waste disposal and better household food security and nutrition (ACF-IN, 2007). Similarly, *type of bathing facility* ranged from a private, indoor and piped water facility, to the usage of an outdoor water body such as a pond for personal bathing. The hypothesis here is that the more permanence in any given structure and the higher the quality of materials used to create the structure, the better the overall household shelter conditions in terms of health, space and safety. Households that can afford a better home environment are also more likely to be better nourished and food secure.

The category *Neighborhood Environment* was encompassed by the remote sensing variables. Here, *vegetation* was significant. *Vegetation* represents the proportion of vegetation cover visible in each EA as determined by the remote sensing analysis described in the previous section. In this study on urban food security, this variable is the most theoretically significant since it represents a departure from traditional socio-economic or household environmental variables most cited in the literature. The fact that *vegetation* was a statistically significant variable in the final regression model supports my theory that remote sensing data can be of value when trying to determine the extent and distribution of food security patterns across an urban landscape. Generally, areas of higher concentrations of vegetation cover in urban areas represent higher income housing (Jensen and Cowen, 1999). This may have particular significance when undertaking studies in data poor areas where a census or survey may not be readily available. General inferences may be made about the environmental, demographic and economic landscape of a city from remote sensing data alone.

The final category, *Health and Wellness*, was composed of two variables: *overall self-reported health,* and *breast-feeding.* These are considered to have positive relationships with food security. Households who reported better levels of overall health are also more likely to have healthier habits and be more food secure. Studies have also shown that there are positive links between breastfeeding and better child nutrition and health (Wright and Schanler, 2001; Cadwell, 1999). The selection of breastfeeding as an important variable is significant in this study and can further promote the practice of breastfeeding among mothers.

7.0. Discussion

This analysis has shown that predictor variables for urban food security are decidedly “urban” in nature. From the ownership of certain electrical appliances to the composition of the urban environment, these variables differ from those traditionally used in food security studies. On the one hand, this is to be expected. Urban households are removed from farm land and must rely on a market and monetary based system to access food supply. On the other hand, this study has exposed the academic stagnation of food security research which has not evolved in tandem with urbanization to put forth well documented conceptual models that explain urban food security.

Some basic principles remain the same. Food security theory supports the notion that households can leverage assets in times of hardship or crisis to purchase basic needs such as food (FAO, 2000). Households that have accumulated wealth in terms of assets are therefore better off in securing a constant, adequate food supply. Without savings or accumulate wealth, poor urban households are more likely to go hungry or skip a meal in times of hardship. Under the socio-economic grouping *housing tenure,* and *ownership of a refrigerator* were significant. They describe the security of the housing unit and household assets. Families with greater stability in their living arrangements can consistently distribute more resources to developing livelihood strategies including income earning activities, education and health care. Stable living conditions allow families to save resources and accumulate wealth. Wealth in turn, can be represented by the ownership of such assets like refrigerators. These results beg the deeper question of *what are the predictor variables of wealth and poverty in urbanizing areas of developing countries?* What urban constraints do poor households face in accumulating assets?

The second conceptual grouping, Home Environment, was represented by *solid waste collection* and *bathing facility.* Again we see variables that add structural value to the living environment. Households able to invest more wealth into their home will have better quality building materials and facilities. The positive relationship between these variables and household food security support the food security literature that link economic assets to better access to food (Maxwell et al, 2000). Additionally, cleaner, more secure structures are conducive to healthier and safer environments for families. According to the food security literature, health and safety provide the needed environment for the biological utilization of food (FAO, 2000; WFP 2007). Fewer injuries or incidence of disease increase the ability of an individual to metabolize all the necessary nutrients that come from food. The data also show a positive relationship between household access to services such as solid waste disposal and food security. Again, chances of household utilization of food increase when located within a healthier, more hygienic environment. Basic service such as water and sanitation and proper solid waste management are fundamental to the eradication of disease. Neighborhoods that are properly serviced are healthier and thus less likely to be regularly inflicted with harmful disease.

Vegetation, the only significant neighborhood level variable as well as the only remote sensing variable, provides insight into the neighborhood physical environment. Households located in neighborhoods with greater proportions of vegetation are also more likely to be food secure. In cities like Accra, where urban planning lags behind urbanization and urban growth, neighborhoods that express more vegetation may be older, formal developments, representative of higher income or social class which give higher value to green spaces. Conversely, low income neighborhoods have cleared most vegetation in exchange for higher density living. In Accra, wealthy residents are more likely to live in single family structures with landscaped gardens and roads. Vegetation, therefore, was indeed representative of higher socio-economic status.

In the Health and Wellness category, two variables, *self reported health and breastfeeding* were significant. Both positively related, they support food utilization theory. Breastfeeding not only provides infants with all the critical nutrients they need, but research has shown (cite) that breastfeeding also significantly strengthens a baby's immune system. In areas where clean water may not always be a guarantee, eliminating the use of baby formula may also be a lifesaver. Adults that reported better self reported health were also more food secure. The direction of this variable however is somewhat ambiguous. While better health may be indicative of better nourishment, it may also be reflective of improved income earning opportunities and thus a healthier diet, because of better health.

The relationships which emerged from this study are important in that they support the main body of food security literature (FAO 2000, WFP 2007). Household social and economic wellbeing increase household access and utilization of food. However, this study was particularly important in recognizing the urban variables that translate to socio-economic wellbeing. Household assets such as refrigerators and higher quality building materials reflect the kind of wealth accumulation which is relevant to urban dwellers. Important public health services that are normally provided by municipal governments such as solid waste disposal are also fundamental basic services for the urban household. Relationships to other variables such as overall health and breastfeeding support the traditional rural-based food security literature. These latter variables are more related to food utilization than access and would likely transfer similarly between rural and urban individuals.

In Chapter Two I also hypothesized that the data would show significant intra-neighborhood variability in regards to food security. This was not so. Most of the variability occurs at the household level. In examining the spatial organization of food (in)secure households, I showed that food insecurity is not spatially concentrated in certain areas of the city. The organic and relatively unplanned growth of a city like Accra, has favored a greater socio-economic mix of households across the city. Therefore, food insecure households have nearly equal chances of existing in any part of Accra.

When designing urban food security policy, decision makers must take particular account of variables that are urban in nature. Assuming that that the same rural principles apply to the built environment may reduce the effectiveness of food policy. Households in urban environments face obstacles and opportunities that are place specific and these obstacles and opportunities must be recognized and understood before designing policy. In this study we also learned that variability exists at the households and not neighborhood level. Therefore programs that target specific neighborhoods may exclude a large portion of the food insecure population.

8.0 Conclusion

Using survey and remote sensing data, this paper explored the socio-economic, environmental and spatial predictor variables of urban household food security in Accra, Ghana. The methods were instrumental in advancing geographic studies of human-environment relationships in urban settings. The ability of geographic technology to combine different sources of data into one unified geo-database, expands the opportunities for exploration of health-related studies. This study, in particular, showed how the introduction of remote sensing variables to a social-science health study can better inform the research topic. In data-poor areas, high resolution imagery can provide valuable environmental information. The application of remote sensing and GIScience can be useful to a number of social-science, public health and environmental disciplines or to any study which emphasizes human-environment relationships.

The resulting predictor variables in this study support food security theory and reflect the process of urbanization and accompanying health factors for Ghanaians. The outcomes show how access to urban infrastructure and services are related to food access in the city and necessary for human wellbeing. The data show clear relationships between poor housing conditions and public services and higher probabilities of food insecurity. Conversely, better housing security and infrastructure are more likely to be related to food security. Again, the remote sensing data uncovered the relationship between neighborhood environment and household food security. In this case, households that live in neighborhoods with greater proportions of vegetation (and less of bare soil or impervious surface) are also more likely to be food secure. The implications for the use of remote sensing in such analyses are therefore rich. For example, remote sensing can be used relatively inexpensively to draw important environmental variables from the ground which otherwise could be costly and time consuming to collect. Satellite imagery literally provides the “big picture” and can be updated frequently to chart the trends in urbanization. Especially in data-poor or resource strapped areas where local governments may not have the resources to conduct an urban environmental study, high resolution satellite imagery can quickly provide reliable, detailed data.

The results of this study can inform policy in several different ways. First, while some neighborhoods which exhibit more slum-like conditions may exist or be well known, food insecurity is a city wide problem and programs to help households access sufficient foods should be implemented across the municipality. School feeding programs, food banks, and organized food markets should be accessible in all parts of the city. Second, policy makers should make an effort to make a wide-range of foods economically affordable so that households are nutritionally secure in terms of micro-nutrients and not just calories. Urban dwellers are not as likely as their rural counterparts to be malnourished in terms of calories, but they are at risk of being malnourished in terms of diet quality. Third and finally, urban food security is the result of many structural and historic factors which have spurred rapid urbanization and urban poverty. Stronger agricultural systems, less reliance on more expensive imports, and better health, education and economic prosperity can help millions of households reach their nutritional goals.

Quantitative data sets used in this analysis remain inadequate in terms of food security and nutrition data despite the fact that they are the best standardized data sets available for exploring nutritional health in Accra. Most demographic and health data sets insufficiently sample the population in terms of nutritional health issues and are geared only for detecting situations of long-term famine rather than shorter term but reoccurring food insecurity. Second, the spatial variation of different food secure groups may be causing a “cloudy” pattern within the data set rather than a more clearly defined trend line. In other words, food secure and food *in*secure households may be situated within similar geographical regions (EAs) and therefore neighborhood level variables may not be clearly influencing the outcome. Therefore future research should be employed with more specific datasets that are specifically designed to address urban food security.

More comprehensive data sets designed for a food security study in particular are needed to better understand the breadth and depth of the phenomena. Qualitative surveys are also necessary for the validation and interpretation of results. They can provide important new independent variables that otherwise may not be available in traditional quantitative surveys. Qualitative work can also inform quantitative survey design and diminish interpretive errors between surveyors and participants. They provide an informative contextual backdrop for quantitative surveys to be implemented. As urban centers gain importance in the developing world, a better understanding of how local food systems work is also necessary. Without such research, it is impossible to know how many millions of urban dwellers go hungry ever night, and what can be done to feed them.

Referenced Literature

Action Against Hunger International Network (ACF – IN). 2007. Water, Sanitation and Hygien Policy ACF – IN. Action contre la Faim, Paris.

Akash, Bilal A; and Mohsen, Mousa S. 1999. Energy analysis of Jordan's urban residential sector. *Energy.* Vol. 24. pp. 823-831.

Amoah, Albert GB 2007. Sociodemographic variations in obesity among Ghanaian adults *Public Health Nutrition*: 6(8), 751–757

Biritwum, R.B., J. Gyapong, and G. Mensah, 2005. The epidemiology of Obesity in Ghana. *Ghana Medical Journal:* 39 (3).

Beaglehole Robert, Srinath Reddy and Stephen R. Leeder, 2007. Poverty and Human Development: The Global Implications of Cardiovascular Disease *Circulation* 116;1871-1873

Balkau Beverley, John E. Deanfield, Jean-Pierre Després, Jean-Pierre Bassand, Keith A.A. Fox, Sidney C. Smith, Jr, Philip Barter, Chee-Eng Tan, Luc Van Gaal, Hans-Ulrich Wittchen, Christine Massien and Steven M. Haffner, 2007. International Day for the Evaluation of Abdominal Obesity (IDEA): A Study of Waist Circumference, Cardiovascular Disease, and Diabetes Mellitus in 168 000 Primary Care Patients in 63 Countries *Circulation* 116;1942-1951

Caballero, B and B. Popkin, 2002. *The Nutrition Transition: diet and disease in the developing world.* Academic Press, London.

Cadwell, K. 1999. Reaching the goals of "Healthy People 2000" regarding breastfeeding. *Clin. Perinatol*(26): 527 – 537.

Chambers, Robert. 1995. Poverty and Livlihoods: Whose Reality Counts? *Environment and Urbanization.* **7**(1), pp. 173-204.

Cohen, Barney. 2004. Urban growth in developing countries: a review of current trends and a caution regarding existing forecasts. *World Development* 32(1), pp. 23-51.

Duda, R., M. Kim, R. Darko, R. Adanu, J. Seffah, J. Anarfi, and A. Hill, 2007. Results of the Women's Health Study of Accra: Assessment of blood pressure in urban women. International Journal of Cardiology 117 (2007) 115–122.

Doak, Colleen, Linda S. Adair, Margaret E. Bentley, Fengying Zhai, and Barry M. Popkin, 2002. The underweight/overweight household: an exploration of household socio-demographic and dietary factors in China. *Public Health Nutrition* 5(1A):215-221

Doak, Colleen, 2002. Large scale interventions and programmes addressing nutrition related chronic diseases and obesity: Examples from 14 countries. *Public Health Nutrition* 5(1A):275-277

FAO, 1996. *Rome Declaration on World Food Security and World Food Summit Plan of Action.* Rome, Italy.

FAO, 1997. *Preventing micronutrient malnutrition a guide to food-based approaches – Why policy makers should give priority to food-based strategies.* International Life Sciences Institute, Washington DC.

FAO, 2001. Gender and nutrition. *SD Dimensions.* http://www.fao.org/sd/2001/PE0703a_en.htm.

Galal, Osman M. 2002. "The nutrition transition in Egypt: obesity, undernutrition and the food consumption context." *Public Health Nutrition* 5(1A):141-148

Garrett, James. L. 2000. Overview. In *IFPRI 2020 Vision, Achieving Urban Food Security and Nutrition in the Developing World.*. Focus 3, Brief 1 of 10.

Gatrell, Anthony C. and Janette E. Rigby. 2003. "Spatial Perspectives in Public Health." in *Spatially Integrated Social Science*, edited by M. F. Goodchild and D. G. Janelle. New York: Oxford University Press.

Ghassemi, Hossein, Gail Harrison, Kazem Mohammad, and Ahmed Ali Nour Balaa. 2002. "An accelerated nutrition transition in Iran." *Public Health Nutrition* 5(1A):149-155

Grant, R. and Yankson, P. 2003. Accra. *Cities* 20 (1): 65-74.

Haddad et al. 1999. Are urban poverty and undernutrtion growing? Some newly assembled evidence. *World Development* 27(11), pp. 1891 – 1904.

Hanson, S. 1999. Isms and Schisms: Healing the rift between the nature-society and space-society traditions in human geography. *Annals of the Association of Professional Geographers* 89(1):133-143.

Hardoy, Jorge E., Diana Mitlin, and David Satterthwaite. 2001. *Environmental Problems in an Urbanizing World*. London: Earthscan Publications.

Harpham, Trudy and Michael Tanner, editors. 1995. *Urban Health in Developing Countries: Progress and Prospects.* Earthscan, London.

Herold, Martin, Joseph Scepan, and Keith C. Clarke. 2002. "The use of remote sensing and landscape metrics to describe structures and changes in urban land uses." *Environment and Planning A* 34:1443-1458.

Hill, Allan, R. Darko , J. Seffah , R.M.K. Adanu , J.K. Anarfi , R.B. Duda, 2007. Health of urban Ghanaian women as identified by the Women's Health Study of Accra. *International Journal of Gynecology and Obstetrics* 99, 150–156

Jensen, J.R. and Cowen, 1999. Remote sensing of urban/suburban infrastructure and socio-economic attributes. *Photogrammetric Engineering and Remote Sensing.* vol. 65:5, pp. 611-622.

Jensen, J.R. and D.L. Toll, 1983. Detecting Residential Land-Use Development at the Urban Fringe," *Photogrammetric Engineering and Remote Sensing,* 48: 629-643.

Kessides C, 2007. The urban transition in Sub-Saharan Africa: challenges and opportunities. *Environment and Planning C: Government and Policy* **25**(4) 466 – 485

Landers, John. 1993. *Death and the Metropolis: Studies in the Demographic History of London, 1670 – 1830.* Cambridge University Press, UK.

Langevin, C. and D. Stow, 2004. Identifying change in a dynamic urban landscape: a neural network approach to map-updating. *Progress in Planning* 61: 327-348.

Lopez, Anna Carla and John R. Weks. 2008a. Socio-economic, environmental and gender differentials of urban food insecurity in Accra, Ghana. Submitted to *Environment and Urbanization.*

Lopez, Anna Carla and John R. Weeks. 2008b. Validation, corroboration and interpretation of the quantitative survey and remote sensing analysis using qualitative in-depth household interviews. Submitted to *The Professional Geographer.*

Maxwell, Daniel. 1999. The Political Economy of Urban Food Security in Sub-Saharan Africa. *World Development.* **27** (11), pp. 1939-1953

Maxwell, Daniel; Carol Levin; Margaret ARmar-Klemesu; Marie Ruel; Saul Morris; Clement Ahiadeke. 2000. *Urban livelihoods and food and nutrition security in Greater Accra, Ghana*. Research report of the International Food Policy Research Institute, Washington D.C.

Maxwell, Daniel; Clement Ahiadeke, Carol Levin, Margaret Armar-Klemensu, Sawudatu Zakariah, Grace Mary Lamptey. 1999. Alternative food-security indicators: revisiting the frequency and severity of coping strategies. *Food Policy* **24**(4): pp. 411-429.

Micklin, Michael and David F. Sly. 1998. "The Ecological Complex: A Conceptual Elaboration." Pp. 51-84 in *Continuities in Human Ecology*, edited by M. Micklin and D. L. Poston. New York: Plenum Press.

Monteiro, Carlos A., Wolney L. Conde, and Barry M. Popkin, 2002. Is obesity replacing or adding to under-nutrition? Evidence from different social classes in Brazil. *Public Health Nutrition* 5(1A):105-112

Namboodiri, Krishnan. 1988. "Ecological demography: its place in sociology." *American Sociological Review* 53:619-633.

Omran, Abdel R. 1971. The epidemiological transition: a theory of the epidemiology of population change. Milbank Memorial Fund Quarterly, 49: 509-538.

Peet, R. and M. Watts, 1996. Liberation ecology: development, sustainability, and environment in the age of market triumphalism, in *Liberation ecologies: environment, development, social movements.* New York, Routledge.

Pelling, Mark. 2003. Toward a Political Ecology of Urban Environmental Risk: The Case of Guyana. In *Political Ecology.* Zimmerer, K and Bassett T (Eds). The Guilford Press, New York.

Pellow, 2002.

Phinn, S.R., M. Stanford, P. Scarth, A.T. Murray, and P.T. Shyy. 2002. "Monitoring the composition of urban environments based on the vegetation-impervious surface-soil (VIS) model by subpixel analysis techniques." *International Journal of Remote Sensing* 23:4131-4153.

POPIN, 2003. *World Urbanization Prospects: The 2003 Revision.* Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. New York.

Popkin, Barry M. 1993. Nutritional Patterns and Transitions. *Population and Development Review.* (19) 1.

Popkin, Barry M., 2002. "The shift in stages of the nutrition transition in the developing world differs from past experiences!" *Public Health Nutrition* 5(1A):205-214

Rasbash, J., F. Steele, W. Browne, B. Prosser, 2005. A User's Guide to MLwiN version 2.0. The Centre for Multilevel Modeling, University of Bristol. UK.

Rashed, T, Weeks, J.R., Roberts, D., Rogan, J., and R. Powell, 2003. Measuring the physical composition of urban morphology using multiple endmemeber spectral mixture analysis. *Photogrammetric Engineering and Remote Sensing* 69 (9), pp. 1011-1020.

Rashed, T, Weeks, J.R., Stow, D., and D. Fugate, 2005. Measuring temporal compositions of urban morphology through spectral mixture analysis: toward a soft approach to change analysis in crowded cities. *International Journal of Remote Sensing* 6(4): 699-718.

Ridd, M. 1995. Exploring a V-I-S (Vegetation-Impervious Surface-Soil) model for urban ecosystem analysis through remote sensing: Comparative anatomy of cities. *International Journal of Remote Sensing,* 16 (12), pp. 2165-2185.

Robbins, Paul. *Political Ecology: a critical introduction.* 2004. Blackwell Publishing, Massachusetts.

Sampson, Robert J. and Jeffrey D. Morenoff. 2003. "Spatial (Dis)Advantage and Homicide in Chicago Neighborhoods." in *Spatially Integrated Social Science*, edited by M. F. Goodchild and D. G. Janelle. New York: Oxford University Press.

Satterthwaite, D. 1995. The underestimation of urban poverty and its health consequences. *Third World Planning Review,* 17(4), R3-R12.

Songsore, J. and G. Goldstein. 1995. Health and Environment Analysis for Decision-Making: field study in Accra, Ghana. *World Health Statistics Quarterly.* 48: 108-117.

Songsore J. and G. McGranahan. 1998. The political economy of household environmental management: gender, environment and epidemiology in the Greater Accra Metropolitan Area. *World Development* 26: 395-412

Songsore, Jacob and Gordon McGranahan. 1993. Analysis of intra-urban differential within the Greater Accra Metropolitan Area, Ghana. *Environment and Urbanization* 5:10-34.

Strahler, A.H, Woodcook, C.E, and J.A. Smith, 1986. On the Nature of Models in Remote Sensing. *Remote Sensing of the Environment* 20: 121-139.

Tickamyer, Ann R. 2000. "Space Matters! Spatial Inequality in Future Sociology." *Contemporary Sociology* 29:805-812.

Tzoulas-K.; Korpela-K.; Venn-S.; Yli-Pelkonen-V.; Kazmierczak-A.; Niemela-J.; James-P, 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and urban planning* 7 vol:81 iss:3 pg:167

United Nations-HABITAT 2001, *The State of the World's Cities 2001.* UN HABITAT, Kenya.

United Nations-HABITAT 2003. *Global Report on Human Settlements.* UN HABITAT, Kenya.

United Nations –HABITAT 2004. *The State of the World's Cities 2004/2005.* UN HABITAT, Kenya.

United Nations-HABITAT 2006. *Statistics*. www.unhabitat.org

United Nations-POPIN, 2007. *DATA*. www.un.org/popin/data.html

United States Census Bureau, 2008. www.census.gov

Weeks, J.R., 2003. Using remote sensing and geographic information systems to identify underlying properties of urban environments, in *New Forms of Urbanization: conceptualizing and measuring human settlement in the twenty-first century,* edited by A.G. Champion and G. Hugo. London: Ashgate Publishing Limited.

Weeks, John R., A. Hill, D. Stow, A. Getis, and D. Fugate, 2007. Can we spot a neighborhood from the air? Defining neighborhood structure in Accra, Ghana. *GeoJournal* 69:9.

Weeks, John R., Dennis Larson, and Debbie Fugate. 2005. "Patterns of Urban Land Use as Assessed by Satellite Imagery: An Application to Cairo, Egypt." Pp. 265-286 in *Population, Land Use, and Environment: Research Directions*, edited by B. Entwisle and P. C. Stern. Washington, DC: National Academies Press.

Williams, Naomi and Chris Galley. 1995. Urban-rural Differentials in Infant Mortality in Victorian England. *Population Studies*, Vol. 49, No. 3

Anne L. Wright and Richard J. Schanler 2001. The Resurgence of Breastfeeding at the End of the Second Millennium J. Nutr. 131: 421S-425S.

Zimmerer, Karl L. and Bassett, Thomas J. ed. *Political Ecology: an integrative approach to geography and environment-development studies.* 2003. Guilford Press, New York.