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Spatial Inequalities

Health, Poverty, and Place in Accra, Ghana

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Part I
Introduction

Chapter 1
Introduction to the *Accra School*: An Overview of Health, Poverty, and Place in Accra

John R. Weeks, Allan G. Hill, and Justin Stoler

Most of the future growth of population in the world is expected to take place in cities of developing countries. This fact alone provides a rationale for this volume, but there are also broad policy and programmatic reasons for our interest in the demography, health and well-being of urban centers in low income countries. Cities in developing countries are the power-houses of national economic growth, not least because they contain some of the most skilled, best educated and economically productive people in their respective countries. Despite these advantages, there are major threats to the future success of such cities, including those related to governance, provision of water, sanitation and housing, as well as the emergence of stark inequalities in income, wealth, and health. These issues offer challenges to our knowledge and understanding of the processes of urbanization and economic growth, provoking comparisons with the late nineteenth and early twentieth century transitions in health, mortality, fertility and economic activity in the industrializing cities of northwest Europe and North America. Today's high income countries are struggling with the administration and financing of their modern welfare states,

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while leaders in low income countries are casting around for equitable solutions that produce full employment and rising incomes without leaving large sections of the population impoverished and resentful of the success of their neighbors.

It is our premise that the wealth of a city (and, of course, the country within which that city is located) is indexed importantly by the health of its residents. We adopt a systems approach to understand this linkage because it is not a linear cause-and-effect relationship. People who are physically and mentally healthy will be economically more productive, while at the same time a place that is economically productive is more likely to have the resources to improve the health of its residents. These are both "global" and "local" in the scale at which they operate. At the more global level, a richer city will generally be characterized by healthier residents. But at the local level there may be considerable variability from one part of a city to another. We expect that these inequalities in health and wealth will be starkest and most visible in cities of developing countries. Measuring and understanding these spatial inequalities in Accra, the capital of Ghana in West Africa, is at the heart of all of the research presented in this book. Although the analyses have their theoretical origins in different academic disciplines, the authors have collectively addressed some of the most pressing challenges facing a city like Accra. There are important public policy decisions that depend on our collective ability to follow and interpret the social and political implications of rapid economic development in Africa's urban places. Our goal in this volume, as in our research more generally, is to link the technical innovations emerging in geospatial analysis with the substantive results from spatially-informed socio-economic analyses to address the development challenges faced by Accra and by extension, other such cities in tropical Africa.

1.1 Accra as a Case Study

Accra, our case study for this approach, does have some distinctive features that have facilitated research. Ghana was the first sub-Saharan African country to gain full independence from Britain and despite episodes of military rule, has emerged as one of the more prosperous and stable democratic countries in a region that remains very poor and prone to civil war. Like all other Sub-Saharan countries, Ghana is experiencing rapid population growth and very rapid urbanization, and the future of the country depends very largely on economic, social, political and cultural development in its cities. For several years our research team has joined others striving to understand the urban dynamics in this burgeoning West African metropolis, with a focus on urban disparities in health and well-being. Among ourselves we call this the "Accra School" of urban analysis, since few cities in the global south have been examined from so many different perspectives. Our analysis employs a wide range of GIScience methods, including analysis of remotely sensed imagery and spatial statistical analysis, applied to a wide range of quantitative data, including census, survey and health clinic data, all of which are supplemented by field work, including systematic social observation, focus groups, key informant interviews and other qualitative elements. The purpose of this volume is to explain and highlight this mix of methods and the important findings that have been emerging from this research, with the goal of providing guidance and inspiration for others doing similar work in cities of other developing nations.

1.2 Urban Health and Mortality

For most of human history, until the late nineteenth century, levels of morbidity and mortality were higher in urban than in rural settings. That all changed with the public health revolution in the newly industrializing nations and by the subsequent advances in medicine. Since the beginning of the twentieth century the industrial and post-industrial cities have been healthier places than rural areas (Wrigley 1987; Weeks 2011). Fragmentary evidence, drawn especially from data for children in Demographic and Health Surveys, suggests that this urban advantage exists now in developing countries as well as in industrial and post-industrial nations (Balk et al. 2004). While this urban superiority is not challenged in general terms, there is ample evidence that significant health disparities and inequalities exist even within cities of richer countries (Montgomery and Hewett 2005; Mitchell et al. 2002; Rytkonen et al. 2001), and that these disparities are especially noteworthy in cities of developing countries (Van de Poel et al. 2007). It is becoming increasingly clear that residents in city slums in developing nations may well have health levels that are worse than those experienced by people living in rural areas of the same nation (Fry et al. 2002; Haddad et al. 1999; Menon et al. 2000; Timaeus and Lush 1995; UN Habitat 2006; Montgomery and Ezeh 2005). As we discuss in more detail later, this slum/not slum dichotomy also hides a great deal of inequality because not all slums are alike and the variability within and between slums is crucial to our understanding of health inequalities (Montgomery and Hewett 2005).

The history and development of African urban places is by no means a linear tale of increasing sophistication and prosperity (Anderson and Rathbone 2000). Gould (1998) has argued that there are reversals in sub-Saharan Africa and that a narrowing of the rural-urban health gap is partly a result of the deterioration of health levels in cities. In sub-Saharan African countries, with the fastest national rates of population growth in the world, the fastest growth rates are found in urban places (United Nations Population Division 2012). Sub-Saharan Africa is still viewed as a predominantly rural region but UN projections suggest that the majority of the region's people will live in urban places 25 years from now, with Ghana already having reached that, according to preliminary data from the 2010 census. Furthermore, the growth is expected to occur especially in the mid-to-large cities, rather than in mega-cities. Since almost all sub-Saharan African countries are led by a primate city that is in the mid-to-large range, these are the places that will be most noticeably affected by persistent population growth.

This growth will not be evenly spread within the urban areas, however. In some instances growth is concentrated in slum areas within the older city limits, in other cases it is filling in less dense wealthier parts of the city, while in other situations it is distributed around the expanding periphery. Either way, the rates of local population growth far outstrip the capacity of city or local governments to keep pace with the provision of education, housing, water, sanitation and other social services (Yankson et al. 2007; Pellow 2002). International pressures, under the rubric of structural adjustment or neo-liberal economic policies, have exacerbated the situation for the urban poor as responsibility for the provision of education and health facilities as well as housing and urban infrastructural developments have devolved to local levels of governments or to private households with slender budgets and weak technical capacities to respond. The net effect is that urban poverty is almost certainly deepening and concentrating itself especially within slum areas. The 'urban penalty' for health and mortality has been discussed extensively (Schell et al. 1993; McGranahan et al. 2001), including in a National Research Council report (Montgomery et al. 2003). The evidence is strong that the poor not only have less money, but are worse off than others in terms of health and almost every demographic indicator (World Bank 2005). Thus, it is now within neighborhoods in cities rather than in the rural areas where the starkest contrasts in health are likely to be observed. If we are to improve health outcomes in developing countries we must understand urban neighborhoods and the impact that neighborhoods can have on health.

People make what adaptations they can to the challenges of a degrading urban environment. In Accra, it is estimated that as a result of inadequate sanitation children in slum and poorer neighborhoods are nearly three times as likely to have diarrhea, cholera, and other enteric diseases as are children of wealthy families with better sanitation services (Songsore and McGranahan 1998; Timaeus and Lush 1995). Indeed, using pooled birth history data from Demographic and Health Surveys and the Women's Health Study of Accra (discussed below) we have calculated that in Accra the under-five mortality ranges from 21 per 1,000 in some parts of the city to 78 per 1,000 in other areas within the city (Jankowska et al. 2013). Further, 68 % of households in Accra, again mostly the poor, cook with charcoal or wood, with all the attendant health risks of using these fuels in crowded quarters (Jankowska et al. 2011). These include not only the risk of fire, but also the more pervasively long-term risk of poor health from the effects of the locally created air pollution as a consequence of local concentrations of particulates and toxic oxides of heavy metals in crowded household environments (Zhou et al. 2011). Although most homes in Accra have piped water in or near the house, the quality of the water is variable, and disposal of liquid and solid waste is haphazard, polluting waterways and public roads, leading to the invasion of rodents and other vermin and generally helping to spread disease. Altogether, the combination of rapid population growth and resource-poor, dense urban environments provides a new challenge for the understanding and then the resolution of the problems faced not just by urban West Africans, but by urban dwellers throughout the developing world.

Sustainable development in Africa, as elsewhere in the world, requires that future population growth be absorbed by cities, because only in or near cities can we anticipate the kind of employment growth needed to rise above and stay above the poverty level. At the same time, sustainable development requires a healthy population because only a healthy population can generate the levels of economic productivity necessary to lift an economy out of widespread poverty. The conjunction of these two propositions means that sustainable development in the context of continued population growth demands an urban environment that promotes improved levels of health services, as well as of health equity among its residents. Because of the very limited resources available to most nations of sub-Saharan Africa, urban health promotion in the future will require ever more efficient, parsimonious use of scarce resources (World Bank 2005). Economic development was once thought to be the precursor to improved nutrition, but there is increasing recognition that improved nutrition and health can in fact help to promote economic development. It is thus important to identify the minimum threshold requirements of adequate levels of health in the urban environment, so that resources can be devoted to bringing every neighborhood up to at least that level.

1.3 The Role of Place Within the Urban Environment

We posit that variability in health within urban places, just as between urban and rural places, is importantly a function of the composite characteristics of *place*, not just of the people themselves. The medical model of health has, since the nineteenth century introduction of the germ theory, emphasized the risk of disease experienced by individuals, regardless of context, whereas a purely ecological approach would emphasize the importance of contextual environmental factors (Meade and Earickson 2000). A more holistic, human ecological, or social epidemiological, approach places dual emphases on people and place. Characteristics of place include the provision of potable water, adequate sewerage and disposal of waste, accessibility (geographic and financial) to health clinics and personnel, as well as the adequacy of housing (protection from heat, cold, and water intrusion), the overall quality of the built environment in protecting people from pests and environmental hazards, the physical structure of the neighborhood that promotes or prevents the spread of communicable disease, the exposure to disease vectors such as mosquitoes (Tatem and Hay 2004), and the promotion of adequate diet and exercise (Ellaway et al. 2005; Saelens et al. 2003; Diez Roux 1998), along with the institutional structure that exists to service the needs of the population (Hardoy et al. 2001; Montgomery and Ezeh 2005; Geronimus 2000). Personal characteristics such as education, income, and occupation clearly play a role, of course, in determining access to an adequate diet, personal hygiene, disease avoidance, access to health care professionals, and adherence to medical regimens, but the literature suggests that personal characteristics often interact with neighborhood characteristics to produce health outcomes that are joint products of who a person is and where they live (e.g., Ellen et al. 2001; Cohen et al. 2003; Williams et al. 2003). Since we are starting to appreciate the importance of epigenetic effects on health and life course outcomes, exposures to key risk factors, strongly linked to place, are likely to assume greater salience in future attempts to explain income and welfare differentials within cities and regions.

Differences in mortality by social status are among the most pervasive inequalities in modern society, and they are most noticeable in cities (Weeks 2011). So, an individual who is in a family of low socioeconomic status is at greater risk of death. Data from nearly all places in the world suggest that the higher one's position in society, the longer he or she is likely to live (Weeks 2011). These same personal characteristics may also influence the level of advocacy that will lead to demands for access to communal infrastructure (e.g., water, sewerage, solid waste disposal) that can improve health levels. Thus, to understand health levels we must understand the characteristics of people themselves, and also the characteristics of their environment. Mitchell, Dorling and Shaw (2002:15) capture the idea this way: "The first explanation, commonly referred to as 'compositional', suggests that area level mortality or morbidity rates reflect the risks of ill health which the resident individuals carry with them. The relationships between individual level factors such as social class and employment status, and the risk of mortality or morbidity, are well documented, powerful, and very robust. The composition thesis thus argues that places with apparently high levels of sickness or death rates are those in which a higher proportion of the residents are at higher risk of sickness or death. The second explanation, commonly referred to as 'contextual', suggests that the nature of day-to-day life in an area can exert an influence on the population's overall health and well-being and thus the mortality risk of residents, over and above their individual characteristics. The influences might, for example, stem from the social or physical environment. Somehow, life in an area raises or lowers the risk of ill health for the resident individuals so that they experience different risk of illness from that which they might experience living somewhere else."

An important conceptual issue is whether or not the neighborhood effects are endogenous to the compositional characteristics of those neighborhoods, and thus essentially indistinguishable from the compositional effects (Kaufman 2006) Researchers such as Stjärne et al. (2006) in their study of neighborhood impacts on myocardial infarction in Stockholm, have concluded that they are, in fact, distinguishable. In the research reported in this volume, however, the neighborhood context is measured not just from aggregations of individual characteristics, but more specifically from the physical context that defines a neighborhood. It may be that definitive answers to such questions of context and individual agency depend on detailed ethnographic enquiries at a local scale, as Renne (2003) has elegantly illustrated. Our research attempts to combine measurements of the physical context with ethnographic work and with data aggregated for individuals.

We recognize that in a geographically mobile world measuring exposure can be problematic. People may work in a different place than they live, they may traverse other environments between home and work, and they may travel to different places for personal and/or economic reasons. This is the classic challenge for the epidemiologist trying to detect the various places where an infected/affected individual was exposed to a health risk. In developing countries, albeit less so in West Africa, adult males tend to be more mobile than women or children, and so it may be that the health of women and children will be more closely linked with the place of residence than that of males. This may help us to understand the finding that in Ghana, for example, urban poverty is a stronger predictor of poor health for women and children than it is for men (Taylor et al. 2002). Nonetheless, whether correctly or not, place of residence is almost uniformly the place to which people are attributed when it comes to the measurement of morbidity (the incidence and prevalence of disease) and mortality.

Data on the 'compositional' or personal characteristics of people living in an area are typically drawn from a combination of censuses, surveys, and vital statistics. From these data we can calculate rates of morbidity and mortality by age, sex, as well education, occupation and other socio-demographic characteristics according to their availability from the questions asked on the census, survey, or vital statistics records. It is much more difficult to obtain data about the environmental context in which people live. Housing data from censuses can often be aggregated to yield overall measures of the economic well-being of a neighborhood with, for example, indicators of the average number of connections of housing units to water mains or electricity. Similar data are often provided in surveys. There is no consistency in the availability of such data, however, and they do not provide global measures of the overall built environment and its relationship to the natural environment within a neighborhood. Often, for reasons of privacy, only averages are available for the statistical units in question. Yet the neighborhood ecology is potentially a major contributor to the variability in health levels and so it is crucial that we measure it consistently if we are to understand intra-urban variability in health. This is where remotely sensed imagery plays a role and where opportunities exist to help close the gaps that currently exist in our knowledge of the relationship between the urban environment and health.

1.4 The Use of Remotely Sensed Imagery to Measure Urban Neighborhood Ecology

In order to appreciate the value of remotely sensed imagery for analysis of urban places, it is important to understand what information can be extracted from such images. The source image comprises a two-dimensional array of pixels from which radiant energy has been captured for an area on the ground that is equal to the spatial resolution of the image. The brightness within a given spectral band is assigned a digital number. The combination of digital numbers representing relative reflectance across the different bands of light yields the spectral signature of that pixel. Particular types of land cover (e.g., vegetation, soil, water, impervious surface) tend to have unique spectral signatures. The more bands that a sensor has the more detailed can be the land cover classification. If there are only a few bands it is possible to differentiate vegetation from non-vegetation, but with more bands it may be possible to differentiate a field of corn from a field of wheat or, within the urban area, it may be possible to differentiate a tin roof from a tile roof. The general tradeoff in imagery is that lower spatial resolution imagery will tend to have more bands (i.e., higher spectral resolution), as well as cover a larger spatial extent, than higher spatial resolution imagery.

Our team's experience working with imagery for urban places suggests that higher spatial resolution is more important in characterizing an urban place than is the number of bands available for analysis (Rashed and Weeks 2003; Rashed et al. 2001, 2003; Weeks 2004b; Weeks et al. 2005). This is because the built environment is configured differently, and normally less homogeneously, than the natural environment. Also, the two most useful ways that we have found of quantifying urban places from imagery are in terms of (1) the proportional abundance or *composition* of fundamental land cover classes (as mentioned above); and (2) the spatial *configuration* of the pixels identified with each land cover class. The latter can be measured by landscape metrics, which are algorithms to quantify the spatial configuration of the pixels of specific land cover classes (known as "patches") in a given area (such as a census tract) (McGarigal 2002). They allow us to produce 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. They were developed originally for applications in landscape ecology, but have been shown to have considerable potential value for describing the urban environment (Herold et al. 2002; Weeks et al. 2005).

Although still in its "infancy," the literature on urban remote sensing has expanded dramatically in the past few years (see, for example, Mesev 2003; Ridd and Hipple 2006; Patino and Duque 2013), as the value of imagery, and its limitations, become better known. Among the more influential of these have been the volume on *People and Pixels: Linking Remote Sensing and Social Sciences* (Liverman et al. 1998), the volume on *Remote Sensing and Urban Analysis* (Donnay et al. 2001), the volume on *People and the Environment* (Fox et al. 2003), *Remotely Sensed Cities* (Mesev 2003), to which we made a contribution (Weeks 2003), the volume on *Population, Land Use, and Environment* (Entwisle and Stern 2005), to which we have made a contribution (Weeks et al. 2005), and *Remote Sensing of Human Settlements* (Ridd and Hipple 2006). We have also made other contributions to this literature (Weeks et al. 2000, 2004, 2007, 2012; Rashed and Weeks 2003; Rashed et al. 2001, 2003, 2005; Weeks 2004b, 2010; Engstrom et al. 2011, 2013). Thus far our studies are among the few to have linked the characteristics of neighborhoods, as derived from the imagery, to the levels of morbidity and mortality that are experienced by the people in those places.

Having said that, we recognize that in past few years the literature on the use of remotely sensed imagery in the health field has expanded significantly. This is exemplified by the volume on *Remote Sensing and Geographical Information Systems in Epidemiology* (Hay et al. 2000), by a special issue of the journal *Acta Tropica* in 2001 on remote sensing in epidemiology, followed by another special issue in 2004 on spatial perspectives in epidemiology that included two articles on remote sensing and health (Graham et al. 2004). The journal *Photogrammetric Engineering and Remote Sensing* also had a special issue on remote sensing and health in 2002. Without exception, however, these compilations and other singly published studies (e.g., Rogers et al. 2002; Jackson 2003; Tatem and Hay 2004; Qi et al. 2012) have focused on the natural environment in terms of habitat for infectious disease vectors, or in terms of pollutants as potential carcinogens. These are important studies, without any question, but none of them addresses the issue of variability in human health in urban neighborhoods.

What can we tell about a neighborhood from the imagery? The remotely sensed imagery provide proxy measures of the way in which land is used (e.g., agriculture and bodies of water, commercial, dense residential), and arranged (e.g., orderly or random patches of vegetation), buildings are sized (e.g., large compounds or small separate places) and arranged (e.g., irregular as in informal settings or regular as in planned communities). There is no other inexpensive and efficient way to derive these kinds of measures of the human-built and natural environments, particularly in less developed nations. Imagery allows us to characterize the built and natural environments in ways that are theoretically possible, but largely impracticable, using any other method. As we measure and classify the information from the imagery, we have two purposes. The first is to allow us to differentiate the characteristics of one neighborhood from another, so that we can quantify aspects of the neighborhood context and incorporate those as variables into our predictive models. In this use, we define a neighborhood from sources other than the imagery, and we use the imagery to create variables for each neighborhood that are not available from any other source. The second use is to define neighborhoods derived from the imagery itself—to find patterns of similarities and differences in the imagery that permit us to create an independent definition of a neighborhood which will then be validated from other sources of information, including field work on the ground.

Within a city the social context will vary from place to place, in a pattern that might be called intra-urban ecology. This idea is also captured by the concept of environmental context—that the community within which you live will influence your behavior because we are social creatures who respond to the behavioral cues of people around us. Gladwell has called this the "Power of Context," which powerfully shapes our lives: "... the streets we walk down, the people we encounter—play a huge role in shaping who we are and how we act" (Gladwell 2000:167). As Weeks (2004a) has pointed out, neighborhood context is one of the theoretically more robust ways in which spatial analysis has entered social science and health science theory as an updated version of human ecology. Population size, density, and demographic characteristics interact with social organization, the environment and technology, to produce the behavior that constitutes human society. In turn, human behavior influences population, organization, the environment, and technology and for this reason the concept is that of a system, as we noted above. Furthermore, local context has emerged as an important way of conceptualizing inequalities in the social world (Tickamyer 2000; Gatrell and Rigby 2003; Sampson 2003; Montgomery et al. 2003), which is a key element in the research reported in this volume.

1.5 The Spatial Demographic Context of Accra

The variability in local context is an important part of a city's pattern of spatial inequality, but that landscape is far from fixed. Both the built environment and the resident population change much more rapidly than would be found in rural areas, and much of this change is driven by the continuing flow of migrants into the city. The clearest illustration of the importance of migration and its associated selection effects on the composition of the population can be seen from the distribution of the population by age and sex in the Greater Accra Region and in the country as a whole (Fig. 1.1). The Greater Accra Region (one of the country's ten regions—the first-order administrative level) encompasses some rural and semi-urban areas, yet the graphs of the age distribution by age and sex still show a much more pronounced concentration of working-age adults than for the country as a whole.

A distinctive feature of the West African pattern of rural-urban migration is the over-representation of women in the migrant stream. As the sex ratios (males per females) by age for Accra and the whole country illustrate (Fig. 1.2), between the ages of 20 and 49, women outnumber men in the working age groups. The national level deficit of some 525,000 men between the ages of 20 and 49 is a measure of the greater propensity of men to go abroad to earn money to send back home, although both men and women emigrate.

Against this background of selective movement both between rural and urban areas and between Ghana and the rest of the world, we have to set the major transitions in child survival and fertility which have taken place in the country as whole, but at an accelerated pace in urban places and especially in Accra. Ghana has a rich series of survey and census data, allowing us to back-project trends in fertility and child mortality to the years prior to full independence. The trends in

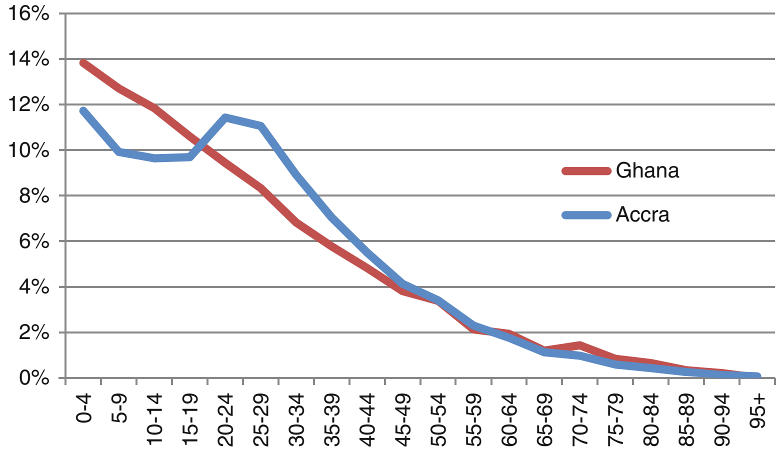

Fig. 1.1 The proportional distribution of the population of the Greater Accra Region and all of Ghana from the 2010 census

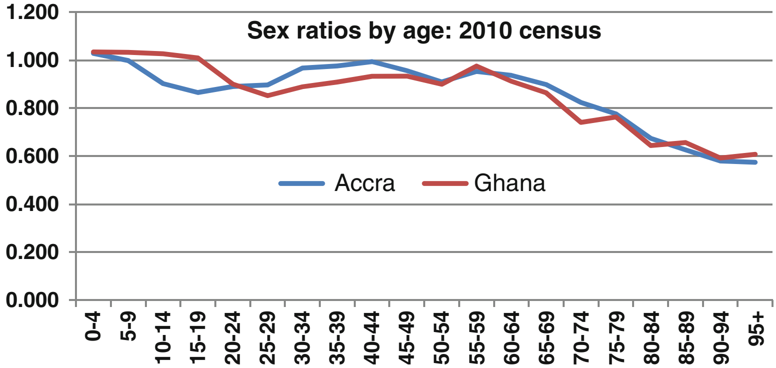

Fig. 1.2 Sex ratios (M/F) in the Greater Accra Region and in Ghana, census of 2010

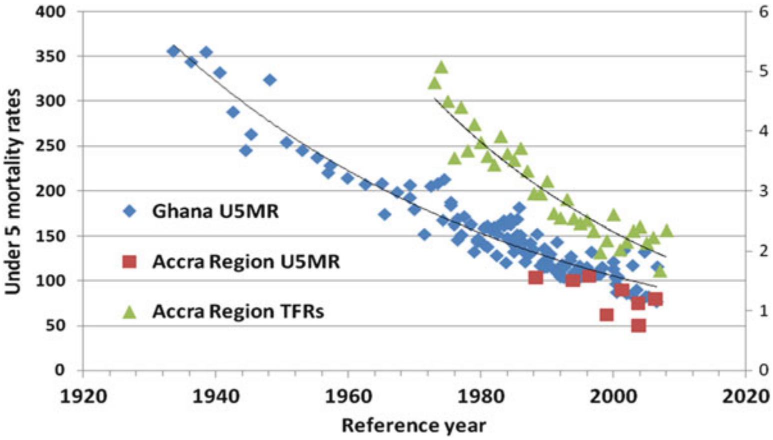

Fig. 1.3 Trends in fertility and child mortality in Accra and Ghana (Source*:* Authors' calculations and child mortality data base on www.childinfo.org). *Note*: *U5MR* under 5 mortality rate*, TFR* total fertility rate

fertility and child mortality are summarized on Fig. 1.3. The striking feature is the early onset of child survival improvements and the early reduction of urban fertility, well ahead of trends in the rest of the country and indeed in Africa as a whole (Garenne 2008).

The key point about these geographically distinct movements of people as well as the major transitions in fertility and mortality hinted at in Fig. 1.3 is that they are distinctly spatial in nature. That is, for Ghanaians, the date of onset, the strength of the population movements and the dynamics of the fertility, health and mortality transitions all depend on their geographical location in the country. For those in the Northern, Upper East or Upper West Regions, these waves of change in fertility and mortality are still at an early stage, although of course all three regions have been sending migrants to the central and coastal parts of the country for many decades.

These movements and changes are selective by age, gender, social class and other less easily measured attributes such as cognitive abilities and individual initiative, affecting both the sending and the receiving communities. It is no easy task to grasp the causes and consequence of such processes at the national level but we believe that dealing with Accra as a starting point or point of entry opens up new routes to understanding especially when the framework of analysis is essentially spatial.

1.6 The Women's Health Study of Accra (WHSA)

The overall spatial demographic context of Accra helps to explain why the researchers in this volume all chose to focus very clearly on Accra. The city is intimately involved in processes at work in Ghana as a whole, and a record of studies, censuses and reports, some of which reach back many decades, provides a basis for documenting trends over time and space. This coincidence of a well-documented colonial and post-colonial past as well as a growing national concern for health and well-being drew the research team to Ghana where colleagues had been researching such topics for many decades. However, despite the relatively rich materials from the censuses and other official reports, there proved to be a dearth of spatially-specific material on health in particular. As a consequence, Hill and others led an initiative to collect new material on health, mortality and fertility for a representative sample of households in the Accra Metropolitan Area, the urban core of the Greater Accra Region. The first round of the Women's Health Study of Accra (WHSA-I) collected data in 2003 through a multi-stage cluster probability sampling process. Full details are published elsewhere (Douptcheva et al. 2011; Duda et al. 2007). Importantly, a geographically located and representative sample of 3,175 Ghanaian women was interviewed by nurses and social workers from the University of Ghana with over-sampling of the elderly and coverage in 200 of the city's 1,730 enumeration areas. The survey instrument included questions about self-reported illnesses, reproductive history, health practices, Short Form (SF) 36 questions (Ware 2006) to measure general health morbidity, risks for illnesses, and social history. A sub-sample of women agreed to the collection of biometric data.

Each woman interviewed in 2003 was asked if she would be willing to be re-interviewed and nearly all women agreed to this so that we were able to re-interview women between October 2008 and March 2009 in WHSA-II. This work was done under the auspices of the Institute for Statistical Social and Economic Research (ISSER) at the University of Ghana. Of the original respondents, 1,810 of the original cohorts were re-interviewed, while an additional 1,004 respondents were substituted for those women who had died, moved, or otherwise could not be found. Nonetheless, almost two-thirds of the originally surveyed women were identified and successfully re-interviewed 5–6 years after the initial contact. Existing cartographic information was combined with the digital boundary files that we had created for the city (Weeks et al. 2006) and satellite imagery (Weeks et al. 2007) into a geodatabase from which details could be printed out for sections of the city, thus allowing interviewers to navigate each neighborhood of the city successfully (Verutes et al. 2012). Follow-up was also aided immeasurably by the remarkable penetration of mobile telephone use. We found that 90 % of households in the survey owned a mobile telephone—much higher than expected even though Africa has been experiencing the most rapid increase in its use (Tryhorn 2009). For women who were found to have moved within the Accra Metropolitan Area (AMA), the team made every attempt to locate them in their new residence and interview them as part of the study. For women who were found to have moved outside AMA, replacements matched by age and EA of residence were identified and asked to join the study. For women who were found to have died, a later study was carried out, in which a verbal autopsy was conducted to ascertain probable cause of death.

Ancillary studies were conducted to provide additional data on income, time use and living standards, on reproductive health and on health and mortality in the very poorest neighborhoods, deemed 'slums' using the UN Habitat definitions of such places. The first component of the data collection was a relatively large household survey labeled the "Time-Use and Health Study" (TUHS). Using the original sampling frame for the WHSA, 1,200 women were selected for a more detailed household level interview. The TUHS collected detailed information about all household members' current schooling and employment status, as well as regular sources of income, including remittances and transfers from relatives and friends in a baseline survey. Since the focus of this project was to understand the burden of ill health for the average household in the modern, urban sub-Saharan environment of Accra with different health problems in the wet and dry seasons, a rolling-sample design was used that involved following sub-sets of households over 12 weeks (Douptcheva et al. 2011; Fink et al. 2012b).

The second sub-component of the WHSA-II was a mixed-methods quantitative and qualitative study of reproductive health, directed by Kelly Blanchard and Naomi Lince of Ibis Reproductive Health. The overall aim of the Focused Investigations on Reproductive Health (FIRH) sub-study was to generate data on women's reproductive health including cultural norms and beliefs about sexual behavior, contraceptive use, abortion, labor and delivery; women's practices for maintaining good reproductive health; experiences of reproductive ill health; the costs associated with reproductive health; and the impact of recent changes in insurance/coverage on access, utilization, and cost (Adanu et al. 2012; Douptcheva et al. 2011).

Thirdly, researchers from the University of Ghana at Legon and Harvard School of Public Health, directed by Livia Montana, relisted the 37 slum EAs surveyed in 2003 by UN Habitat and the Ghana Statistical Service to select a new sample of households to be interviewed in 2009–2010. The aim of this study of health and welfare in Accra's slums, known as the HAWS survey, was to assess the current health status and living standards and changes between 2003 and 2009–2010 of the population in these slum areas as they were defined in 2003. Main fieldwork for the survey began in September 2009, and was completed in March 2010. The survey consisted of a household interview and individual interviews with all women aged 18 and above in the household. The individual woman's questionnaire consisted of sections on background characteristics, migration, health insurance, general health, mental health, nutrition, malaria, a full pregnancy history, pre- and post-natal care and immunizations for children born in the last 5 years, marriage and sexual activity, reproductive health, family planning, and fertility preferences. In addition, height and weight measurements for all women in the household, and all children under the age of five were collected. Of 2,140 eligible women in participating households, 2,017 women completed the individual interview. Details of the methods and main results have been published elsewhere (Fink et al. 2012a; Stoler et al. 2011).

While these household-level data collection efforts were under way, a team of geographers from The George Washington University were conducting field work throughout the Accra Metropolitan Area to identify neighborhood boundaries and explore locally varying health hazards. This research revealed that some neighborhoods are more crisply defined than others, but overall we mapped out 108 "vernacular" neighborhoods that help to define spatial variability within the city (Weeks et al. 2010, 2012; Engstrom et al. in press).

1.7 Lessons Being Learned

What are we learning as a result of this intense engagement with the economic and social development of a major African city? First, despite the modest geographical extent of the city (it is less than 12 km from the northern edge of the Metropolitan area to the coast), the census, survey, satellite imagery, and field data all indicate very sharp discontinuities in the surfaces of income, well-being and health. These sharp contrasts, often marked only by the width of the road, are in part the result of the local scale of the analyses reported in this book. More importantly, however, the work points to the very fine grained nature of social sorting within urban places. Many of the surface-fitting techniques of spatial interpolation associated with other levels of geographical analysis or indeed with the analysis of physical features are not relevant to this form of analysis since the gradients are far from smooth and are marked by clear spatial discontinuities. This means that integrating point data, such as the information from households sampled using cluster probability methods, with continuous distributions observed from satellite imagery or aerial photography, requires innovative forms of statistical analysis and modelling.

The second lesson emerging from the analyses presented in this book is that the processes of social sorting operate in powerful but distinctive ways in Accra and possibly in other African cities. In Accra, rich and poor live closer to one another than in many European or North American cities, following patterns which are more reminiscent of the living conditions in nineteenth-century industrial cities (Booth 1969 [1902]). In addition to patterns of compound living which persist in the city to this day, the lack of effective time planning controls means that squatting in temporary housing, so-called kiosks or containers is quite common throughout the urban area, including even in the better off neighbourhoods. There are clearly different patterns of social identity in African cities compared with elsewhere. Race and color may not have the same meaning as elsewhere, but certainly the census data indicate persistent and strong preferences for intermarriage within the same ethnic or language groups (Weeks et al. 2011). Pentecostal and charismatic churches have recruited members from a wide range of social strata, adding to the complex mix of people who worship and socialise together (Gifford 2004). Further, the high levels of literacy in the population means that health and other messages are widely received through FM radios, televisions and, increasingly through social media, thus breaking down some of the barriers between the less-educated and better-educated that are found in many other urban environments.

These and other complex processes at work in the city mean that the study of differentials and inequalities is particularly difficult and requires some new thinking about the meaning of neighbourhoods and districts within cities. To this end, a range of different classifications were developed for this project to try and capture the very wide ranging characteristics of areas where people live. Many of the anticipated social and health gradients turned out to be weaker or missing in some of these analyses. For example, Fink et al. (2012b) have drawn attention to the surprisingly good child mortality figures in some of the slum areas that may be at least partly attributable to increasing awareness of local environmental sources of infection, along with the rise in the use of sachet water for drinking (Stoler et al. 2011). The narrowness of the health differentials by social class is also a surprise and can only be partially explained by considering the joint effects of neighbourhood and their interaction with individual characteristics (Darko and Hill 2012). Clearly, one of the challenges in looking at spatial differentials in health and well-being is that we are looking at a cross-section of the population whereas many of the outcomes of interest may stem from earlier life course exposures. In short, despite the richness of the materials presented here, we may have to rely on longer term follow-up of cohorts studied in the city in order to come closer to a fuller explanatory interpretation of the differentials in living standards seen in the city. Indeed, a recurring theme throughout the book is the complexity of relationships that we observe in Accra. There is still a lot to learn in the "Accra School."

1.8 What Is the Rest of the Book About?

In the rest of this book, we present analyses that detail the richness of the research underway in Accra. This introductory chapter represents Part I of the book. Part II describes Accra's neighborhood structure and urban morphology, beginning in Chap. 2 with an overview by Engstrom, Ofiesh, Rain, Jewell, and Weeks of the history of Accra's neighborhoods and our attempts to define them based on the combination of census data, local expert knowledge, and extensive field work, including observations and responses from residents. One of the central findings of this process has been that some neighborhood boundaries are fuzzier than others. In Chap. 3, Jankowska lays out a more traditional approach to defining neighborhood boundaries using variables derived from the 2000 Census of Population and Housing, discovering a fairly high degree of consistency with the methods used in Chap. 2. She also compares the spatial patterns in several health variables resulting from different ways of defining neighborhoods, emphasizing in particular the importance of scale effects. Then in Chap. 4 Lippitt, Stow, Toure and Vejraska show how high resolution imagery can be analysed for the purpose of delineating neighborhoods within the city, comparing the imagery-derived boundaries with those derived from the methods used in Chaps. 2 and 3. In Chap. 5, the final chapter in Part II, Møller-Jensen takes us outside the central part of Accra and shows how moderate spatial resolution satellite imagery can be used to describe the way in which Accra has grown and changed over time.

Part III explores substantive results that compare health and well-being among Accra's neighborhoods. In Chap. 6 Tutu discusses the results of his research among migrants in Old Fadama, one of the largest slum areas, used by many migrants as a springboard to a better life. In Chap. 7 Aggrey-Korsah and Oppong move our attention to health levels in Nima, which is arguably the city's most famous slum neighborhood. This chapter utilizes data from the WHSA. Chapter 8 also employs WHSA data but with a spatial twist, in which each respondent's neighborhood is defined by a buffer around her address differing from her neighbors in terms of the percentage of that area that is covered by vegetation, as determined from satellite imagery. These are known as egocentric neighborhoods and Zvoleff, An, Stoler, and Weeks show that, despite their uniqueness, they are not necessarily superior as neighborhood definitions to the more standard territorial definitions of neighborhoods, at least in terms of differentiating health outcomes as measured in the WHSA. Given the complexity of creating egocentric neighborhoods, this will probably be viewed with relief by those doing neighborhood context research. In Chap. 7 Benza moves the discussion to reproductive health and shifts the focus to the larger area surrounding the Accra Metropolitan Area. She is interested in the relationship between the extent of urbanness and fertility levels and she uses satellite imagery to define urban as a continuum, and then draws on 2000 census data to compare fertility levels and living arrangements at different points along the urban gradient. In Chap. 10, the final chapter in Part III, Weeks, Stoler, Hill, and Zvoleff examine fertility levels from the perspective of the same egocentric approach used in Chap. 8. Once again, the egocentric neighborhood approach, per se, did not materially improve our understanding of the rather substantial spatial inequalities that exist with respect to fertility in Accra. However, they do find that spatial clustering of women does help to explain fertility differences, by identifying parts of the city where women are more prone to postpone children, which is a major proximate determinant of fertility in Accra.

Part IV is devoted to analyses that have a potential not just for understanding spatial inequalities in health, but for doing something about them. In Chap. 11 Stoler discusses his analysis of the spatial pattern of sachet water use, which has replaced other forms of drinking water in many neighborhoods within the city, albeit not without substantial environmental costs. In Chap. 12 Arku, Mkandawire, Luginaah, and Baiden examine the linkage unmet need for health care and a variety of housing, infrastructure and SES variables in three different neighborhoods in Accra. They show that even when controlling for other variables, the neighborhood itself remained as the most significant predictor of unmet needs. Finally, in Chap. 13, Lopez-Carr reports on her analysis of food security at the household level, based on interviews in several different neighborhoods with women who were respondents to WHSA-I. In particular, she draws attention to the increasingly common combination of obesity and under-nutrition in different parts of the urban population.

A single volume such as this cannot possibly cover the many technical intricacies of analysis and the substantive complexities of life in the city of a developing nation. At the same time, the research reported here moves our knowledge forward while acknowledging the important base of research on which all of these chapters are built. Neighborhoods play an important and evolving role in the health of urban residents, even as the health and mortality transitions are themselves being altered by the life circumstances that are very different in cities than in the rural areas and different in cities of developing nations than they are in post-industrial cities. The identification of spatial inequalities, and the finding that sometimes they do not exist as we expect them to, are key elements in understanding, and thus improving, health in a city like Accra. We believe that the research presented in this book makes important contributions to this ongoing effort, and we hope that it will spur others to undertake historical and contemporary examinations of social, economic and political processes in both time and space in other African cities.

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Part II
Accra's Urban Morphology and Neighborhood Structure

Chapter 2
Defining Neighborhood Boundaries for Urban Health Research: A Case Study of Accra, Ghana

Ryan Engstrom, Caetlin Ofiesh, David Rain, Henry Jewell, and John R. Weeks

The neighborhood has been used as the unit of analysis for a variety of studies including health, wealth, and ethnic diversity (Yen and Kaplan 1998; Diez Roux 2001; Morland et al. 2002; Weiss et al. 2007; Agyei-Mensah and Owusu 2009; Santos et al. 2010). While this unit of analysis is acceptable to many social science researchers, defining what a neighborhood is has been left up to the individual researcher. In many cases a proxy such as the census tract, ZIP Code or other pre-defined unit of analysis is used. Using a pre-defined unit of analysis reduces the amount of work involved and allows for comparisons to be made between the phenomenon under study (i.e., health, wealth, race) and the information for which the unit was created (i.e., census demographic variables). While allowing for a more straightforward, simpler study, predefined units do not always represent socially meaningful areas that are of symbolic significance to residents or the actual neighborhood boundaries that residents would use to describe their neighborhood. In addition, the choice of the neighborhood unit can affect the results of any study because of the modified areal unit problem (MAUP) (Openshaw and Taylor 1979). Therefore, choosing the appropriate neighborhood boundaries is an important part of any neighborhood study.

There is a consensus within the literature (e.g., Weiss et al. 2007; Chaskin 1997; Gephart 1997), that a neighborhood is defined as a unit of relatively limited geographic size that contains a homogeneous housing and population, with some level of social interaction and symbolic significance to the residents. While there

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is a definition of what a neighborhood is, there can be tremendous subjectivity to defining the boundaries of each of the neighborhoods that make up an entire city (Weiss et al. 2007). This subjectivity is due to the notions of what a relatively limited geographic size is and what constitutes social interaction within a spatial unit. If a neighborhood is too large in size, there can be substantial variability within the unit and the resident populations and housing types could be too heterogeneous within the unit to provide a meaningful unit of analysis. The neighborhood unit of analysis is one that should isolate social and/or environmental factors that create a diversity of outcomes. This diversity in outcomes is most readily seen at the neighborhood unit and this is the primary reason that this unit is used for analyzing spatial patterns. The social interaction can vary by neighborhood because in one area the driving social interaction may be through a common place of worship, the local market, the place where one works, or in some areas there may be little social interaction within the geographic unit. Together, this variability in size and social interaction leads to the subjectivity of defining the boundaries for neighborhoods.

While the boundaries of neighborhoods can be subjective and even fuzzy, the neighborhood is an important geographic unit for delineating the variations within city. In the city of Accra, Ghana the neighborhood has had a long history as the way of differentiating one area from the other within the city (Grant and Yankson 2003). Additionally, the city of Accra has limited street signs and a lack of street addresses for individual houses and businesses. Therefore, providing the name of a neighborhood is one of the only ways for people traveling within the city to describe where within the city they are from or would like to go. Moreover, neighborhoods are vernacular units in that most everyone already knows them. This has led the neighborhood to being a central unit for understanding the city of Accra and the mapping of the different neighborhoods vital for understanding spatial variability in any phenomenon within the city.

As a part of a large NIH-funded project that aims to look at disparities in health within the city of Accra, our team created a map of all of the neighborhoods within the city. In this study we describe the methodology by which we have mapped these neighborhoods to what the residents would call the area (i.e., the vernacular name for an area). This map was created using the 2000 Ghanaian census enumeration area (EA) boundaries as the base unit for creating neighborhoods, and so therefore an EA can be in one and only one neighborhood. The base unit of the EAs was originally created by the Ghana Statistical Service (GSS) for purposes of conducting the census of population, with an EA to be composed of approximately 1,000 people per unit. In total, there were 1,724 EAs for the entire Accra Metropolitan Assembly (AMA) urban region that were converted into 108 neighborhoods within the city.

2.1 Background

The city of Accra began in the late sixteenth century as a coastal fishing port with some of the earliest townships of James Town, Christianborg and Usher Town dating back to the 1870s (Grant and Yankson 2003). Accra is now the rapidly growing largest city in Ghana. The beginning of the modern growth phase of Accra was the movement of the colonial headquarters from Cape Coast in 1877, a move thought to be primarily for health reasons (the Europeans believed that they would be protected from native-born diseases in a new area) and geography (Brand 1972; Grant and Yankson 2003). In addition, the earthquake of 1862 had destroyed much of Accra and the colonial rulers could use the city as a blank slate for rebuilding and re-organizing the city (Grant and Yankson 2003). The era of colonial rule along with the original fishing villages started to create the neighborhoods that we see today in modern day Accra.

Three European forts – James Fort, Ussher Fort and Christiansborg Castle – were all built within 3 miles of each other during the early portion of the colonial period. These forts were interspersed with native Ga villages that traded with the Europeans (Grant 2009:23). Later in the nineteenth century the forts became the centers of administration, housing government, officials and police within the city. During this period, the Europeans moved out of the forts into the present day Accra and started the initial stages of settling the city (Grant 2009:24). After the British moved the colonial headquarters to Accra in 1877 the city starting to expand from its fishing village roots. During this period the European commercial (i.e., Victoriaborg) and residential areas (i.e., Cantonments and Ridge) that were at higher elevations were distinctly separated from the native commercial and residential areas that were located near the coast (Grant 2009:24). The city was primarily organized around the port with a well-defined and organized European central business district. A second business district with traditional markets or bazaars was located within in the area "Native Town" that was inhabited by the local Ga population. The colonial government paid little attention to zoning and urban planning within the Native Town area and thus it was characterized by congestion, poor structures, and unsanitary health conditions (Grant 2009:24–25). The European central business district and the Native town were physically separated by a designed, open green space. The segregation implemented during colonial times is still etched into modern day Accra.

The cocoa trade in the 1920s had a substantial impact on the Accra landscape with the founding of new neighborhoods within the city. These areas included Korle Bu, the big downtown market of Makola and areas such as Tudu, Adabraka, Korle Gonno, Mamprobi, Sabon Zongo and others. These areas represented new developments that were taking in residents that were part of the rural to urban migration that was expanding the city. Meanwhile the areas where the indigenous Ga populations lived continued to increase in density. After the 1939 earthquake, new neighborhoods were built in South Labadi and Abossey Okai and others. After World War II, the Muslim enclaves of Nima and Sabon Zongo began to be occupied along with the elite Airport Residential Area (Rain et al. 2011).

The spatial organization of Accra was affected again upon independence from Great Britain in 1957. At this time the former European central business district were taken over by the national government and the former Native Town became even more characterized by small-scale businesses, as the larger businesses moved into the old European areas (Grant 2009:26). Since independence the urbanization of Accra has not happened in a planned and orderly way. The traditional land tenure system within Accra is complicated. There is state land, stool land, and freehold land that layers within a system of tribal and family ownership that makes it extremely costly and time consuming to make land transactions. This has acted as a barrier to urban development and difficult for the government to control commercial building within the city. Together, these issues have led to a shortage of available land for commercial use and a haphazard development within the city (Grant 2009:27). The overall history of Accra is still reflected in the urban landscape today. The original Ga fishing villages are now neighborhoods along the coast. The castles are landmarks used to name the local neighborhoods (and one, Osu Castle, still serves as a Presidential residence) and the regular, colonial European settlements are still easily distinguished from the areas that made up the original Native Town.

The areas that have built up over time are now the modern day neighborhoods of the city of Accra. Maps delineating the neighborhoods of Accra have been published as early as the 1950s (Boateng 1959), with newer maps being used in more recent publications (Konadu-Agymang 2001; Songsore et al. 2005; Agyei-Mensah and Owusu 2009). These generally depict a few (Boateng 1959) to all of the neighborhoods within Accra (Konadu-Agymang 2001; Songsore et al. 2005; Agyei-Mensah and Owusu 2009). Typically these neighborhood maps were used to select specific neighborhoods for study and/or for comparisons between neighborhoods of different or ethnicity. The source of the maps were the Accra Planning and Development Program in 1990 (Konadu-Agymang 2001) and the Ghana Statistical Service (GSS) (Agyei-Mensah and Owusu 2009). While informative and good base examples of maps, both of these maps were created without the digitized version of the 2000 Ghanaian Census. While they reflect the general location of neighborhoods, these maps are limited in their ability to relate them with census variables because their borders do not coincide with the ones created from the census and are not in an easy to use geographic information system (GIS) format. Therefore, this study does not represent the first attempt to map the neighborhoods within Accra, however it does represent the most recent, and with the advantage of digital GIS it is the easiest one to link with census data for improving demographic mapping and understanding variability within the modern day city of Accra.

2.2 Methods

2.2.1 Study Area

The study area for this project is the administrative unit known as the Accra Metropolitan Area (AMA) as of 2000 (the AMA boundary has changed since the 2000 census). Responsibility for the health, welfare and governance of this urban population rests with the Accra Metropolitan Assembly. According to the March 2000 census, the metropolitan area comprised 1.6 million people (365,550 households) and is estimated to have reached over 2 million as of 2010. For the 2000

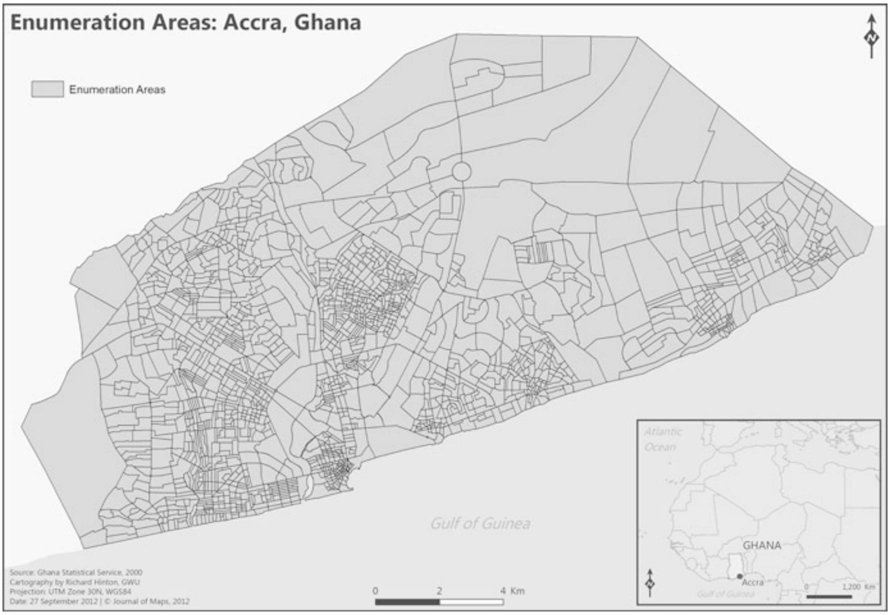

Fig. 2.1 Enumeration areas of Accra Ghana from the 2000 Ghanaian census

census, the Ghana Statistical Service delineated EAs for the entire country including 1,724 for Accra. EAs are akin to census tracts and follow recognizable boundaries such as roads and drainage canals. The individual EA units in Accra range in size from 0.0024 to 1.1 km^2 and previously only existed as hand drawn maps. These data were digitized in a prior study (Weeks et al. 2007) and converted to a GIS-compatible shapefile format. The EAs were designed to each contain approximately 1,000 people, however in reality they range in population from 60 to 10,370 and average 986 people. In this study, these EAs were used as the building blocks for the neighborhoods so that no neighborhood boundary crossed an EA boundary; in other words, EAs nest within neighborhoods (Fig. 2.1).

The creation of the neighborhood map followed a multi-step neighborhood definition process consisting of development of census block groups (EAs in this study), review of land use data, field visits, and observation in each of the communities. The first step of the process was to find maps of the city that could be used to help establish the names and rough outlines of the neighborhoods of Accra. This was not a straightforward task because large portions of Accra do not have street names or addresses, and detailed maps of the city are not readily available. The most useful map happened to be a tourist map with general locations of neighborhoods that could be bought at the local hotels and grocery stores. This map was scanned and then geo-referenced to the EA map, and then EAs were aggregated to form a new set of local neighborhoods. Similar to Weiss et al. (2007), the neighborhood boundaries were created using natural barriers in the landscape whenever possible. Natural barriers included lines of transportation (major roads and railways), drainage channels, rivers, and the ocean. This practice, when combined with some preliminary field work, allowed the team to generate an initial map of neighborhood boundaries. The next step was to verify the accuracy of both neighborhood names on the tourist map and those on the map we generated. In order to do this, the team traversed the neighborhoods where we had questions or difficulties in ascertaining borders.

2.2.2 Neighborhood Creation

Accra is a city where car ownership is relatively low and many residents commute by public transportation, either public minibuses (called *tro-tros*) or taxis. Since there are few street addresses, taxi drivers must know the general name or location of the neighborhoods where their customers want to go. Therefore, the team used the local knowledge of taxi drivers in the neighborhood verification process. If the driver knew the name and took the team to the location we expected, this provided the team with its first step towards validating the neighborhood in our preliminary map. Once there, the team would traverse the neighborhood and ask the local residents and shopkeepers questions, including 'What is the name of this neighborhood?', 'Where does it end?', and 'How do you define it?'. In addition, while traversing the neighborhoods the team would look for street names within the area. In most areas there are no street signs lining the streets, however in many places the street name would be written on a fence or a wall. If this was the case, we spot-checked our tourist map compared to the name written on the wall to both determine the location and check the accuracy of the map. Overall, the team found the map to be very accurate.

These preliminary field observations were then tested against the expert knowledge of the Ghana Statistical Service (GSS). GSS is tasked with doing all census and survey work in Ghana including the city of Accra. The team held multiple meetings with members of GSS where team members would show them our preliminary maps. We would discuss our areas of uncertainty and ask for alternate names for different neighborhoods. Through a back-and-forth discussion names where changed, the team described what we had found, and altered the borders between neighborhoods. After going through this process a number of times and walking all of the areas in question the team created the final neighborhood map of the entire city of Accra.

2.3 Results and Discussion

After walking most of the city of Accra and collaborating with local people and government officials alike, the team aggregated the 1,724 EAs into 108 neighborhoods covering the entire AMA (Fig. 2.2). This map was created by dissolving the

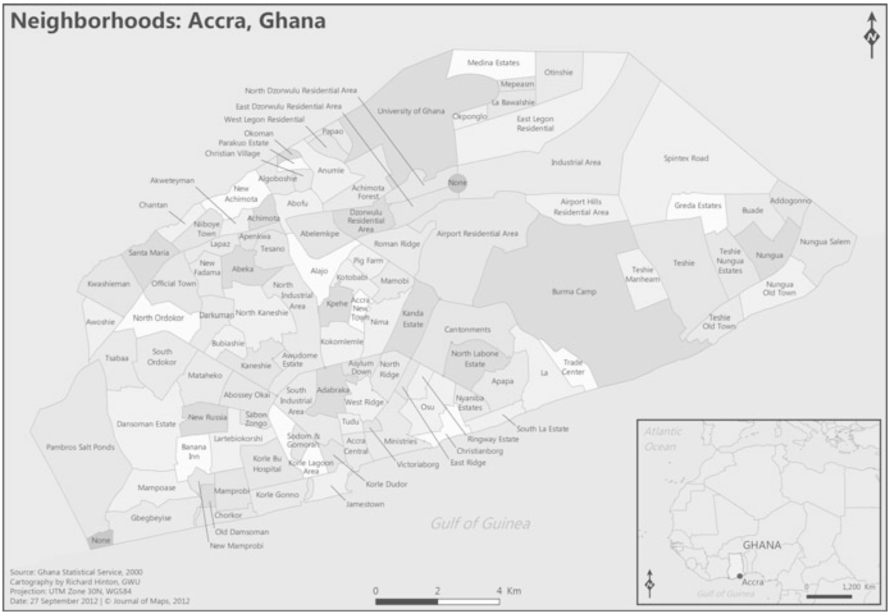

Fig. 2.2 Neighborhood map of Accra Ghana displaying all 108 neighborhoods within the city

EAs into the neighborhoods using ArcMap 10.0. Neighborhoods range in size from a single EA, particularly in the northwest portion of the AMA, to 74 EAs in the densely populated center city areas, with an average of 16 EAs per neighborhood.

Determining neighborhood boundaries was relatively straightforward in some areas and more difficult in others. In general, the areas easiest to define were in the older parts of the city that were established prior to or during colonial times. These areas represented what Grant (2009) described as the European Central Business District and the Native Towns and include the fishing villages of Chorkor, Teshie, La, and Jamestown that existed prior to the British moving the capital to Accra. In many cases these particular neighborhoods are still inhabited by the people from the Ga ethnic group that were the original settlers of Accra (Agyei-Mensah and Owusu 2009). The Ga are a fishing people and have stayed along the coast and continue to fish today. Other neighborhoods that were straightforward to define include those in the higher elevations that were laid out during colonial times such as Roman Ridge and Cantonments, and have a more planned feel to them. Other neighborhoods with more straightforward boundaries included some of the more famous slums of Accra including Nima, Sabon Zongo and Old Fadama (known locally as 'Sodom and Gomorrah'). Overall, many of the areas that were straightforward to map had substantial physical features such as roads, drainage canals (the Odaw river), or the ocean shaping the majority of their boundaries.

Other more recently established neighborhoods outside the downtown core were more difficult to precisely define. These areas tended to be on the outer edges of the AMA or were areas of infill into the open space that occurred after the colonial period. Examples of these neighborhoods include Nii Boy Town in the northwest, newly-settled Spintex Road in the northeast and Mamprobi, Dansoman, and New Russia (the last named after a failed Soviet project) in the western part of the city. These neighborhoods are generally less dense and follow more of a sprawling suburban model with informal pockets of housing and commercial activities interspersed.

In a previous study, (Engstrom et al. 2013), we compared our neighborhood names to the responses provided by female survey respondents in the WHSA-II and found an overall accuracy of 71 % of the EAs to the same neighborhoods as those self-reported in the survey data. This indicates relatively good agreement between our mapped neighborhoods and locals' description of the city. We were incorrect for approximately 30 % of the neighborhoods, and the suspected leading cause was the open-ended nature of the question about neighborhoods as asked in the WHSA-II. Many of the respondents named areas that were smaller than the neighborhood size we assigned or used an alternative name for the same area. In some areas there was confusion between the neighborhood name and the AMA sub-district name, while in others indigenous sub-neighborhood designations were used. Some areas had two different names, such as New Mamprobi which also went by the name of Banana Inn. When walking through this neighborhood one would see both names and which name was provided depended on whom you talked to. Both answers could appear to be correct.

While some confusion was due to differences in naming conventions within an area, other issues were in defining the boundaries of neighborhoods. Some neighborhoods have "crisp" boundaries recognized by a very high percentage of residents, whereas other neighborhoods have "soft" boundaries that are less likely to be agreed upon by the local population. Examples of crisp boundaries are those found between the neighborhoods of Nima and Mamobi, and between Nima and Kanda Estates. It is well understood within the area that Mamobi is to the North of the drainage channel while Nima is to the South (Fig. 2.3). Additionally, the border between Nima to the West and Kanda Estates to the East is another crisp border. This is due to the fact that Nima is a slum neighborhood with houses in close proximity, narrow passageways, and generally crowded conditions, while across the Kanda Highway there is the organized, neatly planned area that is Kanda Estates. In these cases it is very straight forward to create the boundary for the neighborhoods (Fig. 2.4).

While some areas have crisp boundaries, others are soft and difficult to discern. This is the case in the northwestern part of the city. This area is more recently settled and has similar housing types throughout. The area around Darkuman is an example of this. Within the area there are the neighborhoods of New Fadama, North Kaneshi, Bubiashie, South Ordokor, North Ordokor, Official Town, and Darkuman. This area has similar single family dwellings, is laid out in a rather systematic way, and has a limited number of easy to define boundaries. Because there are no drainage ditches, major roads, or other easy to define borders, these neighborhoods blend into one another (Fig. 2.5). Because we are limited by the EAs for creating the borders, as well as the need to define a sharp line for each border, we had to use our

Fig. 2.3 Drainage channel separating Nima and Mamobi neighborhoods. Nima is on the *left* and Mamobi is on the *right*

best judgment. This judgment was made by walking around the area, talking to the government officials at GSS, and talking to locals within the area.

While the northwestern portion of the city was fuzzy to map because of softer boundaries, the northeastern portion of city was difficult to map because of the large size of the EAs. At the time of the 2000 census the northeast portion of the city was not very populated and the EAs were created based on population size. Therefore, the EAs in the northeast portion of the AMA are generally much larger (see Fig. 2.1) than in the rest of the city and in some cases only one EA was considered a neighborhood (see Fig. 2.2). Since the EA was the base for mapping neighborhoods, this limited our ability to create neighborhoods of limited geographic size that is part of the definition of a neighborhood described earlier. Therefore, there may be some inaccuracies in this portion of the AMA within the neighborhood map. In the time since the 2000 census, this area has grown tremendously and would most likely contain many more EAs in the 2010 census.

2.4 Summary and Conclusions

In summary, we have produced a neighborhood map of the entire AMA circa 2000, where the boundaries we defined were based on the general vernacular name of the area. These neighborhoods represent the best fit for a vernacular area commonly

Fig. 2.4 The crisp border between Nima and Kanda Estates. To the *left* is Nima with its poorly organized, small dwellings and to the *right* Kanda Estates with its orderly, planned large dwellings and well defined roads

known and used by residents. The neighborhood map was created with the objective to study variations within the city and represent a testable unit to ascertain how well a field-based investigation can produce a map useful for a variety of studies. This may be advantageous in case-study style projects focusing on a range of issues within a city, where it may not be feasible to create a different neighborhood map for each outcome being investigated. This map has already been used by several researchers exploring income and health disparities within the city (Engstrom et al. 2011; Weeks et al. 2012).

When defining neighborhoods, one of our observations for Accra was the impact of history on both the neighborhood names and boundary delineation. In many cases the colonial development of the city is still present in terms of both the names and the character of the neighborhoods in question. Typically these older areas were easier to delineate and name when mapping the city. The more recently developed the area was the more difficult it was to determine the boundary. This was especially the case in the Northwest and Northeast portions of the city. In the Northwest portion of the city, it was difficult to define a precise border because of the lack of easy to define boundaries, while in the northeast the EA boundaries were very large and the areas were sparsely settled at the time of the 2000 census. As time has passed since the census, the northeastern areas of Accra have grown at a rapid rate and new neighborhoods may have been created that will need to be mapped in the future.

Fig. 2.5 The northwest portion of the Accra Metropolitan Area (AMA) around Darkuman. This area has borders that are difficult to define. The *thicker white lines* are neighborhood boundaries, while the *thinner black lines* are the enumeration area boundaries

This field-based methodology to mapping neighborhoods is a relatively accurate way to delineate neighborhoods in developing urban areas; however it is very time and labor intensive. While requiring significant time in the field walking the streets of the city and interviewing local residents, this research provided us with a rich knowledge of the variations in living conditions that exist across this rapidly developing city. This knowledge was instrumental in interpreting the remotely sensed observations used in other aspects of our large NIH study. Also, it greatly informed many of our other analyses and proved invaluable information for understanding many of the statistical and survey results that have come from the study. The large variations in housing and living conditions observed within the city may be affecting health outcomes and can provide us with substantial insight as to both the dynamics and diversity of this ever changing city. Finally, this study provided everyone on the team with a greater appreciation for the warm and friendly people of Accra.

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Chapter 3
Neighborhoods of Health: Comparing Boundaries for Measuring Contextual Effects on Health in Accra, Ghana

Marta Jankowska

The concept of neighborhood is at the forefront of place and health research as an appropriate scale of study (Sampson 2003; Riva et al. 2007). What actually constitutes a neighborhood is subjective at best, but an underlying idea of a geographic unit of limited size with some degree of social interaction is generally acknowledged (Weiss et al. 2007). The last two decades have seen significant evidence that the neighborhood influences health beyond individual characteristics in the developed and developing world (Pickett and Pearl 2001; Sampson et al. 2002; Stafford and Marmot 2003; Montgomery and Hewett 2005; Perera et al. 2009; Diez-Roux 1998; Robert 1999). While there are a number of issues for health and place research, establishing geographical boundaries that define 'place' has been the subject of significant debate in the field (Diez Roux 2001; Entwisle 2007; Gauvin et al. 2007).

As part of this debate, a number of recent studies have tested various methodologies for defining place with a particular focus on boundaries that have meaning for health outcomes (see for example Chaix et al. 2009; Tatalovich et al. 2006; Parenteau et al. 2008). This type of research is an essential step towards a better understanding of how places impact health, however currently it is almost entirely confined to the developed world. Boundary delineation techniques utilized in developed urban areas may not be directly applicable to developing world cities, which may result in unanticipated consequences for place and health models. This chapter highlights three important issues for neighborhood definition and boundary delineation in the developing urban world as compared to the developed world that should be considered in health related research: (1) differences in place-based drivers and resulting health outcomes, (2) alternative socio-economic and structural organization, and (3) limitations in spatial data sources. It then describes methods

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used for creating 22 neighborhood boundaries for studying the effects of place on health in Accra, Ghana. Finally, the boundaries are compared using descriptive analysis, measures of variance, and correlations of individual and place-based variables with health outcomes. Discussion focuses on how the above issues may influence our interpretation of neighborhood influences on health.

3.1 Why Boundaries Matter

Neighborhood is a complex social concept varying in meaning, scale, and purpose depending on who is defining it (Kearns and Parkinson 2001; Bruhn 2009). In health and place research, neighborhood can be defined as one sub-urban scalar representation of place that contains contextual influences on individual health outcomes. There has been significant theoretical progress in linking place to health through avenues like physical features shared by residents, the presence of environments that support healthful lifestyles, the quality of services, sociocultural features, social capital, and area reputation (Macintyre and Ellaway 2003; Bernard et al. 2007; Kawachi et al. 2008).

If the neighborhood is a theoretical representation of place, the neighborhood boundary is the operational definition of place. The importance of this operational definition is rooted in the modifiable areal unit problem (MAUP). MAUP is a potential source of variation associated with aggregating data into arbitrarily bound groups resulting in summary values and statistical properties of variables that may be influenced by the boundaries themselves as much as by on-the-ground phenomena (Openshaw 1984; Fotheringham and Wong 1991; Greenland 2002). MAUP is always an issue to be considered because all boundaries that are created are relatively arbitrary, but it is especially of concern when there is no hypothesis about the theoretical mechanisms at work within the boundary (Haynes et al. 2007).

There has been substantial criticism that the theory of neighborhood as it relates to health has been poorly translated into boundaries (Diez Roux 2001; Lupton 2003; Guo and Bhat 2007). For example, the most commonly used operational definitions of neighborhoods are administrative boundaries, but theoretical justification for these delineations is often lacking (Sampson et al. 2002; Riva et al. 2007; Flowerdew et al. 2008). Cummins et al. (2007) point out that the importance of place as a factor for health is being diminished due to the conventional, strict, and repetitive conceptualizations of place in the literature. In response to such criticisms, studies are increasingly examining the impact of using diverse boundaries for modeling place effects on health with results ranging from insignificant variation in outcomes (Cockings and Martin 2005; Ross et al. 2004; Stafford et al. 2008; Jones et al. 2010), to highly significant impacts on place effects (Tatalovich et al. 2006; Santos et al. 2010; Flowerdew et al. 2008; Root 2012). Such research teases out how diverse measures of place and health are influenced by boundaries, creating a consensus on the impact of MAUP in such research, and improving our understanding of how geographical notions like zoning and scale may provide new clues to the links between health and place.

Advances in geographic methods have expanded spatial delineation techniques, and within health and place studies three main boundary types have emerged: (1) administrative-based boundaries; (2) observation-based boundaries; and (3) data-driven boundaries (with overlap and mixing between boundary types often occurring). These boundary types fall under the general category of territorial neighborhoods, defined as being mutually exclusive areas (Guo and Bhat 2007; Diez Roux and Mair 2010). Methods that incorporate egocentric (person-specific), and fuzzy or overlapping boundaries are a growing area of new research (see Chaix et al. 2009 for a review, as well as Chaps. 8 and 10 in this book). The remainder of this chapter focuses on mutually exclusive boundaries as the dominant boundary type currently used in health and place research.

3.2 Boundary Delineation in the Developing World

Studies on the effects of boundary delineation for place and health research are almost exclusively limited to the developed world. Western notions and definitions of 'place' are often replicated in third world studies on place and health, and there has been little exploration concerning the importance or utility of geographically specific definitions of place for health research. Even if the theoretical connections between place and health may be similar between the developed and developing world (an assumption that will need considerable future research), the social and physical environments are often vastly different, presenting a host of issues in translating boundary delineation techniques to the developing world.

Health in rapidly developing urban areas is extremely complex (Montgomery 2009), partly because cities in the developing world are characterized by wide swaths of poverty of varying magnitude, as well as by pockets of extreme affluence (Montgomery and Hewett 2005). A consequence of this urban complexity is that traditional individual-level risk factors for health can become complicated by overwhelming environmental burdens of living conditions such as lack of sanitation and poor air quality (Boadi and Kuitunen 2005; Vlahov et al. 2007; de Snyder et al. 2011). This can also work in the positive direction with environmental characteristics, such as improved access to nutrition, medical care, or pure drinking water in the form of sachets that shield individuals from higher than expected mortality and morbidity (Stoler et al. 2011).

As several chapters in this volume demonstrate, the third world urban environment creates a complex dissonance between the risk profile of an individual, observed health of surrounding residents, and expected effects of contextual surroundings on health outcomes. One result of this dissonance is that theories accounting for how place influences health in the developed world may not be applicable in the developing world. There is a need for better theoretical frameworks that integrate complexities unique to the developing urban world into place effects on health pathways, and furthermore, these new theories must be reflected in operational boundaries.

A second issue for boundary delineation is the socio-economic and structural organization of the developing urban world, which is often more heterogeneous than in the developed world (Songsore 2009), potentially exacerbating efforts to create homogenous bounded regions. In the case of administrative boundaries (if they even exist), decision rules for boundary delineation are often not available, leaving little ability to understand what they contain. Such boundaries would need to be carefully examined and tested to assess their social and structural characteristics, and to understand if they reflect real-world organizational patterns of the city.

Spatial organization is particularly relevant for data driven methodologies, which draw boundaries based on variables such as wealth, housing structure, density, education, and other place-based characteristics thought to influence health outcomes (Clapp and Wang 2006). Most of these methods are created to build or aggregate units based on the homogeneity of a given variable or set of variables. However, scattered or disrupted spatial patterns may be a significant obstacle in creating cohesive neighborhoods. Furthermore, most data driven methods require user input for decision rules and desired outcomes. Without experience or knowledge of third world urban organization, significant bias may be introduced into boundary delineation. Some of these problems may be mitigated by the use of methods for observation-based boundary creation, which incorporate local, expert, historic, or stakeholder knowledge, as discussed in the previous chapter.

Another significant issue for creating boundaries in the developing world is a lack of data, particularly geo-referenced information. Data-driven methods require spatially referenced attribute data for continuous areas of a city in order to be able to carve boundaries, or aggregate existing administrative boundaries. Lack of this type of data severely limits where health and place research using data-driven boundaries can be conducted. One potential solution is the use of variables derived from remotely sensed imagery to create neighborhoods (Stow et al. 2010; Weeks et al. 2007 and Chap. 4 of this volume), however imagery may not be able to capture more socially nuanced characteristics of places. Concurrent with general lack of spatial data is the deficiency of consistent and official place and street names. Many methods developed for observation-based neighborhoods such as use of resident perception, community actor consultation, and systematic street observation (Haynes et al. 2007; Parenteau et al. 2008; Raudenbush and Sampson 1999) rely on methodical naming conventions to achieve agreement on place groupings and delineations. Without such reference points, observation-based boundaries may have difficulty achieving consistency and reach, although that remains an open area of investigation.

In the course of studying health in Accra, Ghana, through a spatial lens, the use of multiple methodologies to create and utilize administrative, observation-based, data-driven, and most recently egocentric boundaries has consistently exposed our research to the issues discussed above. The effects of these problems on the boundaries is not known since the neighborhood sets have not yet been rigorously tested as potential inputs for a statistical model that examines effects of each of these place definitions on health. This chapter compares 22 different neighborhood boundaries developed for Accra, focusing on the desired outcome of creating a set of neighborhood boundaries that most accurately reflects our hypothesized pathways between health and place, and that can facilitate the statistical modeling of these relationships. Two health outcomes are measured for each neighborhood: (1) body mass index (BMI); and (2) general health. Three predictor variables are used: (1) wealth; (2) illiteracy; and (3) percent of compound households in a neighborhood. The derivation of boundaries and the creation of variables are discussed below.

3.3 Data

The study site is the Accra Metropolitan Assembly (AMA), as discussed in Chap. 1. Data come from the 2000 Ghana Census of Population and Housing and from the second wave of the Women's Health Study of Accra (WHSA-II), as also discussed in Chap. 1. An important component of the WHSA-II is the inclusion of basic anthropometric measures, and the 36-item short form survey (SF-36) developed by Ware and Sherbourne (1992). The SF-36 is a measure of self-reported general health status. This study utilizes two measures of health from the WHSA-II: (1) BMI calculated as a woman's weight divided by her height squared; and (2) self-reported "general health" calculated from a principle components analysis for SF-36 questions pertaining to general health. A third source of data is remotely sensed imagery, as discussed in more detail in Chap. 4 of this volume. The percent of vegetation in a neighborhood is utilized as a proxy for overcrowding and socio-economic status of an area (National Research Council 2007). Vegetation, impervious surface, and soil for neighborhoods in Accra were calculated using Ridd's vegetation-impervious surface-soil (VIS) model (Ridd 1995) from a combination of QuickBird and ASTER imagery of Accra in 2001 and 2002 (Stoler et al. 2012; Stow et al. 2007).

3.4 Methods

A total of 22 mutually-exclusive neighborhood boundaries were developed from the three categories of administrative, observation, and data-driven boundaries. All but three boundaries were created specifically for the project.

3.4.1 Administrative Boundaries

As discussed in Chap. 1, Ghana Statistical Service has created a set of administrative boundaries for the entire country. The first administrative level is the Region, of which there are ten in the country. The second administrative level is the district, of which there were 110 as of the 2000 Census. All districts reside within a specific region. Urban districts are divided into localities (of which there are 43 in the Accra Metropolitan Assembly), and they are divided into enumeration areas (EAs), of which there were 1,724 in the AMA in 2000. In less densely populated districts, the finest level of geography is the EA, but without an intermediate locality. Since the EA is the finest level of geography in Accra, they form the basis of administrative boundaries, and all other boundary sets included in this study are aggregated from the EA boundaries. The two sets of administrative boundaries used in this study comprise all 1,724 EAs, and the 43 Localities in the AMA.

3.4.2 Observation-Based Boundaries

Two observation-based boundaries were utilized, one of which was derived directly from the GSS, which defined a set of 86 EA aggregated boundaries that were believed by GSS to be recognizable to city residents as neighborhoods. Two of these neighborhoods were subdivided by Weeks et al. (2010) to create a total of 88 neighborhoods. The names assigned to these neighborhoods are used in everyday location descriptions such as store signs and directions given to cab drivers, and can be thought of as a "vernacular" set of boundaries.

In order to better understand the socio-economic and structural organization patterns of the city, the second set of observation-based boundaries was created through an integrative field work process, which attempted to encapsulate local resident perceptions, man-made and natural barriers, and socio-economic milieu into a set of 108 neighborhoods (for a full description of this set of boundaries see Chap. 2 in this volume as well as Engstrom et al. 2013). The creation of this boundary set (named "field modified vernacular," or FMV) necessitated extensive time and effort to become deeply familiar with the city's history, culture, nomenclature, and spatial organization. The FMV boundary set has become a key reference point for the project team's knowledge and understanding of the city's spatial and social organization, and has assisted considerably in decisions made during the data-driven processes.

3.4.3 Data-Driven Boundaries

Two data-driven delineation techniques were employed: (1) AMOEBA clustering; and (2) K-means clustering. AMOEBA (A Multidirectional Optimal Ecotope-Based Algorithm) is a clustering algorithm which utilizes the Getis-Ord *Gi** statistic based on z-scores of autocorrelation (Ord and Getis 1995) to perform nearest neighbor autocorrelation on all spatial units of interest (Aldstadt and Getis 2006; Weeks et al. 2010). A key innovation of AMOEBA is that it allows clusters to be created that are irregular in shape, thus quite literally "following" the data to create boundaries in which the constituent EAs are more alike than neighboring clusters. K-means is a non-spatial clustering algorithm (MacQueen 1967), and is often used for neighborhood boundary delineation in health and place studies. It creates data clusters based on similarities of a set of input variables, which can then be mapped.

Variables selected for the data-driven methods focused on aspects of place such as housing and vegetation, and a socio-economic (SES) measure as one of the most important theorized drivers for health outcomes. Housing characteristics (the slum index) and SES were calculated from 2000 census data. The slum index draws on the UN-Habitat (2003) criteria for what constitutes a slum, including structural quality, water access, living area, sanitation facility access, and tenure, creating a score for each household, which can then be aggregated (Weeks et al. 2007). The SES variable is the result of a principal components analysis (PCA) calculated initially at the individual level from the following variables: illiteracy, education, occupation status, and informal work status, and then the mean of these measures was calculated for each EA as input to the PCA, which used the EA as the unit of analysis. A measure of vegetation as described earlier using the VIS remote-sensing model was used as the third data input. For both AMOEBA and K-means approaches, each of the three variables (slum index, SES, and vegetation) was iterated three times at various scales, resulting in 18 neighborhood schemes ranging from 43 to 300 neighborhoods per scheme.

3.4.4 Comparing Boundaries

As noted above, 22 neighborhood boundary sets were utilized for this comparative study – 1 administrative-based, 2 observation-based, and 19 data-driven. The neighborhoods were first compared with visual analysis and descriptive statistics focusing on the numbers and distributions of women from the WHSA-II, using data for the women in the 200 EAs that were included in the WHSA. Boundaries were then compared using measures of variance to assess how they might perform in a multilevel model, which is the statistical model of choice for almost all neighborhood and health studies. Multi-level models measure variance both within and between levels, allowing for an assessment of different level effects (individual and neighborhood) on the outcome variable (Subramanian et al. 2003; Blakely and Subramanian 2006). Changes in boundaries encompass different groupings of individuals as well as altered place level variables, which may translate into different measures of within *and* between group variance, ultimately resulting in changing significance of model variables.

Within-neighborhood, between-neighborhood, and intra-class correlations were calculated twice for the 22 boundary sets: once with the variable BMI, and once with General Health. Two health variables were utilized in the analysis to assess if different boundaries had consistency in results between health outcomes. Higher variance within neighborhoods coupled with lower variance between neighborhoods will make it difficult to measure contextual effects on individual outcomes, as it will leave little explanatory power at the neighborhood level. Intra-class correlation (ICC) measures how much variation in the health variable remains to be accounted for at the neighborhood level once individual level variance is taken into account. In other words, ICC can point to the magnitude of neighborhood effects that can measured by each boundary set. All variance and ICC values were calculated in MLwiN 2.10 using empty two-level models.

Correlations at the neighborhood level were calculated between the two health outcomes, and three explanatory variables: wealth, illiteracy, and percent of compound housing in a neighborhood. The resulting correlation values serve as indicators of how well predictor variables might perform in a regression model. For example, compound housing is an indicator of high living density, which may lead to poorer health outcomes, while illiteracy and wealth are theorized to be proxies for human capital in a neighborhood. Wealth was calculated from the WHSA-II using a PCA from ten questions asking about ownership of durable goods. While aggregated to the neighborhood level as an average, wealth is only representative of the women included in the survey. This is also true, of course, for the health outcome variables. Illiteracy and compound housing were coded as dummy variables from the census, and aggregated as a percentage of the total population or households in the neighborhood.

3.5 Results

A naming convention with three components was applied to the 18 AMOEBA and K-means boundaries to easily differentiate the specific method and decisions used for each boundary scheme. The first component, A or K, represents the AMOEBA or K-means method, respectively. The second component, SES, Slum, or Veg, represents the input variable. The third component, a number, represents the user decision that dictated the number of neighborhoods created (i.e., the scale). In the case of AMOEBA, the number represents the minimum number of units that were required to be included in a neighborhood. For K-means it represents the number of non-spatial clusters created by the statistical algorithm.

Table 3.1 includes basic descriptive values for the 22 neighborhood schemes. There is significant variation in the number of neighborhoods created by each of the methods, ranging from 43 (Localities and KSlum2) to 1,723 (EAs). Each neighborhood scheme aggregates EAs differently, effectively changing the distribution of women in and between neighborhoods. Neighborhoods that contain EAs surveyed by the WHSA-II range from 194 (EAs) to 15 (KSlum2), with most schemes having fewer than 80 neighborhoods that include WHSA-II respondents. Many schemes include neighborhoods with only one, two, or three woman surveyed, which in the case of the WHSA-II may be women who moved from an originally surveyed EA into a new area. The maximum number of women per neighborhood varies from 94 (EAs) to 1,728 (KSlum2). Three schemes – KSES2, KSES3, and KSlum2 – have a neighborhood with more than 1,000 women in it. Generally, the observation-based,

Table 3.1 Descriptive statistics of the 22 neighborhood schemes (highest three values bolded and lowest three values underlined)

Boundary method	Total units	Units with WHSA-II respondents	WHSA-II women min	WHSA-II women max	WHSA-II women mean	BMI mean	Gen health mean
Administrative							
EA	**1,723**	**194**	1	94	14	28.38	67.97
Locality	43	40	**6**	207	70	28.42	67.30
Observational							
Field Vern.	108	71	1	188	39	28.37	67.99
GSS Vern.	88	66	1	165	42	28.40	68.04
Data-driven							
ASES2	169	**77**	1	400	36	28.30	68.32
ASES3	104	65	1	400	43	28.27	68.05
ASES4	74	55	3	478	51	28.27	67.86
ASlum2	152	64	2	393	44	28.34	67.94
ASlum3	101	57	**5**	511	49	28.33	67.79
ASlum4	74	50	**7**	411	56	28.31	68.24
AVeg1	**309**	68	1	398	41	28.30	68.43
AVeg2	134	58	1	448	48	28.34	**68.63**
AVeg3	85	51	1	482	55	28.35	**68.62**
KSES2	104	24	3	**1,385**	**117**	28.47	67.45
KSES3	187	47	2	**1,081**	60	28.16	67.28
KSES4	**300**	**81**	2	432	35	28.37	68.07
KSlum2	43	15	3	**1,728**	**187**	**28.69**	68.37
KSlum3	142	46	2	421	61	**28.50**	67.55
KSlum4	233	72	1	342	39	28.43	68.35
KVeg3	88	24	1	869	**236**	**28.48**	68.59
KVeg4	156	45	3	595	62	28.43	68.24
KVeg5	207	59	1	254	48	28.41	**69.21**

administrative, and AMOEBA clustering techniques produce more consistency in the distribution of women than the more variable K-means results (specifically the boundaries created with 2 or 3 non-spatial clusters). The mean values for BMI and General Health do not change significantly from scheme to scheme, and are comparable with the overall WHSA-II BMI and General Health means of 28.38 and 68.58 respectively.

Table 3.2 displays each scheme's within and between boundary variance, as well as the intra-class correlation for BMI and General Health. As in Table 3.1, the three highest values are bolded, and three lowest are underlined. Variances for BMI are consistent between the boundary schemes, and are generally low, indicating that BMI may not be a variable that experiences significant place effects. KSlum4, EAs, and Field Vernacular boundaries have the highest between boundary variance and ICC values, while KSES2, KVeg3, and KVeg4 have the lowest. General Health has higher variance values than BMI, and demonstrates some potential for measurable place effects. There is more variability in the variance between boundary

Table 3.2 Variance within and between boundaries, and intra-class correlation (ICC) for the Body Mass Index and General Health variables (highest three values bolded and lowest three values underlined)

Boundary method	Body mass index: Within variance	Body mass index: Between variance	Body mass index: ICC	General health: Within variance	General health: Between variance	General health: ICC
Administrative						
EA	45.04	**1.69**	**3.62**	341.91	**71.37**	**17.27**
Locality	46.09	0.59	1.25	384.26	39.50	9.32
Observational						
Field Vern.	45.62	**1.20**	**2.55**	374.41	42.51	10.20
GSS Vern.	45.85	0.90	1.92	371.31	49.09	11.68
Data-driven						
ASES2	45.93	0.89	1.90	378.48	51.66	12.01
ASES3	45.92	0.98	2.09	383.48	40.26	9.50
ASES4	46.09	0.73	1.56	384.86	42.07	9.85
ASlum2	45.96	0.87	1.86	379.03	47.93	11.23
ASlum3	45.99	0.92	1.97	384.57	37.70	8.93
ASlum4	45.96	0.94	2.01	387.19	34.42	8.16
AVeg1	46.04	0.71	1.51	368.89	65.89	15.16
AVeg2	46.26	0.42	0.91	368.61	**73.59**	**16.64**
AVeg3	46.27	0.43	0.91	369.75	71.25	**16.16**
KSES2	**46.38**	0.38	0.81	**402.29**	32.86	7.55
KSES3	46.22	0.84	1.79	**392.97**	40.38	9.32
KSES4	46.09	0.70	1.49	388.72	33.49	7.93
KSlum2	**46.36**	0.64	1.36	389.80	**71.58**	15.51
KSlum3	46.18	0.62	1.33	386.36	49.68	11.39
KSlum4	45.89	**1.05**	**2.23**	369.70	65.11	14.98
KVeg3	**46.43**	0.41	0.88	**395.61**	53.64	11.94
KVeg4	46.35	0.38	0.81	381.38	47.60	11.10
KVeg5	46.27	0.43	0.93	374.46	67.61	15.29

schemes, indicating that some boundaries may perform better in capturing place effects. The highest between boundary variance values are measured for the AVeg2, KSlum2, and EA boundaries, and highest ICC values are measured for AVeg2, AVeg3, and EAs.

Bivariate correlation coefficients were calculated between the two health variables and wealth, illiteracy, and compound housing and then ranked for all neighborhood schemes from highest to lowest correlations. Almost all boundary schemes show positive correlations between wealth and BMI (wealthier neighborhoods have higher BMIs), and wealth and General Health (wealthier neighborhoods have better general health). Correlations range from just over zero to 0.56. Correlations between the health variables and illiteracy are mostly in the negative direction, indicating that neighborhoods with higher illiteracy have lower BMIs and General Health outcomes. Correlation values range from 0.28 to – 0.57.

Table 3.3 Correlation coefficients for each neighborhood boundary between two health variables (BMI and General health) and three independent variables (wealth, illiteracy, and compound housing) averaged and ordered to give a total correlation ranking

Boundary	Average rank	Average correlation	Rank of correlation
FMV	5.17	0.355	1
KVeg3	5.83	0.345	2
GSS	4.83	0.312	3
KSes3	6.00	0.297	4
KSes4	6.83	0.273	5
KVeg4	8.67	0.261	6
EA	8.00	0.235	7
KSlum2	10.17	0.229	8
KSlum4	9.50	0.219	9
AVeg1	10.50	0.213	10
AVeg2	11.67	0.195	11
KSlum3	12.33	0.193	12
KSes2	13.33	0.191	13
AVeg3	11.83	0.190	14
KVeg5	12.33	0.169	15
Aslum3	15.67	0.122	16
ASes2	15.83	0.122	17
ASes3	15.83	0.121	18
ASes4	15.83	0.118	19
ASlum4	16.00	0.109	20
ASlum2	17.50	0.089	21
Locality	18.83	0.085	22

Compound housing, an indicator of neighborhood density, also displays mostly negative correlation values, ranging from 0.15 to -0.45. The overall correlation values are consistent with results from wealth and illiteracy, and results point to higher percentages of compound housing in a neighborhood being correlated with lower BMIs, but also lower General Health. The rankings of correlation values were averaged, producing the results in Table 3.3. Based on the average correlations, the top four performing neighborhoods are the FMV, KVeg3, GSS, and KSes3 boundaries.

The boundary definitions with the top four correlations are displayed in Fig. 3.1, mapped according to the spatial pattern of General Health, with the darker shading indicative of better self-reported health. Similar patterns can be observed between the two observation-based boundaries, and the two K-means boundaries. Patterns between the observation-based and data-driven are harder to discern, however certain neighborhood areas appear to be consistently ranked between all four schemes such as the Korle Bu hospital area with excellent health, and the middle coastal area of La with poor or fair health.

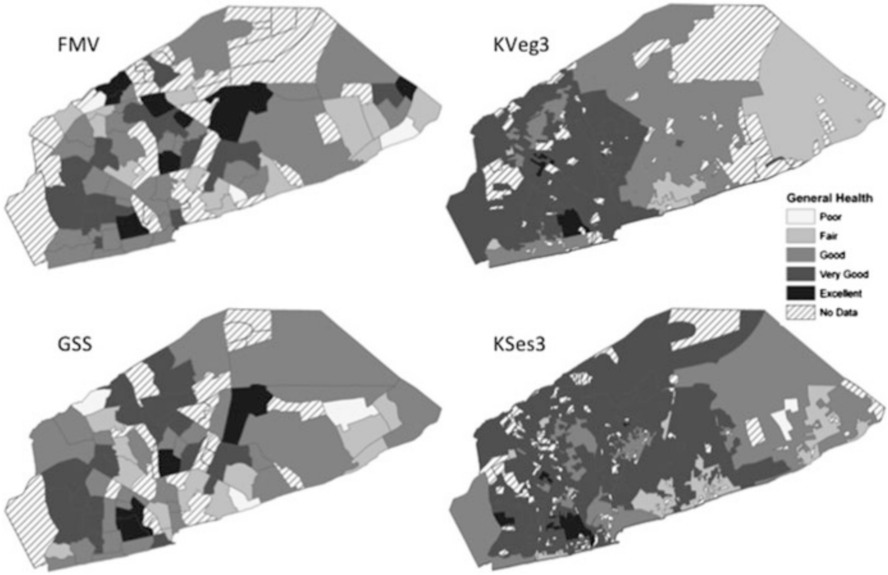

Fig. 3.1 FMV, KVeg3, GSS, and KSes3 boundaries with neighborhood level General Health values

3.6 Discussion

The 22 different boundary sets provide diverse definitions of place for Accra. These definitions range in scale and zoning, come from different theoretical understandings of place, and represent assorted methodological approaches. The three obstacles presented earlier play a primary role in the number and types of boundaries that can be developed, as well as how these boundaries perform in statistical modeling.

A primary goal of the project has been to create boundaries that have meaning for theorized processes between health and place. This is a challenging starting premise as there is little research linking neighborhoods to health in the developing urban world, and literature on measured effects from which to draw is scarce. While theory about place effects on health in the developed world can serve as a beginning point, we cannot automatically assume that these same pathways are at work in the developing urban environment. One of the primary reasons that pathways may be different is the unique social and environmental structure of these rapidly expanding urban centers. One of the ways of overcoming these obstacles was experimentation with the boundaries themselves, which allowed some insight into place-based health processes that operate at different scales and across diverse contexts. The experimentation was based on three common boundary methodologies: (1) the use of pre-existing administrative boundaries; (2) the creation of boundaries from intensive observation; and (3) the application of data-driven clustering algorithms that are able to generate multiple boundary sets in a short period of time. Results from comparing the boundaries demonstrate little consistency and considerable complexity for modeling place effects on health in Accra, but they do provide some insight into the social and physical neighborhood-level processes that are influencing health in Accra.

The diversity of the 22 different boundary definitions is quickly apparent when comparing them numerically. Particularly noticeable are the differences between the equally sized observation-based boundaries, and the more heterogeneously scaled data-driven methods. There has been a tendency in the literature to prefer compact and equally sized boundaries, which is largely due to a preference for administrative boundaries. However, the ability of such boundaries to represent on-the-ground phenomena is questionable. In Accra, while the vernacular neighborhoods tend to encapsulate equally sized areas, there is considerable social and physical heterogeneity within these larger boundaries. The data-driven methods hone in on these differences, and while the resulting boundaries may not be 'pretty' in a spatially compact sense, they are more likely to follow the spatial divisions of social and physical processes on the ground. However, a negative aspect of heterogeneous boundary sizes within one scheme is concurrent heterogeneity in the number of women assigned to each boundary, as demonstrated in Table 3.1.

Comparisons of the variance and correlation values underscore the challenges that spatial heterogeneity pose in Accra. There is little consistency in ICC values for boundary method or scale. While EA boundaries have the highest ICC, not all fine-scaled boundary schemes have high ICC values. This lack of consistency underscores the volatility of changing the aggregations of women and their surrounding neighborhoods, which is likely the reason for the inconsistent changes in ICC values across the boundary schemes and scales. To complicate matters further, there is little consistency between health variables, signifying that the changes in scale and zoning have different effects on the ability to measure BMI as compared to General Health place effects. This result is consistent with other studies that have examined the use of neighborhood boundaries on diverse health outcomes – often a different boundary scheme may need to be selected for each health outcome, as different scales and spatial patterns are at play in the pathways that lead to one health outcome as compared to another. BMI has very low between-neighborhood and ICC variance values across all neighborhood boundary schemes, indicating that this health outcome may not have significant measurable neighborhood level effects. General Health, on the other hand, has much higher between-neighborhood and ICC variance values across all schemes, indicating that General Health outcomes may be partially explained by the neighborhoods in which women live. For General Health, the use of either the AVeg boundaries or EAs would provide the highest neighborhood-level explained variance. EAs have the highest ICC variances for both health variables, a surprising outcome, as there is no theoretical connection between EA boundaries and health outcomes. This result, however, may indicate the need to work with smaller scales of place.

Correlation values between the health variables and predictor variables proved to be in a consistent direction for wealth, and mostly consistent for illiteracy and compound housing. All three variables demonstrated the same relationships: wealthier, more literate, less densely sparse neighborhoods had higher BMI measures, indicating more obesity. This is a logical result indicating that women living in higher socio-economic status neighborhoods likely have more sedentary jobs, and more access to highly processed foods. Neighborhoods with higher percentages of illiteracy and compound housing, and less wealth were correlated with low general health scores, indicating that women living in low socio-economic status areas generally feel they are of poorer health than women in better-off neighborhoods. The robustness of these results throughout the various neighborhood delineations is encouraging, indicating that changing scale and zoning patterns of the city does not significantly alter general health patterns and associations. However, the few neighborhood correlation results in opposition to the general trends are a warning flag for research that relies on one neighborhood definition. It may be necessary to test correlations for at least one or two other neighborhood sets to be sure that place and health relationships are not a result of MAUP.

By rank ordering, the correlation values between the health variables and three predictor variables, it becomes easy to discern which neighborhood boundary sets provide the best correlations across all three predictor variables. The two observation-based boundaries, the FMV and GSS, as well as the KVeg3 and KSes3 boundaries came out in the top four ranks. Interestingly, the KSes4 and KVeg4 were included in the 5th and 6th spots, indicating that the K-means method using the SES and Vegetation variables produced better boundaries for correlation values. Generally the AMOEBA boundaries performed poorly in correlations. While the correlation results support the use of observation-based, KSes, and KVeg boundaries for associations between health and place variables, the results are difficult to rectify with the variance results, which do not show high ICC values for either health variable for these boundaries (the ICC value for FMV neighborhoods for BMI is one of the highest, however at 2.55, the value itself is very low). In other words, while there may be stronger correlations in these neighborhoods between health and place, there is little variability between neighborhoods to begin with. This, however, is a significant issue for most neighborhoods and health research, and is further compounded by the extreme heterogeneity of lifestyle and health factors seen in developing cities such as Accra.

3.7 Conclusion

Utilizing the variance and correlation results from this study, coupled with an understanding of the issues that neighborhood and place research faces in the developing world, a strong case can be made for the use of observation-based boundaries in Accra, particularly the FMV boundary set. While these boundaries are comparable to other data-driven boundaries in this study, notably the KSes and KVeg boundaries, the observation-based boundaries offer a significant advantage since they are socially recognized units that have some kind of neighborhood identity.

As research into the spatial aspects of health in the developing urban world moves forward, the theoretical and statistical connections between place and health will allow for better models and neighborhood definitions. While literature, methods, and theory put forth for the study of health and place in the developed world serve as starting points for research in other places, there is a need to test and build knowledge that is context specific. There is also a need to be continually innovative with respect to methods of boundary delineation in the face of scarce data resources. The development of neighborhood definitions for Accra, Ghana are both context and project specific, but they offer lessons for translating this research into other cities. Specifically, testing the variance and correlations of multiple boundary sets allows us to ensure robustness in the posited relationships between health and place. This is of particular importance in places of high heterogeneity coupled with lack of knowledge of how health and place operate together. With so little research on neighborhoods and health in the developing world, establishing robust relationships between health and place that are not a result of MAUP should be a significant priority.

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Chapter 4
Delineation and Classification of Urban Neighborhoods of Accra, Ghana, from Quickbird Imagery: Manual vs. Semi-automated Approaches

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Neighborhood is a term that, though part of the common vernacular, has varied and sometimes-conflicting definitions (Sampson et al. 2002; Talen 1999). Neighborhoods are commonly understood to be defined spatial units within a city, but as is discussed in other chapters within this volume, neighborhoods are social constructs for which definitions in physical space vary among inhabitants and observers. The research relating to neighborhoods described in this book was conducted with two related objectives: (1) understanding the social interaction and transfer of knowledge relating to health outcomes within neighborhoods and (2) delineation of spatial units for which health, socio-economic, and environmental data can be summarized to support statistical analyses. The research described in this chapter relates to the second of these two objectives and, therefore, considers a 'neighborhood' to be a definable spatial unit that may or may not contain residents who share a common identity or behaviors. Specifically, it seeks to test the feasibility of defining spatial units (i.e., neighborhoods) of relatively homogeneous health outcomes and, as a proxy, socio-economic conditions from satellite image data. This objective was achieved by assessing (1) methods for the delineation of neighborhoods from satellite image data and (2) the relationship between satellite remote sensing derived land surface properties and factors affecting health outcomes.

Accra, Ghana provides a good case for the evaluation of neighborhood effects on health because relatively robust census and women's health surveys were completed recently and the city exhibits substantial inter-urban variation in health

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outcomes prototypical of cities in many developing countries (Weeks et al. 2006; Montgomery and Hewett 2005). As with any census or survey, the Ghanaian Census of Population and the Woman's Health Study of Accra (WHSA) generated survey data that are reported in units (enumeration areas) that vary in size, shape, and distribution. Attempts to draw statistical inference from these variable units are compromised by the modifiable area unit problem, in which it is recognized that relationships may vary according to the characteristics of the underlying geographic units (Openshaw 1984). Nonetheless, the delineation of neighborhoods holds the potential to provide common spatial units on which statistical analysis can be appropriately conducted, thus enabling the evaluation of neighborhood effects on health outcomes. Commercial satellite remote sensing data provide sample units (i.e., picture elements or "pixels") that are independent of survey samples and substantially smaller than survey reporting units, and therefore can provide a means for delineating spatial-analytical units through aggregation of image pixels (Stow et al. 2010). In this chapter we report on the evaluation of several methods for the delineation of neighborhoods from satellite remote sensing data: (1) aggregation of census enumeration areas based on satellite derived land surface properties, (2) direct delineation of neighborhood boundaries through object-based image analysis, and (3) manual delineation of neighborhoods by both naive and informed analysts.

4.1 Background

Satellite image data provide a wealth of information on environmental condition and composition, which has been shown to correlate to both socio-economic status (Stow et al. 2007) and housing quality (Stow et al. in press). While there are clearly important factors of neighborhood formation that may have no physical manifestation in the landscape (e.g., identity), many of the factors typically used to define one neighborhood from another can be detected or measured from high-resolution remote sensing imagery (Rashed et al. 2001, 2005; Knudsen and Olsen 2003; Weeks et al. 2007). Major roads and waterways that might form boundaries of neighborhoods are readily identified (Herold et al. 2004). Factors such as building size and density, vegetation abundance, and the proportion of impervious versus bare soil ground cover can be mapped from remote sensing sources and have been shown to correlate to housing quality or socio-economic status (Stow et al. 2007, 2010, in press; Boentje and Blinnikov 2007; Jensen et al. 2004).

Given the range of landscape features that are both detectable from remote sensing sources and influential to the formation of neighborhoods, the delineation of neighborhoods from satellite observation offers some compelling advantages over traditional ground surveys alone. Satellite image data provide an independent source of spatial aggregation to support statistical analysis (Stow et al. 2010), permit monitoring of factors affecting health outcomes where ground surveys are not possible due to safety or political concerns (Stow et al. in press; Weeks et al. 2007), and provide an independent observation with the potential to permit the estimation of variables effecting health outcomes in areas where ground surveys have not been conducted (Stow et al. 2007, in press).

4.2 Study Area

The study area is the Accra Metropolitan Area (AMA), which is the core district of the Greater Accra Region. Accra is one of the fastest growing cities in Africa and hosts a diverse population of approximately four million in the Greater Accra Region, about half of which is within the AMA. Like many developing cities, Accra continues to experience rapid population growth due to migration from rural areas (Montgomery and Hewett 2005). Population in the AMA increased by nearly half of a million people between the 2000 and 2010 censuses. The majority of these new inhabitants reside in informal settlements with limited sanitation services, water availability, or formal structures. The majority of the population of Accra lives in slums as classified by the United Nations (UN-Habitat 2009). These slums exhibit dense settlement and relatively small dwellings, tend to be at lower elevations, and have relatively sparse vegetation (Stow et al. 2010, in press; Rain et al. 2011).

4.3 Data

All analysis was conducted using a cloud-free QuickBird satellite image captured on 12 April 2002. The image covers an extent of 18 km (E–W) 613 km (N–S), encompassing approximately 80 percent of the AMA. Both multispectral (2.4 m ground sampling distance) and panchromatic (0.6 m ground sampling distance) bands were used. The imagery was georeferenced to the Universal Transverse Mercator map projection by Digital Globe to the Standard processing level (CE90523 m; RMSE514 m).

Geographic object-based image analysis (GEOBIA) techniques were tested as a method for the regionalization of census EAs into neighborhoods. The urban vegetation-impervious-soil (V-I-S) model of Ridd (1995) provided a remote sensing approach to deriving measures for regionalization. By combining the V-I-S model with GEOBIA, proportions, sizes, and shapes of basic urban materials and structures provide a potential link between the biophysical urban landscape and neighborhoods (Stow et al. 2007). The proportional cover and average size of vegetation features were assessed as variables for spatial aggregation of EAs into neighborhoods by three methods: (1) polygon merging, (2) segmentation, and (3) size constrained iterative segmentation. Regionalization results were then compared to census derived measures of housing status (i.e., slum index) and a neighborhood definition produced through spatial aggregation of EAs by Max-P-Region, described below (Duque et al. 2007a). To reduce processing time, analyses were conducted on a subset of the AMA.

Data from the 2000 Ghana census were used to derive a slum index for each EA. The index was calculated for each EA by summing five variables based on UN-Habitat (2009) definitions of slums as representing place that have one or more of the following characteristics: (a) no running water inside the house, (b) no toilet connected to sewer system, (c) three or more persons per room, (d) roof of non-durable material, and (e) insecure tenure (e.g., squatting) (Weeks et al. 2007). Slum index values for each housing unit are scaled from 0 to 5, where 0 indicates no slum characteristics and 5 indicates all slum characteristics. The average score for housing units in an EA is the slum index for that EA. Slum index values were used to compare generated neighborhoods in terms of their socioeconomic homogeneity. Slum index values were also used to derived a relative reference map of 277 "analytical regions" (i.e., neighborhoods) through the Max-P-Region (Duque et al. 2007a) approach. The Max-P-Region approach can be considered a special case of clustering where geographic continuity between elements is considered, commonly known as the regionalization problem (Duque et al. 2007b).

4.4 Methods

A bottom-up, hierarchical segmentation strategy with two levels of image objects (Stow et al. 2007) was implemented with e-Cognition (a.ka. Definiens) GEOBIA software. The first and finest segmentation (Level 1) consisted of potential V-I-S patches, which were segmented using the e-Cognition region-based local mutual segmentation routine (Benz et al. 2004) through iterative and interactive control of segmentation scale (i.e., size) and shape (i.e., compactness vs. smoothness) parameters. Inputs were the four QuickBird multispectral wavebands, NIR, red, green, blue, in order of input. A supervised classification approach and a minimum distance to mean classifier were adopted to classify objects as vegetation, impervious, or bare soil based on input features identified through the statistical severability measure imbedded in e-Cognition known as Feature Space Optimization (Definiens 2003). Selected features included spectral and shape features—for a detailed list, see Stow et al. (2010). Level 1 classification results were used to calculated mean vegetation patch size and the proportion of vegetation cover for each EA.

Level 2 (coarser spatial scale) objects were generated through segmentation and spectral merging (Definiens 2003) of EAs based on vegetation patch size and cover proportion. To allow segmentation of the Level 1 summary results directly, it was necessary to import EA summary results back into e-Cognition as if they were a spectral layer and to constrain the Level 2 segmentation by using the EA boundary file as an input to the segmentation routine as a thematic layer. A relatively large scale parameter was used to generate Level 2 objects of similar size to the EA boundaries, ensuring that aggregated segments conformed to EA boundaries.

EAs were then aggregated based on (1) polygon merging, (2) segmentation, and (3) size constrained iterative segmentation. Level 2 vegetation patch size or proportion served as inputs for all EA regionalization methods. Merging was completed using the spectral merge function of e-Cognition, which groups neighboring polygons based on a simple linear distance measure of the input features (i.e., vegetation patch size or vegetation proportion). Segmentation using the e-Cognition region-based local mutual segmentation routine (Benz et al. 2004) was completed through iterative and interactive control of segmentation parameters to maximize aggregation without producing neighborhoods of unrealistic shape (i.e., uncompact, large). Scale, shape, and compactness parameters were set to 15, 0.3, and 1.0 respectively. To further limit the generation of unrealistically large or uncompact neighborhoods, a size constrained iterative segmentation procedure was also tested. After initial segmentation using the above parameters, objects smaller than an empirically defined threshold of 200,000 m^2 were allowed to aggregate further in subsequent segmentations. The scale factor was increased sequentially from 100 to 1,000 in increments of 100.

Given that there is no absolute definition or delineation of neighborhoods, spatial correspondence of the five image-derived neighborhood maps was compared with the reference map (Duque et al. 2007a) to provide a relative assessment of the potential utility of the image-derived maps for representing actual neighborhoods in Accra. Spatial correspondence was assessed by comparing summary statistics and through spatial correspondence overlay analysis. Summary statistics included the number, mean size, and range of sizes of neighborhood units. Spatial correspondence analysis was conducted with the census-derived map as the reference. The mean number of image-derived neighborhood polygons contained within each reference map polygon was tabulated by determining centroids for image-derived polygons and counting centroids contained within each reference polygon such that a smaller average number of contained centroids indicates greater correspondence with the reference map, since the image-derived maps tended to have a greater number of resultant neighborhoods and therefore smaller polygons when compared to the reference map.

4.5 Results

Summary statistics for neighborhoods derived through aggregation of EAs are shown in Table 4.1. Spatial correspondence analysis results are provided in Table 4.2. Except for the neighborhoods generated through size-constrained iterative segmentation, image derived maps contain a greater number of neighborhoods than the reference map aggregated using slum index values. Size constrained iterative segmentation of QuickBird-derived vegetation proportions resulted in the map most similar to the reference map both visually and in terms of the number of neighborhoods generated. Neighborhood maps derived through segmentation procedures produced maps more similar to the reference map than those generated through spectral merging and neighborhoods maps generated based on vegetation proportion were more similar to the reference map than those generated based on vegetation patch size.

Table 4.1 Summary statistics for neighborhoods generated through enumeration area aggregation and spatially constrained clustering (Duque et al. 2007a)

Aggregation approach—feature input	No.	Mean size (m^2)	Std. Dev. size (m^2)
Reference	79	273,827	429,728
Spectral merge—veg %	286	115,441	234,821
Spectral merge—veg size	432	68,892	152,561
Segmentation—veg %	184	116,701	240,995
Segmentation—veg size	309	69,565	159,124
Size-constrained iterative segmentation—veg %	69	314,068	330,642

Table 4.2 Spatial overlay correspondence of neighborhood maps derived through aggregation of enumeration areas relative to the reference map

Aggregation approach—feature input	Mean	Standard deviation	Maximum
Spectral merge—veg %	2.53	2.64	16
Spectral merge—veg size	4.14	3.82	23
Segmentation—veg %	2.47	2.27	9
Segmentation—veg size	4.08	3.38	11
Size-constrained iterative segmentation—veg %	1.01	1.42	8

Values represent number of image-derived polygon centroids within reference polygons. Smaller values indicate greater spatial correspondence

4.5.1 Manual Delineation of Neighborhoods from Satellite Imagery

Though census units (i.e., EAs in the case of Accra, Ghana) provide a ready spatial unit for determination of neighborhood boundaries, the delineation of neighborhood boundaries directly from imagery, independent of census units, is desirable for a number of reasons: (1) neighborhoods derived through census unit aggregation may still exhibit statistical dependency on the census units from which they were derived, (2) censuses are not conducted for many cities in developing countries, and (3) census data are often not publically available for political, security, or economic reasons. Here we explore the potential of delineating neighborhoods based strictly on visual interpretation of QuickBird satellite imagery

If neighborhoods can be delineated from remote sensing sources it seems that the human interpreters, with their keen abilities to visually analyze imagery and innate understanding of human behavior and urban structure, may be the most ready solution. This requires inference of fundamentally social patterns of human interaction and habitation based on the observation of the physical environment provided by satellite remote sensing, a complex task akin to an archaeological approach to interpreting the modern day landscape. To test the feasibility and reliability of mapping neighborhoods based on satellite image data alone, a group of image interpreters was asked to delineate neighborhoods based on a common set of interpretation rules and the resultant estimates of neighborhood boundaries were then compared.

Ten interpreters were recruited to delineate neighborhood boundaries from a high-resolution pan-sharpened multispectral (PSMS) image of a portion of the AMA. To better understand the role of bias due to previous experience interacting with the neighborhoods of Accra, interpreters were stratified into two groups. Half (five) of the interpreters were considered to have "Local Knowledge" of the study area, meaning they had local, ground-based knowledge of the city and its neighborhoods through prior visits to Accra. One of these interpreters had more knowledge than the others and so was considered to be the Local Expert. The other five interpreters were considered to have "No Local Knowledge" and were selected because they had never been to Accra. To standardize the rules by which neighborhoods are defined, interpreters were provided a set of guidelines for manual delineation of neighborhoods and classification of those neighborhoods as either HSE (high socioeconomic status) residential, LSE (low socioeconomic status) residential, or predominantly Non-Residential. The guidelines were given as follows:

- Neighborhoods consist of intra-urban regions where inhabitants tend to share similar socioeconomic, cultural, and health identities;
- Neighborhoods manifest on high spatial resolution imagery as intra-image regions that contain internal consistency in the amount and pattern of primitive land cover types (vegetation, soil, and impervious surface materials);
- LSE residential neighborhoods tend to be comprised of many small, densely-packed housing structures with minimal landscaped vegetation, while HSE residential contains the opposite;
- Major roads and waterways may serve as barriers to movement and communication and therefore they may serve as logical boundaries between neighborhoods;
- The shape of neighborhoods is likely to be compact, as movement and societal interactions tend to decay with distance; and
- Consider the minimum size of a neighborhood to be 0.25 km^2, the median size 1.5 km^2, and the largest size 35 km^2.

Image interpreters used ESRI's ArcGIS software to display and navigate through the PSMS QuickBird image of Accra, digitize neighborhood boundaries, and encode attributes for the three neighborhood types (i.e., High socio-economic residential, Low socio-economic residential, and predominantly non-residential). The resultant maps of neighborhood delineations were compared with each other and with a commonly accepted definition of neighborhoods developed by the Ghana Statistical Service (GSS) in terms of spatial correspondence and the number and size of neighborhoods defined.

From the 2000 census data, GSS created a set of 88 neighborhoods by agglomerating EAs into areas that "that are broadly recognized and agreed to by residents of a

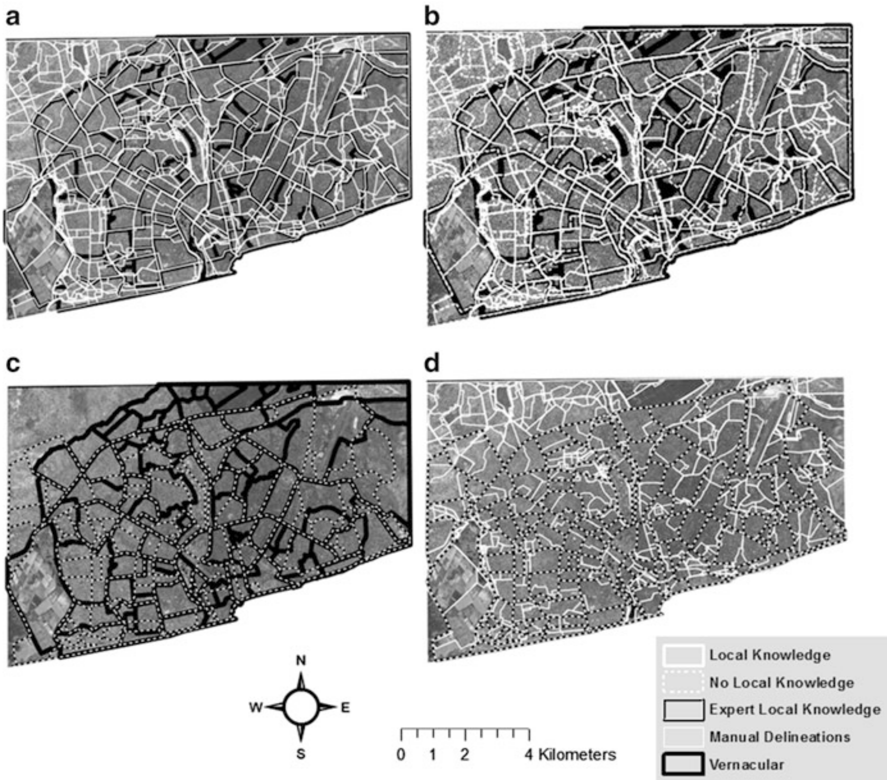

Fig. 4.1 (**a**) All manual interpretation results compared with the FMV neighborhood boundaries, (**b**) interpretation results from interpreters with local knowledge (shown in *thick white*) and without local knowledge (shown in *white-hashes*) compared with the FMV neighborhood boundaries, (**c**) interpretation results from the Local Expert compared with the FMV neighborhood boundaries, and (**d**) interpretation results from Local Expert compared with interpretation results from other interpreters with local knowledge and without local knowledge

given city—in this case Accra, Ghana—even if they may have no premeditated and formal definition. These are the place names, for example, that would be provided to a taxi driver, especially since there is no comprehensive street address system in Accra" (Weeks et al. 2010, p. 563). These boundaries are "similar to what one would find in printed tourist maps of Accra" (Weeks et al. 2012, p. 934). The neighborhood definition used for comparison is based on the original GSS produced map, but provides a finer scale definition, dividing the city into 108 neighborhoods (Rain et al. 2011). This refined definition can be called field modified vernacular (FMV) neighborhoods. For a complete description of the FMV generation process, see Rain et al. (2011) and Weeks et al. (2012).

Visual inspection of manually interpreted neighborhoods reveals clear differences between neighborhood maps created by interpreters with local knowledge and maps created by interpreters without local knowledge (Fig. 4.1a). Interpreters

Table 4.3 Manual interpretation results by individual interpreters compared to field modified vernacular neighborhoods (FMV) and results from Geographic object-based Image Analysis (GEOBIA)

Knowledge source	# of neighborhoods	Mean (km^2)	Min (km^2)	Max (km^2)
FMVs	108	2.25	0.19	21.46
Local expert	115	1.23	0.08	11.02
Local [1]	69	2.46	0.31	19.79
Local [2]	60	2.95	0.10	16.74
Local [3]	77	2.29	0.31	12.67
Local [4]	108	1.65	0.14	8.73
No local [5]	117	1.51	0.21	7.30
No local [6]	97	1.84	0.42	12.51
No local [7]	115	1.54	0.03	18.36
No local [8]	144	1.23	0.15	12.96
No local [9]	94	1.87	0.12	12.24
GEOBIA	105	2.11	0.27	37.54

Table 4.4 Feature rules for classification of object Level 1 used in image-only neighborhood delineation

Class	Objects feature	Short description
Grass	0.6 = < Max. diff. = <1	Maximum difference between any two of the four (4) input wavebands
Tree	Max. diff. >1	
Soil	Max. diff. <0.6	
Impervious	Average length of edges (polygons) > = 7 Pxl	Geometry based on Polygons

with local knowledge (Fig. 4.1b) produced estimates of neighborhoods with strong correspondence to the FMV neighborhoods. Interpreters with local knowledge also tended to estimate neighborhoods as larger and more similar in size to the FMV definition than those without local knowledge (Tables 4.4 and 4.6). Visual inspection reveals agreement between interpreters with and without local knowledge where there are large roads or waterways that form the boundary of neighborhoods, but disagreement where there is no such landscape feature. Almost all interpreters subdivided the rapidly growing informal settlements contained in the FMV neighborhood of Gbegbeyise into several smaller neighborhoods.

Table 4.3 shows the number of neighborhoods delineated by each interpreter and Table 4.6 shows the number of neighborhoods delineated by interpreters with and without local knowledge compared to those generated by the local expert and defined in the FMV neighborhoods. In general, interpreters with local knowledge delineated a smaller number of neighborhoods than those without local knowledge. Counter intuitively, the number of neighborhoods delineated by the Local Expert was most similar to interpreters without local knowledge. This is primarily due the finer-scale delineation of neighborhoods in the dense informal settlements of southwestern Accra by that person when compared to both the FMV neighborhood definition and other interpreters with local knowledge. The number of neighborhoods delineated by interpreters with local knowledge was closer to the number of FMV neighborhoods than those without local knowledge.

In general, there was more agreement on the boundaries of neighborhoods between interpreters with local knowledge and less agreement between interpreters without local knowledge. As expected, boundaries generated by interpreters with local knowledge are more similar to those produced by the Local Expert than those produced by interpreters without local knowledge.

4.5.2 Neighborhood Delineation Through Direct Image Segmentation

Given the relative consistency of neighborhood delineations between the group of interpreters and the comparability of those delineations to the FMV neighborhood map produced through ground survey, it seems that the delineation of neighborhoods through semi-automatic aggregation of satellite remote sensing pixels holds promise. To test the feasibility of automating the estimation of neighborhood boundaries from satellite remote sensing sources, a map of neighborhood boundaries was produced by implementing the above guidelines for neighborhood delineation and classification using a GEOBIA approach. More automated approaches to image-based delineation of neighborhoods should minimize the bias associated with manual interpretation and is potentially more time and cost efficient.

The neighborhood interpretation guidelines outlined above were implemented through a bottom-up hierarchical segmentation strategy in e-Cognition. The first and finest object level was created through segmentation of the four QuickBird multispectral wavebands using an e-Cognition Scale parameter of 40, Shape weight of 0.1 and Compactness weight of 0.7, which were selected through iterative segmentation to achieve maximum object size while maintaining only single land cover class per object. Objects were classified using a modified V-I-S (Ridd 1995) classification scheme: Grass, Trees, Impervious, and Soil. A simple two-feature rule set was used to define the four classes, as seen in Table 4.4.

Level 2 (coarser scale) was segmented and classified through a rule-based strategy intended to replicate the above defined interpretation guidelines. Table 4.5 provides the features and rules that were used to generate an image-only estimate of neighborhoods. Most rules were expressed through the segmentation process, which used a Scale parameter of 500, Shape weight of 0.5, and Compactness weight of 0.8. The Scale parameter was selected through iterative segmentation to limit the size of resultant objects to the range defined in the rule set. The relatively high Shape and Compactness weights were selected to generate compact objects representative of the compact nature of neighborhoods defined in the rule set.

Objects were first classified as residential or predominantly non-residential based on an all-direction homogeneity (Definiens 2003) texture measure (i.e., inverse difference moment of the second order), where residential areas are described as

Table 4.5 Image-only segmentation and classification strategy and associated manual interpretation guidelines

Interpretation guideline	GEOBIA implementation
Neighborhoods consist of intra-urban regions where inhabitants tend to share similar socioeconomic, cultural, and health identities.	
Neighborhoods manifest on high spatial resolution imagery by intra-image regions that contain internal consistency in the amount and pattern of primitive land cover types (vegetation, soil, and impervious surface materials).	The rule was expressed through an arithmetic feature establishing a relationship between the amount of vegetation and impervious material. *Arithmetic Feature 1 = [Rel. area of sub objects Grass (1)]/[Rel. area of sub objects Impervious (1)]*
LSE residential neighborhoods tend to be comprised of many small, densely-packed housing structures with minimal landscaped vegetation, while HSE residential contain the opposite.	The rule was expressed by stratifying neighborhoods based on [Arithmetic Feature 1] *[Arithmetic Feature 1]* $\geq$ *0.6 = HSE* *[Arithmetic Feature 1] < 0.6 = LSE*
Major roads and waterways may serve as barriers to movement and communication, therefore, they may serve as logical boundaries between neighborhoods.	The rule was expressed iterative adjustment of segmentation parameters to ensure that objects did not cross major roads or waterways
The shape of neighborhoods is likely to be compact, as movement and societal interactions tend to decay with distance	The rule was expressed by weighting object shape (0.5) and compactness (0.8) heavily in the segmentation process
Consider the minimum size of a neighborhood to be 0.25 km^2, the median size 1.5 km^2, and the largest size 35 km^2.	The rule was expressed through iterative selection of the scale parameter (500) to limit object size to between 0.25 and 35 km^2

having higher texture values due to the density of housing structure when compared to commercial structures. A single feature was calculated based on the relative area of grass objects, which primarily represent landscaped and manicured property, divided by the relative proportion of impervious objects, which exist in much higher proportion in high density, low-socioeconomic status areas, and was used to stratify HSE and LSE residential areas. This feature, which we call the socio-economic land cover index (SLI) was found through iterative threshold selection and visual interpretation to separate HSE from LSE objects using a threshold of 0.6, where HSE areas are described as having a SLI value of $\geq$0.6 and LSE areas as having an SLI value of <0.6.

The delineation of neighborhood boundaries based only on the grouping of satellite image data pixels by image segmentation and object-based classification is shown in Fig. 4.2a. Visual comparison to FMV neighborhoods and neighborhood estimates produced through GEOBIA (Fig. 4.2b) reveals that, in general, the GEOBIA-derived neighborhoods tended to be larger (Table 4.6) than the FMV or manual delineated neighborhoods. The larger size of GEOBIA-derived neighborhoods results in fewer neighborhoods than from manual image inter-

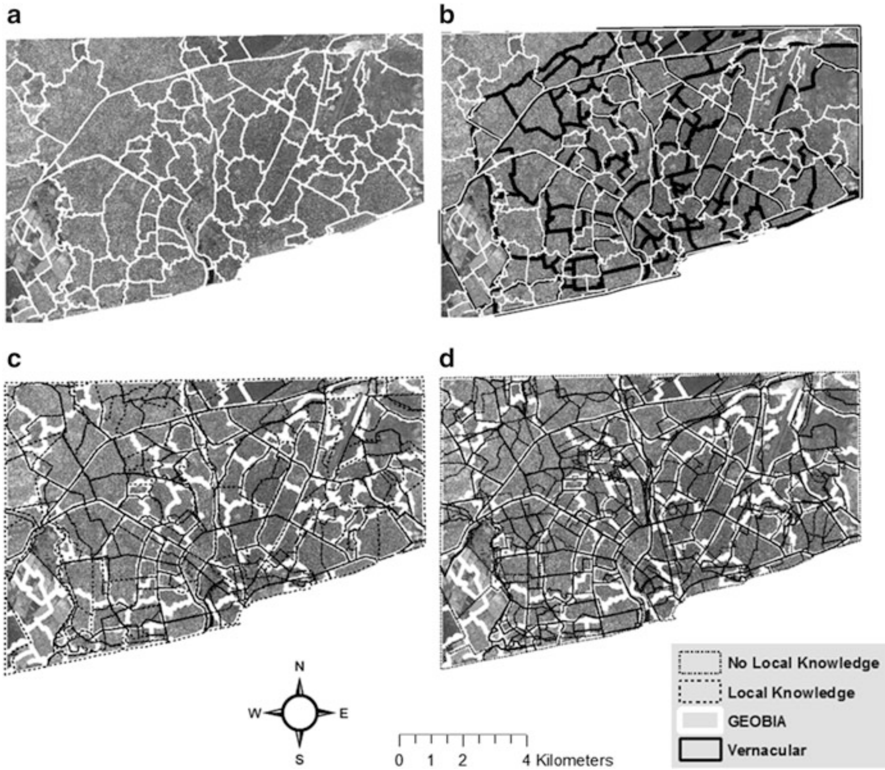

Fig. 4.2 (**a**) Neighborhood boundaries derived through Geographic Object-Based Image Analysis, (**b**) neighborhood boundaries derived through Geographic Object-Based Image Analysis compared with FMV neighborhoods, (**c**) neighborhood boundaries derived through Geographic Object-Based Image Analysis compared with neighborhood boundaries derived through manual interpretation by interpreters with local knowledge (shown in *large hash marks*), and (**d**) neighborhood boundaries derived through Geographic Object-Based Image Analysis compared with neighborhood boundaries derived through manual interpretation by interpreters without local knowledge (shown in *small hash marks*)

Table 4.6 Comparison of manual and GEOBIA neighborhood delineation results

Knowledge source	Size statistics (km^2)					Count statistics				
	Mean	St. Dev.	Med.	Min	Max	Mean	St. Dev.	Med.	Min	Max
FMVs	2.25	2.94	1.54	0.19	21.46	108[a]				
Local expert	1.23	1.38	0.88	0.08	11.02	115[a]				
Local	2.23	2.34	1.64	0.10	19.79	78.5	20.9	73.0	60	108
No local	1.56	1.84	1.08	0.03	18.36	113.4	20.0	115.0	94	144
GEOBIA	2.11	3.83	1.24	0.27	37.54	105[a]				

[a]Actual count; no average available

pretation or the FMV definition (Table 4.6). This results in numerous cases of GEOBIA-defined neighborhoods containing more than one FMV neighborhood. There are, however, several cases where GEOBIA-derived neighborhoods make up a single FMV neighborhood, particularly in the northeastern portion of the study area surrounding the airport and the FMV defined neighborhood of Gbegbeyise.

As with manual interpretation, GEOBIA-derived neighborhood boundaries align with FMV neighborhood boundaries in cases where large roads and waterways form the neighborhood boundary, but deviate in areas where the boundary is formed by small roads or where there is not an image-apparent landscape feature forming the boundary. Similarly, visual comparison of GEOBIA-derived neighborhood boundaries to those generated by manual interpreters (Fig. 4.2c and d) reveals alignment along major roads and waterways and disagreement where there is no clear landscape feature to indicate the presence of a boundary.

4.6 Discussion and Conclusions

The delineation of spatial units for which health, socio-economic, and environmental data can be summarized is critical to support statistical analyses and appropriate survey and census design. These spatial units, which we refer to as 'neighborhoods', may or may not represent areas that contain residents who share a common identity or behaviors, but according to Tobler's first law of geography (Tobler 1970), likely do share more common identities and behaviors than residents of other neighborhoods. While it is clear that electro-optical signals recorded by imaging satellites cannot detect behavior, identity, or health outcomes, it seems equally clear that they can detect phenomena in the physical environment that affect these outcomes or are manifestations of them. The strong correlation between vegetation and socio-economic status (Stow et al. 2010), vegetation and housing quality, and between neighborhood boundaries derived from local interviews and place names (i.e. FMV neighborhoods) with boundaries derived from manual and automated image interpretation, suggest that high spatial resolution satellite image data can provide a useful tool for the delineation of neighborhoods in lieu of detailed local knowledge gained through direct survey and observation. This research represents a preliminary investigation into the feasibility of defining neighborhoods from satellite image data, and more research is needed to determine the most appropriate methods, the stability of results, and what biases are introduced relative to traditional survey based methods.

While there is promise, there are also clearly limits to the utility of satellite image data for the delineation of neighborhoods. Not all social phenomena manifest themselves in the physical landscape, which is what remote sensing observes. Of the social phenomena that do manifest in the physical landscape, only a fraction is detectable by satellite remote sensing. The ambiguity in neighborhood boundaries that are not defined by large roads or waterways is one such example of these limitations, although this may also be reflected in the "fuzziness" of neighborhood boundaries as expressed by local residents (see Chap. 2 of this volume). Even in cases where social phenomena do have clear manifestations in the physical landscape and those landscape features are readily detectable by remote sensing, the physical manifestation of various social phenomena may not be consistent from place to place or over time (Ogneva-Himmelberger et al. 2009). Once again, however, many phenomena are subject to this type of spatial heterogeneity, as noted in several chapters in this volume.

It is important to remember that, unlike most applications of remote sensing, the delineation of neighborhoods is an estimation of fundamentally social phenomena. Like many who have written of the "God's eye view" of remote sensing, Haraway (1991, p. 188–189) warns that the objective view of remote sensing leads "to distance the knowing subject from everybody and everything . . . but of course that view of infinite vision is an illusion, a god-trick". If we are to infer social phenomena or properties from remote sensing, we must, as Kwan (2002, p. 649) suggests, "recognize that vision is always partial and embodied and . . . acknowledge the risk of privileging sight". So, as we acknowledge the power of satellite remote sensing to provide information on social phenomena like neighborhoods, we must keep in mind that satellite imagery provides only a partial view of the physical landscape and that the physical landscape provides only a partial view of complex social phenomena and conceptualizations like "neighborhoods."

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Chapter 5
Methods for Texture-Based Classification of Urban Fringe Areas from Medium and High Resolution Satellite Imagery

Lasse Møller-Jensen

The spatial expansion of Accra's residential areas has been remarkable during the last decade. Following the implementation of liberalization policies from 1983 to the present, many legal obstacles to investments in the housing sector were gradually removed. As a consequence, remittances from international migrants are channeled into capital investments, especially housing and land (Grant 2007). According to Yeboah (2003), the expansion of Accra is associated with relatively high quality residential buildings owned almost exclusively by the rich. Most areas are, however, in need of services and infrastructure. The peri-urban development is dominated by residential areas of low density with one- or two-story houses containing single household dwelling units. There is a strong functional interaction between the peri-urban areas of Accra and Accra Metropolis itself, based on journey-to-work and shopping patterns (Yeboah 2003).

It is possible to identify two divergent patterns of new residential development: individual house-building, and development projects carried out by private estate developers (Grant 2007). Individual development dominates the peri-urban scene while developer projects constitute smaller enclaves. Individual builders typically erect houses gradually over several years whenever funds are available, as mortgage schemes are often not available. Property developers target the upper end of the housing market consisting of individuals in Ghana and abroad who can afford to pay premium prices for better-serviced residential units.

The physical manifestations of the two strategies are quite different. For private estate developers, projects are often characterized by planning and uniformity. In contrast, individual housing development (often bungalow or villa type dwellings) typically takes place before infrastructure and service provision is implemented or even planned. Due to the slow building process, many outer areas constitute

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rural-urban transition zones with houses in various stages of completion. The visual landscape of these new urban areas is often dominated for several years by a high percentage of plots with natural vegetation or exposed surfaces between half-finished brick walls. Most of the new development in peri-urban Accra is characterized by this appearance: wide areas of land dotted with large villas at various stages of completion, in the midst of which are fairly compact indigenous villages consisting of compound earth houses (Gough 1999). Many of these areas lack basic infrastructure and services like piped water and regular sanitation collection. The road system often evolves gradually in an unplanned, *ad hoc* manner, and there are virtually no paved access roads leading into the new developments, thus relegating traffic to an irregular pattern of dirt roads. This lack of accessibility and infrastructure may prove very costly to resolve.

Generally speaking Accra is expanding into its fringe areas (to a geographic extent that rivals most other cities in the developing world) in a largely uncontrolled manner without any rational urban planning strategy. This creates a sprawling low-density development that is uneconomic in terms of land use (Yankson et al. 2007). It is evident that planning and development control measures have been inadequate or ineffective in containing this expansion. Even when plans for urban development exist, implementation is hampered by a mixture of inadequate enforcement, a general lack of funding, problems related to surveying and land registration, land ownership disputes, and the sheer magnitude and speed of urban development.

Figure 5.1 provides an example of a peri-urban development plan established by local authorities before any substantial development in the area took place. A comparison with recent satellite images of the area indicates that virtually none of the planned road infrastructure is in place. Locations of houses constructed later seem to indicate at least some agreement with the delineations set out by the development plan. A number of new houses are, however, in violation of the plan and obstructing the overall development of infrastructure.

5.1 Urban Remote Sensing Challenges

To address problems related to the ongoing process of urban sprawl, spatial information is needed to determine the growth rate and spatial growth pattern of the city. Netzband and colleagues (2007), assessing the status of remote sensing as a tool for urban planning and sustainable development, argue that maps of growth and a classification of urban structure (including factors such as building density and spread of impervious surfaces) derived from remotely sensed data can “assist planners to visualize the trajectories of their cities, their underlying systems, functions and structures.” Sudhira and colleagues (2004) identify metrics for modeling urban sprawl in a developing world perspective, and argue that more information related to the rate of growth, pattern, and extent of sprawl is required by urban planners to provide basic infrastructure facilities and services. This chapter will focus on the classification of peri-urban neighborhoods according to the degree

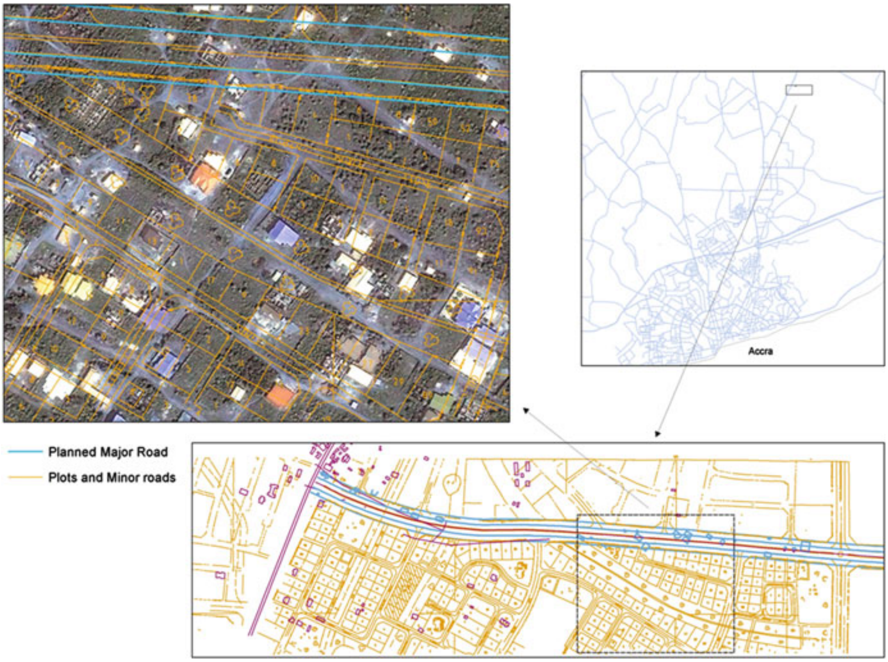

Fig. 5.1 An example of a peri-urban development plan established 1996. A comparison with recent satellite images of the area indicates that virtually none of the planned road infrastructure is in place. Some buildings comply with the plan while others do not

of urban development with the aim of ultimately (in future applications) being able to apply this knowledge to support a more efficient planning process for service and infrastructure provision.

Neighborhoods have been studied and defined in the remote sensing literature as spatial units within which urban residents share common socio-cultural behaviors and identities (Weeks et al. 2007; Stow et al. 2007, 2010). One of the objectives of these prior studies was to delineate such neighborhoods based on relevant physical parameters that are obtainable by remote sensing. In this chapter the neighborhood concept is used in a comparable manner although the target properties of the neighborhoods are somewhat more physically defined. The neighborhoods considered here are small, localized regions within which urban development has reached a nearly-uniform level with similar character and appearance, though distinctly different from adjacent areas. More specifically, the chapter focuses on methods for mapping the continuum of urban development levels found within the fringe areas of Accra. The goal is to produce maps that depict the spatial properties of this gradual rural-to-urban transition zone more accurately than those produced using traditional image classification strategies.

Satellite-based mapping and monitoring of urban growth and detection of urban land-cover is a relatively well-established field. Several studies have shown that

Landsat-TM data with a 30 m spatial pixel resolution (or similar) is potentially useful for classifying urban land cover on a generalized level, provided that the classification methods adopted are targeted towards urban areas (Moller-Jensen 1990; Barnsley et al. 2001; Pesaresi and Bianchin 2001). Compared to new satellite data sources with higher spatial resolution, the advantages of lower spatial resolution data include a more favorable price per area unit, the ability to analyze larger spatial extents within a single image, and the existence of well-tested classification methods. However, the use of pixel resolution of less than 1 m acquired by the later generations of satellite sensors enables a more detailed assessment of land cover for specific planning purposes.

As discussed in numerous studies, the more traditional classification strategy based entirely on the spectral properties of the individual pixels is not sufficient for adequately classifying urban land cover (Moller-Jensen 1997; Weber 2001; Herold et al. 2003; Myint and Lam 2005; Pacifici et al. 2009). This is because the generalized urban land cover classes that may be identified from these images are often not comprised of spectrally homogeneous areas (such as cultivated fields). The urban land cover is distinctly characterized by the pattern of the physical structures, which in turn influences the texture of the satellite image. Some form of texture-based method is, therefore, often suggested as a requirement for urban analysis using remote sensing.

Texture-based classification presents some additional challenges and decision making compared with per-pixel classifications. One such issue is the selection of the basis for the texture computation. This can be either the raw image pixels or the pattern created by smaller image segments, i.e., clusters of pixels that constitute some sort of basic entity. Another unresolved concern is the question of how to perform the necessary pre-segmentation of the image on which to base the texture computation. There are three main strategies described in the literature: (1) use of already existing administrative boundaries, (2) use of moving fixed windows, and (3) application of a segmentation algorithm.

5.1.1 Pre-defined Administrative Boundaries

Existing administrative boundaries were used by Baud and colleagues (2010) to identify sub-standard residential areas in Delhi by computing a number of spatial indices of urban areas defined by electoral wards. Weeks and colleagues (2007) constructed “analytical regions” by clustering existing enumeration areas in order to create a slum index according to UN-Habitat criteria. The main disadvantage of these approaches is the requirement for suitable segment boundary data that correspond to texturally-meaningful image segments. Any existing dataset of administrative boundaries may divide urban areas arbitrarily with respect to the physical characteristics and structure of the urban area and therefore be less suited as a basis for texture computation. On the other hand, pre-defined boundaries frequently offer comparability with other existing ancillary attribute data, and the benefit of not having to perform image segmentation.

5.1.2 Fixed Windows

The main advantage of the moving fixed windows approach is that no existing boundary data or segmentation algorithm are needed. It can be viewed as a way of obtaining areas for texture computation without pre-considering the textural patterns of the area as segmentation algorithms often do. Fixed windows are primarily used to produce pixel-level texture products for further use in classification. As a consequence, the approach normally excludes the possibility of incorporating texture information derived from the pattern of smaller segments.

The selection of a suitable window size for a specific analysis is crucial; large windows will produce the most reliable texture if positioned completely inside an area of one specific class, while small windows will perform better near the boundaries between classes. Inferior performance of large windows close to boundaries can be reduced by applying a multi-scale approach with windows of different sizes; this approach has been used to identify urban growth in the Accra area using Landsat-TM images (Moller-Jensen et al. 2005). The classification system specifically targeted the areas under rural-urban transition and only three classes were applied: (1) fully urban (almost complete buildings on more than ¾ of the plots), (2) under transition (new buildings constructed or under construction on more than ¼ of the plots), and (3) rural areas with only traditional buildings. A multi-scale moving window approach was developed that applied pixel-level texture information from co-occurrence-matrices (Haralick et al. 1973) computed in fixed windows around each pixel. Texture was computed separately for the following four window sizes (in 30 m pixels): 5×5, 9×9, 15×15 and 29×29. These window sizes were selected because they cover a spatial extent that was expected to capture relevant texture information created by the urban objects given the spatial resolution of the image (see Myint 2003 for a discussion of window size versus image resolution). The results obtained from the four different levels were combined based on the hypothesis that a large window provides a very strong indication of a correct class assignment for a pixel. The results (Fig. 5.2) showed that urbanization of the fringe areas of Accra was occurring at a pace that had increased from 10 km^2 per year for the period 1985–1991 to 25 km^2 per year for the period 1991–2002. The urbanized areas of Accra constituted 555 km^2 by 2002 compared to just 216 km^2 in 1985. An additional 196 km^2 were under conversion from rural to urban use.

5.1.3 Application of a Segmentation Algorithm

A third method for defining local regions as inputs for texture computations is the application of a suitable image segmentation algorithm that divides the image into a set of smaller segments. This approach has gained momentum in recent years in part due to requirements associated with increased spatial resolution of the satellite sensors (Blaschke 2010). Segmentation offers potentially improved performance in

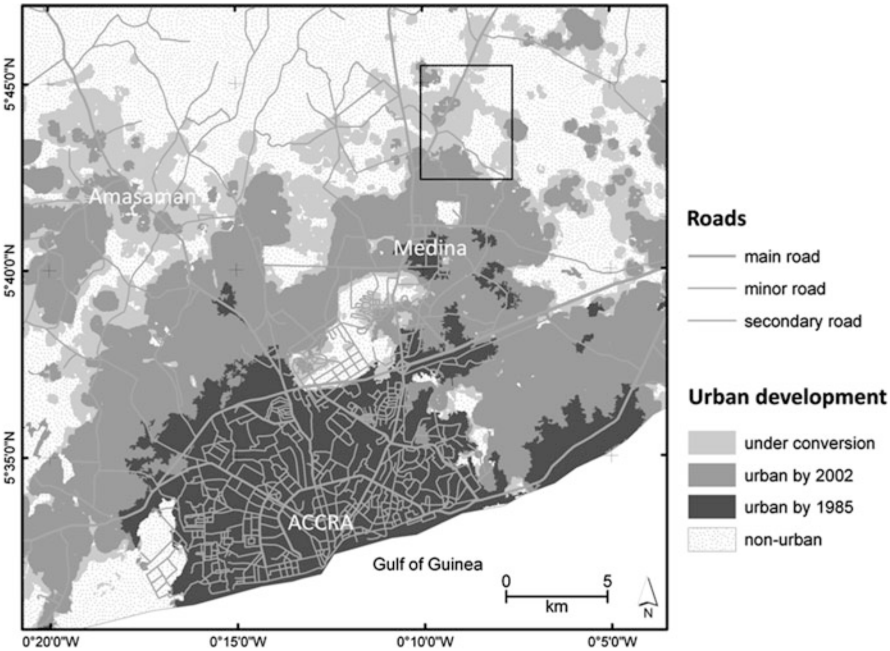

Fig. 5.2 Accra growth map resulting from texture-based classification. A multi-scale moving windows approach was applied (Adapted from Moller-Jensen et al. 2005). The *box* indicates location of the test site for the current study in the transition zone of Northern Accra

complex areas (such as near urban class boundaries) where fixed windows may encounter problems. The segmentation algorithm can be applied at different spatial scales producing a hierarchy of segments. This approach facilitates the computation of texture values based on the spatial properties of segments on a more detailed level (sub-segments). The spatial properties used may include size, shape, and relative location of sub-segments. Herold and colleagues (2003) discuss the use of texture and spatial metrics from high-resolution images for urban classification and argue that texture information should be extracted from basic land-cover segments in the image rather than by pixel. Others have applied a segmentation and hierarchical classification approach based on QuickBird images with the goal of delineating residential land use and identifying socio-economic status (Stow et al. 2007). Segmentation was obtained by applying a bottom-up, hierarchical segmentation strategy.

It is not straightforward to produce image segments that reflect meaningful properties of the urban scene in a coherent way. In some cases, texture evaluation is incorporated into the segmentation process itself in order to identify texturally different areas. One example integrates complex texture features in the core functionality of a region-based, multi-scale segmentation algorithm (Tzotsos et al. 2008). Methodologically, it seems reasonable to interpret this as a weakening of the borderline between the segmentation process and the classification process (as also discussed by Lang 2008). Texture properties are applied in both steps, although no class labels are assigned during the segmentation.

5.2 Estimating the Degree of Urbanization

This section presents a sub-segment texture method for mapping the continuum of urban development levels found within the fringe areas of Accra. The physical manifestation of development reflects the gradual, and often haphazard, transition from predominantly rural to predominantly urban. The object of analysis is the neighborhood level, i.e., an intermediate level between the complete urban scene and the individual objects (houses, roads) that comprise the urban areas.

The hypothesis that drives the methodology is that image segments generated at a detailed level (small segments)—while not necessarily able to accurately represent specific urban objects such as buildings—can still provide valuable texture information that may be applied to the characterization of higher-level segments constituting the urban neighborhoods. In fact, the application of a multi-level segmentation approach enables the use of textural information derived from the size, orientation, and layout of the detailed segments without necessarily requiring a pre-classification of these segments into known urban objects. An accurate classification at the detailed level is very difficult to accomplish even with the highest obtainable spatial resolution due to the presence of vegetation and shadow, and the generally complex nature of the urban scene. This hypothesis prompts two important questions:

1. How can the analyst perform suitable image segmentation both at the detailed level and at the higher analysis level (neighborhood)?
2. What type of texture information derived from the detailed segment level will assist the characterization of higher level segments with regard to degree of urban development?

5.2.1 The Test Case: Northern Accra

A section of the urban fringe zone in the northern part of Accra was analyzed for this study (see extent in Fig. 5.2). The experiment was carried out using a 4.5×5.6 km pan-sharpened 4-band QuickBird satellite image acquired 15 January 2009 with a spatial resolution of 0.6 m. There are no visible clouds but some haze and (at a few locations) smoke.

To begin, a set of 165 reference points in a grid was created and ground validation was established for each point by visually inspecting the scene (see Fig. 5.3). The ground validation and feature identification was performed manually and

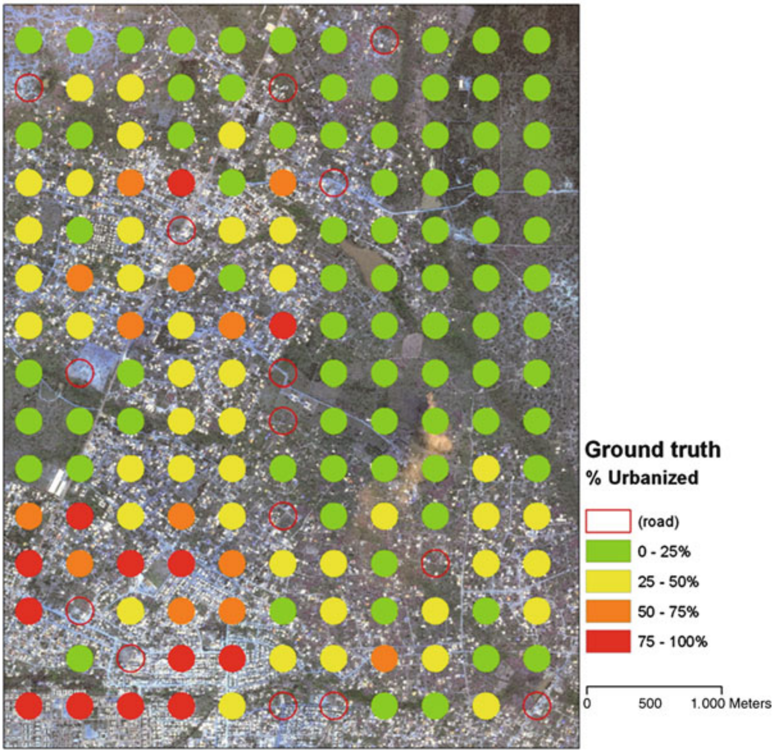

Fig. 5.3 Location of 165 ground validation reference points

independently of any automated image segmentation process using the following strategy. The predominant homogeneous land cover type originating from a given point was identified within a 100 m radius, and three properties were determined: (1) the land cover type, (2) the degree of urbanization, and (3) the structural properties of the area. The land cover type was reported as Urban Residential, Urban Industrial, Urban Vegetation, or Non-Urban. This classification did not consider the degree of urbanization, i.e., an area was labeled Urban if any portion (even only a small fraction) was developed, while the label Non-Urban was applied to completely rural areas. The actual degree of urbanization was reported as a separate value indicating the approximate percentage of the area covered by urban parcels.

In order to be able to compute valid sub-segment texture values, a suitable two-level segmentation of the image was required. The goals are, however, different for the two segmentation levels. The higher level (neighborhood) segments upon which the final map is based should ideally be texturally homogenous and of a certain size; otherwise any characterization based on texture will not be able to produce valid results, either because the texture values have a mixed origin or because the area is too small to provide a typical texture pattern. This issue is intrinsic to any texture-based image processing strategy. Moreover, the segments should reflect the overall objectives of the analysis; in other words they should be perceivable as a valid subdivision of the urban scene into relatively homogeneous neighborhoods in terms of urbanization level and development type.

The goal for the detailed level segmentation is somewhat different. In the present context the main purpose of the detailed segments is to reflect differences and similarities in spatial structure between the various neighborhood segments in order to characterize them. The detailed segments do not need to accurately delineate objects such as individual houses, but they need to reflect the presence or absence of such objects and the overall spatial structure provided by their location.

The segmentation process was performed using the multi-scale segmentation algorithm present in the eCognition image processing software. Segment target size is controlled through a scale parameter, and shape and compactness parameters provide additional control over segment form. The parameter values applied for the current study were based on visual inspection of the resulting segments when compared to the stated objectives of the segmentation. A set of scale parameter values was evaluated ranging from 25 to 100 for the detailed level, and from 100 to 800 for the neighborhood level. It is important that boundaries between neighborhoods of different appearance are determined (i.e., that the segments are not too large) while it is of lesser importance if some ‘unnecessary’ internal boundaries are identified (if the segments are too small). The analysis continued as described below.

Small segments were first created using a scale parameter of 25. This produced segments that constitute sub-parts of the urban neighborhoods with an average segment size of 95 m^2. A second run of the segmentation algorithm with a scale factor of 400, and as ‘merge-only’, produced larger segments by selective merging of the existing segments. Visual inspection of the created segments indicated that what are perceived as individual neighborhoods with distinct characteristics are reasonably well contained in relatively few, large segments with an average size of approximately 37,000 m^2. The scene is somewhat over-segmented in the sense that some internal segment boundaries are present within homogeneous neighborhoods, but an increase in the scale parameter value results in the omission of many relevant boundaries. Examples of resulting segments for the two levels are provided in Fig. 5.4.

Texture was computed for the neighborhood level based on the spatial and spectral properties of the sub-segments. Ten texture measures were considered using stepwise linear regression on the set of 127 polygons. The set of texture measures computed is listed in Table 5.1 with a short description of each; four measures contributed to the final texture model ($R^2 = 0.763$). Texture measures A and B reflect pixel values in selected bands through the computation of pixel mean values of the sub-segments (using band 4 in this case), while C–J are based entirely on shape and location of sub-segments. Therefore, statistical models based on measures A and B would likely be more data-set-specific and less generic than models based on measures C–J.

Linear regression analysis was applied in order to model the relationship between the degree of urban development and the computed sub-segment texture values for a given neighborhood. To prepare the dataset for the statistical analysis, the collected point-based ground validation information was associated with the created

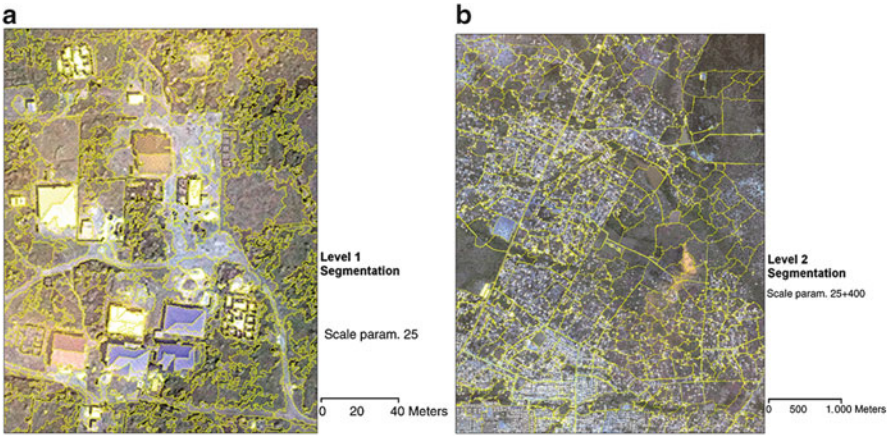

Fig. 5.4 Examples of (**a**) detailed-level segments, and (**b**) neighborhood-level segments

Table 5.1 List of texture features considered for modeling urbanization

Measure	Short name	Description	Sig.
Texture based on color variations in sub-segments:			
A	SVal_stdv	The standard deviation of the mean pixel values of the sub-segments	x (band4)
B	Neigh_diff	Calculates mean difference in pixel values between neighboring sub-segments	x (band4)
Texture based on shape and location of sub-segments:			
C	Area_mean	Area of sub-segments	x
D	Area_stdv		
E	Den_mean	Shape of sub-segments: the closer to a square, the higher density value	
F	Den_stdv		x
G	Asym_mean	Degree of elongation of the sub-objects, computed from an approximated ellipse	
H	Asym_stdv		
I	Dir_mean	Orientation of the sub-objects	
J	Dir_stdv		

segments. Ground validation values for a point were transferred to the neighborhood segment in which it was located using a spatial overlay process. One hundred and thirty two segments contained only one ground truth point, while 15 segments contained two or more. In most cases where there were multiple points within a segment, the urban percentage values were almost identical for all points and the mean value was applied for the segment. Three segments contained large differences between validation points, indicating a segmentation problem; these segments were omitted during statistical modeling. The resulting data set contained texture values and urbanization percentage for 144 polygon segments within the image. Due to specific interest in modeling the urbanization percentage, completely rural areas were also excluded from further analysis, and the final data set subjected to linear regression analysis consisted of 127 segments. These segments were spatially well-distributed and represented all degrees of urbanization in the analyzed peri-urban areas.

5.3 Results and Discussion

The map in Fig. 5.5 presents the degree of urbanization based on the linear regression model. Visual inspection reveals relatively good agreement between modeled values and observed conditions. To further evaluate the results, a set of ground validation segments was established. Forty-eight neighborhood segments were selected randomly, visually evaluated with regard to degree of urbanization, and categorized accordingly. The observed values were subsequently plotted against the predicted values obtained from the texture-based model, and the overall magnitude of urbanization is well described by the predicted values. However, there is some disagreement concerning the exact values in some areas, especially where urbanization percentages are less than 30 %. The subjective nature of the ground validation process for the type of objects in question introduces some error, and likely contributes to model disagreement.

It can be concluded that significant textural information is found in the spectral properties of the sub-segments in connection with their size and spatial distribution. The standard deviation of the mean pixel values of the sub-segments contained in a neighborhood, as well as the average difference between pixel values and adjacent sub-segments, were identified as indicators of the degree of urban development. Texture properties based entirely on shape and relative location of the sub-segments were found to be less important. However, the mean area of the sub-segments and a measure related to compactness of sub-segments (or, more precisely, how closely the sub-segments resemble a square) also contributed to modeling the level of urban development. The fact that it is possible to establish a relationship between sub-segment-based texture and urbanization within the identified neighborhood segments could indicate that the segmentation process for the two levels has been successful, and that the created segments have the desired properties as noted above. There is, however, little reason to conclude that the segments represent the optimal solution. As discussed, the segmentation process is difficult to control and the results determine the outcome of subsequent classification and modeling efforts. If a target is set for larger segments, then there is increased risk of containing multiple types of urban development within one segment. Smaller segments (i.e. "over segmentation") are often seen as less of a problem assuming that these can subsequently be merged at the classification level, but they constitute a less reliable basis for land cover classification due to textural heterogeneity. The segmentation process may also erroneously identify urban objects such as parking lots, road segments, and very large buildings rather than urban neighborhoods. Therefore a reasonable future goal would be to emphasize the post-processing of segments

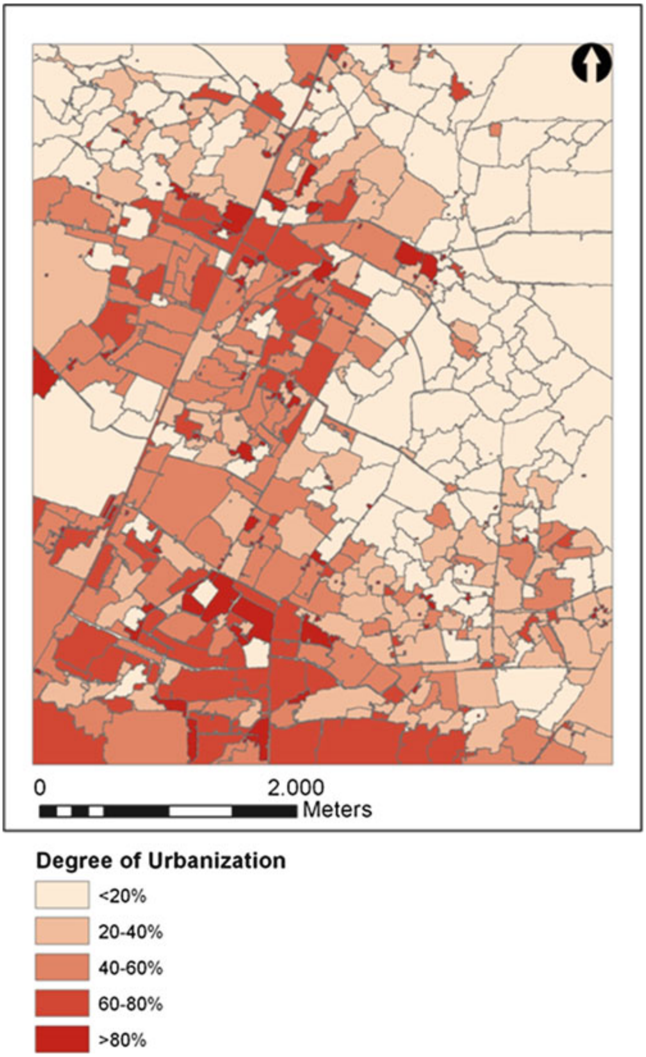

Fig. 5.5 Final map showing degree of urbanization based on predicted values from the regression model

resulting from initial runs of the segmentation algorithms. Efforts to improve the shape- and context-based merging of segments that represent single objects (such as road segments) into the adjacent, larger neighborhood segments would be particularly relevant at the scale of analysis demonstrated in this chapter. Another important avenue for future experimentation is the interplay between object complexity, image resolution, and segmentation scale. Further research into these relationships is required and envisaged.

Satellite-based mapping of urban land-cover is a well-established field, and Landsat-TM data with 30 m spatial pixel resolution have proven useful for classifying urban land cover on a generalized level. Increased pixel resolution of less than 1 m from more recent generations of satellite sensors enables a more detailed assessment of land cover which is relevant for specific planning purposes. The urban land cover is characterized by the pattern of physical structures which in turn influences the texture of the satellite image. Some form of texture-based method is, therefore, normally suggested for urban analysis using remote sensing, though these methods present new challenges. This chapter featured a comparison and discussion of different methods for image segmentation in relation to texture-based classification. Results from an urban fringe zone of Accra from high-resolution images using a two-level segmentation approach indicate that this method is applicable in areas where the transition from rural to urban takes place gradually and in a haphazard manner. This methodology also provides an indication of the degree of urban development in each local area that can be utilized to support decision-making for a variety of urban planning and social applications.

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Part III
Health and Well-Being in Accra's Neighborhoods

Chapter 6
Exploring Social Resilience Among Young Migrants in Old Fadama, an Accra Slum

Raymond Asare Tutu

Multi-faceted and complex factors resulting from the continual changes in our societies are, arguably, negatively impacting the people of the Global South, especially the young ones. These changes, which are characteristically multi-scalar, include ethnic conflicts, decentralization of government structures, poor agricultural yields and food insecurities, and unfavorable environmental issues (Blum 2007). Although these factors, which are felt both on the global and local scales, may lead to genius novelty, they usually bring about social disruption typified by population displacements, refugee situation, urbanization, and general population movements.

Rural-urban migration has exemplified such disruptions in Ghana. A sizeable number of young people—especially women—have been migrating from Ghana's typically rural northern regions to increasingly urban southern regions; usually, they move without parental consent and unaccompanied by any guardian (Awumbila 2007; Kwankye et al. 2007). Unfamiliar with their new environment and unprepared for the city, most of these young people end up living on the margins of society; specifically, they live on the streets or in the slums of the urban destinations. Their place of residence in the urban setting predisposes them to all forms of stressors ranging from poor shelter to sexual harassment (Awumbila 2007; Awumbila and Ardayfio-Schandorf 2008; Jorgensen 2008). In this chapter, I discuss the experience of a sample of young migrants in Old Fadama, an urban slum in the city of Accra, Ghana, and assess what constitutes their resilience to stressors. Resilience in this study refers to an individual migrant's ability to withstand stressors. By way of structure, first, I situate this research in the broad conceptual framework of the coupled Migration-Vulnerability-Resilience interactions. Second, I discuss the study area to demonstrate that Old Fadama epitomizes spatial health inequality

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in the city of Accra. Third I will discuss the data and methods, and close by presenting the results and discussing their connotations. Lastly, I provide a short summary.

6.1 Environmental Vulnerability and Migration

Migrants to urban places dwell in diverse neighborhoods. While a few prepared and well-to-do migrants settle in middle income residential areas, most poor migrants live on the fringes of urban spaces, that is, the slums and the streets. Poor migrants, with limited resources and less power over the choice of their residential location, face multiple environmental threats ranging from water contamination and unavailability of potable water to piles of garbage (Davis 2007; Tschakert and Tutu 2010; Tutu 2010). While exploring migrants' settlement in Albania, Filcak (2010) asserts that migrants found themselves living on lands that are highly contaminated and bounded by heaps of industrial waste. These places were also endangered by security and health hazards. Conceptually, Filcak (2010) argues that the allocation of spaces for migrants' settlement is a product of "exogenous and endogenous" factors. Exogenous factors describe circumstances under which new migrants find themselves on the margins of society; these include social, economic, and environmental elements. Social aspects include lack of resources (poverty), disputes, different ethnicities, and differences in cultural values. Economic factors include land prices (which may have implications for the extent of contamination of lands and other environmental hazards), and competition on the job market. Environmental factors that often dictate whether spaces are allocated for poor migrant settlements include "access to water and natural resources, level and spatial distribution of contamination, and the socio-environmental syndrome" (Filcak 2010, 139). The socio-environmental syndrome is described as instances where (i) migrants may be directed to settle in places that are deemed marginal and peripheral, or (ii) such settlements become worthless and marginal as a result of being inhabited by perceived human burdens, the poor migrants themselves. The endogenous factors, which are related to individual migrant internal abilities and capabilities to cope with exogenous factors include, among other things, lack of social and financial capital, cultural and language barriers, and lack of information.

Different economic, social, political, and cultural processes combine to shape opportunities available to the poor (Wood and Salway 2000), a subject of interest to urban political ecologists. Urban political ecologists have focused on the basic processes essential to the production of urban environment and the spatial inequality that is characteristic of urban change (Swyngedouw and Heynen 2003; Keil 2005). Holding fast to the Marxist ideology, urban political ecologists assess the unequal allocation of resources among urban population through the prism of the uneven nature of the capitalist system (Keil 2005; Zimmer 2010) while engaging environmental changes in the urban space through the lenses of existing class, gender, and other power struggles in such spaces (Swyngedouw and Heynen 2003).

Furthermore, the same processes that combine to shape opportunities for the poor also contribute to their vulnerability. Such occurrence has been explained through the concepts of urban environmental vulnerability. Urban environmental vulnerability is defined as the product of hazard, assets, and fragility, where hazard is the frequency and magnitude of natural events, asset is the population and shelter exposed to hazard, and fragility is government neglect of environmental safety (Davis 2007). The elements of the urban political ecology framework and such urban environmental vulnerability clarify the fact that socio-cultural, political, and economic procedures are combining to shape prospects and asymmetry in the fields of urban actors. Thus, urban areas present opportunities and stressors to people, and therefore, individuals' resilience (ability to withstand stressors) is an important research consideration.

Urban political ecology and urban environmental vulnerability have similarities and differences. Both concepts focus on matters pertaining to the poor who live on the urban periphery. But while urban political ecology deals with the processes resulting in unequal resource allocation as an outcome of capitalism or systematic power inequality, urban environmental vulnerability focuses on the frequency and magnitude of natural events happening in space, and assets that are exposed to such events. Despite this difference, these frameworks provide useful insights for understanding the differential disadvantaged positions of rural-urban migrants who settle on the margins of their destinations, even though such places are perceived to offer an expectation of better economic opportunities for the migrants.

6.2 The Youth Resilience Framework

The Youth Resilience Framework, expounded in the United States, serves to address individual and socio-cultural risk variables and protective factors that can either promote or thwart positive and negative health outcomes (Rew and Horner 2003). While risk factors are associated with any condition or experience that increases the probability that a problem will be formed, maintained, or exacerbated, protective factors refer to personal and environmental resources with the potential of minimizing the impact of risks (Jenson and Fraser 2005). Rew and Horner (2003) argue that the socio-cultural context is crucial for understanding risk behavior among adolescents. While the family and school, for example, may be risk factors, they may also be protective. Familial factors such as high socio-economic status, effective family functioning, and good community factors such as positive peer relationships are protective factors that enhance resilience (positive health outcomes). On the other hand, negative influence from peer relationships such as early onset of sexual activity (a risk factor) may result in a negative health outcome.

Rew and Horner (2003) postulate that there are individual risk factors and individual protective factors; that is, personal factors are related to individual abilities and inabilities. Examples of individual risk factors include sex, distress, difficult temperament, and poor school performance. Regarding sex, for instance, males have been found to cope with stress by expressing their feelings centrifugally in high-risk behaviors like belligerent driving, while females may cope with stressors by displaying signs of depression. With respect to distress, the overextension of youths' individual resources for responding to stressful events can lead to distress. Stressful events such as parental disunity and domestic violence can have protracted adverse effects on the young, thereby affecting their emotional, physical, and social functioning. Poor school performance may lead to dropping out of school altogether, and subsequently increase engagement in other risky behaviors that may inhibit the ability to respond effectively to stressors. Individual protective factors, on the other hand, include competence, coping skills, humor, connectedness, and knowledge of health behaviors and risks. These protective factors modulate the response of youth to stressors, thereby buffering "the impact of the risk factors" on the youth (Rew and Horner 2003, 382).

An individual ability like competence—characterized by physical ability, social skills, educational ability, and high self–esteem—makes possessors of such a quality less vulnerable to risk factors that reduce resilience. For example, it has been found that high academic performance is associated with fewer violent behaviors, drug abuse and delayed onset of sexual activity (Resnick et al. 1997). A sense of humor, exemplified by creating, welcoming, and positively reacting to humor, is a significant protective resource that helps youth to withstand stressors (Wooten 1996; Rew and Horner 2003). Studies have found that resilient children scored high on humor generation compared to their less resilient counterparts. A crucial individual protective factor is connectedness—the perception that one can reliably count on others to provide emotional and instrumental support. Social support that buffers the negative impacts of poverty and its attendant inadequate provision of the basic necessities of life—particularly in crime-infested and violent neighborhoods—are important protective factors. Protective factors that exhibit connectedness and social support involve absence of abuse in the home, strong parental expectations of high academic performance, and presence of at least a reliable and steady caretaker. Research has shown that adolescents who perceived their teachers as caring exhibited high academic motivation and self-confidence (Ryan et al. 1994). Also, family connectedness, an essential component for resilience, is demonstrated by engagement in communal family activities, care of family members through actions and communication patterns, and ensuring steady parental presence at systematic intervals during the day (Resnick 2000; Rew and Horner 2003). McDonald and colleagues (2009) found that strong family ties (exemplified by a high sense of loyalty and protection) are an important determinant of positive sexual and reproductive health. In a study of reproductive health among immigrant Latino youth in the United States, strong family ties support healthy sexual and reproductive development, including delayed sexual initiation and improved condom use (McDonald et al. 2009). Caring relationships between adults and children, another element of connectedness and social support, is a protective resource from undesirable developmental outcomes. Caring teachers enhance healthy youth development and boost children's ability to respond to stressors. The influence of caring teachers can help motivate youth to behave well in school and ensure high academic performance.

Resilience of the youth, that is, the youths' capacity to adapt successfully in the presence of risk and adversity (Jenson and Fraser 2005, 2006) is a function of risks as well as protective factors. Therefore an individual's youth resilience is based on the interaction between risk variables and protective resources. For the purpose of this chapter, I adopt the explanation of risks as described above. The term stressor was explained during the fieldwork as any problem, difficulty, or trouble that causes worry and discomfort. In the next section, I briefly discuss the study area to demonstrate how it epitomizes spatial health inequality and environmental vulnerability.

6.3 Old Fadama

Old Fadama, popularly referred to as Sodom and Gomorrah, is a slum in the heart of Accra, the administrative capital of Ghana, and has become a major destination area for migrants from the north of Ghana (see Fig. 6.1). Old Fadama began as a temporary living quarters for displaced people from the north of Ghana fleeing the Nanumba-Konkomba ethnic conflicts in the 1980s. The slum is about four acres in area (Bentil 2009), and it is estimated to be home to about 10,600 people (AMA 2007), though more recent estimates of combined stock and flow populations approach 80,000 (Housing the Masses 2010). Since it is not officially designated as a residential area, the slum does not receive any form of social services or assistance

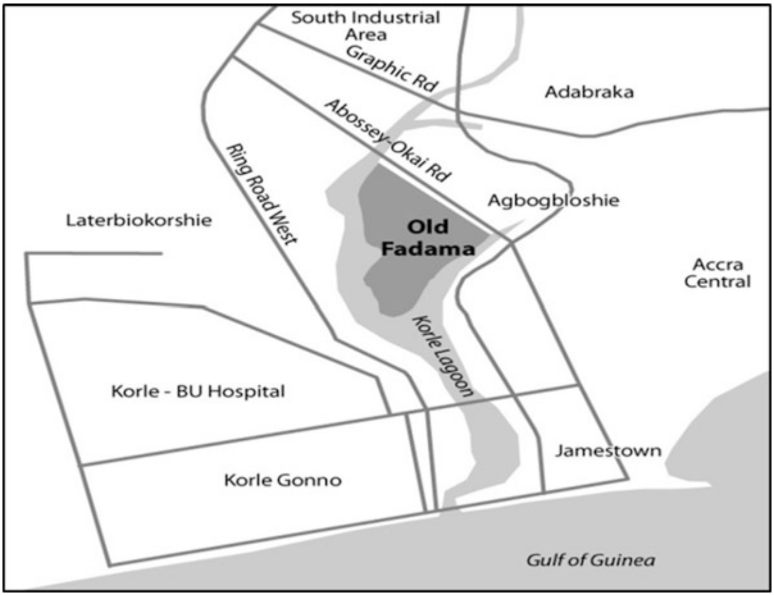

Fig. 6.1 Map of Old Fadama

Fig. 6.2 Wooden houses and refuse dump at Old Fadama

like garbage collection and proper toilets. Such neglect by officialdom aggravates the susceptibility of residents to health and environmental stressors (Tutu 2010). The slum lacks adequate potable water, it does not have proper toilets, and it does not provide good shelter. However, Old Fadama continues to expand in size with the construction of kiosks of the size 2 m × 2 m for housing residents in rubbish dumps (see Fig. 6.2). The neighborhood is characterized as an environmental and social problem typified by defecation into the lagoon, drug peddling, and commercial sex (AMA 2007). The perception of Old Fadama as a place full of social vices is responsible for its alternate label, Sodom and Gomorrah. In the Bible, the towns of Sodom and Gomorrah refer to places of sin characterized by deviant behaviors which led to their destruction by God. In Genesis 19:24, the Bible says, "Then the Lord rained brimstone and fire on Sodom and Gomorrah, from the Lord out of the heavens . . . "

6.4 Interviews and Surveys

This study adopts the conventional definition of migration—that is, "the geographic movement of people across a specific boundary for the purpose of establishing a new permanent or semi-permanent residence" (Haupt and Kane 2000). It uses a mixed-methods approach for data collection. A total of 104 semi-structured interviews and surveys were administered in Old Fadama with young migrants aged 10–29 years during the summer of 2009. While the World Health Organization (WHO) defines young people as between the age bracket of 10–24 years, the organization indicates that youth are from ages 15 to 24 years. Ghana's youth policy categorizes the young as males and females in the age bracket 15–35 years (Government of Ghana 2010). Focusing on young people from age 10 to 29 accommodates the lower limit of WHO standards while extending the upper limit closer to Ghana's definition of youth. Accidental random sampling, a non-probabilistic sampling method, was used to select research participants since the slum setting does not allow for stratified sampling. However, to ascertain varied experiences regarding resilience in the slum, no two individuals from the same household or housing structure were selected to participate.

To measure young migrants' response to stressors, a semi-structured interview and a survey were administered. The goal of the semi-structured interview was to generate enough qualitative data to aid the interpretation of the survey data. Also, a survey was implemented containing a list of statements regarding expected well-being and capacity to adapt to stressors, per the resilience literature and the theoretical frameworks discussed. Bearing in mind that resilience is dependent on the interaction between risks and protective factors, the survey statements reflect these dynamics by including content about individual risk factors, individual protective factors, familial factors, and community variables. The statements were meant to assess the level of well-being of the young migrants, such as coping strategies in the context of uncertainties in their place of residence and their ability to withstand other stressors in the slum. Study participants rated their attitude to these survey statements using a four-point Likert scale where responses are categorized as either *strongly disagree*, *disagree*, *agree*, and *strongly agree*. A total of 36 statements were used in the survey (see Table 6.1). Through a reliability analysis (using Cronbach's α), which is premised on the computation of the correlations among the expected well-being statements, the statements that contributed to the internal consistency of the scale for ability to withstand stressors were included in the analysis (Chen and Popovich 2002). A Cronbach's α value of 0.7 or higher indicated a very reliable scale. In order to distill the specific constituents of ability to withstand stressors encountered by the young migrants in the context of uncertainty in their new cultural and economic environment, a Principal Component Analysis (PCA) data reduction technique was used (Jolliffe 2002; Marshall and Marshall 2007). Using a PCA (in this case with varimax rotation and Kaiser normalization), one is able to identify various statements that constitute as comparatively independent subsets of content. PCA methodology assumes that a particular subset of latent variables, smaller in number than the original number of statements, are responsible for and representative of the co-variation among the responses. To efficiently analyze what constitutes the resilience of young migrants encountering health and environmental stressors in the slum using the PCA, each component identified is carefully labeled based on the statements it encompasses. The semi-structured interviews served as a means of validating the interpretation of the PCA.

Table 6.1 Descriptive statistics and reliability analysis for the responses of the sample of young migrants to each survey item regarding their resilience

Survey items	Mean	SD	Item-total correlation	α if item deleted
I am confident that I could always get healed if I get sick	3.01	0.570	0.589	0.879
I am confident that I could always afford medicine if I get sick	2.55	0.732	0.395	0.881
I can always recover (go about my normal duties) after rape/defilement	2.12	0.773	0.305	0.883
I am confident that I can always recover from disasters (e.g. fire) whenever it occurs	2.46	0.658	0.576	0.878
I usually seek information regarding my general welfare	1.92	0.786	0.532	0.879
I usually seek information about how to prevent being harmed by stressors (reduce risks)	1.88	0.738	0.522	0.879
I know exactly where to get information about how to deal with stressors	1.92	0.679	0.529	0.879
I am learning new skills to reduce risks from stressors	2.40	0.873	0.561	0.878
I am learning a trade to be able to reduce risks	1.96	1.050	0.394	0.882
I can read from newspapers and leaflets on how to reduce risks from stressors (getting harmed)	1.65	0.965	0.245	0.885
I listen to the radio so I always learn about how to reduce risks from stressors	2.00	0.853	0.419	0.881
I watch television so I always learn about how to reduce risks from stressors	1.71	0.705	0.465	0.880
I know the social institutions that can help me reduce risks from stressors	2.21	0.827	0.405	0.881
I use the social institutions that help me reduce risks from stressors	1.41	0.633	0.499	0.880
I have a large social network I can rely on to help me survive	2.42	0.730	0.516	0.879
I can rely on leaders in the community to help me when needed	2.01	0.693	0.412	0.881
I am confident that my friends here in the community will never let me down	2.24	0.668	0.094	0.886
I am confident that my family back home will always help me if I get in trouble here	2.26	0.763	0.239	0.884
My personal regular income enables me to be resilient to stressors (recover quickly, or not being harmed at all)	2.47	0.785	0.469	0.880
I have some personal savings that do enable me to be resilient to stressors	2.23	0.966	0.355	0.882
I have assets (e.g. infrastructure, technology etc) that enable me to be resilient to stressors	1.82	0.818	0.301	0.883
I have started a business that will enable me to be resilient to stressors	1.91	0.928	0.407	0.881

(continued)

Table 6.1 (continued)

Survey items	Mean	SD	Item-total correlation	α if item deleted
I am confident that I am prepared for any uncertainty	2.14	0.734	0.616	0.877
I am confident my interpersonal networks (relatives, friends and family members) will help me withstand stressors in the future	2.78	0.658	0.476	0.880
I do have interpersonal networks (e.g. relatives and family members) who do help me withstand stressors	2.76	0.687	0.456	0.880
I am confident that relationships of trust (boyfriend, girlfriend, sugar mum and dad, chaperone) can help me withstand stressors in the future	2.58	0.890	0.496	0.879
I do have relationships of trust that help me withstand stressors	2.18	1.102	0.240	0.886
I am confident that none of my friends (and other relationships of trust) will ever cheat on me	2.14	0.575	−0.064	0.888
I am confident that my membership in a group (church, mosque, ethnic) will help me withstand stressors	2.51	0.698	0.354	0.882
I cannot survive if we should be ejected from this neighborhood	2.68	0.497	0.453	0.881
I cannot survive if I lose my social network here	2.81	0.854	0.321	0.883
I cannot survive if people lose their trust in me	2.21	1.024	0.283	0.884
If harassment from city authorities/neighbors/fellow workers should continue, I cannot survive	2.12	0.773	0.429	0.881
I am more likely to adapt to stressors compared to other migrants I know here	2.21	0.632	0.376	0.882
If I should lose my current employment I cannot survive (i.e. if working)	2.18	0.698	0.329	0.882
I am now a stronger person than when I arrived here	2.05	0.851	0.511	0.879

Notes: The data for all negatively worded statements were reversed before analysis; α is Chronbach's α; no statements were removed because of a large Chronbach's α value

6.5 Results and Discussion

In all, 36 statements in the survey were used to examine what constitutes the resilience of young migrants to stressors encountered in their new cultural environment. All statements reliably measure resilience with a Chronbach α value of 0.88. Table 6.1 indicates the descriptive statistics and the reliability analysis for each of the survey items used to explore resilience.

The results indicate that the relative contributions of the survey items to the total variance are largely distributed among many different factors. The PCA shows that responses regarding ability to withstand stressors, as per the statements of expected well-being and coping capacity, are best described by 11 components (the mapping of each response to a component is shown in Table 6.2). These 11 components account for 73.8 % of the variance (as summarized in Table 6.3) and can be further consolidated into four main themes: (1) perceived abilities and willingness to learn (from components 1, 5, and 9); (2) buffers from and confidence in social relations and the perceived fear of loss of support from social relations (from components 2, 4, 6, 7, and 8); (3) perception of financial abilities (from component 3); and (4) perceived personal initiatives and efforts (from components 10 and 11). The semi-structured interviews shed more light on the responses of the young migrants, thereby illuminating various complexities in the resilience components outlined.

6.5.1 Perceived Abilities and Willingness to Learn

Young migrants assessed their capabilities to withstand stressors on the basis of their individual abilities and willingness to learn. The personal attributes for examining resilience include: ability to afford medication in the event of sickness, their ability to recover due to their perceived innate adaptive capacity, and increased strength acquired upon arrival in the slum. Young migrants who perceived their physical strength to have increased since arriving in the slum felt more resilient. Young migrants who demonstrated consciousness of the stressors in their new environment and were learning or willing to learn about how to withstand the stressors felt less vulnerable to the probability of harm from a stressor. Respondents assessed their general expected well-being on the basis of concrete actions such as seeking information about how to prevent being harmed by stressors, knowing where to get information concerning how to deal with stressors, and following television and radio programs that are related to stressors faced. While exogenous factors have allocated these young migrants to the urban slums, some migrants are pushing back on endogenous factors in an effort to avoid perpetual vulnerability (Filcak 2010). In assessing information networks and their impacts on health care access, Devillanova (2008) asserts that immigrants' access to primary healthcare utilization accelerated due to reliance on information networks, though reliance on *strong ties* (friends and kin) for information was more helpful than reliance on *weak ties* (acquaintances).

Learning by experience and in anticipation of stressors is relevant to the resilience of the young migrants. Responding to a question on whether he has learned enough since arrival in the slum to anticipate his next trouble or stressor, a male respondent said:

> . . . yes, especially with fire . . . when it starts from a distance (not too close to my building structure), sometime I help in breaking down the wooden structures around ours before the fire gets extreme . . .

Table 6.2 Principal component analysis matrix of the responses to expected well-being and ability to withstand stressors

Survey items	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
I usually seek information regarding my general welfare	0.859										
I usually seek information about how to prevent being harmed by stressors (reduce risks)	0.799										
I use the social institutions that help me reduce risks from stressors	0.742										
I know exactly where to get information about how to deal with stressors	0.609										
I am confident that I could always afford medicine if I get sick	0.549				0.516						
I am confident that I could always get healed if I get sick	0.537										
I watch television so I always learn about how to reduce risks from stressors	0.537								0.443		
I have a large social network I can rely on to help me survive		0.807									
I am confident my interpersonal networks (relatives, friends and family members) will help me withstand stressors in the future		0.738									
I do have interpersonal networks (e.g. relatives and family members) who do help me withstand stressors		0.719									
I am confident that my membership in a group (church, mosque, ethnic) will help me withstand stressors		0.684									

(continued)

Table 6.2 (continued)

Survey items	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
I am confident that relationships of trust (boyfriend, girlfriend, sugar mum and dad, chaperone) can help me withstand stressors in the future		0.477						0.425			
I have some personal savings that do enable me to be resilient to stressors			0.863								
My personal regular income enables me to be resilient to stressors (recover quickly, or not being harmed at all)			0.855								
I have assets (e.g. infrastructure, technology etc) that enable me to be resilient to stressors			0.604							0.549	
I am confident that I am prepared for any uncertainty			0.450								
I know the social institutions that can help me reduce risks from stressors			0.402								
I cannot survive if people lose their trust in me				0.865							
I cannot survive if I lose my social network here				0.852							
I cannot survive if we should be ejected from this neighborhood				0.615							
If I should lose my current employment I cannot survive				0.475							
I am now a stronger person than when I arrived here					0.730						
I am confident that I can always recover from disasters (e.g. fire) whenever it occurs					0.609						
I am more likely to adapt to stressors compared to other migrants I know here					0.606						

I am confident that my friends here in the community will never let me down	0.783					
I am confident that none of my friends (and other relationships of trust) will ever cheat on me	0.551					
I can always recover (go about my normal duties) after rape/defilement	0.519					
I listen to the radio so I always learn about how to reduce risks from stressors	−0.460			0.402		
I do have relationships of trust that help me withstand stressors		0.836				
If harassment from city authorities/neighbors/fellow workers should continue, I cannot survive		0.689				
I am confident that my family back home will always help me if I get in trouble here			0.872			
I can read from newspapers and leaflets on how to reduce risks from stressors (getting harmed)				0.819		
I have started a business that will enable me to be resilient to stressors					0.712	
I can rely on leaders in the community to help me when needed					0.414	
I am learning new skills to reduce risks from stressors						0.789
I am learning a trade to be able to reduce risks						0.539

Note: Factor loading scores of less than 0.40 are not displayed

Table 6.3 Eleven principal components of ability to withstand stressors after extraction, with descriptors and theme

Component	% of variance	Statement descriptors	Theme
1	11.7	Perceived individual abilities to withstand stressors and the willingness to learn and adapt	Perceived abilities and willingness to learn
2	9.4	Perceived buffers from social relations	Social relations and loss of support
3	8.2	Perceptions of financial abilities to withstand stressors	Perception of financial abilities
4	7.9	Perceived fear of loss of social support	Social relations and loss of support
5	6.7	Perceived increase in individual abilities to withstand stressors	Perceived abilities and willingness to learn
6	5.5	Perceived confidence in the support from social relations	Social relations and loss of support
7	5.2	Fear of exclusion and loss of social support	Social relations and loss of support
8	5.0	Perceived distant family support	Social relations and loss of support
9	4.9	Perceived individual literate abilities	Perceived abilities and willingness to learn
10	4.9	Perceived personal initiatives and efforts	Perceived personal initiative and efforts
11	4.4	Actual learning of skills and learning in general	Perceived personal initiative and efforts

The reference to fire in this quote is suggestive of the frequency of fire outbreaks in Old Fadama (Tutu 2010) and in many other slums around the world (Davis 2007; Kramer 2006). The young migrants who have learned to anticipate stressors were more positive in their perception of their ability to learn and strategize for possible future stressors.

6.5.2 Social Relations and Loss of Support

Young migrants with high social connectivity were more optimistic in their perception of their ability to withstand stressors. The level of social connectivity was assessed based on the following: perceived largeness of migrants' social network; confidence in interpersonal networks such as friends, relatives, and family members; actual help received from interpersonal networks; confidence in the possibility of help from being a member of an association; confidence in aid to be received from relationships of trust (boyfriend/girlfriend) and actual material resources received from relationships of trust; confidence in support from family in the home of origin; fear of loss of social network; and fear of the loss of the current place of residence and employment. Young migrants, who perceived their social network as a large one, were confident about receiving support from them, and those who did receive material support from these social relations were more likely to feel less vulnerable to risks and more likely to feel optimistic about their ability to withstand stressors. Some of the material support received from social relations ranged from financial provision to food and clothing. A female research participant asserted that the financial support she receives from her boyfriend (relationship of trust) is what enables her to withstand the stressors she encounters:

> ...the income I earn from my work is very small and so I don't know what I could have done without the money my boyfriend gives (me). It is very helpful to me and so I am confident... whatever the situation, I will survive since he cares (about me).

Connectedness is an important protective factor against stressors (Rew and Horner 2003). In this study, young migrants are insulated against conditions of adverse health outcomes as a result of their perceived and actual reliability of their social relations since, as Denny and Watson (2004, 115) put it, "caring and supportive environments act to buffer the effects of socio-economic hardship..." This also confirms why the fear of loss of social support is a major component of resilience among the migrants (representing 7.9 % of the variance).

Although perceived distant family support represent only 5.0 % of the variance, it is instructive to know that bridging social capital—ties between distant groups and relations, e.g. friends and family—is a constituent of the resilience among the young migrants. This is because research has shown that most of the migrants move without parental consent (Awumbila 2007). However, it confirms Kwankye and colleagues' (2009) finding that the movement of some young people for improved livelihoods is a family decision. A quintessence of the broader debates on migration as a household livelihood strategy, migration is considered as a strategy to diversify and possibly improve households' livelihoods in combination with other strategies like farming and other small scale activities (Castles and Miller 2009).

6.5.3 Perception of Financial Abilities

Young migrants perceived their ability to withstand stressors in monetary terms. Those who were earning regular incomes, had saving and assets (mainly household goods, e.g. television, fan, refrigerator) were more positive about their current and future well-being. As indicated by a male participant:

> ...and I do have some household belonging like radio set, TV, and fan, and if something happens, I will sell them fast ...

From the semi-structured interview, some young migrants engaged the services of *susu* collectors. These are "deposit collectors" who pay daily visits to their clients to collect a specified amount of money as saving for a commission. Although the interviews revealed that it is a high risk venture because some collectors have bolted with the saving of their clients, the *susu* system seems to be very popular in the informal sector as evidenced by Yeboah's (2008) study among female porters in Accra.

6.5.4 Perceived Personal Initiative and Efforts

Young migrants who were purposefully learning new skills to reduce probable harm from stressors were positive in their perception of their ability to withstand stressors. Study participants who were learning a trade (dress making, tailoring, auto mechanics, and catering) as a way of ensuring less susceptibility to hazards also felt less vulnerable than their colleague migrants who were not learning a trade. Along the same theme of personal effort, migrants who acknowledge taking some initiative were more confident of their ability to withstand stressors. For example, while the slum is generally an unkempt environment, some of the young migrants clean their immediate surroundings as often as possible. A male responded noted that:

> ...hmm...I keep my immediate surrounding clean very often..., but, here, we do not have a compound (courtyard). No one has a compound. Someone's backyard is another person's bedroom. That is why the place cannot be very neat.

While lamenting the uncleanliness of some neighbors, he has taken the initiative to make sure his immediate surrounding is clean. The seeming unwillingness of all residents to communally keep the neighborhood tidy signifies the attendant problems associated with such a dense and heterogeneous society. According to Armah and colleagues (2009), the heterogeneity of Old Fadama has been a source of factionalism and, consequently, disputes among different groups in the slum. This dispute has been a bane of the management of the Korle Lagoon, and has thus kept Old Fadama—albeit unflatteringly—in the public eye. However, individual efforts toward ensuring improved well-being and the ability to withstand stressors are on course among some young residents.

6.6 Summary

Multi-scalar factors such as ethnic conflicts, decentralization of government structures, poor agricultural yields and food insecurities, and environmental issues have been argued to be influencing changes in our societies and impacting the youth of our world; especially, those living in sub-Saharan Africa. A major outcome has been the displacement and voluntary movement of the young people to the margins of urban spaces in anticipation of a better life. In Ghana, the migration of young people from the mostly-rural north of the country to the increasingly-urban south has become a major trend. Upon arrival, endogenous and exogenous factors combine to relegate migrants to the margins of various cities including Old Fadama, the largest slum in Accra. The illegitimacy of the slum, from the perspective of officialdom, denies them social services required for decent living, thereby aggravating the already unclean environment in the slum. Young people quickly become susceptible to various stressors ranging from poor sanitary conditions to inaccessibility to public social services.

The health and environmental stressors encountered by migrants have necessitated the need to understand how the young residents react to them and their ability to withstand these stressors. In this chapter, I have explored what constitutes the social resilience of young migrants facing multiple stressors in Old Fadama. Drawing on environmental vulnerability and the youth resilience framework, I used a survey questionnaire to elicit information on expected well-being, and ability to withstand stressors as a basis for examining social resilience. While resilience is a multifaceted notion, the result of this study has shown that the basis of resilience among young migrants, with 73.7 % reliability, is characterized by (1) perceived abilities and willingness to learn, (2) buffers from and confidence in social relations and the perceived fear of loss of support from social relations, (3) perception of financial abilities, and (4) perceived personal initiatives and efforts. Compared with surrounding neighborhoods, Old Fadama typifies spatial inequality with serious repercussions for health inequalities of its residents, who are already at the bottom of the socioeconomic ladder. By understanding migrant resilience and coping patterns, intervening authorities may more efficiently introduce community services that aim to reduce the vulnerability of young slum dwellers in Accra and beyond.

***Editors' Note*:** For a detailed map of Old Fadama, see: Gregory M. Verutes, Magdalena Benza Fiocco, John R. Weeks & Lloyd L. Coulter (2012): "Health, poverty, and place in Accra, Ghana: mapping neighborhoods," *Journal of Maps*, 8(4):369–373.

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Chapter 7
Researching Urban Slum Health in Nima, a Slum in Accra

Emmanuel Aggrey-Korsah and Joseph Oppong

The UN-Habitat defines a slum as a human settlement with inadequate access to safe water, inadequate access to sanitation and other infrastructure, poor structural quality of housing, overcrowding; and insecure residential status (UN-Habitat 2005; Riley et al. 2007). In 2007, these characteristics defined 43 % of combined urban populations in developing countries and about 78 % of the urban population in least developed countries (Vlahov et al. 2007). An estimated one billion people live in slums and this number is expected to rise to about two billion by 2030 and about three billion by 2050 if current trends continue (UN-Habitat 2005). Slum growth is mostly a result of high population growth with low industrialization, a predominant feature in less developed countries (LDCs) of Asia and Africa. The huge gap between the available facilities and needs of slum dwellers produces rapid deterioration of amenities due to excessive pressure (Arku et al. 2011).

Slums are known incubators of disease because slum conditions facilitate the spread of communicable diseases such as cholera, diarrhea, tuberculosis and polio. For example, cholera outbreaks are common in slums. (CNN 2010c) reported the death of about 1,555 people from a cholera outbreak in Nigeria with another 40,000 also infected with the disease. Similarly in (CNN 2010b) with cholera in Haiti due to the January 2010 earthquake and the resulting unsanitary conditions (CNN 2010a, b; Farmer et al. 2011). In March of 2011, an outbreak of cholera killed 69 people in Ghana with 5,200 cases recorded (Myjoyonline 2012). Globally, about 4,500 people die daily due to inadequate access to water and sanitation (UNICEF 2006).

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7.1 Slum Conditions and Health

Inadequate access to safe water and sanitation pose a serious threat to the health of urban slum dwellers (WHO/UNICEF 2006). WHO/UNICEF identifies access to safe water and improved sanitation to be fundamental for human health, survival, growth and development (WHO/UNICEF 2006; Sheuya 2008). Buttenheim (2008) explains how the young in most of the rural areas of Bangladesh defecate in the open because of inadequate access to latrines. Poor sanitation is 1.6 times more likely to cause morbidity and diarrhea (Sheuya 2008). According to UN-Habitat (2003), an excreta disposal system is adequate if it is shared by just two households, but in most slums there are either no such facilities or there are about 150 people sharing one pit latrine (Gulis et al. 2004; Milbert 2006). In Mumbai, India, about five million slum dwellers do not have latrines and one latrine caters for about 10,000 people (Unger and Riley 2007). In some slums in Kenya and other parts of the world, people defecate into plastic bags which are thrown away like any other solid waste (Gulis et al. 2004; Davis 2006).

Overcrowding, defined as "low space per person, high occupancy rates, cohabitation by different families and a high number of single-room units" (UN-Habitat 2003), is associated with high infection rates of communicable diseases. When more than two people share one room, that room is considered overcrowded (UN-Habitat 2003). While overcrowding facilitates disease spread, slums provide cheap affordable housing for the poor (Curran 2011). Infectious diseases such as influenza and tuberculosis are common in crowded environments. Large concentrations of vulnerable people ensure the easy spread of diseases (Wallace and Wallace 2003). In their work on the incidence of tuberculosis in New York City, Wallace and Wallace discussed the impact of high-population density on incidence of tuberculosis in the Lower East Side and then Central Harlem. They concluded that high rates of tuberculosis were initially tied to the most vulnerable places of the city before it began to spread to other places.

7.2 Poor Structural Quality of Housing and Health

Government's inability to address the housing deficit in urban centers of most LDCs has allowed the development of slums "as a form of low cost urbanization" (Curran 2011; Milbert 2006). UNCHS in 2001 stated that "36 % of urban households in all developing countries have an income below poverty line" which affects the housing structures and the health of the people. A good quality house should be one built in a non-hazardous area and with permanent materials capable of protecting dwellers from the elements of the weather, disease causing agents and other hazards. In contrast, slum housing structures are usually built of low quality materials due to the poverty of their owners and the temporal nature of access to most of the lands on which they are sited.

Sub-standard housing has been associated with some chronic illnesses in slums, Influenza, cough, common cold and other infectious respiratory diseases have been associated with poor housing in Kenya (Gulis et al. 2004; Taffa and Chepngeno 2005) while dampness in homes is significantly associated with most illness in homes (Shaw 2004). Also, deviation from the relatively normal room temperature is associated with cardiovascular diseases (Krieger and Higgins 2002; Sheuya 2008) and reduced general health of dwellers (Evans et al. 2000). Moreover, poor ventilation in slums has been associated with increased respiratory infections which are attributed to increased smoke exposure (Ezzati and Kammen 2001). Asthma has been associated with indoor exposure to nitrogen dioxide. Finally, substandard housing in slums experience destruction from fires, frequently caused by electrical faults or in rare cases pipeline explosions as occurred in Nairobi, Kenya. In the Nairobi incident of September 2011, about 75 people died with hundreds of houses flattened (CNN 2011).

7.3 Insecure Residential Status and Health

Insecurity of tenure is the norm in urban slums (UN-Habitat 2003). Most people living in slums do not have titles to the houses they live in; they can be evicted from their homes at any time. In extreme cases, houses may be demolished, which increases the susceptibility of dwellers to the elements of the weather. Nevertheless, housing deficits in slums force dwellers to settle in marginal areas, frequently close to waste dump sites, on landslide areas, in flood prone areas, or other unsafe or polluted industrial environment. Such conditions are hazardous to the health of dwellers due to the potential of landslides, floods and earthquakes and the associated injuries, loss of lives and property. Nearness to waste dump sites and other polluted industrial sites is also associated with some infectious and respiratory diseases.

7.4 The Gaps

Despite these challenges of slums, our understanding of the spatial dynamics underlying urban slum health is severely limited. In Africa, slum health studies have focused primarily on Kenya to the neglect of other countries. Thus, very little is known of the health conditions of slum dwellers outside Kenya. Moreover, the few studies in the urban slums of Ghana, especially Nima-Maamobi, have not addressed the associated health issues but have often focused on the social and economic vulnerability (Weeks et al. 2007; Arku et al. 2011). Thus, this research seeks to shed some light on the slum health situation in Ghana using the vulnerability framework. Three main questions are addressed in this research:

1. **How do housing structures, sanitation, access to water, overcrowding, and tenure practices impact health conditions in Nima-Maamobi?** As noted above, previous literature suggests that concentration of poor housing structures, lack of access to water and sanitation as well as crowdedness creates places that are vulnerable to the spread of communicable diseases.

2. **How does vulnerability vary within Nima-Maamobi?** Which areas are more vulnerable and which are less vulnerable?
3. **How does vulnerability affect the health of Nima-Maamobi residents?** What is the health impact of vulnerability among dwellers of Nima-Maamobi?

7.5 Study Area and Methods

The study area of Nima-Maamobi is a poor community located within the Accra Metropolitan Assembly (AMA), as shown in Fig. 7.1. According to the AMA, Nima-Maamobi is a third class residential area (AMA 2011a, b) which is characterized by poor sanitation, poor access to safe water, and dilapidated housing. For example, an estimated 30 people share a toilet, 48 people share a kitchen, and 22 people share a bathroom. Also about 18 % of the people do not have access to toilet facilities (AMA 2011b). In contrast, first class residential areas have excellent infrastructure and other amenities and are not densely populated. Examples include Airport Residential Area, Cantonments, East Legon, Labone, Ridge and Roman Ridge (Arku et al. 2011). Nima-Maamobi had a population of 117,000 as of the 2000 census and although local level data are not yet available from the 2010 census, it is estimated that the community now has a population of about 150,000 people living on a land size of about 6 km^2 with extremely high population densities (Hip-Ghana 2011). The high population density and shortage of sleeping space has resulted in the conversion of non-sleeping facilities into sleeping rooms. Sewers are mostly open, and most residents obtain potable water through private, commercial sources, or by tapping into pipes that do not enter the household. Poverty is so dire that the people cannot protect themselves from insults from the environment within which they live.

7.6 Methodology and Data

The study was conducted at the EA level which is similar to the US Census Block Group. An EA has an average population of about 1,000 (Weeks et al. 2007). Using census 2000 data and a vulnerability framework, we examined how conditions in Nima-Maamobi make this place vulnerable to diseases. Demographic and housing data used for this research were from the 2000 Population and Housing Census organized by the Ghana Statistical Service (GSS). GSS is a government institution responsible for statistical analysis in the country, hence making these data the appropriate source for this research. From the dataset, Nima-Maamobi has a population of 116,749 people, of whom 49.5 % were males and 50.5 % were females. The study area also comprises 105 EAs covering a land area of 3.025 km^2. Housing variables extracted from the census portray the living conditions of the dwellers. Some of the variables include; outer walls of dwelling units (DU) materials – cement blocks, stones, burnt bricks, sandcrete/landcrete, bamboo, wood,

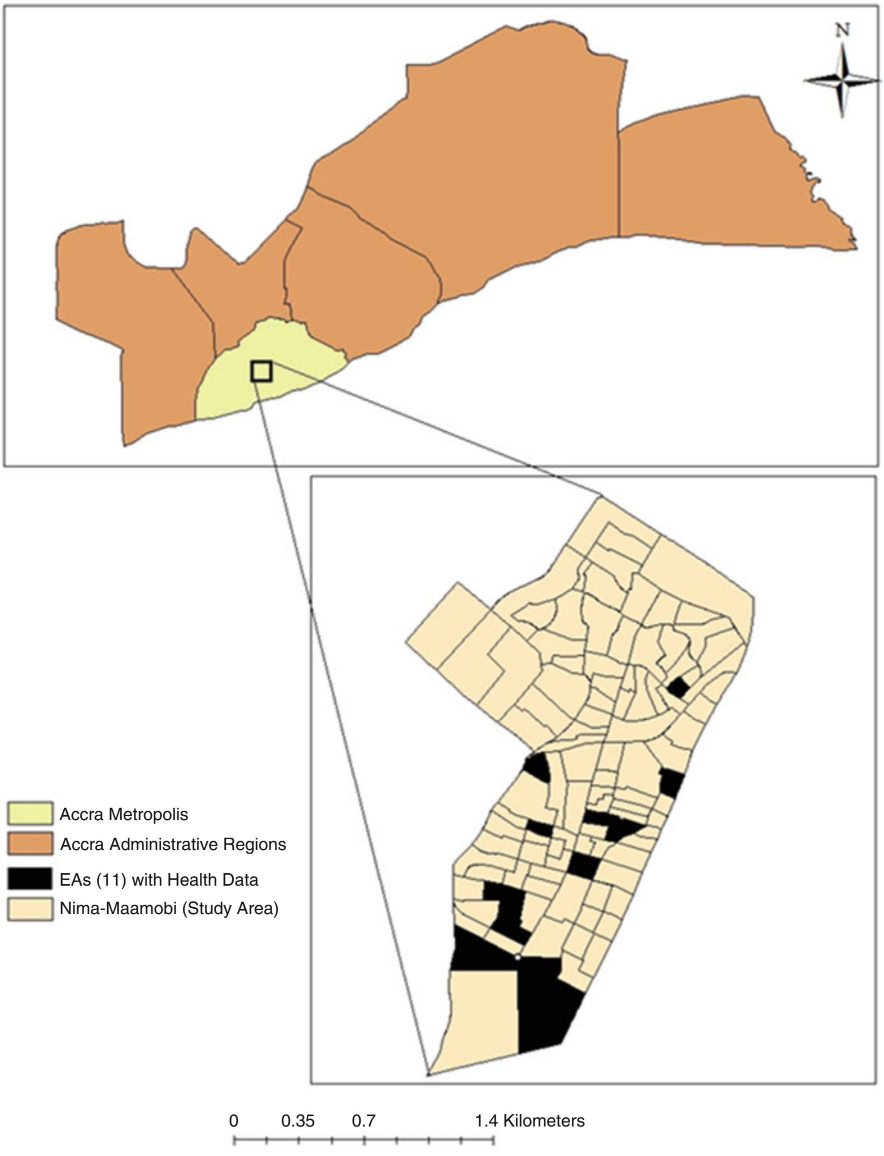


Fig. 7.1 Study area showing 11 EAs with Health Data

asbestos, metal sheets and mud; materials used for making the floor of DUs were also compiled. Other variables used include type of access to water and method of waste disposal.

Using the (UN 2003) definition of slum, and the following indicators, poor access to water, poor sanitation, non-durable housing, overcrowding and insecurity

Table 7.1 Summary indicators of slum vulnerability

Indicators	Nima-Maamobi	11 EAs with health data
Poor access to water (%)	71.7	64.3
Poor sanitation (%)	93	75.8
Non-durable housing materials (%)	41	29.4
Overcrowding (population density)	38,594 persons/km^2	34,187 persons/km^2
Insecurity of tenure (%)	66.4	60.8
Population	116,749	11,282
Area (km^2)	3.03	0.33

Source: Population and housing census 2000 data (GSS 2000)

of tenure, we created a Slum Vulnerability Index (SVI). For this research, poor access to water refers to dwelling units without pipe water in their homes. Using this definition, about 71.7 % of DUs in Nima-Maamobi have poor access to safe water. Poor sanitation for this research is defined as DUs without proper sewerage for liquid waste disposal or whose solid waste is not collected. About 76.9 % of households in Nima-Maamobi disposed of waste poorly. The commonest means of solid waste disposal in the study area was public dumping, but for liquid waste it was dumping into the gutter. Most of the public dumps and gutters are uncovered which puts residents at risk of contracting diseases such as cholera and diarrhea.

Non-durable housing poses a serious threat to the health of dwellers. For this research, non-durable housing is defined by the outer wall of DU not made of concrete, stones, cement blocks, landcrete/sandcrete or burnt bricks. About 31.3 % of DUs used non-durable housing materials. Compared to Ghana's population density of about 100 persons/km^2 (TradingEconomics 2012), Nima-Maamobi has a population density of about 38,594 persons/km^2. This crowdedness facilitates the spread of communicable diseases (WHO 2013; Arku et al. 2011; Farmer et al. 2011; Unger and Riley 2007).

Variables such as renting, perching and rent-free were used to show tenure insecurity. Only those dwelling units that were owned by their residents were excluded in this indicator. Research indicates that, people who rent are more likely to report poor mental health status than owner occupiers (Arku et al. 2011; Dunn 2002). An estimated 66.4 % of DUs in Nima-Maamobi are rented. The variables that will be input to the SVI are shown in Table 7.1.

In creating a Slum Vulnerability Index we first experimented with a principal component analysis, but the variables tended not to overlap statistically, suggesting that each variable is measuring a different aspect of vulnerability, rather than all variables being collinear. For this reason, an additive index seemed most appropriate and so, following a somewhat similar approach by Weeks et al. (2007), we created the SVI by standardizing the five variables to a common scale, and then computing the average z-score for each EA, as follows:

$$\text{SVI} = \frac{\sum(\text{z scores of Indicators})}{5}$$

Table 7.2 Disease frequency and respondents in EAs

		Disease (total yes)					
EAID	Total respondents	Malaria	High blood pressure	Diabetes	Anemia	Arthritis and joint pains	Gastro-reflux disease
502002	10	3	3	1	0	0	0
502007	13	4	1	0	1	0	0
502009	15	7	3	1	1	1	0
502012	21	3	2	1	0	0	0
502023	19	3	3	2	0	1	0
502030	26	6	5	3	0	1	1
502038	13	4	3	1	1	1	0
502045	8	2	0	1	0	0	1
502054	10	3	1	1	1	4	3
502059	30	12	5	3	3	3	5
504007	23	9	3	2	1	4	2
Total	188	56	29	16	8	15	12

Source: Women's Health Study of Accra: Wave II 2008–2009

Health data for this research were derived from the Women's Health Study of Accra 2008–2009 and graciously provided by Professor John Weeks (see Chap. 1 for more details). The survey covered the household and family characteristics and previous and current health conditions of respondents as well as in-depth health examination and measurements including blood pressure, height, and weight of respondents. Questions such as these were asked during the interview: "Have you been told by a doctor or a health professional that you have the condition?" "Have you been told by a doctor or a health professional or have you self-diagnosed the condition?" For these questions, answers were coded 1 and 0 for yes and no respectively. Disease rates were computed from the responses given.

All the 188 surveys completed by women from 11 EAs in the study area were selected for analysis. Overall, the total number of women interviewed within an EA ranged from 8 in EAID 502045 to 30 in EAID 502059 (Table 7.2). The most frequently reported diseases in the survey, malaria, diabetes, high blood pressure, anaemia, gastro reflux disease and arthritis/joint pains were included in this study. Malaria was reported most frequently – by 56 out of the 188 women interviewed, as shown in Table 7.2.

Using the health data, disease rates were computed by dividing the number of respondents in each EA who have the disease by the total number of people interviewed in the EA, and multiplying the result by 1,000 (results are shown in Table 7.3).

$$\text{Rate} = \frac{\text{Respondents with Disease}}{\text{Total Number of Respondents in EA}} \times 1000$$

Table 7.3 Disease morbidity rates per 1,000 within 11 EAs in study area

	Disease rates per 1,000					
EAID	Malaria	HBP	Diabetes	Anaemia	Arthritis and joint pains	Gastro-reflux disease
502002	300	300	100	0	0	0
502007	308	77	0	77	0	0
502009	467	200	67	67	67	0
502012	143	95	48	0	0	0
502023	158	158	105	0	53	0
502030	231	192	115	0	38	38
502038	308	231	75	77	77	0
502045	250	0	125	0	0	125
502054	300	100	100	100	400	300
502059	400	167	100	100	100	167
504007	391	130	87	43	174	87
Average	298	154	85	43	80	64

Source: Morbidity rates were calculated from the data obtained from the Women's Health Study Wave II, 2008–2009

Table 7.4 Disease aggregate and non-communicable disease rates per 1,000

EAID	Disease aggregate	Non-communicable diseases (HBP and diabetes)
502002	117	200
502007	77	39
502009	144	134
502012	48	72
502023	79	132
502030	103	154
502038	128	154
502045	83	63
502054	217	100
502059	172	134
504007	152	109
Average	121	120

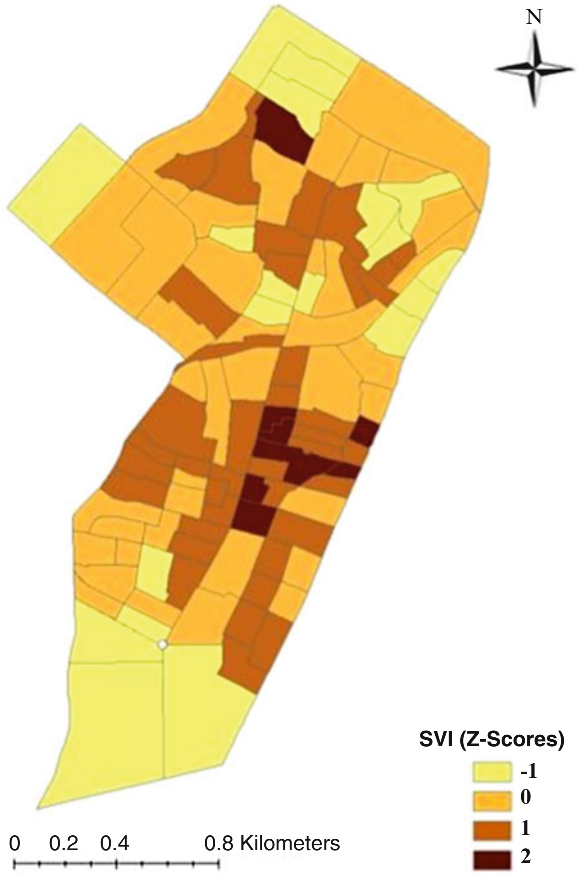
Source: Women's Health Study Wave II, 2008–2009

Due to the small numbers of cases in the EAs, we aggregated the disease count for each EA. This was done by adding all the disease rates at each EA and dividing that by 6 (the number of disease categories) to get an average rate. These results are shown in Table 7.4.

7.7 Results

Although Nima-Maamobi is a poor community, it is clear from the data that there is considerable variability within the neighborhood in terms of vulnerability. Figure 7.2 maps the SVI for each EA and it can be seen that vulnerability is much

Fig. 7.2 SVI map of Nima-Maamobi



higher in the middle and northern portions of the study area. Most EAs in the south reported low z scores for vulnerability. These places appear to be less vulnerable and have better access to services and good infrastructure because they are adjacent to a higher class residential area.

7.7.1 Cluster Analysis

Figure 7.2 shows clearly that vulnerability scores are not spatially random within the community – there are apparent patterns of clustering. Previous research indicates that it is the concentration of vulnerable people or groups that creates vulnerable places (Kneebone et al. 2011; Oppong and Harold 2009; UN-Habitat 2010), but not their existence in isolation. Since slums are considered vulnerable places to diseases, it was important to identify the spatial pattern of clustering in the Slum

Vulnerability Index. Aside from serving as a dimension reduction tool to make data more meaningful for analysis, cluster analysis (CA) also creates natural groupings for variables. We grouped the variables to see the hierarchical structure they will reveal and the linkage that exists between them.

Using the hierarchical method of clustering, the distances (in standard deviation units – not physical space) that exist between EAs based on the five indicators were identified. The five indicators were those created for use in creating the SVI. The Hierarchical method of clustering first starts by identifying each case (EA) as a cluster and links the clusters sequentially using distances between them until a single cluster is formed. Ward's method was used as the form of linkage because it uses the analysis of variance approach and considers the "total sum of squared deviations from the mean of a cluster". Aside from being the commonest approach, this method also provides a more compact cluster with well distributed sizes (Sage Pub 2012; Wulder 2009). All variables were standardized to a common scale and this eliminated the effect of outliers on our analysis.

From the resultant agglomeration schedule, 4 clusters were identified out of which 43 EAs were grouped under cluster 1, 26 under cluster 2, 32 under cluster 3 and 4 under cluster 4. We then mapped the clusters to show where they occur in the study area (Fig. 7.3).

Clustering of vulnerable indicators is high in the middle and the northwestern part of the study area compared to the southern portion. Also, clustering in the south suggests the concentration of better access to social amenities and other variables. Though the map shows that there is less-than-perfect spatial clustering of these non-spatial clusters, it provides important insights into the nature of the community.

In Table 7.5 below, we use average values to show the level of variation in the variables used for the CA. The values seen here are from the z-scores generated from the indicators used for calculating the SVI. These variables were used to ensure an easy comparison between the maps produced.

Furthermore, we created a hot-spot cluster map using the Getis-Ord Gi* statistic. This statistic creates two additional fields (z-scores and p-values) in the output feature class which provide insight into the nature of clustering in the study area. A higher z-score and a small p-value mean clustering of high values while a low negative z-score and a low p-value mean clustering of low values. However, a z-score near 0 indicates no apparent spatial clustering. The created map (Fig. 7.4) from the Gi* z-score output revealed high clustering in the middle and towards the northern half of our study area. This output in a lot of ways complements the SVI map and to some extent the CA map. All three maps show clustering of high values in the middle of the study area with the southern tip exhibiting low spatial clustering values.

We then compared the aggregate disease rate to the rates for non-communicable disease to see their variation in space. It was clear that whereas aggregate diseases were uniformly distributed across the study area, the non-communicable disease rate was higher in the southeastern tip of Nima-Maamobi. This phenomenon supports the current spatial trend of degenerative diseases – the poorer, more vulnerable areas had

Fig. 7.3 Hierarchical clustering within study area

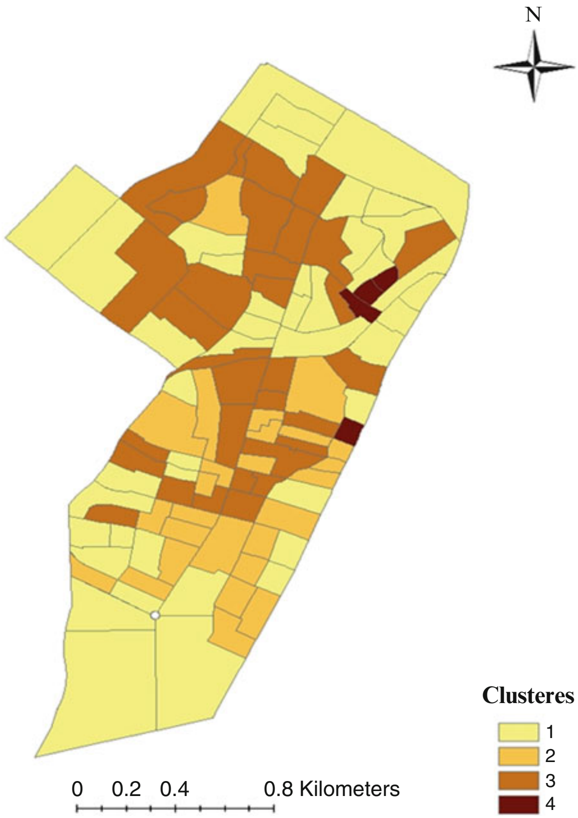


Table 7.5 Average values for variables in the four clusters

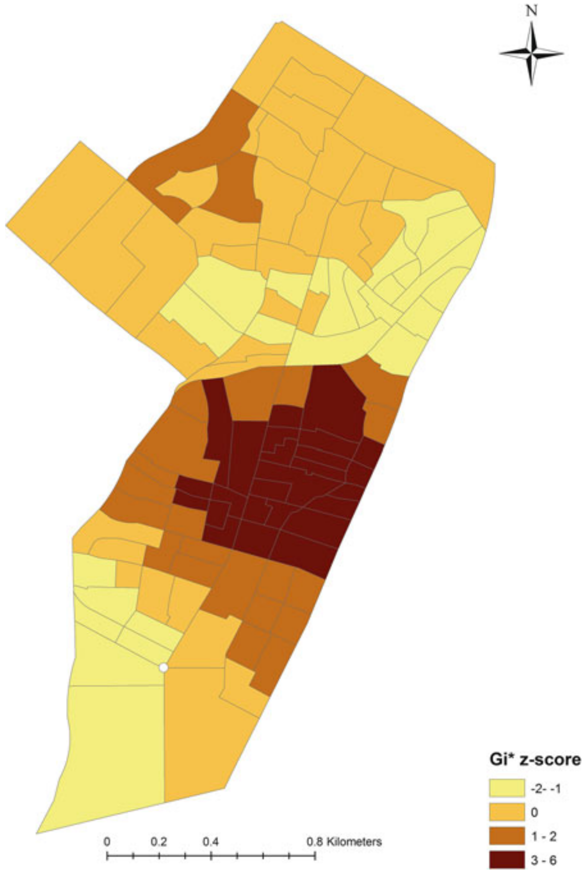
	Average values			
Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Non-durable materials	−.515	1.446	−.449	−.267
Population density	−.301	.057	−.123	3.849
Tenure insecurity	−.428	.097	.587	−.733
Poor water access	−.605	.011	.773	.251
Poor sanitation	−.512	.136	.511	.540

Data Source: Population and Housing Census 2000, GSS

higher rates of communicable diseases, while the less vulnerable, relatively affluent areas had higher rates of noncommunicable diseases. These results are shown in Fig. 7.5.

In Fig. 7.5, EA 502054 in the northwest recorded the highest aggregate rate of 217 per 1,000 due to high rates of malaria (300/1,000), arthritis and joint pains (400/1,000) and gastro-reflux disease (300/1,000). On the other hand, the map for the non-communicable diseases (HBP and Diabetes) showed a high rate for EA

Fig. 7.4 Cluster map from Getis-Ord Gi* Z-score



502002 in the southeastern corner of the study area. This particular EA had a SVI of −1 which makes it less vulnerable than the average EA within the study area. This is consistent with the epidemiological transition theory (Meade and Emch 2010).

We also applied a bivariate correlation to see whether there was an association between the five indicators and the six diseases used for the research. We expected poor sanitation to correlate highly with the rate of malaria. However, poor access to water was the only indicator which significantly correlated with gastro-reflux disease. There was a strong association of .74** which was statistically significant at the .01 level. Gastroesophageal Reflux Disease (GERD) occurs when acid from the stomach flows backwards into the esophagus and exposes the patient to the risk of physical complications or result in an impairment to well-being (Katelaris et al. 2002). Taking anti-GERD medicine with a lot of water has been found to help in controlling GERD (NCBI 2011) while drinking a lot of water daily also contributes to diluting the acid content in the stomach (Ramaiah 2007). Hence, good drinking water daily is necessary to dilute gastric acid.

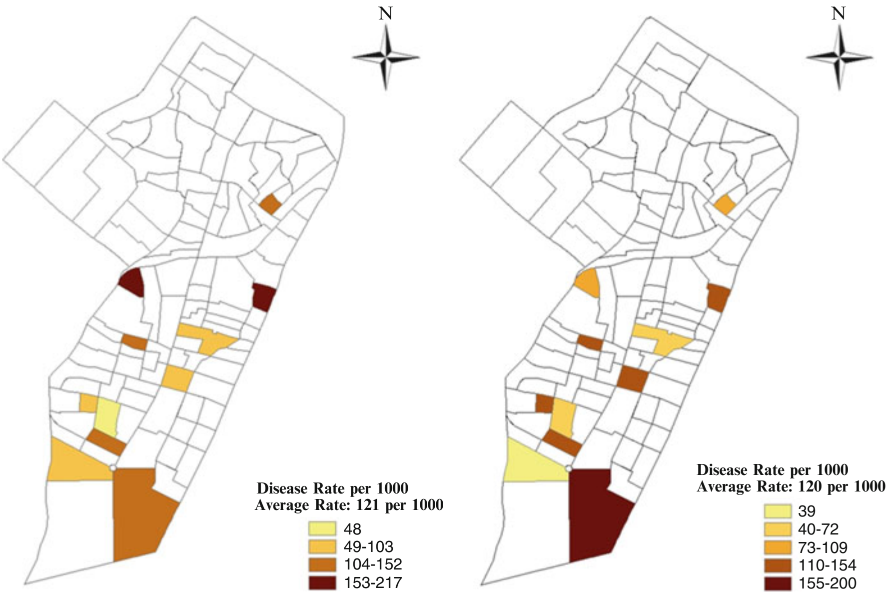


Fig. 7.5 Maps of aggregate disease rate and noncommunicable disease rate

7.8 Findings, Limitations and Future Research

The goal of this research was to shed some light on the health conditions of dwellers in Nima-Maamobi using the vulnerability framework. Our results show a clear geography of vulnerability in Nima-Maamobi – the southern part is less vulnerable and has lower rates of communicable diseases but much higher rates of noncommunicable diseases. Prior to this research, we did not really know the patterns of diseases such as diabetes and hypertension in the study area. The research shows clearly that Nima-Maamobi, like most urban settings in LDCs, is experiencing a dual burden of disease, and disease risk depends on where people live. More vulnerable areas have higher rates of communicable diseases; less vulnerable areas have lower rates.

Disease data at the EA level were available for only 11 of the 105 EAs in the study area. Consequently, it is not possible to generalize from such a small sample. Nevertheless, the results shed light on the spatial variation within Nima and confirm the utility of the Slum Vulnerability Index. Furthermore, the issue of the Modifiable Area Unit Problem (MAUP) is clearly shown on the maps created. The choropleth maps which were created using the natural breaks method will be different from patterns that will be produced from classification methods such as quintiles and equal intervals. Similarly, using the dendrogram to show the number of clustering in the study area has an inherent element of subjectivity and thus can influence the cluster patterns generated.

The political ecology model will be applied in subsequent studies to show a different dimension to vulnerability in the study area. This model postulates that a disease can be better understood within the political and socioeconomic framework of the area (Mayer 1996). We would also like to show how decisions taken at higher levels in society shape the reaction of dwellers with the environment (Meade and Emch 2010). Using the SVI as the foundation, we will engage the community members in creating a community map which will better reflect the current layout of the study area. We hope to achieve this through a mechanism termed Public Participatory Geographic Information Systems (PPGIS).

7.9 Conclusion

Slums are a threat to global health because they constitute an incubator and facility for the spread of communicable diseases. However, they are not monolithic – the more vulnerable EAs, those with poorer indicators in sanitation, access to water, and high population density have much higher rates of communicable disease, compared to the relatively more affluent EAs which have more degenerative diseases. The research suggests that a person's risk of disease varies significantly depending on where they live in the slum. EAs with low SVIs reported high rates of non-communicable diseases. Because communicable diseases do not remain where they are incubated, but spread to adjacent areas, improving conditions in slums to reduce their vulnerability is critically important. It is good public health (Eaves 2007).

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Chapter 8
What If Neighbors' Neighborhoods Differ? The Influence of Neighborhood Definitions of Health Outcomes in Accra

Alex Zvoleff, Li An, Justin Stoler, and John R. Weeks

Neighborhood context is recognized as an important predictor of individual-level behaviors and health outcomes (Pickett and Pearl 2001; Lee and Cubbin 2002; Sampson 2003). Neighborhoods, however, are difficult to define both in theory and in practice, and are often drawn to follow existing administrative boundaries or sampling schemes, or must be set arbitrarily due to a lack of sufficient data. Given the role of neighborhood context in influencing health outcomes, it is crucial that the area of influence surrounding the unit of analysis (be it a person, household, etc.) be properly defined. As already discussed in previous chapters, if we do not identify neighborhoods correctly, we cannot properly evaluate neighborhood effects. Defining neighborhoods is a challenge across the social sciences; investigations of the role of neighborhood context in decision making and shaping of individual-level outcomes are seen in public health, geography, demography, and sociology with no consistent approach to identifying and evaluating neighborhood effects. In this chapter, we outline several types of neighborhood definitions from the literature, and then, using data from the Women's Health Study of Accra, implement a spatial model together with a simulation approach to examine how two alternative neighborhood definitions affect modeling of individual-level health outcomes.

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To ground this work, we first discuss how neighborhoods have traditionally been represented in the literature. Neighborhood context has been recognized as an important component of models of many demographic and health indicators (e.g. fertility, morbidity, mortality), and is often accounted for by using multi-level models that account for hierarchically structured study designs (Subramanian 2010). Neighborhood effects represent the portion of the variance in an outcome variable that is attributable to individuals' shared experience as residents of a single area. Neighborhood effects account for common exposure to institutions, social networks, environments, etc. A key decision to be made in structuring models that account for neighborhood effects is the definition of neighborhoods. To ground our study, we briefly review several approaches to defining neighborhoods that have been used in the social science literature.

We distinguish between two major types of neighborhood definitions: a territorial definition and an egocentric definition. In a territorial definition, an individual belongs to a shared neighborhood based on a higher-level variable (such as administrative boundaries), or some other defining characteristic (local tradition, spatial homogeneity, etc.). A territorial neighborhood is shared by a set of individuals, all of whom reside within the same spatially contiguous neighborhood. By contrast, in an egocentric definition each individual is assigned to a unique neighborhood based on his or her location in space and, as implemented here, a fixed radius around that point. As noted in Chap. 3, both the scale and shape of neighborhoods can have important effects on modeling of health outcomes. It is important that analysts make informed choices regarding the tradeoffs between alternative approaches to parameterizing neighborhood effects.

One alternative to administrative boundary-defined neighborhoods is to construct divisions of space based on other criteria, such as social connections and the likely spatial background area inhabited by each individual. "Vernacular" neighborhoods (a territorial type of neighborhood definition) are perhaps the most intuitive approach. Vernacular neighborhoods are defined using local knowledge to construct a set of neighborhoods based on residents' commonly accepted divisions of an area, and are closest to the colloquial definition of neighborhood. Local residents might use a vernacular neighborhood name to, for example, direct a taxi to a particular area of a city (Weeks et al. 2010).

Vernacular neighborhood definitions are advantageous compared to exogenous constructions like census tract boundaries because they capture social dimensions not often considered in the design of survey sampling frames. As described in Chap. 2, vernacular neighborhoods are often defined based on a combination of census data, in-depth field work, and focus group research, which allows researchers to understand how residents define core and boundary regions of their neighborhoods. Once the boundaries are defined, if the sampling units of a relevant social survey data set are available at a finer scale than the final vernacular neighborhoods, construction of a spatial vernacular neighborhood-linked data set (including any number of other sources of spatial data) becomes a matter of agglomeration of survey units into the proper sets. When neighborhood boundaries and sampling unit boundaries do not coincide, as is often the case, vernacular neighborhood boundaries must be approximated, either by using the judgment of researchers to merge them into the most appropriate units, or by disaggregating them to a finer scale so that they can be appropriately recombined.

Another technique of constructing territorial neighborhoods is to use an "organic" approach. This method has been successfully used in Accra as a basis for mapping units determining contextual influences on processes including marriage timing and fertility (Weeks et al. 2010). Organic neighborhoods enjoy the advantage of having well-defined (by design) statistical properties. The AMOEBA (A Multidirectional Optimum Ecotope-Based Algorithm) approach works by using a local spatial autocorrelation statistic to define clusters of related spatial units using an iterative process (Aldstadt and Getis 2006). AMOEBA "let the data speak for themselves" by arriving at a set of empirically defined neighborhoods based on any characteristic chosen by the analyst (e.g. land cover, a demographic indicator, or some composite index). The organic approach allows maximization of the homogeneity of neighborhoods, while maximizing the heterogeneity between neighborhoods (Weeks et al. 2010), thereby closely matching our informal definition of a neighborhood as an area defined by its unique characteristics.

Whereas past approaches to neighborhood definition were limited to merging or splitting of areal units (as applied to a survey sampling design, for example) individual-level survey data are increasingly available in a geo-referenced format that offers the ability to construct new measures of neighborhood context defined at the individual or *egocentric* level. Individual-level measures of context allow us the ability to use individual-level spatially explicit modeling strategies, in addition to the more common multi-level modeling approach used to account for nested survey data.

Egocentric definitions are one way of operationalizing this conception of an individual-level measure of neighborhood effects (Reardon et al. 2008). Egocentric neighborhoods allow an explicit examination of the effects of the scale of analysis on measures of neighborhood effects. With an egocentric definition, alternative spatial scales can be tested and examined, and theoretical conceptions of scale can be compared to what is observed empirically (Lee et al. 2008). One limitation of the egocentric approach, including our implementation here, is that, similar to territorial approaches, it assumes that all areas of the egocentric neighborhood are equally accessible and influential. This problem can be addressed to some extent using inverse distance or other weighting schemes; however it can be difficult to define resistance layers for physical neighborhood effects at multiple scales such as roads, rivers, or compound walls.

One advantage of territorial neighborhood definitions over egocentric definitions is that for some applications (such as planning interventions or designing survey sampling schemes) broader-scale patterns are most important. One example is the broad-scaled mapping of health trends, as might be done from remotely sensed imagery (Weeks et al. 2007). As discussed in Chap. 4, in cases where geospatial data are sparse, the ability to identify boundary polygons for neighborhoods using remote sensing could be an important tool.

To explore the impact of alternative neighborhood definitions on our ability to predict individual-level health outcomes, we compare egocentric and territorial definitions using a spatial regression model and simulation approach. We first use spatial modeling to estimate neighborhood effects using each definition, and then use the results of this model as input to a simulation model of three representative areas of varying socioeconomic status in Accra, Ghana. This approach lets us take advantage of the precise estimates of coefficient values and standard errors that can be obtained with the spatial regression models, while also investigating the impact of each neighborhood definition type on modeling of health outcomes through time.

In the simulation model, we vary neighborhood context over time and compare how the egocentric versus territorial definitions predict the combined physical functioning score from the SF-36 survey questions, using real survey data for comparison. We hypothesize that egocentric definitions of neighborhood context will better represent the influence of neighborhood context on health outcomes than territorial definitions due to their ability to incorporate local neighborhood context without suffering from boundary effects typical of territorial definitions.

8.1 Analysis Part 1: Spatial Regression Approach

To test our hypothesis, we use data from the Women's Health Study of Accra (WHSA). The WHSA is a community-based longitudinal study focusing on a sample of women from the Accra Metropolitan Area (Hill et al. 2007). Initially, 200 enumeration areas (EAs, similar to census tracts) within Accra were randomly selected with probability proportionate to size (number of people). After creating a list of eligible women in these EAs, a sample of 3,200 women was drawn with probabilities fixed by the age group of each woman, and the socioeconomic status of her EA. See Hill et al. (2007) and Douptcheva et al. (2011) for details on the study design. The WHSA was first conducted in 2003 (WHSA-I), and a second wave was completed in 2008–2009 (WHSA-II).

Our outcome variable, physical functioning (PF) score, is a measure derived from a series of questions borrowed from the Short Form-36 (SF-36) questionnaire (Ware et al. 1994) administered during the WHSA. The SF-36 questionnaire is a short survey designed to be easily administered while providing reliable and consistent measures of general health. The SF-36 has proven to be a reliable means of measuring health through self-reports, and has been administered in numerous countries, in varying contexts. The SF-36 survey is equivalent to the RAND 36-Item Health Survey, with the exception of some scoring differences that are not relevant for calculation of the PF scores we discuss here (see Hays et al. 1993 for scoring details).

The PF score is an individual measure based on a series of ten questions that focus on the degree to which health limits a number of common physical activities such as walking, bending, and climbing stairs. The three possible responses to each question indicate the degree to which health limits an individual's ability to engage in each activity: yes – limited a lot, yes – limited a little, and no – not limited at all. Following the established methodology for calculating the PF score, the response to each of the ten items was recoded to a 0–100 scale (100 = not limited at all, 50 = limited a little, 0 = limited a lot), and the mean response calculated (Hays et al. 1993; Ware et al. 1994). With the PF score, as with SF-36 and RAND summary measures in general, a higher score indicates a better degree of health (meaning less limitation on physical functioning in the case of the PF score).

We choose the PF score for our study because previous work has shown physical functioning to be, of the eight SF-36 scales, the most highly correlated with physical health. A physical health summary measure (also taking into account bodily pain, general health, and limitations in work and daily activities) can also be derived from the SF-36 (Ware et al. 1994). For clarity of presentation and interpretation, we use the physical function score, which focuses on a more limited subset of the SF-36 questionnaire, for this study.

We use the percent of vegetated land cover (derived from high-resolution satellite imagery) as the measure of neighborhood context in our models. Vegetative land cover has been linked to neighborhood structure in Accra (Weeks et al. 2007; Stoler et al. 2012). Areas with a high percentage of vegetative cover tend to be city parks, higher income areas, or areas neighboring forests. Areas with low vegetative cover tend to be heavily built up areas, such as large industry or low income residential areas. At a fine scale, less vegetative cover can also be due to the influence of large roads. The lack of vegetation in low-income residential areas allows us to use vegetative cover as a proxy for neighborhood effects on PF score. We would expect to find lower PF scores in lower income areas (with less vegetative cover), due to reduced access to health services, poorer sanitation facilities, and increased likelihood of exposure to environmental hazards.

To map vegetative cover, we use two QuickBird multispectral images from April 2002 and January 2010 (2.4 m spatial resolution). Following radiometric correction from digital numbers to spectral radiance, the images were atmospherically corrected using the empirical line method, clouds were masked, and a vegetation/non-vegetation map was produced using NDVI thresholds. The final product offers a 2.4 m resolution map of vegetative cover for the Accra Metropolitan Area, as described in Chap. 4.

We define our neighborhood effects measure for two neighborhood definitions (territorial and egocentric). For our territorial neighborhoods, we calculate percent vegetative cover within "Field Modified Vernacular neighborhoods" (FMVs) that have been previously defined for Accra. The FMVs were constructed by modifying a map from the Ghana Statistical Service, following extensive fieldwork and focus group interviews, to create a set of 108 FMVs (see Weeks et al. 2012; Engstrom et al. 2011; and Chap. 2). For comparison with the territorial FMV approach, we use an egocentric approach where we calculate the percent of vegetative cover within a circular buffer of each woman's household (obtained via GPS during the WHSA-II survey). Because our *percent cover* measure is derived from remote sensing imagery, there are some missing values in the data (areas of cloud cover, or where a portion of a woman's egocentric neighborhood extends off the image). In some cases, a large portion of the land area surrounding a woman's location is unobserved in our imagery; this occurs for women whose location is obscured by clouds in the image, and for women located near the edge of the study site. To correct for this problem, we calculate the percent cover of each egocentric neighborhood using the total observed neighborhood area in the denominator, rather than total neighborhood area (as would normally be done for a percentage calculation). This presumes that unobserved areas of a particular egocentric neighborhood have the same average land cover composition as the observed area of that same neighborhood. To minimize bias from incomplete observations, we drop from our analysis all women where data are missing for more than 25 % of the land cover pixels in their egocentric neighborhood. This yields a final sample size of 1,114 women from WHSA-I, and 2,279 women from WHSA-II.

To determine the size (radius) of the egocentric neighborhood for our models, we examine the relationship between the egocentric variable (log percent vegetation) and PF score at a range of radii. We find that the relationship levels off with increasing radius (remembering that the area of each egocentric neighborhood increases with the square of the radius). Around about 700 m radius, the correlation coefficient between percent vegetation and PF score levels off at approximately 0.05 and is statistically significant ($p < 0.05$). We therefore chose to use a 700 m radius for our models. Though it is possible we would see changes beyond a 1,000 m radius, it is unlikely that the results for these egocentric neighborhoods would differ from those for the FMV neighborhoods we present here (unless constructed with far larger radii than we would consider reasonable, in which case we would expect the correlation to converge to zero).

We present two regression models to compare two neighborhood contexts (FMV and egocentric). In both cases, the metric is the log of percent vegetative cover. We use the log transformation of percent cover to improve the distribution of the otherwise highly positively skewed data. The log transformation also conforms to our expectation, and findings from other studies, such as Yabiku (2006), that the difference between neighborhoods with low levels of vegetative cover (e.g., 20 % compared to 10 %) is likely to have more of an impact on an individual than the difference at high levels (e.g., between 90 and 80 %). Even though the absolute change is the same, a change from 20 to 10 % is likely to be more noticeable to an individual, as it represents a halving of the vegetative cover in a neighborhood.

We first experimented with using ordinary least squares (OLS) regression models for our models of PF scores. However, given the nature of our data, we expected that spatial autocorrelation might make an OLS approach inappropriate. Spatial autocorrelation may exist in the residuals due to the presence of unobserved covariates (indicating a spatial error model might be appropriate), or due to spatial dependence in the dependent variable itself (suggesting a spatial lag model), or due to both simultaneously (Anselin and Lozano-Garcia 2009; Getis 2009). Lagrange multiplier (LM) tests (Anselin and Rey 1991) were used to test for spatial effects in the residuals of the ordinary least-squares (OLS) representations of both the egocentric and FMV models presented in Table 9.1. In both cases, the LM tests indicated statistically significant spatial lag effects.

Failure to account for spatial autocorrelation can lead to bias and inefficient estimates of regression coefficients (Getis 2009). To account for this spatial autocorrelation, we use a spatial simultaneous autoregressive lag model. In addition to the usual data matrix (X), coefficient matrix (β), and error term (ε) of an ordinary least-squares (OLS) regression, spatial lag models include an additional term with spatially lagged values of the dependent variable (y), weighted according to a weights matrix (W) and autoregressive lag coefficient (ρ) (LeSage and Pace 2009). This results in the model formula:

$$y = \rho W y + X\beta + \epsilon$$

In our models, we define the spatial weights matrix as including as neighbors all surveyed households within 700 m of each individual, using inverse distance weighting. The inverse distance weighting reflects our expectation that neighboring households will be more closely related to each other than to distant households. All the models we present here were calculated in R version 2.14.2 (R Development Core Team 2012) using version 0.5–45 of the 'spdep' package (Bivand 2012). A multilevel model is another potential approach, particularly for the FMV neighborhood model; we use a spatial lag model for both models to simplify inter-comparisons. The inclusion of spatial effects within a multilevel model is an active research area (Corrado and Fingleton 2011).

The results of the two spatial regressions testing the influence of the two different parameterizations of neighborhood-level percent vegetative cover on predicting PF scores are in Table 8.1. Both models include the same controls; however, the egocentric model includes a measure of percent vegetative cover calculated over a 700 m egocentric neighborhood, while the FMV model uses a measure of vegetative cover calculated over a territorial neighborhood. For both models, the LM test p-values indicate no significant spatial autocorrelation in the residuals due to spatial lag.

The coefficients for age and age-squared are both highly significant, and in the expected directions in both models. While the linear term on age indicates higher PF scores with increasing age, this effect is attenuated by the negative coefficient on the quadratic term. The Ga are associated with higher PF scores than all other ethnic groups (although the only marginally significant effect is between the Ga and Akan, $p < 0.10$). As expected, education is positively associated with PF, with greater PF scores as the level of education increases ($p < 0.05$ for all the terms except for the difference between the no-schooling and primary schooling-only groups).

The relationship between the use of charcoal in cooking and PF score is not clear; the effect is surprisingly positive, although with a large standard error. We would expect charcoal usage to be negatively associated with PF scores, as charcoal usage was intended to act as a proxy for lower income households, who likely have less access to health services. Furthermore, there are direct effects of charcoal on health, which makes the positive coefficient surprising, though not significant. Ownership of a toilet, an indicator of higher socioeconomic status, and possibly of less exposure to environmental health hazards, is also unexpectedly negatively associated with PF

Table 8.1 Comparison of egocentric neighborhoods and field-modified vernacular neighborhoods (FMV) spatial lag models

	700 m radius egocentric neighborhood model				Field-modified vernacular neighborhood (FMV) model			
	Beta	Std. Err.	Prob. (> |z|)		Beta	Std. Err.	Prob. (> |z|)	
log(percent vegetation egocentric)	1.50	0.78	0.055	·				
log(percent vegetation FMV)					1.86	0.69	0.007	**
Age	0.34	0.13	0.007	**	0.34	0.13	0.007	**
Age^2	−0.01	0.00	< 0.001	***	−0.01	0.00	< 0.001	***
Ethnicity (Akan)	−1.70	0.96	0.076	·	−1.68	0.96	0.080	·
Ethnicity (Ewe)	−1.34	1.24	0.278		−1.26	1.24	0.308	
Ethnicity (Other)	−0.96	1.26	0.444		−0.75	1.26	0.554	
Education (primary)	2.38	1.50	0.113		2.46	1.50	0.100	
Education (middle)	3.42	1.21	0.005	**	3.45	1.21	0.004	**
Education (secondary)	3.76	1.48	0.011	*	3.79	1.48	0.010	*
Education (higher education)	4.08	1.71	0.017	*	4.04	1.71	0.018	*
Charcoal for cooking	0.30	0.93	0.750		0.41	0.94	0.663	
Has own toilet	−1.53	0.95	0.109		−1.63	0.95	0.087	·
Years in house (5–15 years)	0.47	1.20	0.694		0.36	1.20	0.762	
Years in house (15–30 years)	−0.53	1.20	0.661		−0.64	1.20	0.596	
Years in house (>30 years)	−2.92	1.37	0.032	*	−3.02	1.36	0.027	*
Intercept	88.44	3.93	< 0.001	***	87.57	3.82	< 0.001	***
Rho		0.016				0.016		
Rho standard error		0.008				0.008		
Log likelihood		−9,878.99				−9,877.25		
AIC		19,793.98				19,790.50		
n		2,279				2,279		
LM test statistic		0.187				0.162		
LM test p-value		0.665				0.687		

Note: Both models use spatial weights matrix of neighbors within a 700 m radius, with weights inversely proportional to distance. All factors are coded with treatment contrasts: for ethnicity coefficients, Ga is the reference class; for education, "no education" is the reference class; for "Years in house", 0–5 years living in the house is the reference class

Significance is coded as: · for $p < .1$; * for $p < .05$; ** for $p < .01$; *** for $p < .001$

score (insignificant in the egocentric model, $p < 0.10$ level in FMV model). The time of residence in the area is significant only for the coefficient for residents who have lived in their home for more than 30 years (who have significantly lower PF scores than those who have been resident for 5 years or less).

The log percent vegetation term is highly significant for the FMV model ($p = 0.007$), and marginally so for the egocentric model ($p = 0.055$). The term is positive in both models as expected: areas with higher vegetative cover tend to be of higher socio-economic status. Residents in lower socioeconomic status and industrial areas are expected to have higher exposure to environmental stressors, and to have worse access to sanitation and health services (see Chap. 7), thereby resulting in lower PF scores. The size of the neighborhood effect increases and is more significant with the FMV term than with the egocentric term, although the standard errors for the parameters overlap. Judging by log likelihood and by AIC, the FMV model provides a better fit to the data.

8.2 Analysis Part 2: Spatial Simulation Approach

With the completed spatial regressions, we explore how an egocentric approach and territorial approach compare in predicting PF scores over time using a simulation approach. The results of the spatial regression models are used to predict the physical functioning scores for a sample of WHSA respondents from three representative areas of Accra. Agent-based (or individual-based) models have seen increasing usage in the geographic literature for modeling individual-level decisions and interactions in non-linear systems (Epstein 1999; Axtell et al. 2002; Parker et al. 2003; Grimm et al. 2005; An et al. 2005). Agent-based simulation models are advantageous for study of these systems as they can offer a sort of laboratory in which alternative hypotheses can be tested. Here we use a simple simulation approach to model physical functioning scores of a set of women from each of three different neighborhoods, using data from the WHSA-I to test a series of regression models derived from the WHSA-II surveys. The simulation modeling framework has the advantage of allowing us to test, over time, how the two alternative neighborhood definitions compare in their ability to model neighborhood contextual influences on health outcomes. While the spatial regression approach allows us to estimate effect sizes and significance, it is difficult to visualize the implications of these findings on a broader scale. By using simulation modeling together with spatial regression, we leverage the advantages of each of these two spatial modeling approaches, to more fully test our hypothesis that egocentric neighborhoods will serve as better indicators of neighborhood contextual effects than will territorial definitions.

We chose three FMV neighborhoods for this analysis: Nima, North Kaneshie, and Dansoman Estates (see Table 8.2 and Fig. 8.1). Nima is a well-known and densely populated neighborhood of low socio-economic status. North Kaneshie, located north-west of Nima, represents a middle-income area with slightly lower

Table 8.2 Comparison of characteristics of the three neighborhoods (using data from the WHSA-II)

Neighborhood	Mean PF score	Mean SES	Mean education	Mean age	n
Nima	83.96	1.46	2.27	45.59	74
North Kaneshie	79.68	2.95	3.00	48.86	45
Dansoman Estate	82.26	3.87	3.47	45.50	51

Note: The sample size (n) listed here is the sample size for the total number of women in that neighborhood from the WHSA-II survey. The ABM sample is smaller (see text)

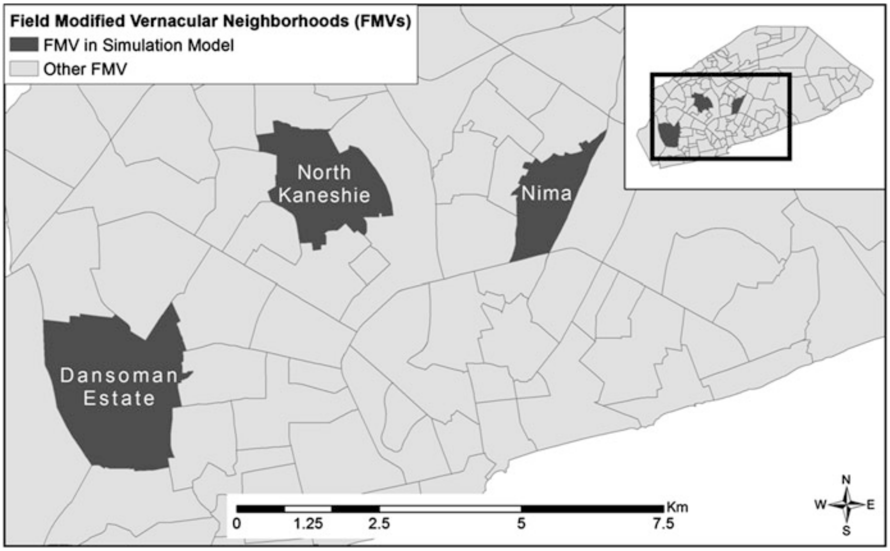

Fig. 8.1 The three representative areas of the Accra metropolitan area included in the simulation model. The three areas coincide with field-modified vernacular (FMV) neighborhoods

PF scores on average than Nima or Dansoman Estates, slightly older residents on average, and moderate educational levels. Dansoman Estates is a higher income area with higher education levels but with PF scores and mean ages similar to Nima. For the simulation model, we use sets of residents from each of the three areas who lived in the same location during both the WHSA-I and WHSA-II surveys. By using these three areas for comparison, we are able to focus in detail on the processes occurring at a neighborhood level. In addition, since the enumeration areas sampled during the WHSA are not spatially contiguous, our analysis of each of these three areas independently also simplifies interpretation of our simulation modeling results.

To run the simulation model, we need to model the change in neighborhood context over time. In the simple case presented here, we model land cover change to predict the percent of vegetated land cover in each neighborhood at each time step. There are many models of land cover change of varying complexity in the literature (Brown et al. 2000; Lambin et al. 2001; Petit et al. 2001; An et al. 2006; Millington

Table 8.3 Markov transition matrices for the three Nima clusters (rows are from 2002 image, columns are from 2010 image)

	Non-vegetation	Vegetation
Nima cluster		
Non-vegetation	0.9931	0.0069
Vegetation	0.0069	0.9931
North Kaneshie cluster		
Non-vegetation	0.9868	0.0132
Vegetation	0.0244	0.9756
Dansoman Estates cluster		
Non-vegetation	0.985	0.015
Vegetation	0.0244	0.9756

et al. 2007; An and Brown 2008). As our primary concern is to understand the effects of alternative neighborhood definitions on models of physical functioning rather than to model the generative process behind land-cover change in Accra *per se*, we choose a series of simple first-order stationary Markov models of land-cover change as inputs to our simulation model. We generate one Markov model for each of the three representative areas we consider, using the two classes *vegetation* and *non-vegetation*.

A Markov model is a simple model of land change that represents change using a matrix of transition probabilities. Markov models rely on the assumption that land-cover change can be represented as a stochastic process in which the probable future state of a system can be derived based on knowledge of prior states of the system. Using a transition matrix, a Markov chain can be constructed, representing transition of the landscape between a series of states, with each state dependent on only the transition probabilities, and the last observed (or modeled) state of the system (Brown et al. 2000; Petit et al. 2001).

As we have only two observations (2002 and 2010), we assume a constant rate of change in each neighborhood in the 8-year period between the two images. In a typical Markov model, the probability of transition between states is calculated by considering the probability of transition at a pixel level, by considering the initial and final states of each pixel. However, due to misregistration and misclassification, comparison of two images at the pixel-level can lead to high levels of error, and inaccurate transition probabilities. To alleviate this problem, we calculate the transition probabilities used in the model over a five-by-five pixel moving window (Brown et al. 2000). After calculating the transition probabilities using the land cover map from the 2002 and 2010 QuickBird images, we use matrix algebra to correct the transition probabilities (derived from an 8-year window) to apply to the 1-year time step on which we run the model (Petit et al. 2001). After this calculation, we obtain the final transition matrices (Table 8.3).

Though we would prefer to parameterize our simulation model using regressions from the WHSA-I dataset, GPS coordinates were not collected for WHSA-I respondents, so we are unable to accurately calculate egocentric neighborhoods for these women. Using the WHSA-II dataset to parameterize our simulation model is, in a sense, cheating, as we are using future data to parameterize a model that is then run starting in the past. As we do have GPS coordinates for women from WHSA-II, we attempted to run our regressions on the WHSA-I panel, by only using women known to have resided in the same location in WHSA-II and I (so that we have precise location data for egocentric neighborhood calculation, by using matched coordinates from the 2008 WHSA-II survey). This restriction drastically reduces the sample size, limiting our ability to obtain unbiased estimates from the data. Therefore, we use WHSA-II data to parameterize our models, and run the simulations starting in the year 2003, assigning characteristics to the women in the simulation directly from the WHSA-I data. For the simulation models, we only use women surveyed in both WHSA-I and II. This ensures we can compare the predicted PF scores from 2008 from the simulation models with the observed scores from the same women from the WHSA-II survey conducted in 2008.

We run the model using three different types of scenarios. The first scenario includes no neighborhood effect (using the regression coefficients from a spatial lag model without a neighborhood effects term, but with identical controls to the models presented in Table 8.1). The second type of scenario uses the results of the egocentric spatial lag model presented earlier, with percent land-cover calculated for each woman at the beginning of each time step over a 700 m egocentric neighborhood. The third type of scenario uses the FMV neighborhood definition, with percent land cover calculated for each woman according to the FMV neighborhood in which she resides. We integrate our Markov models of land cover change to provide the land cover estimates needed in these models. For each of the three representative areas (Nima, North Kaneshie, and Dansoman Estates), we calculate independent Markov transition matrices, allowing the pace of land cover change to vary for each area.

For each scenario, the model runs on a 1-year time step. The model is initialized with the set of WHSA women resident in the neighborhood during WHSA-I, and land cover is assigned to the neighborhood as a grid of 2.4 m resolution cells (as a binary vegetation/non-vegetation map) based on a 2003 QuickBird classification. At the beginning of each time step, the PF score is predicted for each woman using the appropriate model from Table 8.1, and the appropriate neighborhood definition to calculate percent vegetative cover depending on whether it is an egocentric, territorial (FMV) or a no-neighborhood-effects scenario. Land cover change is then modeled using the appropriate Markov transition matrix for the neighborhood, and the resulting land cover is carried forward to the next time step. At the end of each time step, the age and length of time at her residence are incremented for each woman.

For each of the three test areas (Nima, North Kaneshie, and Dansoman Estates), we run each of the three types of scenarios, resulting in a total of nine different simulations. For each simulation, we ran 35 model runs, a sufficient number of model runs to ensure a good estimate of the variance in the mean of the model runs (the variance did not increase as we added additional runs). We present the mean of these 35 model runs in our results to show the spread of variability that manifests from the stochasticity in the land-change model. Given the low amount of stochasticity in these simulations, the variance around these means is essentially invisible. This is not meant to overstate the accuracy of our predictions, but rather to indicate *a priori* that the model runs, by design, do not have a high degree of variability in their results within each of the nine different simulations.

We run each simulation for 17 time steps, representing the years 2003–2020. The initial time step therefore coincides with the WHSA-I survey date, and the sixth time step (2008) coincides with the WHSA-II survey date. Mortality is not included in these models. We experimented with including age dependent mortality in the model using World Health Organization (WHO) data; however, age-specific mortality is not available with a high enough degree of temporal resolution for Accra (WHO data are only available in three age groups: 0–15 years, 15–60 years, and over 60 years old). Neglecting mortality is not an issue for the WHSA-I to WHSA-II time interval (2003–2008) that we focus on in this paper, as the women included in the model represent real women who were surveyed and known to be alive in both 2003 and 2008. We continue our model runs after 2008 not as a predictive tool, but to descriptively compare the evolution of the PF scores as simulated on a longer timescale. If we were focused on population dynamics or on making accurate predictions of PF for these neighborhoods out to 2020, neglecting mortality would not be defensible.

The simulation results for the three representative neighborhoods are presented in Fig. 8.2. The most noticeable trend is the decline in PF scores over time. This trend is due to the increasing age of the respondents in our cohort. As we restrict our sample to include only women sampled in the same location in both the WHSA-I and WHSA-II surveys, the average age of our sample is relatively high (around 48 years old at the beginning of the model). This is in part because younger, more mobile women have been filtered out (as they would not be in the same household twice). The decline in mean PF score can also be seen to increase with time; this is due to the effect of the quadratic term on age.

We can also compare the three models across each scenario. In all three areas, the mean PF score as modeled by the no neighborhood effects model, egocentric model, and FMV (vernacular) neighborhoods models are all very similar. This is due to the relatively small effect of neighborhood context (as determined by the regression models) on PF score as compared to the size of the age effect. The age effect dominates when we model PF scores through time. The FMV model tends to predict higher PF scores than the egocentric model, due to the influence of the larger intercept term in the FMV model. Through time, the FMV neighborhood and egocentric neighborhood models track closely together, although the no-neighborhood-effects model diverges slightly, most evidently in the North Kaneshie simulation. Here we see the small, though visible, impact of ignoring neighborhood effects in our model.

In Table 8.4 we compare the mean PF scores for each area as calculated by the simulation models using the PF scores from the survey data. We see the closest match between our model output and the observed data for the Nima and North Kaneshie neighborhoods. In both cases the FMV neighborhood definition tracks a bit more closely with the observed data. However, in North Kaneshie the observed data (as seen in the left two columns of Table 8.4) shows an increase in the

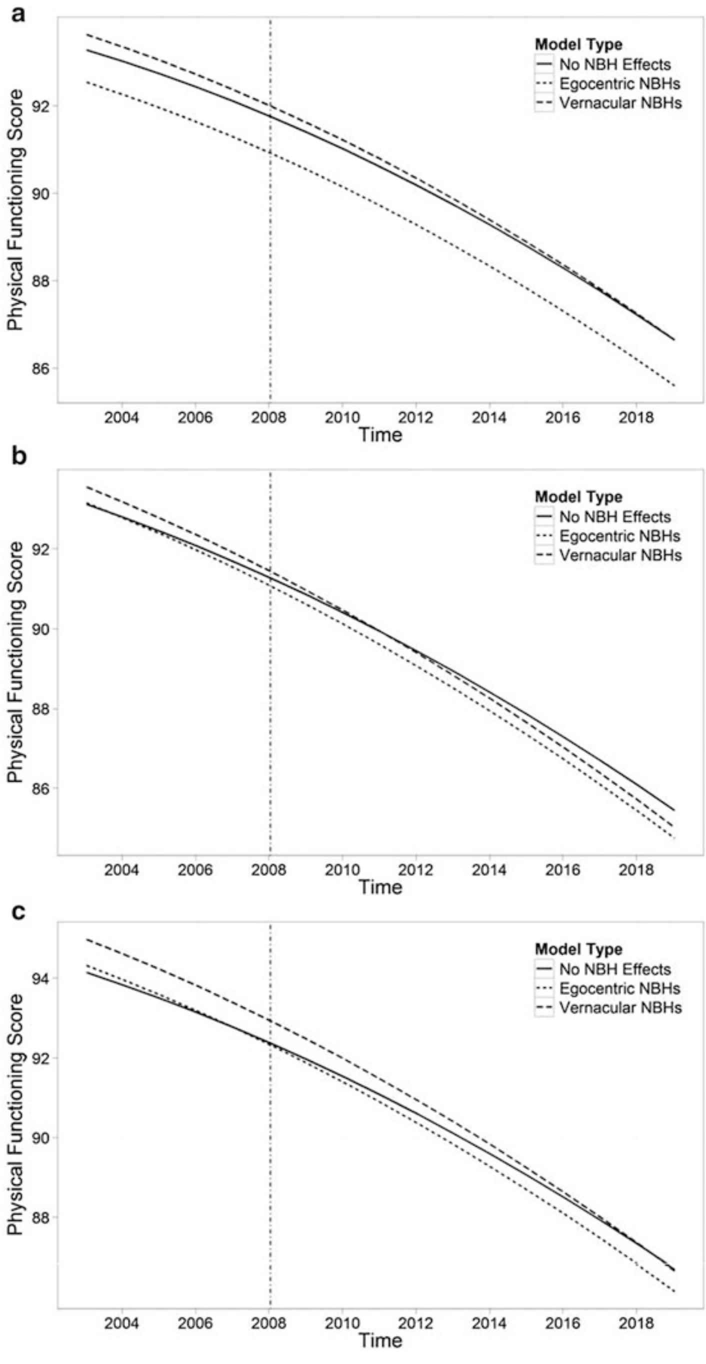

Fig. 8.2 The simulation results for (**a**) Nima, (**b**) North Kaneshie and (**c**) Dansoman estates. The *vertical dotted line* in each figure represents WHSA-II survey date

Table 8.4 Comparison of the mean physical functioning (PF) score of the three neighborhoods included in the simulation model, from the WHSA surveys and from the model results

Neighborhood	WHSA-I (2003)	WHSA-II (2008–2009)	Modeled 2009 (Egocentric)	Modeled 2009 (FMV)
Nima	95.94	91.89	90.92	91.99
North Kaneshie	89.53	92.78	91.07	91.43
Dansoman Estate	87.64	87.65	92.32	92.93

Note: Column 2 is the mean PF score from the WHSA-1 survey. Column 3 is the mean PF score from the WHSA-2 survey. Column 4 is the mean PF score from 2009 from the simulation, modeled using the egocentric neighborhood definition. Column 5 is the mean PF score from 2009 from the simulation, modeled using the FMV neighborhood definition

mean PF score; our model greatly over-predicted the 2003 observed values and produced a decrease in PF score up to 2008 that ended up matching the observed data. Clearly the model requires fine-tuning if we were to seek to match the process more closely in North Kaneshie. In Dansoman estates we see essentially no change in the observed mean PF scores, but the simulation model again predicts a decrease. Spatial heterogeneity in the observed relationship between PF score and neighborhood context is a possibility that should be further explored.

8.3 Conclusions

Although we expected to derive more predictive power from the egocentric neighborhood definition than from territorial measures, our results do not indicate that the egocentric approach is superior to the territorial FMV definition. The spatial regression models indicate that the size of the neighborhood effect from an egocentric neighborhood is similar (though less) in magnitude to that measured from a territorial neighborhood. To further compare the two neighborhood definitions and explore their dynamics over time, we used a simulation modeling approach. Our simulation results show a similar pattern. For the prediction of 2008 PF scores, the territorial and egocentric neighborhood definitions both perform similarly, and on a longer timescale, the results predicted under both definitions track closely together. The egocentric metric applied here, percent of vegetated land cover within a given distance buffer, is exceedingly simple. A more advanced approach that considered texture measures from the imagery, as demonstrated in Chap. 5, might better account for important neighborhood characteristics such as sharp boundaries between areas. Our comparison of the observed data with our simulation model results suggests that there may be spatial heterogeneities in the relationship between PF score and neighborhood context. Future work to untangle this relationship would inform our understanding of the relation between neighborhood context and health.

The egocentric neighborhood approach shows promise for estimating the relevant scale to be used in modeling neighborhood effects on individual-level health, and more sophisticated techniques of measuring these neighborhoods may unlock additional predictive power. Although we see similar effects between the egocentric and territorial definitions for PF score as our outcome variable, the same may not be true in general when other health outcomes are considered. An understanding of the spatial process itself is essential to choosing the proper parameterization of neighborhood context. When calculated as a continuously varying measure at the individual level, egocentric neighborhood context measures may be a useful addition to the analyst's tool kit. With the ability to better control for spatial autocorrelation in this type of modeling framework, the use of egocentric neighborhoods presents a potential alternative to multilevel modeling techniques traditionally used for exploring neighborhood effects.

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Chapter 9
Living Arrangements and Fertility: A Case Study in Southern Ghana

Magdalena Benza

The traditional fertility transition model has been criticized because it is based on the demographic changes that occurred throughout Europe and the West at the end of the nineteenth century, where urbanization and industrialization were identified as major drivers of fertility decline. In other regions of the world, it appears that fertility transitions are driven by multiple interacting factors (Mason 1997) that are increasingly associated with an urban transition rather than industrialization and economic growth. It is now widely recognized that urban areas tend to have lower fertility rates than their rural counterparts (White et al. 2005). Given Africa's current rapid pace of urbanization (United Nations 2006), one would expect a strong decline in overall fertility rates, though such declines have stalled in much of the continent, possibly attributable to the cultural importance given to reproduction as a means to ensure the survival of traditional lineages (Caldwell 1996).

Sustained fertility decline, as Coale (1973) explained, only occurs when three preconditions are met: fertility must be within the calculus of conscious choice, reduced fertility must be seen as advantageous and effective, and techniques of fertility reduction must be available. Although Coale's original concepts apply most readily to individuals, women in many societies, especially in sub-Saharan Africa, are embedded in families and households where other family members importantly influence individual decision-making about reproduction. My research is thus guided by the hypothesis that, in sub-Saharan Africa, the family—and more specifically the structure of the household—plays a major role in defining women's perception of reproduction as advantageous or disadvantageous, thus influencing couples' fertility choices. The goal of this chapter is to explore the relationship

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between fertility levels and household structure in two regions of coastal Ghana, focusing specifically on whether a woman's level of reproduction is related to the type of household in which she lives. Using census data at the individual level and enumeration area (EA) level, the relationship between living arrangements and fertility is estimated through linear regression for Greater Accra and the Central regions. The relationship between fertility and urbanization is assessed by incorporating an independent urban rate variable extracted from data classification of satellite imagery. The strength of the relationship between household structure and fertility is then evaluated through space at the EA scale by looking for patterns of spatial dependence using the G_i^* spatial clustering statistic and a related spatial filtering technique.

9.1 Background

Bongaarts and Watkins (1996) explain that, in developing countries, reproductive decisions are highly influenced by levels of social interaction. Regions that have not gone through fertility transitions are often places that are relatively isolated in terms of social interaction. In the case of West Africa, Addai and Trovato (1999) discuss the prevalence of a high "ethnic fertility" characterized by a cultural background that promotes high reproductive expectations. Fertility levels that appear to be strongly influenced by this ethnic component are susceptible to a process of structural assimilation, where assimilation is defined by increasing levels of education, delayed marriage, and a stronger female presence in the labor force (Weeks et al. 2004). Urbanization stimulates assimilation and social interaction, and thus has been regularly linked to fertility declines in both developed and developing countries (Mason 1997). Ghana's southern regions, which are the most urban areas of the country, have a clear tendency towards lower fertility. This stands in contrast with the more traditional and rural northern regions that characteristically exhibit much higher fertility (Caldwell 1967). Migration to the city and the process of assimilation to the urban lifestyle have been shown by White and colleagues (2005) to have an impact on reproductive decisions.

Reproductive decisions in Sub-Saharan Africa are highly influenced by religion (Caldwell and Caldwell 1987) and family system (Caldwell 1996). In Ghana, Gyimah and colleagues (2008) have shown that there is a connection between a couple's religion and level of fertility. Couples belonging to traditional African faiths have higher fertility rates than Muslim and Christian couples. Kinship not only represents the foundation of the organization of traditional groups in Ghana, it defines clans at the regional scale and lineages at the local scale (Nukunya 2003). In West Africa, Caldwell (1996, p. 335) highlights the cultural significance of lineages for their 'reverence for ancestry and descent,' referring to them as a 'continuing line stretching infinitely backward into the past and forward into the future.'

Lines of descent play an important role in shaping everyday life in Ghana, including patterns of residence. Ghana is predominantly matrilineal when it comes to descent patterns, and the Ashanti (a major subgroup of the Akan, the largest ethnic group in the country) are a matrilineal society. However, smaller patrilineal groups have an important presence at regional scales as is seen among the Ga in Greater Accra (Nukunya 2003). Ga men and women typically live in different compounds with boys moving out of the female's compound at puberty (Nukunya 2003). Similarities exist with matrilineal societies in which men and women usually reside in different compounds, while children are generally not allowed to live with their fathers (Nukunya 2003). Children's residential arrangements in fact are very diverse because of the importance of fosterage practices in the region which allows parents to send their children to be raised in a different household (Caldwell 1996). While lineages have very specific rules defining residence patterns, extended family co-residence is a prevalent living arrangement throughout West Africa (Adepoju and Mbugua 1997).

Household structure has been linked to fertility from different perspectives in prior research. Studies have found that household size correlates positively to fertility, even beyond the fact that more children obviously increase household size (Bongaarts 2001), that couples' individual characteristics relate to reproduction rates (Oheneba-Sakyi and Takyi 2001), while polygamy has been associated with lower fertility rates per woman (Bongaarts et al. 1984; Dodoo 1998). Research that focuses on living arrangements has found that parent-child cohabitation plays a role in defining reproduction decisions (McDaniel and Zulu 1996), and female cohabitation with a family member of the same generation has a negative relationship to birth rates (Moultrie and Timaeus 2001). This chapter explores the hypothesis that fertility varies according to the organization of the family structure in the household. Specifically, the relationship between living arrangements and fertility is expected to have an important spatial component that reflects the degree of urbanization of a woman's community. In order to evaluate the influence of urbanization on the relationship between living arrangements and fertility, an independent definition of place for the study area is created through remote sensing tools.

Remotely sensed imagery, given its geographically comprehensiveness, is an effective alternative for estimating the extent of urban areas, and thus is a useful tool for quantifying and monitoring the distribution of human settlements (Harris and Longley 2000; Small 2003; Weeks 2004). Urban applications of spectral mixture analysis (SMA) based on Ridd's (1995) vegetation, impervious and soil (VIS) model have produced satisfactory land cover classifications for cities in the United States (Wu and Murray 2003; Wu 2004; Lu and Weng 2004), Australia (Phinn et al. 2002; Ward and Phinn 2000), Thailand (Madhavan et al. 2001; Song 2005), Egypt (Rashed et al. 2001), and more recently in Ghana (Weeks et al. 2007; Stoler et al. 2012). At the global scale, Small (2005) demonstrated that the method is adequate to detect human settlements by comparing cities in different regions.

9.2 Defining the Urban Rate Variable

The creation of an Urban Rate variable was based on data from five 30-m Landsat Enhanced Thematic Mapper Plus (ETM+) scenes with 10 % cloud coverage or less from the years 2000, 2001, 2002 and 2003. One additional 15-m Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) scene from 2007 was included because of the inability to locate cloud free ETM+ data for one portion of the study area. All images are clipped and mosaicked in order to maximize the removal of cloud coverage. Pure land cover classes are selected using the pan-sharpened images in combination with a pixel purity index (Rashed et al. 2005). Following pure class selection for each one of the images, a constrained linear un-mixing model is performed to extract the proportions of pure classes for each pixel (Roberts et al. 1998). The resulting impervious or built proportions are then classified in ArcGIS using a built threshold of either 50 or 75 %. The overall accuracy of the resulting built-environment map was assessed by extracting a sample of more than 100 stratified points from the built-environment raster map. Each of the sampled pixels classified as urban is visually inspected by overlaying it on top of higher spatial resolution imagery (Quickbird and ASTER for Accra, pan-sharpened Landsat, and Google Earth coverage wherever available) which serve as a ground reference data set for the final urban environment error assessment. The classified built proportions are then summarized at the EA level, and the urban rate variable is generated by calculating the ratio of urban area to the total EA area (Fig. 9.1).

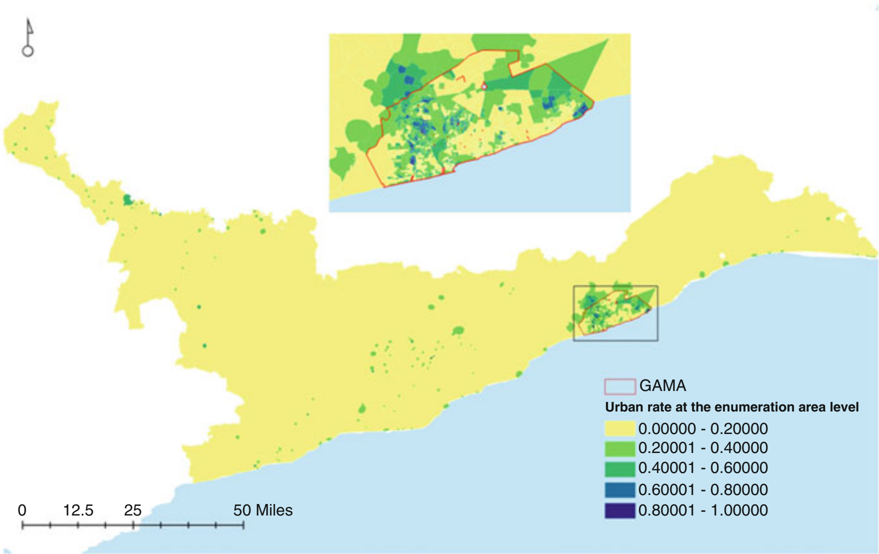

Fig. 9.1 Urban rate at the enumeration area level

9.3 Household Structure and Fertility at the Enumeration Area Level

The relationship between household structure and fertility for Greater Accra and the Central Regions is examined using data from Ghana's 2000 Population and Housing Census aggregated by EA. Linear regression models are used to predict fertility based on the urban rate and a set of different living arrangements while controlling for ethnicity, religion, housing characteristics, and the demographics of women residing in the household. The dependent fertility measure, abbreviated as CEBz, is an age standardization of the census variable "children ever born" (CEB):

$$CEBz = \frac{CEB_{individual} - avgCEB_{agegroup}}{Standard\ deviation_{agegroup}}$$

Individual relationships with the head of the household are used to identify different types of living arrangements which are then aggregated to the EA level and modeled as independent variables of interest. Households are classified as two-parent, single parent, polygamist, and extended family. Cohabitation patterns are further analyzed by identifying the presence of different generations within the household, i.e. parents and grandchildren of the head. Households with female heads are identified, as are the number of household members. These control variables are added in four general blocks of covariates: (1) household structure and urban rate, (2) religion and ethnicity, (3) characteristics of the dwelling, and (4) demographic characteristics of the women residing in the household. The residuals from the linear regression are mapped and then further analyzed for spatial autocorrelation.

9.4 Spatial Dependence and Spatial Filtering

Each independent variable is analyzed for spatial autocorrelation using the GeoDa software package by specifying a Queen's spatial weights matrix with two orders of contiguity. After identifying variables with high spatial autocorrelation, these variables are further evaluated for spatial dependence using the Getis and Ord G_i^* spatial autocorrelation statistic (see below) where d is defined as the distance between locations i and j; w is defined as the weights matrix defined by the connection between i and j; xi and xj are the original attributes of x for locations i and j. High $G_i^*(d)$ values indicate that there is a high spatial autocorrelation in the high values of x, whereas low $G_i^*(d)$ indicates that there is a high autocorrelation in the low values of x.

$$G_i^*(d) = \frac{\sum_j w_{ij}(d)x_j}{\sum_j x_j}$$

The variables with high spatial autocorrelation are filtered using the Getis Spatial filtering technique by isolating the spatial component in each variable (Getis and Griffith 2002). The filtering technique generates an x_i^* filtered variable that is based on the Getis and Ord G_i^* spatial autocorrelation statistic:

$$x_i^* = \frac{x_i\left[\frac{W_i}{n-1}\right]}{G_i^*(d)}$$

The filtered variable is a result of the comparison of the observed G_i^* with its expected value, given no spatial autocorrelation. Running the spatial filter for the independent variables allows us to obtain an unbiased relationship between fertility, household structure, and the urban rate. The linear regression is then replicated with filtered variables and their spatial components in order to identify how much of the relationship between fertility and household structure is explained by spatial dependence.

9.5 Geographically Weighted Regression

The final step of the spatial analysis focuses on the evaluation for the existence of spatial heterogeneity through Geographically Weighted Regression (GWR). As with the linear regression, fertility is defined as the dependent variable while household structure and percent urban are defined as the independent variables plus an additional variable corresponding to the spatial component, where (u_i, v_i) correspond to the coordinates of the *i*th point and *k* denotes the number of independent variables:

$$y_i = b_0(u_i, v_i) + \sum_k b_k(u_i, v_i)x_{ik} + e$$

GWR generates as many models as points included in the regression and the strength of the relationship between dependent and independent variables is affected by its neighbors. The following equation describes the beta coefficients calculated by GWR:

$$b(u_i, v_i) = (X^T W(u_i, v_i)X)^{-1} X^T W(u_i, v_i)y$$

Where W corresponds to the weight that is assigned in each model to the neighboring points, at the same time neighboring points are defined in a Kernel based on a distance decay function. The hypotheses being tested in steps one and two of the spatial analysis are first, that there is a relationship between fertility, household structure and urban phenomena that is independent of location and secondly, the strength of this relationship is not homogeneous through space.

9.6 Results

The first glance at living characteristics in our study area shows that households with extended family are very prevalent. Even though there are some differences between the two regions we can clearly see that co-residence with grandchildren for both Greater Accra and the central region is common, as is the practice of fosterage (Table 9.1).

Both regions have an average of at least one extended family member residing in the household. Greater Accra's average number of extended family members in the household is 45 % higher than the Central region's average pointing to the predominance of denser households in urban Accra. Greater Accra's larger extended family households can be attributed to the importance of the practice of fosterage but also to the limited access to housing in the city that promotes inter generational co-residence. In terms of fertility levels we can see that the Central region has a CEBz 35 % higher than Greater Accra's showing the declining trend of urban fertility. The overall impact of living arrangements on fertility levels is estimated in the following section through linear regression model.

For each linear regression model fitted at the EA level of aggregation, variables are organized into four different blocks. The first block contains the variables of interest pertaining to household structure, while the remaining blocks contain the control variables for head of household, housing, and demographic characteristics. Results from the linear regression with the first block of variables indicate that household structure alone explains 30 % of the variability of fertility levels (Table 9.2). When including the additional control variables the R^2 value increases to 0.63. The beta coefficients for the household structure variables, *grandchildren of the head*, *parents of the head*, and *foster children living in the household*, exhibit a slight positive effect on fertility. The *urban rate* variable, which was derived from the satellite imagery, exhibits an inverse relationship with fertility: more highly urbanized EAs have significantly lower reproduction levels.

Table 9.1 Summary of variables of interest for Greater Accra and Central Regions

	Central Region		Greater Accra	
	AVG	SD	AVG	SD
CEBz	2.318	0.404	1.726	0.322
Number of extended family members in HH	1.215	0.625	1.763	1.072
Grand children of head in HH (%)	18	12	11	7
Parents of head in HH (%)	2.8	4.6	2.9	2.7
Foster children in HH (%)	33	16	51	13
Single parent household (%)	25	14	22	9
Two parent household (%)	23	14	16	7
Polygamist household (%)	0.4	2.0	0.2	0.5
Female head of the household (%)	38	17	36	10
Urban rate (%)	7.3	10.2	25.5	21.1

Table 9.2 Beta coefficients for the variables explaining fertility (CEBz) at the enumeration area level for the Greater Accra and the Central Regions

Model	β block1	β block2	β block3	β block4
Constant	**	**	**	**
Number of household members	−0.004	0	−0.003	0.017
Grandchildren of the head in household	0.257**	0.091**	0.054**	0.124**
Parent of the head in household	0.07**	0.04**	0.03*	0.024*
Foster children in household	−0.087*	−0.026	0.041	0.073**
Single parent household	0.012	−0.015	0	−0.031
Two parent household	0.238**	0.092**	0.102**	0.017
Polygamist household	0.076**	0.032*	0.018	0.007
Urban rate	−0.315**	−0.172**	−0.09**	−0.062**
Female head of household		−0.022	0.016	0.002
Head of the household self employed		0.369**	0.158**	0.063**
Head of the household Catholic		−0.116**	−0.083**	−0.034*
Head of the household Protestant		−0.323**	−0.233**	−0.13**
Head of the household other Christian		−0.19**	−0.126**	−0.058**
Head of the household Muslim		−0.172**	−0.124**	−0.076**
Head of the household Akan		0.107**	0.066**	0.035*
Head of the household Ga		0.021	0.035**	0.035**
Head of the household Ewe		−0.074**	−0.087**	−0.071**
Living in an independent house			0.024	0.004
Cement wall			−0.233**	−0.144**
Household member owns the house			0.041**	0.047**
Household has piped water			−0.163**	−0.106**
Household has own toilet			−0.06**	−0.004
Women with primary education				0.077**
Women with no education				0.207**
Women working in the informal sector				0.078**
Women head of household				0.165**
Women wife of the head of household				0.242**
R^2	0.333	0.557	0.609	0.662
Adjusted R^2	0.331	0.554	0.606	0.659

*p < 0.05; **p < 0.01

Using a queens-case second level of contiguity weights matrix in GeoDa, a global Moran's *I* statistic was estimated for the residuals. The calculated global Moran's *I* of 0.0492 was found to be statistically significant generating a p-value of 0.001 with 999 permutations. Each independent variable was separately evaluated for spatial autocorrelation using the same spatial weight matrix. From the 27 independent variables, 10 were deemed to have high spatial autocorrelation by virtue of a Moran's *I* value of 0.3 or higher and p-values below 0.01. Those ten spatially-autocorrelated variables were then independently evaluated with the G_i^* statistic using a set of spatial lags in order to identify critical distances of spatial dependence. The variable-specific critical distances identified with the $G_i{}^*$ statistic were subsequently used to filter each one of the variables using the Getis spatial filtering technique. The spatial filter generated a filtered component and a spatial component for each of the independent variables. The R^2 slightly improved to 0.67 when including the filtered and spatial components as independent variables in the linear regression (Table 9.3).

The filtered variables *grandchildren of the head* and *foster children in the household* remained significant after the spatial filter was applied. The isolated spatial component of the variable *grandchildren of the head* exhibited a significant positive effect on fertility, a result that supports the hypothesis of spatial dependence in the correlation between family arrangements and fertility. When the urban rate variable was filtered, the original negative effect on fertility shown in the unfiltered result was decomposed into one positive and one negative effect. This result indicates that the negative effect originally observed with the unfiltered variable is defined entirely by the spatial component of the urban variable.

Results from the Global Moran's *I* and regression models using spatially filtered variables indicate that some of the independent variables included in the model were spatially autocorrelated. In order to attempt to capture the spatial heterogeneity in the independent variables, a geographically weighted regression (GWR) tool was employed. GWR, in contrast to the spatial filtering technique, allows the use of an adaptive kernel when defining spatial heterogeneity; a feature that permits the capture of variability in EA sizes. GWR weights the independent variables based on their spatial behavior and generates spatially distributed coefficients. The R^2 values for each one of the variables of interest ran independently ranged between 0.65 and 0.66, which is comparable to previous results using the spatial filtering techniques. The key distinction in these techniques however is the ability in GWR to decompose the correlation between the variables of interest and fertility producing a spatial range of coefficients (Fig. 9.2). This allows for a detailed spatial view of the effects of each independent variable on fertility.

The results in Fig. 9.2 reveal that the variable "parent of the head in the household" has two distinct effects on fertility occurring across space. Negative effects on fertility (shown in blue) can be seen in the western side of the Central region and a small section of Accra. Positive effects on fertility (shown in red) occur predominately in the peri-urban region of the Greater Accra Metropolitan Area (GAMA).

Similar spatial patterns emerge when Applying GWR to other household structure variables explaining fertility levels. Figure 9.3 reveals the mostly negative correlation occurring between polygamist households and fertility. The one exception to this occurs in the area surrounding the district of Tema, east of Accra, where polygamist households exhibit higher fertility levels in comparison to the rest of the study area (Fig. 9.3).

When looking at the urban rate variable (Fig. 9.4) a number of spatial patterns appear in the resulting map of GWR coefficients. The more traditional coastal neighborhoods of Accra and Cape Coast show a correlation between increased urbanization and higher fertility levels. Given the tendency towards an inverse relationship between fertility levels and increasing urbanization (White et al. 2005), this result is rather surprising. GWR is therefore an effective means for identifying spatial clusters that might otherwise be undetected.

Table 9.3 Beta coefficients for the spatially filtered variables explaining fertility (CEBz) at the enumeration area level for the Greater Accra and the Central Regions

	β block1	β block2	β block3	β block4
Constant	**	**	**	**
Number of HH members	0.001	0.002	0	0.014
Grand children of the head in HH, filtered	0.055**	0.016	0.011	0.067**
Spatial component of grand children of the head in HH	0.027	−0.002	0.019	0.079**
Parent of the head in HH	0.035**	0.026*	0.022	0.019
Foster children in HH, filtered	0.041	−0.002	0.039	0.067**
Spatial component of foster children in HH	−0.044*	−0.088**	0.006	0.039
Single parent HH	0.011	−0.029	−0.016	−0.038
Two parent HH	0.147**	0.064**	0.082**	0.012
Polygamist HH	0.039**	0.018	0.013	0.006
Urban rate, filtered	0.75**	0.386**	0.222**	0.195**
Spatial component of urban rate	−1.035**	−0.552**	−0.332**	−0.28**
Female head of HH		−0.009	0.006	−0.002
Head of the HH self employed, filtered		0.183**	0.11**	0.037*
Spatial component of head of the HH self employed		0.227**	0.102**	0.131**
Head of the HH Catholic		−0.121**	−0.094**	−0.045**
Head of the HH Protestant		−0.236**	−0.185**	−0.098**
Head of the HH other Christian		−0.135**	−0.093**	−0.035*
Head of the HH Muslim, filtered		−0.065**	−0.046**	−0.027
Spatial component of head of the HH Muslim		−0.085**	−0.072**	−0.052**
Head of the HH Akan, filtered		−0.047**	−0.011	−0.005
Spatial component of head of the HH Akan		−0.006	0.017	0.006
Head of the HH Ga		0.065**	0.055**	0.051**
Head of the HH Ewe, filtered		−0.044**	−0.063**	−0.06**
Spatial component of head of the HH Ewe		−0.003	−0.037*	−0.048**
Living in an independent house			0.013	0.001
Cement wall, filtered			−0.199**	−0.121**
Spatial component of cement wall			−0.238**	−0.158**
HH member owns the house			0.023	0.038**
HH has piped water			−0.152**	−0.092**
HH has own toilet, filtered			−0.126**	−0.074**
Spatial component of HH has own toilet			−0.048**	0.002
Women with primary education				0.061**
Women with no education, filtered				0.161**
Spatial component of women with no education				−0.015
Women working in the informal sector				0.083**
Women head of HH				0.16**
Women wife of the head of HH				0.23**
R^2	0.526	0.609	0.63	0.676
Adjusted R^2	0.524	0.606	0.626	0.672

HH household
*$p < 0.05$; **$p < 0.01$

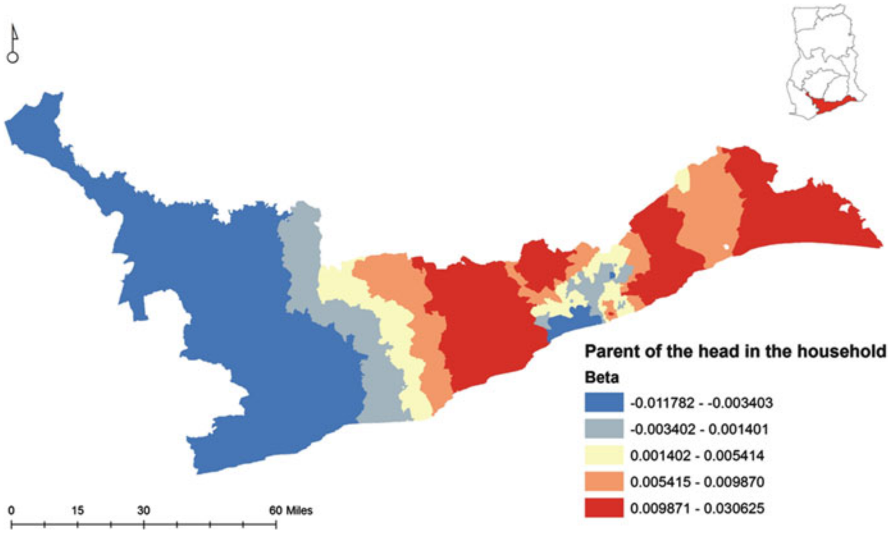

Fig. 9.2 GWR coefficients for parent of the head in the household with CEBz defined as the dependent variable while controlling for urban, household head, housing and women's characteristics

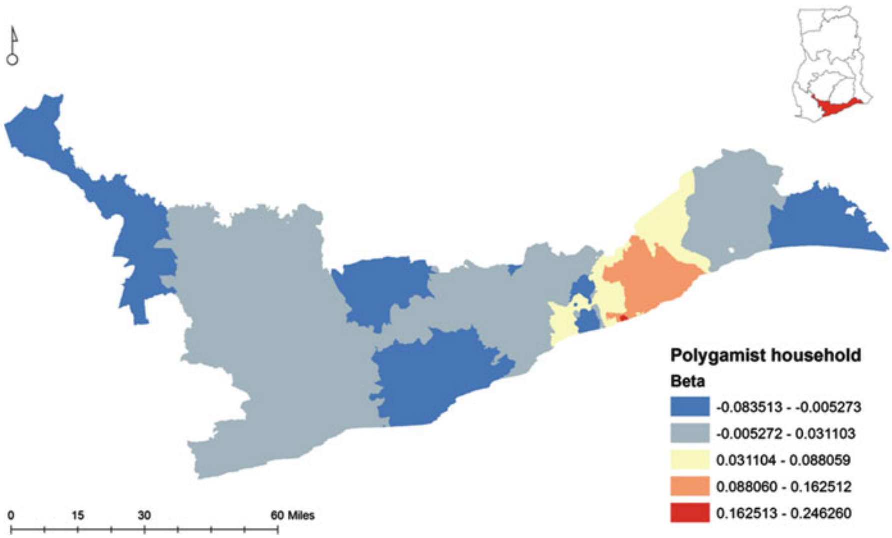

Fig. 9.3 GWR coefficients for polygamist households with CEBz defined as the dependent variable while controlling for urban, household head, housing and women's characteristics

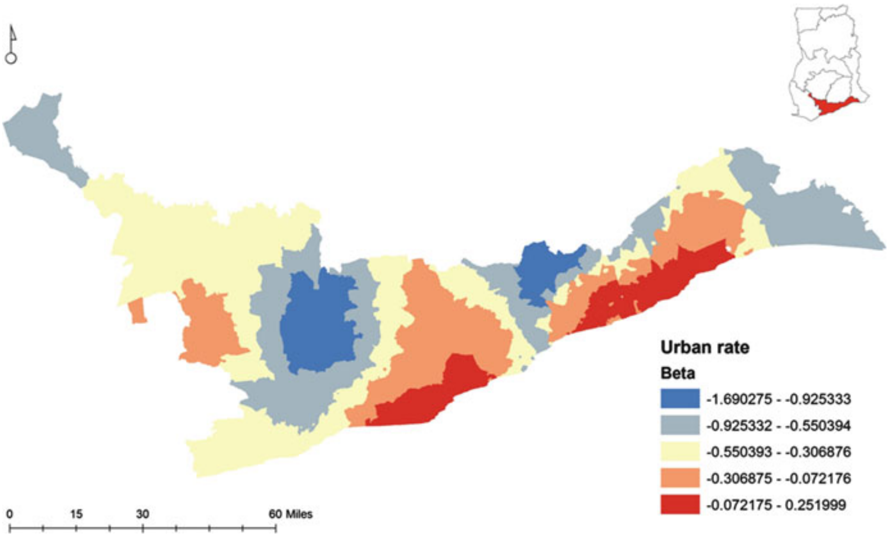

Fig. 9.4 GWR coefficients for the urban rate variable with CEBz defined as the dependent variable while controlling for household head, housing and women's characteristics

9.7 Conclusions

The hypothesis driving this research is that decision-making involving reproduction in West Africa is influenced by the social interaction of family members in the household. Measurement of these complex social interactions presents a challenge for demographic research. For the purpose of this study the assumption was made that indicators of household structure serve as a proxy for the nature of interpersonal relations that are taking place within the household. Furthermore, I suggest that for the case of Ghana the correlation between household structure and fertility is not constant across space.

Results from linear regression for Greater Accra and the Central regions indicate that households where *grandchildren of the head*, *parents of the head* and *foster children* resided had significantly higher fertility levels than other types of households. At the same time households located in more urbanized EAs had significantly lower fertility levels compared to less urban EAs. After applying a spatial filter to the independent variables the effects of independent variables changed in the regression analysis. Both spatial and non-spatial components of the variable *grandchildren of the head* residing in the household have significant positive impact in reproductive levels. On the other hand the spatial and non-spatial components of the urban rate variable are associated with reproduction levels in two different statistical directions. While the spatially-filtered component of the urban rate variable has a positive effect on fertility levels, its spatial component has a significant negative effect on it. Results from the GWR indicate that with varying degrees of urbanization household structure can have differing effects on reproduction levels. For example the variables "parent of the head residing in the household" and "polygamist households" have a range of positive and negative effects in fertility levels.

The study of urbanization and its effects on demographic trends is limited by the definition of the concepts of "urban" and "rural" spaces, a distinction that varies from country to country based on a wide variety of preconditions such as density, infrastructure, services, and population size (Tacoli 1998). In this chapter, the use of a continuous measure of urban rate extracted from satellite imagery provides a more detailed characterization of the place of residence as compared to the rural-urban dichotomies defined in traditional household censuses and surveys. The results demonstrate the potential for accurately characterizing urban phenomena and its effect on demographic trends using an increasingly available online public archive of satellite imagery. This is of particular importance when working in data-poor developing countries where socioeconomic data are rarely collected due to sociopolitical or logistical constraints. Automated processes to classify remotely sensed imagery and construct similar urbanization metrics, such as those discussed in earlier chapters, may one day facilitate rapid demographic analyses of census data at larger spatial scales.

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Chapter 10
Fertility in Context: Exploring Egocentric Neighborhoods in Accra

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As recently as 1988 the total fertility rate (TFR) in the Greater Accra Region of Ghana was 4.7 children per woman (compared to the national average of 6.4). The most recent (2008) Ghana Demographic and Health Survey estimates the TFR in the Greater Accra Region to be down to 2.5 (compared to 4.0 for the country as a whole). Within the core metropolis of the Greater Accra Region—the Accra Metropolitan Assembly or Accra Metropolis, our data (described below) suggest that fertility has dropped to near replacement level as of 2008–2009. Within Accra, as throughout the nation, this has been accomplished especially through a delay in marriage and reductions in exposure within marriage, accompanied by an increase in the use of abortion and modern contraceptives. At the same time, reported levels

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of abortion and contraceptive utilization remain substantially below what would be expected in order to achieve Accra's low fertility. Thus, the exact proximate determinants of the decline remain a bit murky.

10.1 Background

10.1.1 Fertility Transitions in Sub-Saharan Africa

Fertility transitions throughout sub-Saharan Africa have been somewhat different than expected by standard demographic theory. Caldwell et al. (1992) argued that "the social structure of West Africa presents in its strongest form sub-Saharan Africa's resistance to fertility decline" (p. 212). These social structure features include: (1) the importance of ancestry and descent which makes childlessness or rearing few children an act of evil; (2) separation of reproductive decision-making from the cost of childrearing because of separate households or household budgets, aggravated by lack of claim of women on their husband's property which meant that their security derived solely from their children; (3) strength and safety in numbers in an economic system based on communal lend tenure and shifting agriculture ["up to today, large families often prosper most, even in nonagricultural activities, because in commerce they can rely on relatives, and large numbers of related persons can secure monopolies, distort markets, or obtain privileges by influencing officials and politicians or by frightening ordinary people"—Caldwell, Orubuyole and Caldwell (1992:214)]; and (4) a general belief that family planning was foreign and incompatible with African culture.

Even at the time they were writing, however, the authors understood that changes were occurring, and they singled out Ghana as the country that had initiated the rise of schooling for females, with the expectation that education would place women into the modernizing economy. But, in a society in which premarital sex is common, a pregnancy to a girl in school could shatter her dreams and shutter her future. For this reason, "abortion has long been a practice associated primarily with schoolgirls" (Caldwell et al. 1992:216). They go on to suggest that the fertility transition in Africa is likely to be one characterized by a similarity in contraceptive use and fertility decline across all age groups. Single women are motivated for the reasons just mentioned—postponing pregnancy allows a postponement of marriage, which then allows a woman to have a career and increase her earning capacity. Younger married women will postpone births to lengthen birth intervals, and at older ages the burden of large families in an era of declining mortality (where more children survive) will lead to women seeking ways to limit fertility.

A decade and a half later, Timaeus and Moultrie (2008) took up the idea from Caldwell and his associates and argued that fertility transitions in Africa may be driven neither by the conscious desire for smaller families nor by the strategy of attempting to space births, but rather by the postponement of pregnancy (or "pausing" as discussed by Bledsoe et al. 1994), which may or may not have anything to do with reproductive preferences per se (e.g., prolonged breastfeeding to improve the health of the child; or avoiding intercourse because of economic and/or familial instability). Postponement has the largely unintended consequence of lengthening birth intervals and thus, since women have a limited number of fecund years, of lowering the overall level of fertility. The key determinant of postponement among Africans in South Africa is, according to Timaeus and Moultrie, the economic uncertainty facing families, and this can happen to women at all ages, consistent with the idea that the fertility transition in Africa occurs equally at all ages. They posit this in terms of apartheid in South Africa, but economic uncertainty is arguably endemic among sub-Saharan households. One could argue that economic circumstances historically were not good, but they were predictably not good. With increasing modernization, the possibility exists of improving one's circumstances, but it is a very difficult and uncertain process. To the extent that modernization has been imposed from the outside, rather than being endogenously induced, a family's reaction to these circumstances may then be uncertainty, leading to a decision to wait awhile until having a first or subsequent child. Timaeus and Moultrie (2008) quote Cleland and Rutstein (1986:85) who suggested that "postponement and limitation constitute a motivational continuum, rather than a sharp dichotomy, with considerable change along the continuum over time." Recent analyses of Demographic and Health Survey data for Sub-Saharan African countries (including Ghana) has underlined the distinctiveness of birth postponement across all ages and parities as a feature of the African fertility transition (Moultrie et al. 2012).

Another important difference in the African fertility transition is the role of men in the decision-making about reproduction. To a certain extent, this speaks directly to Coale's (1973) first precondition for a fertility decline—the perception on the part of women, or couples, that reproductive decisions are theirs to control. As Dodoo and Frost (2008) have pointed out, African couples may well believe that fertility is within their sphere of control, but both men and women may believe that men have more authority to make that decision than do women. This is more nuanced than implied by Coale. His perspective would imply that if women are not in charge of their reproduction or if couples are not making the decision cooperatively, then the first precondition for a fertility decline has not been met. Yet, among African couples there may be considerable variability in the extent to which women have influence over their husband's decision with regard to desired family size or spacing, or postponement. And, in agreement with Timaeus and Moultrie, we argue that the disagreement and/or uncertainty that may exist among couples about reproduction will increase the probability that women—especially educated women in an urban environment—will postpone a birth rather than making a firm decision about spacing or stopping. Indeed, this same set of attitudes is consistent with research showing that fertility preferences among women in sub-Saharan are unstable (Bledsoe et al. 1998; Kodzi et al. 2010).

The dominance of men in the family, especially when it comes to issues of sexual activity and reproduction, suggests to Dodoo and Frost (2008) that even education cannot be expected to have the same impact on fertility in Africa as it has elsewhere. This is partly because the school system itself may instill sexist ideology and practices, and partly because education alone will not necessarily change gender roles. A legal framework of protection of women against abusive husbands is also required, and there is as yet little evidence of that in the region. A study of women's empowerment in four sub-Saharan African countries has demonstrated the variability in women's empowerment, and its relatively unstable relationship with fertility levels. Upadhyay and Karasek (2010) used data from the Demographic and Health Surveys in Guinea, Mali, Namibia, and Zambia to calculate measures of women's empowerment and then related that to women's actual and desired family size in comparison to their husband's preferences, based on linked couple data from the separate men's and women's surveys. "In all four countries, a husband having a greater ideal number of children was associated with the woman having a greater ideal number of children, regardless of her level of empowerment" (p. *i*). This is a reminder that reproductive attitudes and behavior do not take place solely at the level of an individual woman. They are influenced in the family setting, including by the interaction of a woman with her husband and other kin, as well as by friends, all of whom may be influenced by mass media and other communal messages. Even more complex relationships between men and women are described by Johnson-Hanks (2006), and the ways in which these family relationships can influence demographic trends has been discussed in an innovative theoretical context by Johnson-Hanks et al. (2011).

10.1.2 Neighborhood Influences on Reproductive Decision-Making

It is very difficult methodologically to untangle all of these influences, but in general we can apply "the first law of geography" (Tobler 1970, 2004)—that all things are related to one another, but near things are more related than distant things. This means that even though relatives living in a rural region well beyond the city may have an influence on a woman's decision-making about having a child (now, later, or not at all), we can expect that people more geographically proximate in her life will have the biggest influence. This means that we must try to characterize the "environment" in which she lives. Ecological/contextual influences on individual behavior derive from a long line of research in the social sciences, as noted in Chap. 1 and, of course, individual behavior feeds back into the way in which neighborhoods are "constructed" both physically and socially. There is now a reasonably large literature on the effects of neighborhoods on health and mortality, focusing especially on non-spatial multilevel analysis (Halonen et al. 2012; Mowafi et al. 2011; Msisha et al. 2008; Kawachi and Subramanian 2007). There has been much less focus on the contextual effects on fertility, as we have noted elsewhere (Weeks et al. 2004, 2010), and it remains a challenge to specify which aspects of a "neighborhood" bear directly on both health-related and fertility-related behavior and to identify the exact processes by which neighborhoods as places, and people as individuals, interact.

Are women influenced in their reproductive behavior by the environment in which they live? There is a substantial literature on the relationship between health behaviors/outcomes and the kind of neighborhood (the context) in which one lives. While the magnitude of effects varies, the overall conclusion has been that many different types of behavior are related in some way or another to the environmental context. There remains, however, a host of unresolved theoretical and methodological issues (see, for example, Chaix et al. 2009). The principal theoretical concerns relate to what is expected from the environment—how does the environment influence behavior? Will some types of environments influence certain behaviors differently than others? Should we be focusing on residential context or activity spaces or some other conceptualization of the environment in which a person lives? (Kwan et al. 2008; Matthews 2008). This latter issue flows into the methodological question of how a neighborhood or, more generally context, is to be measured. The vast majority of research has employed a territorial measure of neighborhood and assumed that all people within a defined territory/neighborhood/context are affected in the same way by that environment. A new set of studies, small in number so far (e.g., Logan et al. 2011; Matthews 2011; Chap. 8 in this volume), looks at egocentric neighborhoods—environmental contexts that are unique to each individual. Our interest is especially in the relationship between reproduction and the environmental context in which women live, following up on our earlier finding that certain kinds of territorial neighborhood boundaries in Accra do help to explain the variability in fertility from one part of the city to another (Weeks et al. 2010). We want to know if this conclusion is stronger (our expected alternative hypothesis) or no different (the null hypothesis) when we define the environmental context based specifically on the location of a woman's household—an egocentric neighborhood.

Note that we do not assume direct causality between the environment and fertility. Such causality is conceptually viable when the dependent variable is, for example, blood pressure that might be influenced by neighborhood geography, such as opportunities for walking or other physical exercise, or a respiratory disease that might be influenced by local environmental air pollution (see, for example, Sallis and Owen 2002; Lee et al. 2009). The number of children a woman bears is unlikely to be directly affected by the place in which she lives. Rather, we view measures of the physical and built environment as proxies for (indicators of) other latent characteristics/unmeasured variables (beyond her or her partner's sociodemographic characteristics) that influence the decisions that women make about marriage, fertility preferences, and the use of various methods of fertility control to achieve the preferred family size or, of course, to postpone a pregnancy. The neighborhood environment in this instance might represent a proxy for the likelihood that certain kinds of attitudes and behavior will be shared among women (a diffusion effect). A novel element in our research is that we define the environmental context in terms of the physical and built environment as classified from high spatial resolution commercial satellite imagery. We then create buffers (isotropic zones) around the GPS point representing each woman's household. We use buffers of varying size and explore multiple aspects of the imagery (and other variables) to test the sensitivity of fertility rates to different egocentric contexts.

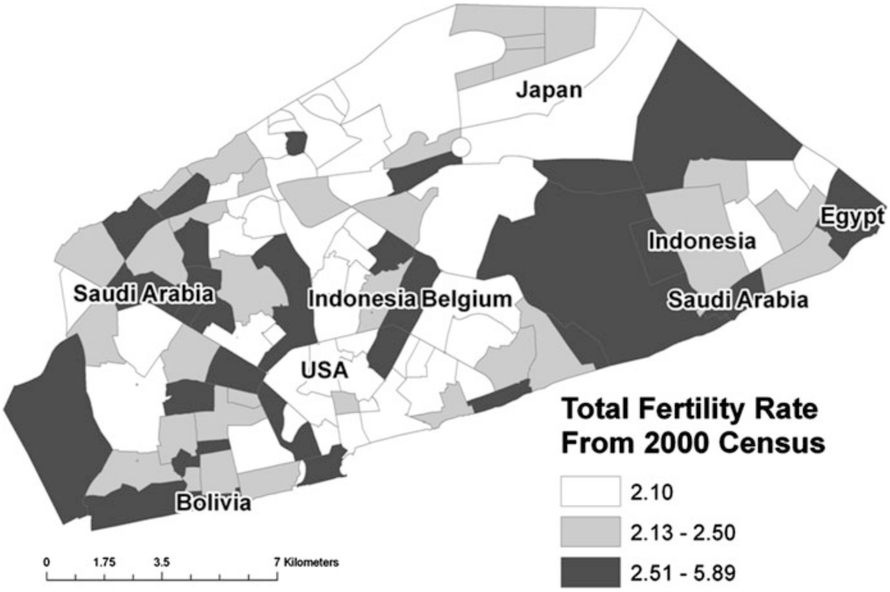

Fig. 10.1 Neighborhood fertility levels based on TFR

10.1.3 Neighborhoods and Fertility Levels in Accra

The 2000 Census of Population and Housing in Ghana asked not only about the number of children ever born to women, but also the number born during the 12 months prior to the census. These data allow us to calculate estimates of the age-specific fertility rates and thus the total fertility rate (TFR). For Accra the resulting TFR was 2.37 children per woman during the year preceding the 2000 census. There was (and still is), however, considerable spatial variability around the city in fertility, as measured at the neighborhood level. We have defined 108 neighborhoods in the city, using field work and focus groups to modify an initial set of 88 neighborhoods created by Ghana Statistical Service. We call these the field-modified vernacular (FMV) neighborhoods (Weeks et al. 2012; Engstrom et al. 2013), as discussed in Chaps. 1 and 2, using the term "vernacular" to refer to neighborhood boundaries that are broadly recognized and agreed to by residents of a given city, in this case Accra, even if they may have no premeditated and formal definition. These are the place names, for example, that would be provided to a taxi driver, especially since there is no comprehensive street address system in Accra (Weeks et al. 2010).

The spatial pattern of TFR by neighborhood is shown in Fig. 10.1, where it can be seen that there are swaths of the city with below replacement TFRs, many neighborhoods where it is 2.5 or higher (with a high of 5.9 in the North Industrial Area, populated by new migrants to the city), and a nearly equal number of neighborhoods that are above replacement, but not as high as 2.5. To better illustrate the variability, we have labeled representative neighborhoods according to a country that currently has the same TFR as that neighborhood. Thus, the middle class neighborhood of Adabraka—where our project office was located—has a TFR similar to the United States. The Cantonments neighborhood—in which the US Embassy is located—has an even lower TFR, comparable to Belgium. The predominantly Muslim neighborhood of Nima has a level of fertility comparable to the world's most populous Muslim nation, Indonesia. This is also the level of fertility in Teshie. Fertility levels are higher in Nungua Salem and are comparable to Egypt. Even higher levels are experienced in the slum neighborhoods of Teshie Old Town and North Ordokor, where fertility is similar to that among women in Saudi Arabia.

There are two important conclusions from this analysis. First, although attention has been drawn to the divergence of urban and rural fertility in Africa (Garenne 2008), this is the first detailed description of differentials within a single urban area. The differences are stark and are not a function of the age composition of the neighborhoods since the figure shows the total fertility rate calculated from the age-specific rates. Secondly, there was a notable geographical clustering of fertility levels, which of course could be driven by different combinations of the proximate determinants, but nonetheless it is striking that differences in fertility levels have such a strong geographical expression in a limited geographical area.[1]

The TFR from the census data for each neighborhood measures the current fertility, but provides no sense of what might have been happening among women living in that neighborhood over the past several years. Furthermore, because of the relatively small number of births in some neighborhoods in the year preceding the census, the TFR at the neighborhood level, even with the aggregation of EA-level data into the defined neighborhoods, may not be an overly robust measure of reproductive patterns. Thus, in addition to the neighborhood level TFR, we also calculated an age-standardized measure of children-ever-born to women of current reproductive age. We have calculated the number of children born to date for each woman (her parity) as a standard deviate relative to women of the same age (measured in 5-year age groups), which we label CEBz (see Chap. 9 for similar calculations). The advantage of CEBz is that it provides a single age-adjusted measure (standardized variable) that can be directly correlated with the environmental context measure that is the focus of this research. Since it is a relative measure comparing women only to their own age cohort, it thus potentially confounds reproductive tempo (timing) and quantum (amount) (see, for example, Bongaarts and Feeney 1998). The more traditional way to approach the measurement of fertility at the individual level is to use the number of children ever born alive (CEB) to a woman while controlling for age in the regression model. We found, however, that the combination of CEB and age is a good predictor of CEBz

[1]The distance from the northern edge of Accra near the University at Legon to Jamestown on the coast is no more than 11 km.

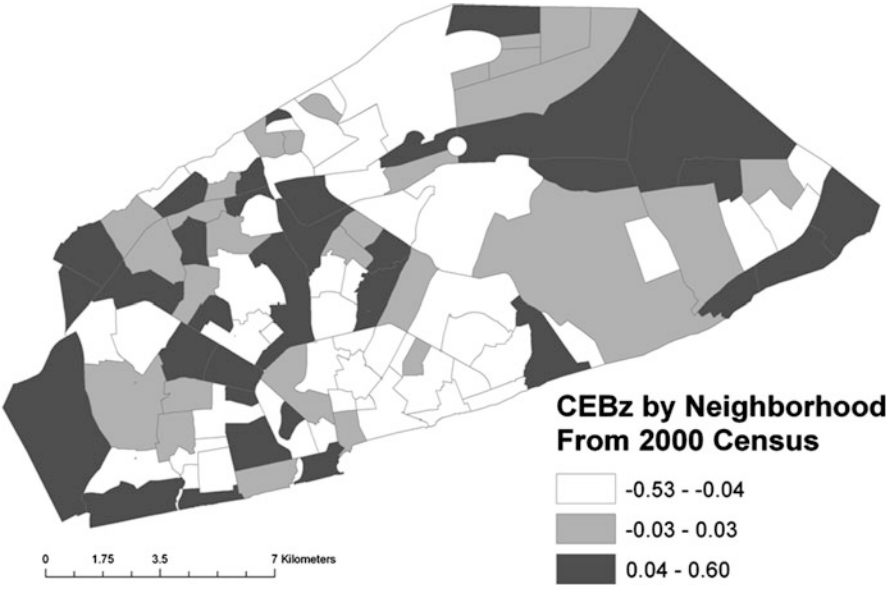

Fig. 10.2 Neighborhood fertility levels based on CEBz

($R^2 = 0.85$), so we feel that the CEBz measure is a robust index of reproductive levels. This approach also works well in this context since it is relative rather than absolute levels of fertility that are we are focusing on in this chapter.

Figure 10.2 shows the average CEBz for each of the FMV neighborhoods, where the lightest shade indicates neighborhoods in which the average woman had borne fewer children than the average for her age, light grey indicates close to the average, and dark grey indicates places where women are above the average. The pattern is similar, but certainly not identical to the pattern for TFR: Spearman's rank-order correlation coefficient between these two measures is 0.45 across the 108 neighborhoods.

To assess the effects of neighborhood on fertility outcomes, we need a measure of fertility that combines current and lifetime fertility since we are assuming that neighborhoods can have both current and prior effects on reproduction. We argue that since migration is substantial within the city and between the city and other places, using the current fertility estimates from the births in the last year before the census may not reflect the true effects of neighborhood. In this analysis, we are less concerned with absolute levels of fertility than with relative differences across the neighborhoods. For this reason, we combined the two values of current and lifetime fertility by calculating which neighborhoods fell into the same quintile with respect to both TFR (current fertility) and CEBz (deviations from a lifetime measure of fertility). There were 10 (out of 108) neighborhoods that fell in the lowest quintile of both TFR and CEBz, and they tend to be in the geographic middle of the city, from Legon (the University of Ghana) in the middle north, down past the airport and the embassy area of town to the Ministries in the lower middle, near the beach. By contrast, 11 neighborhoods fell into the top quintile of both TFR and CEBz. These tend to be located in the western and eastern edges of the city. The remaining neighborhoods are divided among those in which the TFR and CEBz are the same, but not at either extreme (these are scattered throughout the city), those in which the TFR quintile is lower than the CEBz quintile, suggesting a transition to lower fertility (these are also scattered), and those in which the TFR quintile is higher than the CEBz quintile, suggesting possibly a transition to higher fertility. These are also scattered around the city.

10.1.4 Combining the Aggregate and Individual Levels

The data in Figs. 10.1 and 10.2 make it clear that (a) considerable variability exists in fertility within Accra; and (b) there are observable spatial patterns in that variability. Spatial variability indicates that women in some parts of the city are more like one another in terms of their reproduction than are women in other parts of the city. This type of clustering suggests an ecological or contextual influence. However, the census data that we have been using have several limitations: (1) they are georeferenced only to the EA centroid, not to a woman's residence, and (2) they tell us how many children a woman has had to date, but nothing about the timing of those children. Our analysis also requires more detail on the proximate and distal determinants of fertility. For these reasons, we turn to the much richer set of data available to us in Wave II of our Women's Health Study of Accra to provide individual-level data on reproductive behavior, while comparing it to aggregated data in a region around a woman's residence that we call her egocentric neighborhood. The disadvantage of these much richer survey data is that there were a very much smaller number of cases than in the census and so there has to be careful linkage of the census and survey data to allow us to exploit the different strengths of the two data sources.

10.2 Data and Methods

For our analysis, we use data from the second round of the Women's Health Study of Accra (WHSA-II), as described in Chap. 1 of this book. This survey was a stratified self-weighting random sample of households designed to be representative of the entire city. From these data, we are able to calculate our two dependent variables of interest: (1) a woman's CEBz; and (2) the length of the open birth interval (here referred to as "postponement") since her last birth. Although the number of completed interviews in WHSA-II was 2,814, the sample size for our analysis is less than that because here we examine data only for women of reproductive age (under age 50). Furthermore, we are interested in neighbourhood spatial effects, so we randomly selected only one respondent from each household, since the strategy in the WHSA-II had been to interview all eligible women in each selected household. Our analysis thus includes data for 1,498 women. As a way of testing how generalizable our results are from the WHSA-II, we calculated the number of children ever born (CEB) to women by age for the entire Accra population in the 2000 census, and then compared that with the CEB in the 200 EAs from which the WHSA-II sample came. We found that the patterns were virtually identical, indicating representativeness and lack of bias in the selection of the sample EAs for the analysis.

As noted above, our major ecological context measure, which we use to predict children ever born and length of postponement, is a proxy variable for the natural and built environment derived from the classification of high spatial resolution satellite imagery, acquired in 2010. The analysis first classified each 0.6 m pixel in the imagery as being vegetation, impervious soil or bare soil. This framework is derived from the V-I-S model of the urban scene developed by Ridd (1995; Ridd and Hipple 2006). The values for each pixel were then aggregated for areas in a circular buffer surrounding each respondent's household. We calculated these values at distances of 100 m through 1,000 m at 100 m intervals. The majority of neighborhoods in Accra have relatively little vegetation, whereas some are quite highly vegetated. Because of the skewness of the distribution, we calculated the natural logarithm of the percentage of the area covered by vegetation as our measure of ecological context. An important methodological difference between territorial neighborhoods and egocentric neighborhoods is that the former represent a second analytical level in a multilevel regression model, whereas the latter are attributes of individuals and are thus analyzed statistically at the same level as other individual characteristics. At the same time, since egocentric zones may overlap among women, we will test and, if necessary, control for the presence of spatial autocorrelation. The egocentric neighborhood buffer radius that we used for our analysis was 300 m, since other variables that are potential predictors of fertility levels peaked in their relationship to CEBz at that distance. Although it is clearly preferable that our ecological neighborhood area be fully populated with data (as is generally true with data derived from the satellite imagery), we also employed two other egocentric neighborhood variables derived from data in the WHSA-II: (1) the average CEBz among all respondents to the WHSA-II within a 300 m buffer around each woman; and (2) the average length of pregnancy postponement among all respondents to the WHSA-II within a 300 m buffer around each woman.

Control variables in the analysis include both proximate and distal predictors of fertility. The major proximate determinants of fertility are those things that directly influence the chance that a woman will get pregnant, including whether or not the woman has ever been married, is sexually active (as an interaction term with being married), is currently or has ever used contraception (including male methods), whether or not she reports ever having had an abortion, and the length of time since her last pregnancy (or since first intercourse for those with no pregnancies), which we use as the index of birth postponement.

The distal determinants are those things that influence the motivation to have children, including education, labor force activity, religion, the household level of living, and housing insecurity. The literature universally suggests that the more educated is a woman, the fewer children she will have. Rather than use categories of educational attainment, we instead use the interval measure of the age at which a woman left school. For those who were still in school, we coded their current age. For those who never went to school (9 % of respondents), we coded their age at leaving school as six, since that would be the normal age at which a person begins school. It is less clear that being in the labor force will be negatively related to childbearing, but in Accra having a job that is not self-employment is likely to be associated with having fewer children. Thus, we differentiate women who are employed by the government or by a private business from all other women.

Additionally, we have calculated a measure of household wealth, based on the number of consumer goods owned by the household, which is generally negatively associated with fertility. We also predict that women who are living rent-free or perching in their housing situation will perceive their situation to be less secure and thus less likely to want children right now. This lack of housing security may be associated with the recency of migration to Accra, measured as the number of years she has lived in Accra. Finally, religion cross-cuts these variables and so may exert an independent effect on fertility. In Ghana, as elsewhere in sub-Saharan Africa, we can expect that Muslims will have higher fertility than Christians. In rural areas, those who follow traditional religions tend to have the highest fertility, but the proportion of people reporting that they exercise traditional religious practices in Accra is very small. Table 10.1 lists the basic descriptive statistics for each of the variables in the analysis.

One statistical approach to this analysis is structural equation modeling (SEM or 2-stage least squares), but in this analysis we are going to use a more straightforward set of OLS regression models, because it is compatible with the type of spatial analysis that we are undertaking, which includes tests for spatial clustering and spatial heterogeneity (spatially varying regression coefficients).

10.3 Results

10.3.1 Ordinary Least Squares Regression Results

Our analytical approach is to look first at the proximate factors influencing CEBz and pregnancy postponement. We then add the distal factors to the model, and finally we examine whether or not the egocentric neighborhood measures (ecological factors) add to our explanatory power. The data in Table 10.2 indicate that the proximate determinants alone (the first model) are only weakly predictive of fertility, producing an overall adjusted R-squared of 0.099. Only two of the five proximate determinants are statistically significant: postponement and having ever

Table 10.1 Descriptive statistics of variables in the analysis

Variables	Mean	Std. Dev.	Minimum	Maximum
Dependent				
CEBz	−0.02	0.97	−0.84	4.93
Proximate				
Postponement—years since last pregnancy	8.22	6.39	0	44
Interaction of ever-married and sexually active	0.46	0.50	0	1
Ever married	0.71	0.45	0	1
Ever used contraception	0.60	0.49	0	1
Had an abortion	0.17	0.37	0	1
Distal				
Household wealth score	−0.04	0.92	−1.91	2.43
Age left school	16.74	5.75	6	45
Housing insecure	0.30	0.46	0	1
Muslim	0.14	0.34	0	1
Employed in the government or private sector	0.17	0.37	0	1
Average years of residence in Accra				
Ecological				
Ln of percent vegetation at 300 m radius	2.20	0.86	−1.19	4.52
Average CEBz in 300 m radius	0.67	0.62	−0.81	8.80
Average years of pregnancy postponement in 300 m radius	8.3	2.6	1.0	27.0
Valid N	1,320			

been married. In both cases they are in the expected direction, with a longer postponement period being associated with lower fertility, while having been married is associated with higher fertility. The other three variables are also in the expected direction, even if not statistically significant.

When we add the proximate determinants into the model, the explained variance increases slightly to 0.127, with birth postponement and being ever-married emerging as the two most important predictors, followed by housing insecurity, years in Accra, and education (see Model 2 in Table 10.2). None of the other distal determinants is statistically significant, although all relationships are in the expected direction. Finally, we add into the model our three ecological variables, based on data within a woman's 300 m ecological neighborhood (Model 3 in Table 10.2). None of the three makes a statistically significant contribution to our understanding of fertility. This is true even on their own, regardless of the presence of the distal and proximate determinants. The only difference is that with the egocentric neighborhood variables in the model, the household wealth score coefficient tips up just enough to become statistically significant.

The story might have ended there in a classical regression analysis, but an examination of the standardized residuals of the regression model with CEBz as the dependent variable and the egocentric neighborhood variables as predictors revealed a strong pattern of heteroscedasticity produced by a statistically significant level of spatial autocorrelation (Moran's $z(I) = 18.9$), indicating a latent spatial

Table 10.2 Regression results with CEBz as the dependent variable

	Model 1			Model 2			Model 3		
	Beta	t-score		Beta	t-score		Beta	t-score	
Dependent									
CEBz									
Proximate									
Postponement—years since last pregnancy	−0.212	−7.509	*	−0.172	−5.989	*	−0.178	−6.083	*
Ever married	0.184	5.656	*	0.170	4.990	*	0.168	4.817	*
Ever used contraception	0.036	1.286		0.047	1.701		0.049	1.759	
Had an abortion	−0.045	−1.678		−0.039	−1.435		−0.037	−1.342	
Interaction of ever-married and sexually active	0.026	0.781		0.027	0.793		0.015	0.449	
Distal									
Housing insecure				−0.090	−3.418	*	−0.092	−3.444	*
Age left school				−0.069	−2.371	*	−0.070	−2.398	*
Years in Accra				−0.084	−3.047	*	−0.067	−2.378	*
Household wealth score				−0.054	−1.941		−0.064	−2.152	*
Employed in the government or private sector				−0.045	−1.644		−0.047	−1.677	
Muslim				0.034	1.290		0.034	1.234	
Ecological									
Ln of percent vegetation at 300 m radius							0.042	1.437	
Average CEBz in 300 m radius							0.015	0.536	
Average years of pregnancy postponement in 300 m radius							−0.027	−0.962	
Adjusted R-squared	*0.099*			*0.127*			*0.123*		

pattern that was not being picked up by the OLS model. Further diagnostics indicated the presence of spatial heterogeneity in the data. This is also known as spatial non-stationarity, or a pattern of spatially varying relationships (Fotheringham et al. 2002).

10.3.2 Geographically Weighted Regression Results

We examined the relationships in a geographically weighted regression (GWR) and found that the global adjusted R^2 based on predicting CEBz from the amount of vegetation within a 300 m buffer around a woman's housed jumped to 0.14. In other words, the relationship between CEBz and the ecological percent of vegetation in the 300 m zone surrounding a woman's house varies from one part of the city to another. There are specific pockets of the city where the relationship exists (with adjusted R^2 values as high as 0.23) and others where it does not exist. When using the average length of postponement among women in the 300 m buffer, the adjusted R^2 was virtually identical at 0.13, ranging from a low of zero in some neighborhoods to a high of 0.28 in others. Using the average CEBz of women within the buffered zone, the GWR adjusted R^2 was 0.16, ranging from zero to 0.43.

The individual-level variables that were the statistically significant predictors of the spatially varying egocentric neighborhood variables differed somewhat according to the egocentric variable under consideration, as would be expected since the three egocentric neighborhood variables were not themselves correlated. Women for whom CEBz was associated with the percent of vegetation in their egocentric neighborhood had higher than average fertility, less vegetation than average, were more sexually active than average, and had lower household wealth scores than average, based on p-values of 0.05 or less. Women for whom CEBz was associated with the average length of pregnancy postponement among other women in their egocentric neighborhood had lower than average fertility, were more likely than average to be living in an insecure housing arrangement, and had less household wealth than average, again based on p-values of 0.05 or less. Finally, women for whom CEBz was associated with the average level of fertility among other women in their egocentric neighborhood had higher than average fertility, and were more likely than average to be Muslim.

These results suggest the different routes to measured levels of fertility within Accra. On the one hand, low levels of household wealth are associated with higher fertility for sexually active women in low-vegetation neighborhoods, but those same low levels of household wealth are also associated with insecure housing and lower-than-expected fertility. Finally, we can see that in at least a few parts of the city, clusters of Muslim women (mostly migrants from the northern part of Ghana) are associated with higher-than-average fertility.

The neighborhoods in the city where these different relationships exist are shown in Fig. 10.3a through c, in which we highlight the neighborhoods in which a reasonably high proportion of women exhibited a local R-squared value of at least 0.10 for the relationship between her CEBz and one or more of the egocentric neighborhood variables. We used only those neighborhoods for which there were at least five women in the neighborhood (range = 5–90). Teshie is the most unusual neighborhood in that its 40 respondents had relatively high local R-squared values for all three of the egocentric neighborhoods. Among neighborhoods with a high local R-squared specifically related to vegetation (panel A), the three highest (Teshie, Alajo, and Jamestown) were spread out around the city.

The three high neighborhoods with respect to postponement of children as the measure of an egocentric neighborhood (panel B) include Teshie, Pig Farm (which is adjacent to Alajo, and Abossey Okai). There are several neighborhoods in which the clustering of women with a high CEBz is associated with high individual-level

Fig. 10.3 Neighborhoods by local R-Squared GWR results

fertility, as shown in Panel C of Fig. 10.3. These include Teshie and Alajo, as well as neighbors of Alajo and then a group of neighborhoods on the western edge of the city. Note that all three panels have the same general spatial pattern.

We cross-tabulated the neighborhoods appearing in Fig. 10.3 with those that were in top and bottom quintiles with respect to the census data on TFR and CEBz, as shown in Figs. 10.1 and 10.2. Of the ten neighborhoods that were in the top quintile (highest values) with respect to both TFR and CEBz, three of them were also neighborhoods with a high local R-squared with respect to at least one of the egocentric neighborhoods. Abossey Okai had a high local R-squared for postponement (relatively short in this case), while Bubiashie had a high local R-squared for CEBz (high in this instance), and Jamestown had a high-R-squared for vegetation (low vegetation). None of the neighborhoods that were in the lowest quintile with respect to both TFR and CEBz were among those in which a high fraction of women had high local R-squares for one or more the egocentric neighborhoods. From this we can infer that the observed neighborhood clustering effects are more important as contributors to high fertility, rather than to low fertility.

10.4 Conclusions

Fertility levels are generally low in Accra, Ghana, but there is considerable spatial variability in fertility. At the individual level, it appears that fertility is negatively influenced by the postponement of births on the part of women and positively affected by the marriage of women. Neither contraceptive utilization nor self-reported use of abortion was a significant predictor of fertility. Significant distal determinants include housing insecurity, which lowers fertility, education level, which lowers fertility, and the length of time in Accra, which lowers fertility.

Our implementation of egocentric neighborhoods for women surveyed in Accra, Ghana, however, has yielded a more complex set of relationships with fertility than we had anticipated. The global picture suggests that there is no relationship between the percent of vegetation in a 300 m buffer around a woman's house and her level of fertility. This is different from our finding that, at the neighborhood level, aggregated levels of fertility are related to vegetation, such that more vegetated neighborhoods tend to have lower fertility while less vegetated areas have higher fertility. It is not the vegetation per se that is involved, of course, but rather that vegetation serves as a proxy for the built and social environment that may affect reproductive levels. Nor does the average length of postponement of women in that 300 m buffer, nor the average number of children among women in that 300 m buffer bear any relationship to an individual woman's age-standardized level of childbearing

Further investigation yielded the insight that the relationship between egocentric neighborhood measures and fertility varies geographically. There are some parts of the city in which the relationship holds and other parts where it does not. These spatial clusters seem more likely to occur in areas with high fertility than in those with low fertility. Accra is a spatially complex city, and the patterns of reproduction reflect that complexity in ways that are not typical of western cities. Increasing levels of education have almost certainly contributed to the decline in fertility over time, but employment insecurity and housing insecurity may have contributed to a delay in marriage among women, and to a desire within marriage to postpone children while waiting for economic circumstances to improve. At the same time, these factors (which are admittedly difficult to measure) vary in their importance from neighborhood to neighborhood, perhaps being influenced by a variety of cultural factors including religion, ethnicity, and region of the country from which residents have been drawn.

Finally, we note that it is a very complex process to create variables to represent egocentric neighborhoods, and future research will require greater ingenuity in selecting variables to measure. One potential future avenue is to investigate several additional measures that can be derived from remotely-sensed imagery that might provide more predictive power. For example, women located near boundary areas of a territorial neighborhood (such as along a large road) likely experience a very different egocentric neighborhood than those near the core area of the same territorial neighborhood. While a traditional territorial neighborhood would not capture this difference, an egocentric neighborhood including texture measures or threshold measures derived from the imagery might capture this effect more strongly than the simple percentage cover we use here.

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Part IV
Neighborhood Structure: Implications for the Future Provision of Health Services

Chapter 11
The Sachet Water Phenomenon in Accra: Socioeconomic, Environmental, and Public Health Implications for Water Security

Justin Stoler

Just 10 years ago over a billion people lacked access to an improved drinking water source, and in 2008 this estimate dropped to 884 million (WHO/UNICEF 2011). In 2010 the Millennium Development Goals (MDG) drinking water target, which called for halving the proportion of the global population lacking sustainable access to safe drinking water between 1990 and 2015, was achieved ahead of schedule, though with substantial inequality of coverage by continent (WHO/UNICEF 2012). In 2012 the estimate stood at 780 million, and in 2015 an estimated 605 million people will still lack access to an improved drinking water source (WHO/UNICEF 2012). Despite this progress, the lack of safe drinking water continues to yield a substantial morbidity and mortality burden in the developing world, a burden largely borne by children under the age of 5, and roughly half of the developing world population is affected annually by diseases associated with inadequate water and sanitation (United Nations Millennium Project 2005). With the global population poised to rise from seven billion to over nine billion by 2050 and with nearly all of this growth projected to occur in developing cities (United Nations 2010), the number of people affected by water- and sanitation-borne diseases is more likely to rise than fall over the next decade.

Although MDG drinking water targets have been met globally, sub-Saharan Africa is unlikely to meet these targets regionally. Sub-Saharan Africa contains almost all of the nations in which a minority of the population had access to an improved drinking water source as of 2008, and it is the only region where urban access to piped water (either in the home or at a public tap) *decreased* over the last two decades, from 68 % in 1990 to 55 % in 2008 (WHO/UNICEF 2011). These decreases in urban piped water coverage in sub-Saharan African nations are due to rapid population growth and urbanization brought on by robust mortality transitions

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coupled with delayed fertility transitions that have failed to stabilize population growth. Accra, Ghana, epitomizes many of the challenges faced by developing cities in the effort to provide basic services; the Accra Metropolitan Assembly simply has not been able to put water pipes (among other public infrastructure assets) in the ground fast enough to keep up with its growing urban population.

Accra's drinking water shortages are not due to lack of surface water, but rather to production limitations and poor water resource management (Nsiah-Gyabaah 2001). There are just two water treatment plants that serve the city (Weija Waterworks to the west, and Kpong Waterworks to the east), and demand is so high that at any given time, the Ghana Water Company Ltd. (GWCL) can only produce enough water to fill about half of Accra's pipe network. As a result, GWCL implements a rationing program that is influenced by geography—those living near large capacity water mains and valves may have better access—and by income—the wealthy generally enjoy the best maintenance and service levels—yet rationing still yields considerable spatial heterogeneity of water access across Accra. To fill the gaps between water supply and demand, the last decade has witnessed increased privatization of drinking water resources. By far the fastest growing and most successful form of this privatization has been sachet water.

Known colloquially as *pure water*, sachet water refers to 500-ml sealed plastic sleeves of purified drinking water that have become ubiquitous in Accra and most urban areas in West Africa due to generally high quality and low cost (US$0.03–0.06) for both producers and consumers. While sachet water has been responsible for improving water access in many water-stressed neighborhoods, particularly low-income and slum communities, the discarded plastic sleeves have become a sanitation menace and a contemporary hot button issue in Accra. Plastic sachet wrappers litter the streets and clog drains and gutters in the rainy season, increasing the likelihood of floods and leading to subsequent public exposure to untreated sewage and a mélange of health risks. Sachet water has truly become a double-edged sword in West Africa, and has to date been largely ignored by the international development community even as sachets have become a leading source of drinking water—and plastic waste—in many communities. This chapter summarizes recent changes to drinking water access in Accra over the last decade, highlights the key drivers of the sachet industry's growth and future, and closes by recapping recent literature investigating the links between municipal rationing, sachet consumption, and human health effects.

11.1 Sachet Water: A Brief History

Sachet water represents yet another transformation in the delivery of drinking water in a low-resource or developing world setting. The literature on vended drinking water can be traced back to the influential volume "Drawers of Water" (White et al. 1972), which provided a landmark portrait of household water use in East Africa. Research interest in vended water accelerated in the 1980s (Zaroff and Okun 1984;

Lewis and Miller 1987; Whittington et al. 1989, 1991; Cairncross and Kinnear 1991; Katko 1991), and sachets seem to have first appeared in the late 1990s as a replacement for less-hygienic street-vended water sold by the cup and in hand-tied bags (Stoler et al. 2012b). The heat-sealed, single-use nature of today's sachet water is essentially a small technological innovation that has yielded big implications for product portability, ease of storage, and new plastic waste streams.

Residents of Accra that lack their own piped water connection have several options for drinking water provision, each with its own set of tradeoffs. The traditional and most common source of household water for such residents is the water kiosk, or filling station, at which residents fill their own containers at a set price per volume. The water kiosk itself is typically a large tank or concrete basin that the operator uses to store and sell piped water (and occasionally well water) to others. Quality is generally good, though unit cost is incrementally higher for consumers relative to the cost of water from a personal tap. The kiosk's distance from home, and subsequent logistics of transporting multiple large containers of water, is the biggest challenge for many low-income households who lack access to a car or truck. Safe storage of drinking water is an ongoing concern in this context, as a large body of literature has documented the general deterioration of drinking water quality between the tap and point-of-use (Wright et al. 2004) and related adverse health effects (Gundry et al. 2004). Drinking water may also be delivered by pushcart, donkeycart, or tanker truck; these delivery vehicles are rare, but offer increased consumer convenience at a higher unit cost and do not necessarily eliminate the issue of safe household water storage. Tanker trucks generally serve commercial customers in Accra due to the complications of traffic congestion, and are more common for households in lower-density peri-urban areas. Sachet water, despite even higher unit costs than delivered water, has become a compelling choice in Accra given its convenience, universal availability, superior portability, and obviation of the need for safe storage. It is worth noting that bottled water is readily available throughout Accra, but remains the primary drinking water for only 2 % of the general population (Macro International Inc 2011). The unit cost of bottled water is about 30 times that of sachet water, and thus relegates bottled water consumption to wealthy classes, expatriates, and tourists.

The growing appeal of sachet water over the last decade can be appreciated by examining the shift from piped water to sachets as the primary drinking water source across Ghana. As shown by data in Table 11.1 drawn from the last three Ghana Demographic and Health Surveys (GDHS), most of Ghana's administrative Regions experienced flat or modest growth in piped water access between 1998 and 2008, accompanied by modest increases in sachet consumption. Greater Accra is the lone exception, with piped water reliance tumbling from 84 to 58 % while sachet use soared to nearly 35 %. Sachet water use has indeed been an urban phenomenon, and the highest rates of consumption have recently been linked to the lowest socioeconomic classes in Accra (Stoler et al. 2012a). Although there is evidence in the GDHS that early adopters of sachet water came from higher wealth quartiles (Macro International Inc 2011), suggesting relatively higher levels of disposable income, sachet water's surge has largely been associated with the urban poor (Stoler et al. 2012a, 2012b).

Table 11.1 Changes in the percent of households using piped drinking water and sachet/other water as the primary drinking water source among Ghana's ten regions

	Piped water (%)			Sachet and other (%)		
Region	1998	2003	2008	1998	2003	2008
Ashanti	39.5	37.6	43.7	0.0	0.9	3.7
Brong-Ahafo	21.8	35.1	34.9	0.0	0.4	1.7
Central	58.9	38.6	55.9	0.2	1.6	6.2
Eastern	37.9	31.3	39.3	0.0	1.6	7.8
Greater Accra	**84.4**	**82.2**	**58.2**	**0.0**	**6.4**	**34.5**
Northern	15.9	22.2	24.4	0.0	0.4	1.0
Upper East	14.3	8.9	19.0	0.0	0.0	0.0
Upper West	10.5	7.1	18.8	0.0	0.7	0.0
Volta	12.2	29.7	48.6	0.0	0.8	3.7
Western	33.5	37.4	42.4	0.0	1.0	4.9

Source: 1998, 2003, and 2008 Ghana Demographic and Health Surveys

11.2 The Sachet Industry

The sachet water industry is characterized by a wide variety of participants. The one characteristic common to almost all producers is that they are repackaging municipally-produced water that originates at one of GWCL's two water treatment plants and is extracted from the GWCL pipe network at the point of production. Producers also tend to collocate their facilities along the most reliable corridors of water service. The notion that the extraction of large volumes of water by sachet fillers may adversely affect water service to other customers "downstream" in the pipe network has become a recent, albeit low-priority, concern to GWCL. However, although sachet water originated as a response to Accra's perpetual water shortages, sachet production is now so widespread that it may be creating artificial demand as it diverts increasing volumes of water out of the public network. This privatization of a public good presents interesting social justice tradeoffs, as sachet water fills service gaps in some neighborhoods at the possible expense of reduced service to others.

The specific mechanics, logistics, and quality control of sachet production have been reviewed elsewhere (Stoler et al. 2012b). Industry participants vary from small-scale "cottage industry" players to large corporate manufacturers such as Voltic, Standard Water, Mobile, Ice Cool, and Everpure. There are thought to be thousands of producers nationally with no authoritative count available either from industry groups or regulators. The lack of industry data reflects the varying environments of sachet production: registered, gray market, or outsourced. Registered producers conform to official certification and quality control processes with both the Food and Drugs Board (FDB) and Ghana Standards Board (GSB), and pay standard rates to GWCL for water usage. These regulatory boards estimate that half of all sachet producers—though predominantly smaller operators—may not be properly registered. Gray market producers generally risk ignoring official registration procedures, and may draw water from pirated or otherwise unmonitored pipe connections. Once caught by regulatory authorities, noncompliant sachet fillers operating out of a fixed location generally succumb to registration requirements. More mobile producers—perhaps operating one or two machines out of a shack—may simply move to another location, thus inducing a regulatory cat-and-mouse chase. Fully outsourced models of production present the greatest challenges to regulators, as this business model usually owns no assets. A sly entrepreneur may buy the plastic packaging rolls from a plastics dealer, drop them off at a sachet producer to be filled using excess water capacity for pennies on the dollar, and deliver the product to market in a borrowed truck—all with minimal investment. Nevertheless, regulation has improved in recent years, and it has become increasingly common to read about government seizures of unregistered sachets in Accra's local news outlets.

The sachet industry's growth in response to Accra's water shortages can be summarily attributed to multiple factors. The perception of quality has certainly driven sachet sales relative to other vended options. But the general ubiquity of sachet water across the metropolis has been driven by low barriers to entry in the marketplace, low costs of plastics, weak initial regulation, and little accountability for the plastic waste streams that currently plague Accra.

An estimated 270 tons of plastic waste were generated daily in 2004, the vast majority of which came from water and ice cream sleeves (IRIN 2004). No current estimates are available, but the surge in sachet consumption since 2004 implies that plastic waste generation may be higher by several orders of magnitude. The notion that the excess plastic is literally choking the city may not be exaggeration. Repeated governance failures have created no value for the discarded plastic, and recycling proposals have only recently gained traction in the private sector. The Accra Metropolitan Assembly has convened all sorts of committees to address this problem, most notably a failed 2004 Recycling Task Force, but the lack of robust sanitation services remains an ongoing problem. Non-governmental organizations and the private sector have recently stepped in to raise consciousness and create a market for recycled plastics, but these efforts have yet to make a dent in the city's plastic consumption. Biodegradable sachet wrappers have been in development for years, and may be the best hope of curtailing future plastic buildup. Given the difficulty of policing the sachet industry, government or industry group directives to use biodegradable plastics may not be enough. Biodegradables are unlikely to fully penetrate the market until they are inexpensive enough to replace conventional materials on the marketplace.

11.3 Sachets and Public Health

The street name *pure water* has successfully forged sachets' association with quality in the minds of consumers. In low-income families that dismiss sachets as a fad, sachet water is still often fed to infants due to the perceived higher quality, and

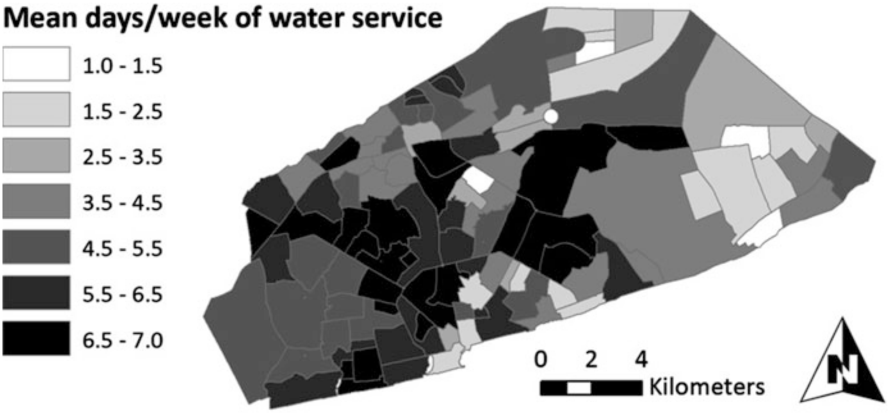

Fig. 11.1 Mean days per week of water service in the Accra metropolitan area estimated by neighborhood from the GWCL 2009 rationing schedule

youths switch to tap water after a few years (Stoler et al. 2012a). Municipal water is treated and generally safe, but rationing introduces constant pressure changes and intermittent backflow, characteristics that are known to adversely affect the bacteriological quality of piped water systems. The biological and chemical quality of sachet water is accepted as quite good in Ghana despite several older studies that have reached contrary conclusions (Stoler et al. 2012b). There have been no studies into the health effects of plastic leachates like bisphenol A—a particular concern given the low grades of plastic used in packaging of a product that is transported, stored, and sold under the equatorial sun—or heavy metals, though life expectancy in Ghana has only recently risen to levels at which long-term exposure to such contaminants could translate into poor health outcomes.

Only one known study has explored the links between municipal rationing, sachet water consumption, and human health effects (Stoler et al. 2012a). The heterogeneity of water service due to GWCL's rationing regime is evident in Fig. 11.1, which shows days of running water by neighborhood in the Accra Metropolitan Area as estimated from 2009 GWCL rationing data. There remain significant connection disparities between high- and low-income neighborhoods, and these inequalities are exacerbated by GWCL's mission to reduce non-revenue water. Non-revenue water refers to water losses attributable to government operations, system leakage, broken meters, and piracy. Although these problems are widespread, GWCL focuses its limited capacity for network maintenance on customers that provide the largest revenue streams with the lowest costs of collection. This practice does not explicitly discriminate against any particular population, but in practice it creates a self-perpetuating cycle of improved service for upper classes while the poor are left behind.

Previous research notes that sachet water consumption is strongly associated with a higher degree of neighborhood rationing (Stoler et al. 2012a), though causality could run in both directions. Sachet consumption is, however, observed to replace consumption of poorly stored water that is often cross-contaminated in low-income households. Sachets are therefore postulated to serve as a sort of natural experiment by interrupting fecal exposure pathways attributable to unsafe household water storage. In a population of 813 children sampled from low-income neighborhoods in Accra, sachet water consumption as the household's primary water source had a protective effect against recent diarrhea episodes after controlling for rationing and other socioeconomic factors (Stoler et al. 2012a). It is encouraging to suppose that regular sachet water consumption—a practice often shaped by neighborhood water rationing and poverty—might overcome the many risk factors of the average slum and improve health outcomes, and the literature on drinking water quality suggest that this is indeed plausible (Clasen and Cairncross 2004; Gundry et al. 2004, 2006). But as already noted, this unintended consequence comes at a severe environmental cost, as sachet water in its current form is not a sustainable vehicle for safe drinking water delivery.

11.4 Future Outlook

Taken together, drinking water data from the last three GDHS, data from a low-income household survey in Accra (Stoler et al. 2012a), and additional unpublished data from the Women's Health Study of Accra–Wave II (WHSA-II, as discussed earlier in this volume) all point to a steady increase in sachet water consumption over the last decade, as well as a transition in consumption from upper to lower classes. Between 2003 and 2008, urban sachet use (as a primary drinking water source) grew from 6 to 37 % nationally (Stoler et al. 2012b), and by 2009 most of the growth in sachet consumption is occurring in low-income communities with 50 % of households relying on sachet water according to a sample from Accra's slums (Stoler et al. 2012a). All of these data sources demonstrate increasing reliance on sachet water by younger, poorer consumers, and excessive municipal rationing seems to be an important factor in converting people into sachet customers. There is also little evidence that the higher unit cost of sachets are an obstacle to escaping poverty, as drinking water expenses represent less than 5 % of a household's core daily expenditures among low-income households (Stoler et al. 2012a). This reality may require a reframing of the argument for water as a basic human right, as the burden of fetching drinking water is perceived as more troublesome than paying for it.

The issues surrounding sachet water are full of contradictions and paradoxes. Many of Accra's most indigent residents are drinking some of the highest quality water available, while in Western nations packaged water is sold as a luxury good. At the same time, the poor may unknowingly receive an indirect health benefit from sachet water, yet the plastic wrappers choke drains, thereby increasing the likelihood of exposure to untreated sewage. Finally, while many upper-class residents profit from their stable water connection by participating in the sachet industry, neighboring upper-class residents' water service may be adversely affected, thus potentially reshaping socioeconomic divisions.

Sachet water is certainly a conundrum for officials in Accra, as efforts to regulate sachets have been met with public and/or industry outrage, and no official government policies have been set. Ghana's Parliament has considered banning sachets outright, taxing sachets, and taxing the plastic raw materials used in production, but all proposals have fallen flat. In Ghana's Northern Region, industry and government officials have floated the idea of adding iodine to sachet water to help combat low iodized salt consumption, thus turning sachets into an overt health intervention. Due to its complex tradeoffs, sachet water is likely to be continually tugged in different directions by government officials in Accra and elsewhere. A key issue—and an important cause for policy inertia—is acknowledging the painful marginalization of sachet consumers that would result if a careful transition to another drinking water supply were not adequately planned. Currently there is no such plan on the table.

While no one believes that sachets are a sustainable drinking water source given the accompanying plastic menace, no one—neither consumers, nor regulators, nor manufacturers—believes sachets are going to disappear anytime soon. Accra's policymakers appear to be waiting for a technological breakthrough or grassroots movement to bail the city out of its plastic burden, but such a silver bullet is not yet on the horizon. In the meantime, there are two potential developments worth considering in Accra over the next decade. The first addresses the peri-urban fringe of low-density middle-class settlements that ring the Accra Metropolitan Area and are currently served by tanker trucks and well water. Tankers and wells can generally support populations of thousands of residents, yet these settlements are forecasted to absorb the bulk of Accra's ongoing urbanization and experience the highest growth rates—tens of thousands of residents—over the next few decades (United Nations 2010). These peri-urban communities lack traditional water and sanitation infrastructure assets, and if overwhelmed by growth, may be poised to become the next urban slums. A second, and more optimistic, development is the potential for urban household water treatment and safe storage (HWTS) projects that capitalize on the appeal of the sachet. There is an ever-increasing portfolio of point-of-use water treatment products reaching the African market. A sustainable solution must be inexpensive and convenient enough to replicate the ubiquity of sachet water, and it is not unreasonable to imagine such possibilities over the next decade. Safe water storage and treatment interventions have traditionally been implemented in rural areas where water is scarce and often from unimproved sources. Given the Western experience of urbanization, it is taken for granted that developing cities have stable access to piped water. Clearly this is not the case, and traditional models of urban water delivery would benefit from reevaluation in light of the West African sachet water phenomenon.

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Chapter 12
Healthcare Access in Three Residential Neighborhoods in Accra, Ghana

Godwin Arku, Paul Mkandawire, Isaac Luginaah, and Philip Baiden

This chapter examines social inequalities in health care access in the context of the rapid urban expansion occurring in Accra, Ghana. In the foreseeable future, cities in Sub-Sahara Africa (SSA) will become the predominant social, political, economic, and cultural contexts for the well-being of the majority of the population. Estimates indicate that by the year 2015, for the first time in continent, more than half of the population will live in urban areas (Cohen 2006; UN HABITAT 2011). Already, Ghana has one of the highest urbanization rates in the SSA, with 51 % of the country's 24 million people living in urban areas. Current estimates show that Ghana has an urbanization rate of 3.4 %, with Accra, the capital city, as the most urbanized city in the country.

Emerging studies from SSA reveal that rapid urbanization is exerting pressure on limited urban amenities and infrastructure, as evidenced by poor housing, the growth of slums, congestion and disorganized public transport, poor water supply and sanitation, and deteriorating public security (Bartlett 2003; Owusu et al. 2008; Arku 2009; Armah et al. 2010; Hoffman 2010; Møller-Jensen et al. 2012). Studies also indicate that the unprecedented increase in urban population has profound implications for health of urban residents (Harpham 1995; National Research Council 2003; Montgomery 2009). For instance, even while cities in SSA continue

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to suffer from the high burden of communicable diseases, chronic diseases are also surging, leading to coexistence of distinctively contrasting causes of mortality and morbidity (Halfon and Lu 2010). For example, under-nutrition is a critical factor in maternal and child mortality, but research also shows that the obesity rate is increasing, too, threatening maternal and child survival. An analysis of national-level data from 23 countries in SSA (Magadi et al. 2003) revealed that although the urban poor generally receive better prenatal and delivery care than rural residents, the care received by the urban poor is significantly less than the care received by the urban non-poor. Similarly, using longitudinal data analysis, Jorgenson, Rice, and Clark (2012) found that while infant and child mortality was generally positively correlated with urban slums in developing countries, the correlation was stronger in African countries and has been increasing. This finding suggests that any claims that urban populations enjoy better health or have better access to health services than non-urban populations should be viewed with considerable skepticism.

Urban health inequalities have also been observed in other aspects of health care and health outcomes. For instance, residents in poorer inner city enclaves and informal settlements in South Africa are more vulnerable to HIV than are the residents in more affluent and upscale areas of the urban landscape (Vearey et al. 2010; Hunter 2010). In Nairobi, Kenya, the mortality burden is reportedly higher in slums than anywhere else in the city, and the under-five population living in shantytowns reportedly suffers a higher burden of morbidity and mortality than similar populations in affluent areas of the city (Kyobutungi et al. 2008; Ngungwa and Zulu 2008; Ye et al. 2009). Similarly, low socioeconomic status, as measured by income and housing status, is strongly associated with abortion-related mortality in Lagos, Nigeria, and self-reported health in Accra, Ghana (Fabamwo et al. 2009; Luginaah et al. 2010; Arku et al. 2011). Studies focusing on psychological aspects of wellbeing have also found that the quality of the dwelling unit is an important context of health, as indicated by high incidence of self-reported poor health among urban residents with sub-optimal housing circumstances marked by congestion and tenure insecurity (Arku et al. 2011).

Although these studies are not exhaustive, they nonetheless demonstrate a consistent pattern of disproportionate disadvantages suffered by the urban poor across a range of health dimensions as the urban population increases in SSA. This chapter contributes to the literature by examining how household health care needs are linked to neighbourhood standards of living in three socioeconomically contrasting neighbourhoods in Ghana's largest metropolis, Accra, controlling for theoretically relevant variables.

Recognizing the links between socio-demographics and health care access, this study controls for age, gender, and marital status. Studies have shown that health needs vary by age, with older people having different health entitlements, information about health services, and resources than younger people (Arber and Ginn 1991; Ahmad and Walker 1997). Men and women, too, have different health needs and face dissimilar barriers to health care services (Nikiema et al. 2007; Dixon et al. 2011). In our study, we also control for marital status, given that conjugal relationships and gender relations that stem from such social relations affect health, health care practices, and well being (Waldron et al. 1996; Nikiema et al. 2007). Additionally, this study controls for socioeconomic status (i.e., education, income, occupation). Individuals with high levels of income or education generally have better knowledge about health services, can more readily afford health care, or possess a relatively high level of self-esteem necessary to adopt positive health behaviours (Janz and Becker 1984; Fisher and Fisher 1992). As a vital emerging context for health, housing also received independent consideration. Housing is a reliable measure of material circumstances and is associated with longevity and other positive health outcomes (Ellaway and Macintyre 1998; Dunn 2002). Thus, this chapter considers how housing tenure, quality, and type, and how ability to pay housing rent are linked to unmet health needs in Accra, Ghana.

12.1 Study Context, Design and Methods

12.1.1 Accra City

Relative to other SSA countries, Ghana has made fairly impressive socioeconomic gains in recent years, but stark spatial disparities in well being remain, with the Upper West Region (UWR) faring the worst (Coulombe and Wodon 2007). As well, dramatic spatial inequalities also exist in urban centers in Ghana. Greater Accra Metropolitan Area (GAMA) is Ghana's national capital and major economic hub. GAMA spans three areas: Accra Metropolitan Area (AMA), Tema Municipal Area, and Ga District. Over the decades, these three areas have converged into a single major urban agglomeration physically, economically, and functionally, although they exist as separate administrative units.

Greater Accra has a current population of about 4 million, up from 2.7 million in year 2000 and 3.2 million in 2005 (Ghana Statistical Service 2010). Given this rapid population growth, GAMA, unsurprisingly, accounts for nearly 17 % of the country's population. This demographic shift has come at a hefty price. The citizens of GAMA face pressing needs for urban amenities, such as quality water, sanitation, and other household environmental services, in all but a few privileged areas where 10–30 % of the metropolitan population enjoy privileged access to the city's social services.

The rapid population growth and physical expansion of GAMA have occurred against a backdrop of an uncertain economic environment. GAMA experienced nearly a decade of economic stagnation in the 1970s prior to the Structural Adjustment Programs (SAPs) in 1980s. SAPs generally failed to restore needed macroeconomic stability and growth and, in some ways, exacerbated poverty and inequalities (Anyinam 1989; Konadu-Agyemang 2000).

Compounding urban difficulties, housing is in critically short supply. The housing deficit in Ghana is estimated at 1.3 million units, and the cost of bridging this deficit is \$17.25bn (GREDA 2008). In GAMA, the growth of the middle class population who lives in gated homes in upscale neighborhoods has proceeded alongside the growth of the population who lives in deficient housing and overcrowded conditions without the resources for decent shelter, access to adequate water, or sanitation facilities. As the gulf between the poor and rich widens in Accra, a large section of the desperately poor is threatened by malaria, respiratory illness, diarrhea, and other infectious and parasitic diseases.

Ghana recently moved to implement a national health insurance policy. The government enacted the National Health Insurance Scheme (NHIS) in 2003, and the scheme was active nationwide within a few years (Agyepong and Adjei 2008). National health insurance schemes are still relatively rare in developing countries, but the widespread unpopularity of the previous cost recovery model of health care fuelled the need to create the NHIS. The NHIS extends to all 138 districts, municipal, and sub-metro areas and covers 95 % of major diseases. Enrollment into the scheme has been impressive, but high dropout rates and declining user satisfaction have caused concerns (Dixon et al. 2011).

12.1.2 Study Neighborhoods

This chapter presents findings of an empirical research study of the relationship between neighborhood livings standards and health, as assessed by unmet need for treatment at the health facility in Accra, the capital city of Ghana. In this study, we collected data from respondents in three spatially dissimilar residential neighborhoods. The neighborhoods are located within the urban core of the Accra metropolis: Labone, Asylum Down, and Nima (see Fig. 12.1). These residential areas are fairly old, and their boundaries are fairly clearly defined, based on Accra Metropolitan Area Planning Department urban planning criteria. We selected Labone because of its relatively high income status within the Accra landscape. The Labone residential area has a relatively good municipal service infrastructure, including steady water supply, a good feeder road network, and upscale housing. These characteristics sharply contrast with characteristics of the Nima residential neighborhood, which remains severely poor. Nima has a poor water supply and sewerage system, poor roads, and a large, overcrowded squatter settlement. Much of the population in Nima consists of in-migrants from other part of the country. Asylum Down occupies an intermediate position between Labone and Nima in that it is a medium-income residential area with a large section of the residents employed in both the formal and informal sector.

12.1.3 Study Instrument and Participants

The study employed a systematic random sampling strategy to optimally select 562 respondents from the three neighbourhoods, and we conducted interviews with one

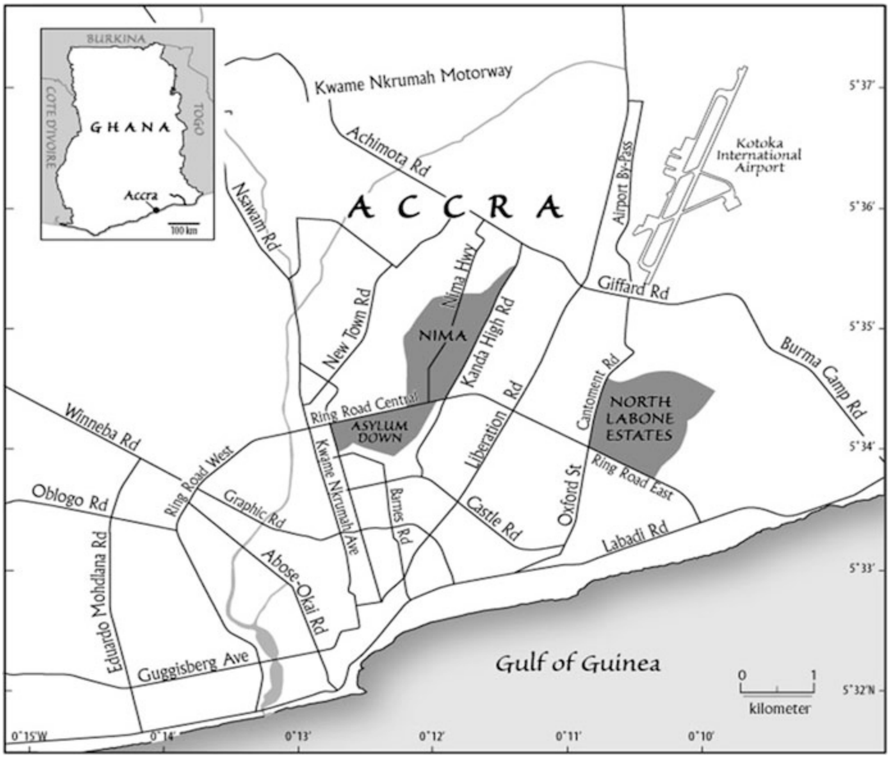

Fig. 12.1 Map of study sites

adult resident in each household. In 2002, AMA began numbering every household in the Accra metropolis. First, we selected every odd-numbered household and then administered the survey face-to-face with the adult aged 18 or older whose birthday was closest to the day of survey. We also attempted to ensure that the number of respondents was proportionate to the population density of the three neighborhoods. Due to the unavailability of a standardized instrument to gather information on Ghanaian residents' housing conditions and unmet health care needs, we adopted standard questions from studies used mostly in developed countries and modified them as necessary, given the study context and purpose. For a detailed description of the sampling technique, study participants, and the survey instrument, see Arku et al. (2011).

Trained research assistants from the Department of Geography, University of Ghana, administered the survey between May and August 2008 under the supervision of one of the researchers. Every research assistant was fluent in English and the two major languages (Ga and Twi) spoken in the AMA. Of the total sample, 166 respondents were from Labone, 190 were from Asylum Down, and 206 were from in Nima.

12.1.4 Measures

The outcome variable of interest examined in this study was self-reported unmet health care need. The variable was measured as a binary categorical variable. Respondents were asked whether some time during the 2 weeks prior to the study they had felt ill and needed medical care but did not receive it. The difference between health care services deemed necessary to deal with a particular health problem and the actual services received is widely used as a measure of inequalities in access to health care among population subgroups (Chen et al. 2002; San et al. 2004). Respondents who answered in the affirmative were coded as 1; otherwise they were coded as 0.

The explanatory variables included in this study are grouped under demographic variables (i.e., age, gender, and marital status), socioeconomic variables (i.e., neighborhood, income, education, and occupation), and housing characteristics (i.e., home ownership, house type, difficulty paying rent, and house require renovation). Age was measured as a nominal variable with the following reference categories: 18–25 years, 26–35 years, 36–45 years, and 46 years and above. Gender was coded 1 for female and 0 for male, with male as the reference category. Marital status was coded 0 if the respondent was married and 1 if single. Income, education, and occupation were measured as binary variables with the following as reference categories: less than GHC 300, less than Senior Secondary Education, and Professionals/Doctors/Nurses, respectively.

We measured housing tenure arrangement as a nominal variable with the following categories: owned, rented, and other. Respondents who owned their homes were treated as the reference category. Housing type was measured as a binary variable, with respondents living in self-contained houses coded as 0 and respondents living in semi-detached/compound house with other residents coded as 1. With respect to the variable 'difficulty paying rent', respondents who reported having financial difficulties in paying their rents were coded as 1, and respondents who did not report difficulties and those who owned their places of residents were coded as 0. Respondents who believed that their house required renovation were coded as 1; otherwise, they were coded as 0.

12.1.5 Analytical Approach

First, we conducted a bivariate analysis using chi-square test of association to examine whether unmet health care needs were associated with the categorical explanatory variables. Next, we conducted multivariate logistic regression to examine the association between unmet health care need and the set of explanatory variables. We chose to use logistic regression because the outcome variable was measured as a binary variable and the explanatory variables were measured as nominal variables. Variables were considered significant if the p-value was less than .05. We used SPSS 18 (SPSS Inc., Chicago, IL, USA) to perform all analyses.

12.2 Results

12.2.1 Bivariate Analysis

Table 12.1 presents the bivariate results between the dependent variable (unmet health care need) and each of the demographic, socioeconomic, and housing variables under consideration. The bivariate analysis shows no significant association between unmet health care need and age, gender marital status, or financial difficulty in paying rent (see Table 12.1). However, neighborhood is significantly associated with unmet health care need. About 11 % of residents in Labone, 59.5 % of residents in Asylum Down, and 52.9 % of residents in Nima reported having unmet health care needs ($\chi^2 = 96.79$, $p < 0.001$).

All socioeconomic variables (i.e., income, education, and occupation) were also significantly associated with unmet health care need. More than half (54.3 %) of respondents who earned less than GHC 300 per month reported having unmet health care needs, compared to 18.8 % who earned GHC 300 or more per month ($\chi^2 = 63.30$, $p < 0.001$). Regarding educational attainment, 60 % of respondents with less than SSS education reported unmet health needs, compared to 35.8 % among respondents with SSS education ($\chi^2 = 28.82$, $p < 0.001$). Similarly, 66 % of respondents whose occupation was self-employed/trader/unemployed reported having an unmet health need, compared to 33 % among those who reported being professional/doctor/nurse ($\chi^2 = 9.88$, $p < 0.001$).

With respect to housing tenure, 53.7 % of respondents who identified themselves as renters reported having unmet health care need, compared to 30.6 % of respondents who were owner-occupiers ($\chi^2 = 27.48$, $p < 0.001$). In addition, 49.5 % of respondents living in semi-detached/compound house reported having an unmet health care need, compared to 25 % of respondents living in detached and self-contained houses. Finally, 59.7 % of respondents whose houses required major repairs reported an unmet health need, compared to 33.5 % of respondents whose houses did not require major repairs ($\chi^2 = 36.14$, $p < 0.001$).

12.2.2 Multivariate Analysis

Table 12.2 presents the three logistic regression models that examine the odds, or the likelihood, of self-reported unmet health care need while controlling for the effect of demographic, socioeconomic, and housing variables. Model 1 controls for respondents' demographic factors. Model 2 controls for respondents' socioeconomic factors, in addition to the demographic factors. Model 3 controls for the effect of housing variables on the likelihood of having an unmet health care need. The odds ratio (OR) is the ratio of the odds, or probability, of an event occurring in one group to the odds of the event occurring in another group (Agresti and Finlay 1997).

Table 12.1 Sample characteristics of respondents by unmet health care need

Variables	Percentage	χ^2 (sig)
Age		5.21 ns
18–25	33.9	
26–35	46.5	
36–45	42.2	
46 and above	46.7	
Gender		2.10 ns
Male	39.9	
Female	45.9	
Neighborhood		96.79*
Labone	11.4	
Asylum down	59.5	
Nima	52.9	
Marital status		1.40 ns
Married	45.5	
Single	40.5	
Income		63.30*
Less than GHC 300	54.3	
GHC 300 and above	18.8	
Education		28.82*
Less than SSS education	60.5	
SSS and above	35.8	
Occupation		9.88*
Professionals/doctors/nurses	33.5	
Self-employed/trader/unemployed/students	47.5	
House ownership		27.48*
Owned	30.6	
Rented	53.7	
Other	34.7	
Housing type		27.20*
Self-contained	25.0	
Semi-detached/compound house	49.5	
Difficulty paying rent		1.10 ns
No	44.0	
Yes	38.7	
House requires major renovation		6.14*
No	33.5	
Yes	59.7	

$^{*}p < 0.05$; $^{**}p < 0.005$

Table 12.2 Multivariate results examining the association between unmet health care needs and demographic, socioeconomic status and housing variables

Variables	Model 1	Model 2	Model 3
Age			
18–25 (reference category)	1.00	1.00	1.00
26–35 years	1.71 ns	1.78*	1.42
36–45 years	1.99*	2.15*	1.60
46 years and above	2.97**	3.23**	2.38*
Gender			
Male (reference category)	1.00	1.00	1.00
Female	1.39	1.23	1.33
Neighborhood			
Labone (RC)	1.00	1.00	1.00
Nima	6.33**	5.97**	4.68**
Asylum down	4.73**	3.15**	3.02**
Marital status			
Married/divorced (reference category)	1.00	1.00	1.00
Single	0.84	0.97	0.77
Income			
More than GHC 300 (reference category)		1.00	1.00
Less than GHC 300		1.81*	1.68
Education			
SSS and above (reference category)		1.00	1.00
Less than SSS education		1.57	1.44
Occupation			
Professionals/doctors/nurses (reference category)		1.00	1.00
Self-employed/trader/unemployed/students		0.89	0.72
Housing tenure			
Owned (reference category)			1.00
Rented			1.76*
Other			0.76
Housing type			
Self-contained (reference category)			1.00
Semi-detached/compound house			1.21
Difficulty paying rent			
No (reference category)			1.00
Yes			2.60**
House requires major repairs			
No (reference category)			1.00
Yes			1.86*

$^{*}p < 0.05$; $^{**}p < 0.005$

An OR of a magnitude greater than 1 means that the event is more likely to happen, and an OR of a magnitude less than 1 means that an event is less likely to happen.

In Model 1, when we considered the effect of neighborhood and demographic factors on unmet health care needs, we found that gender and marital status are not statistically associated with unmet health care needs. However, age and neighborhood were both significantly associated with unmet health care needs. Respondents in the 36–45 years age group were about two times more likely (OR = 1.99) to report that they had unmet health care needs than respondents in the 18–25 years age group. The odds of unmet health care needs were nearly three times greater (OR = 2.97) among respondents in the 46 years and above age group than among respondents in 18–25 years age group (the reference category). With respect to the effect of neighborhood, residents of Nima were six times more likely (OR = 6.33) to report having an unmet health care need, and residents from Asylum Down were more than four times more likely (OR = 4.73) to report having an unmet health care need, than residents of Labone (reference category).

In Model 2, we control for the effect of socioeconomic variables. The findings indicate that respondents whose annual earnings were less than GHC 300 were nearly two times (OR = 1.81) more likely to have an unmet health care need than respondents who earned GHC 300 or more. Education was marginally associated with unmet health care need, but the findings indicated no significant association between occupation and unmet health care needs. Age retained its significant association with unmet health care needs, and the likelihood of having an unmet health need increased with age. Respondents aged from 26 to 35 years (OR = 1.78), 36 to 45 years (OR = 2.15), and over 46 years (OR = 3.23) were more likely to report having unmet health care need than respondents aged 18–25 years. Neighborhood effect also retained its statistical significance, with residents in Nima (OR = 5.97) and Asylum Down (OR = 3.15) still more likely to report having unmet health care needs than residents in Labone (see Table 12.2).

In Model 3, we considered the impact of housing quality and tenure (i.e., house ownership, house type, difficulty paying rent, and house requires major repairs) on the likelihood of having an unmet health care need. The results indicate that respondents aged 46 years or older were more than two times more likely (OR = 2.38) to have unmet health care needs than respondents aged 18–25 years. Neighborhood maintained its strong effect on unmet health care need. Respondents in Nima (OR = 4.68) and Asylum Down (OR = 3.02) were more likely to report unmet health care needs than respondents in Labone. With regard to socioeconomic variables, only income was associated with unmet health need, and the association was marginal. Compared to house owners, renters were 76 % more likely to report an episode of unmet health care need in the 2 weeks preceding the study. Controlling for all other variables, respondents who had difficulty paying their rents were substantially more likely (OR = 2.6) to report having an instance of an unmet health care need. Finally, respondents whose house required major repairs were more likely (OR = 1.86) to have unmet health care needs than respondents whose houses did not require major repairs (see Table 12.2).

12.3 Discussion and Conclusions

This study examined the links between self-reported unmet health needs and neighborhood and living conditions in Accra, Ghana, to help understand social inequalities in health care access in the country's health system within the broader context of accelerating urbanization. Study findings demonstrate sharp spatial inequalities in self-reported unmet health needs in Accra, which support emerging literature that the rapid urbanization in SSA is accompanied by growing inequalities in health outcomes and access to modern health care services (Harpham 1995; Magadi et al. 2003; Montgomery 2009; Jorgenson et al. 2012).

With regard to poor access to health care among respondents who reported having financial difficulties paying housing rent, whose housing units needed major renovation, and who reported that their homes were in dilapidated condition and needed urgent repairs, the concentration of disadvantage in these subgroups signifies the importance of the social determinants of the health framework (SDH) for understanding health inequalities (Wilkinson and Marmot 2006; World Health Organization 2008). Under the SDH framework, housing is one of the most important strategies for dealing with ill-health and for reducing health inequalities. Poorly constructed houses present physical and environmental hazards to health. The issue of housing tenure is equally important. Tenuous housing tenure and the anxieties it creates are vital sources of health inequalities, as revealed by studies that have reported high levels of poor self-reported health and psychosocial stress among populations living in unstable housing arrangements (Dunn 2002; Arku et al. 2011). For instance, people whose housing circumstances are marked by unstable tenure, a common feature in informal housing and slum areas, are also generally more vulnerable to exploitation by unscrupulous landlords and landladies.

A recent study conducted in Accra revealed this tendency in a context where landlords take advantage of the housing crisis and demand hefty advance rents from sitting tenants, sometimes for a period of up to 3 years in direct contravention of the Rental Board Act (Arku et al. 2012). Poor families are afraid to complain because they are scared of eviction, and many families live in substandard housing that, despite its wretched state, they can barely afford. This tendency of landlords to take advantage of the housing crisis can exert severe financial pressure on poor residents, directly pitting housing needs against health care needs, as suggested by this study. The conclusion is that poor housing conditions do not just expose individuals to health hazards but also undermine access to timely and appropriate care.

The importance of neighborhood, as revealed in this study, draws our attention to understand health care access in the context of place. The findings reveal a clear gradient in access to health care, from the most affluent neighborhood of Labone to the most disadvantaged neighborhood of Nima. Health care access was highest in Labone, followed by Nima, and worst in Asylum Down, signaling a correlation between neighborhood socioeconomic status and health care access. Even after controlling for other factors, such as income, housing, occupation, and socio-demographics, the concentration of health care disadvantages in Nima suggests that individual health in Accra in closely tied to neighborhood status. Nima, like other slum neighborhoods, consists of marginalized sub-populations who are threatened by myriad hazards relative to other urban jurisdictions in Accra (Arku 2008; Dionisio et al. 2010; Owusu 2010).

Remarkably poor access to health care among residents in Nima, as revealed by this study, mirrors structural inequalities in other dimensions of life in Accra. For instance, the expansion of Accra over the last decades has occurred alongside increasing spatial and class disparities in environmental quality, water supply, sanitation, housing, and other social amenities (Fobil et al. 2010; Weeks et al. 2006; Grant 2006; Songsore 2012; Stoler et al. 2012). Slums, and the health deficits they produce, reflect spatial manifestation of urban poverty, social exclusion, and inappropriate government policies in Accra (Ahmad and Walker 1997; Sclar 2003). Strategies for reducing emerging health inequalities across the SSA urban landscape partly lie in pro-poor urban planning policies designed to uplift the welfare of the poor. For instance, providing secure tenure rights to residents in informal settlements can reduce housing uncertainty and related health consequences or can legitimize plans for the municipality to provide social amenities, such as health care, to residents of informal settlements.

Given that Ghana has one of the most touted national health insurance schemes in the developing world, the dramatic differences in access to health care suggest that policies for improving the health status of all population sectors must consider strategies beyond hospital user-fee exemptions and subsidies. These strategies should include measures aimed at improving material circumstances and housing conditions of a growing number of people who migrate to the cities. The Millennium Development Goals of reducing mortality and morbidity from such diseases of poverty as malaria and HIV/AIDS will be difficult to accomplish in rapidly urbanizing regions if sufficient attention is not paid to broader factors that impinge on prompt and timely access to health care.

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Chapter 13
Food Security in Accra

Anna Carla Lopez-Carr

It was difficult to hear her speak over the loud din of neighborhood traffic. Her hands gestured gracefully as she patiently answered all the questions I had prepared in my food security survey. Cristina (whose name has been changed to protect her identity and privacy) was 41 years old, living in a family compound with 19 other adults and a dozen children. Several scrawny goats and a chicken roamed the cement floors of the compound's common area. Laundry was hung neatly to dry beneath the searing equatorial sun not far from the battered cooking area.

She wore an old loose t-shirt and skirt. Her flip-flops were well worn and stained by the ruddy African soil. Cristina could have been any of the number of women I interviewed in Nima, one of Accra's poorest and most crowded neighborhoods (see Chap. 7). She had four of her own children to feed. Her husband was the main wage earner, she explained, and though he was paid once a month, his earnings only really lasted 2 weeks. Since food was the family's largest expenditure, it was her responsibility to make sure they could afford to eat for the whole month. Their diet was heavily based on corn, the cheapest staple at the market, and supplemented with rice, yams, and "banku" (fermented cassava dough). Proteins were hard to come by on little more than two dollars a day (which is a typical level of income in Accra, see Fink et al. 2012). She had other payments to think of, including public tap water, school fees, and rent. And though so far she had managed to adequately feed her family, except for a week or so a month, she had reason to worry. Food prices were rising quickly and wages were not keeping up.

It was the summer of 2007 when I interviewed Cristina as part of my food security survey in Accra, the capital city of Ghana. Though it was hardly front page news at the time, global food prices were barreling upward towards crisis

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proportions. The women I interviewed were well aware of the difficulty that lay ahead. Globally and locally the pieces were falling into place that could throw these women and their families into a state of potentially greater food insecurity.

13.1 What Is Food Insecurity?

Accra, the capital city of Ghana, is hardly a place of food shortages. To the casual observer it may seem that so much of the city's economy revolves around food that one may even assume it is available in abundant quantities. With the break of each dawn, trucks ripe with goods from the countryside rumble to the city's food markets, where vendors lay out their colorful offerings of fruits, vegetables, and pre-prepared snacks beneath their market stalls. Women neatly balancing large aluminum tubs of carrots, bananas, and lettuce on their heads amble down the busy avenues of the city centre. Supermarkets open their doors to the day's customers, and fast-food restaurants begin serving hungry folks on their way to work. Food shortages and food insecurity would seem unlikely in this crowded city of two million people. Indeed, it should be rare. But food insecurity is a more subtle form of going without food, and it affects millions of urban dwellers in the world's poorest countries year round.

The United Nations Food and Agriculture Organization (FAO) defines food security as when *all people, at all times, have physical, social and economic access to sufficient, safe and nutritional food that meets their dietary needs and food preferences for an active and healthy life* (1996). FAO (2000) identifies four principal (scale-neutral) factors of food security: *food availability, stability of supply, food access,* and *biological utilization*. Together, these factors encompass a holistic view of food security which ranges from sufficient food production to sufficient food intake. A complete study of food security would theoretically examine all four areas of food security. In a sense it would trace a "farmer to plate (or stomach)" pathway that would measure the efficiency or success of a food security system. However, the complexity of the interactions between these factors (relationships are not necessarily linear) and the colossal amounts of data needed would require enormous computing resources. Food security studies, therefore, tend to focus on one or two of these areas and are often divided among supply issues versus access issues.

Because supply is generally not an issue in urban areas, my study focused on household *access* to food. In urban areas of developing countries, consumers can spend up to 80 % of their income on food purchases (Maxwell et al. 1999; Aragrande and Argenti 2001). The large proportion of income dedicated to a basic need like food puts households in an economically precarious position. After taking into account other necessary expenditures such as rent, school fees, and health related costs, households have little or nothing left for savings. Consequently, with a rise in food prices, or some other economic shock to the household (e.g., loss of employment, illness, etc.), food consumption may suffer. Therefore, urban households that dedicate a large proportion of their income to food are highly vulnerable to food insecurity. This is compounded by urban households' lack of access to natural resources necessary for growing their own food. Additionally, many of the poorest households buy small quantities of food daily and are unable to profit from buying foods in bulk. With no safety-nets in place to help poor urban households, hunger has become an urban reality.

Urban food and nutritional security in developing countries remains underserved by existing theory on food security. The current body of literature on hunger, famine, and food security in the Global South targets mostly rural communities reliant on subsistence farming or agriculture-related livelihoods (Kracht and Schultz 1999). In this body of literature, poverty and failing agricultural systems, poor governance, ailing economies, conflict, and natural disasters are recurrent themes. While scholars address the vast and pressing problem of global hunger which afflicts over 800 million of the world's population, they fail to address policy imperatives by skewing research as though there were an underlying assumption that *all* 800 million hungry people live in rural environments. However, it is important to recognize that the majority of the world's population is now urban and the cold reality is that one in six of the planet's humans lives in a slum area (UN Habitat 2006). In a 2003 report (UN Habitat 2003; Popkin 2002) the UN stated that the absolute number of urban poor is rapidly increasing, as is the number of urban undernourished. Because of the paucity of research in this area, urban hunger may be routinely underestimated (Biritwum et al. 2005). 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.

Because urban households use cash/income to purchase food, affordable food prices are critical for maintaining food security. In the 1960s and 1970s, development policies to encourage industrialization called for subsidized food prices in the cities to appease the working class. Later, in the 1980s and 1990s, structural adjustment policies or neo-liberal economic theory dismantled many of these government programs. Consequently, urban dwellers usually pay much higher prices for food than their rural counterparts. Regular production failures, fuel and transportation costs, inefficient and mismanaged wholesale economies, and undeveloped retail markets can keep urban food prices high (Aragrande and Argenti 2001).

Some mechanisms that urban households have developed to secure a food supply include maintaining social networks with the countryside, or harvesting foods from community gardens (urban agriculture). It is estimated that nearly 40 % of urban dwellers (mostly women) practice some form of urban agriculture in or around cities (FAO 2001). However, because urban agriculture requires access to land, there is some speculation as to whether or not these urban farmers are indeed among the poorest. Also, not all urban areas have enough land available for agricultural activities. Accra, for example, has very little viable green space which can be cultivated, and Stoler et al. (2009) found that plots of urban agriculture in Accra that were large enough to be visible in high resolution satellite imagery tended to be in the somewhat more affluent suburban areas. As an alternative to growing plants, some households may raise small livestock in and around their urban homes, but again, livestock also require adequate space to thrive, although small goats are a fairly common sight in residential neighborhoods of Accra.

13.2 The 2008 World Food Crisis

The Nima market is of institutional fame in Accra. It thrives with vendors and shoppers on a daily basis and stretches across most of Nima's main thoroughfare. Everything from clothing, to hardware, and food is sold in the market. Cars, *tro-tros* (local minivan public transportation), and pedestrians come to an almost inconceivable knot of traffic at the market's central intersection. The constant symphony of honking horns, buzzing scooters, and shouting vendors is as inviting as it is intimidating. Many of Nima's women work here, either in their own market stalls or peddling their own goods on the street. Cristina came to the market twice a week to buy food for her family. Basic staples were more expensive than other years, she told me, and it wasn't on account of normal seasonal fluctuations. Rice, which was part of her daily nutrition, was the most expensive. The cost of rice seemed to be increasing on a weekly, if not daily, basis.

While I was interviewing Cristina and the other women of Accra, farmers in the northern regions of the country were experiencing some of the worst flooding in decades. Anomalies in weather patterns had brought unusual amounts of torrential rain in the normally drier north. Rice farmers saw their crops devastated and those who had managed to salvage some of their yields could not get it to market due to interrupted roadways.

Ghana imports much of its rice supply and in order to ease economic pressure on households, in 2008 the government decided to drop the import tariffs it maintained on the staple good. However, along with other grains, the global rice supply was facing challenges of its own. Severe droughts in global "rice baskets", spikes in oil prices, and the push for biofuel and animal feed production all converged to send rice prices soaring. The food crisis translated into popular uprising in many of the world's poorest nations. Protests were most notable in urban areas where average wages hover around two dollars a day. People could no longer afford to purchase food, and at the same time they were no longer tied to rural areas where subsistence agriculture was still an option.

Although temporary, the global spike in basic grain prices exposed the vulnerability of many poor urban households in urban and urbanizing areas of developing countries. Their food security depends largely on the low cost of food since wages for unskilled labor are unlikely to increase in the context of high rates of rural to urban migration. Many of the safety nets wealthier countries have in place, such as food stamps, community kitchens, and school meal programs, are unaffordable to cash strapped governments. When access to food is gone, food insecurity settles in, and families may have to go without adequate amounts of food for weeks at a time.

13.3 Food Insecurity in Accra

Cristina had no running water in her home. She had to pay for water at the nearest public tap. However, the one closest to her home had stopped working some time ago and there was no knowing when it would be repaired. She had to walk an extra ten minutes in her neighborhood to reach one that was dispensing water. For Cristina, that meant extra time and distance carrying home heavy ten liter jerry cans. Filling one cost her close to three cents. That may not seem like much, but for someone trying to feed her family on less than two dollars a day, the cost of water was a significant portion of her budget.

As I continued to interview women from different neighborhoods in Accra, I was struck by the frequency of food insecurity across my sample. My sense was corroborated by data from the first wave of the Women's Health Study of Accra (WHSA) (Duda et al. 2005 and see Chap. 1 for more details), a larger health survey of 3,183 women in Accra. In 2003, over half, or 57 % of the respondents in the Women's Health Survey of Accra were food insecure, indicating that the majority of women surveyed did not have access to the quantity and quality of foods they desire at all times. Furthermore, 17 % of respondents indicated that they had skipped meals during the preceding 12 months.

The second round of the WHSA was conducted in 2008–2009 (see Chap. 1 for details). Nearly all women interviewed in 2003 had agreed to be re-interviewed at a later date and in the second round 1,732 were successfully reinterviewed. Replacement respondents were selected for those women who were lost to follow-up. Among the women who were reinterviewed, the percent indicating that they had been food insecure in 2003 was 55 %. By 2008–2009 that had dropped to 44 %, indicating that, despite the food price hikes of 2008, the food security figures had improved by more than ten points. Somewhat disturbing, however, was the fact that among women who were lost to follow-up, 60 % had been food insecure in 2003, and that difference is statistically significant beyond the .01 level. Thus, women with food insecurity issues were seemingly at greater risk of either dying or moving in the 5–6 years between surveys.

If we look at the responses for all women in both waves of the WHSA, we find that the percentage of women who were food insecure in the sampled neighborhoods dropped from 57 % in 2003 (as noted above) to 46 %. Furthermore, the percent indicating that they had skipped meals during the prior 12 months dropped slightly from 17 % in 2003 (as noted above) to 15 % in 2008–2009. The descriptive statistics thus point toward a pattern of substantial, yet diminishing, urban food insecurity. Nearly one out of two respondents were food insecure both years the survey was given.

More research is needed to understand the dynamics behind the changes in these figures, but it is likely that this is due to an overall improvement in Accra's economy. The data in Table 13.1 reveal that in 2003, 64 % of women living in the low class enumeration areas (EAs) were food insecure, compared to 49 % in the high class EAs, representing a 15 percentage point gap. In 2008–2009, women in all classes of

Table 13.1 Percent food insecure by SES level of neighborhood

	Percent of women with food insecurity		
Socioeconomic level of the EA of residence	2003	2008–2009	Difference
Low class	64	58	6
Low middle class	58	44	14
Upper middle class	55	41	14
High class	49	41	8
Total	57	46	11

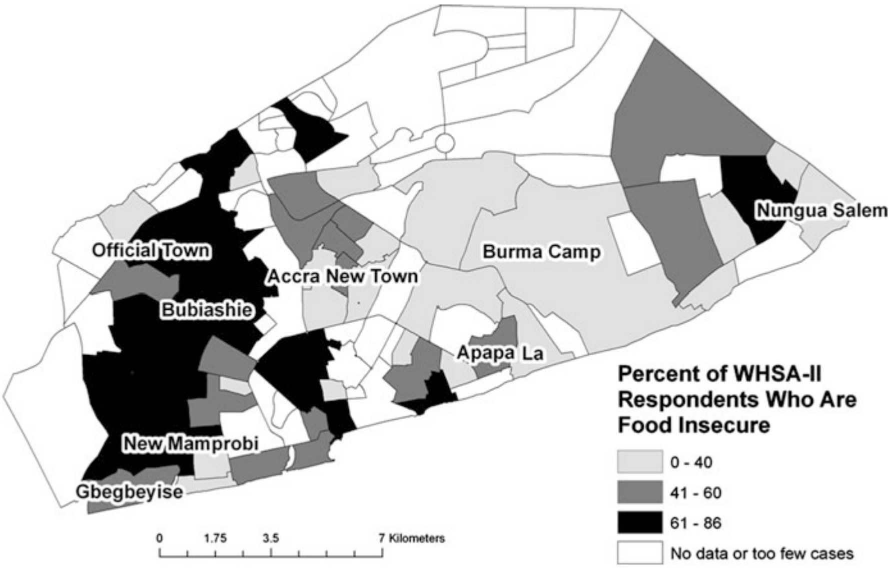

Fig. 13.1 Percent food insecure by neighborhood, Accra, 2008–2009 WHSA-II

neighborhoods were less likely to be food insecure, suggesting that the improvement was evident throughout the city, indicative of an overall economic improvement. Nonetheless, the gap between top and bottom not only continued to exist, but it widened to a 17 point difference between low class EAs (58 % food insecure) and high class EAs (41 %).

The data in Table 13.1 suggest that food security is not randomly distributed in the city, and this impression is confirmed in Fig. 13.1, which maps the percent of WHSA-II respondents who reported food insecurity according to the neighborhood in which they lived. The boundaries are groupings of EAs into what are called "field-modified vernacular" (FMV) neighborhoods, as described by Weeks and his associates (Weeks et al. 2012; and see Chaps. 1 and 2 of this volume). Among the neighborhoods for which we have enough cases (a minimum of 10) to create a percentage of households, the pattern is for food insecurity to be lowest in the higher status central portions of the city, with insecurity rising as one moves toward the periphery. Neighborhoods with at least 50 respondents, representing three low (Nungua Salem, Burma Camp, and La), three moderate (Accra New Town, Gbegbeyise, and Apapa), and three high food insecurity areas (Official Town, New Mamprobi, and Bubiashie) are labeled as examples. Note that Nima and Maamobi are relatively low with respect to food insecurity, probably because of the important role played in the neighborhood by Nima Market. We do not yet have a sufficient database of market characteristics throughout the city, however, to draw more than tentative conclusions about the factors that explain the spatial patterns observed in Fig. 13.1.

13.4 Discussion and Conclusion

It was clear after speaking with women in Accra that the mechanics of food availability, access, and purchase depended on three main factors: income availability, food market location, and price fluctuations. The latter was particular apparent within the context of the food crisis. The first two factors emerged as themes while completing my food security survey.

The economic conflict between food purchases and other household expenses was particularly striking. Many households had to choose between paying quarterly school fees (required at all levels of education) or feeding their families. This seemed to be a particularly wrenching decision for women, all of whom expressed their desire to see their children educated. Out of the subgroup of women who found it particularly challenging to pay for school fees, nearly all of them expressed prioritizing the fees over food. They did not want to see their children drop out of school and therefore felt that a week or so with less to eat was well worth the expense. As food prices have steadily increased over the past several years this budgetary conflict has affected women who had not struggled with the issue in past years.

The task of acquiring food for the households was inhibited or enhanced by the distance between household and fresh food markets. If markets were not available within a neighborhood, the cost of traveling to another part of the city was considerably higher in terms of time and money, especially for lower-income households. Households that were within short walking distance of fresh fruit markets had access to healthier and cheaper foods than households that were not.

Two variables were of particular importance in this study when considering food policy: geographic location of food markets and household economic vulnerability to food prices. The evidence collected from three different neighborhoods of Accra showed that neighborhood experience can influence household access to food. These differences, which are typically concealed beneath aggregate figures for urban areas, demonstrate the need for a neighborhood or small community approach to urban food security.

Opening regulated and appropriate spaces for food markets in all neighborhoods may be one of the best and cheapest ways of helping women with limited resources gain more access to food. Most of Accra's food markets are already overcrowded and poorly managed. Decentralizing markets to give neighborhoods more ownership over their food resources would provide communities with inexpensive and healthier options for food, while decreasing the costs of households that would otherwise have to travel greater lengths. It would also provide input to local micro-economies as many women in Accra are already involved in food-related livelihoods.

Another approach may be to combine education and food policy by promoting school gardens or school feeding programs, giving children the added nutrients they need for the day, and sparing strapped households from having to choose between food and education. These garden and feeding programs would also be managed locally. School gardens and feeding programs have succeeded world-wide in helping parents nourish their children, and helping children improve their learning skills after being properly fed. Better educated children grow into adults who are more likely to make greater economic contributions to their communities.

The city-wide variability in the data suggests that programs to help households access sufficient foods are needed across the municipality. If the goal of policy is to improve urban nutritional health, then policy makers need to make healthy foods available and affordable. The benefits of local food markets and school feeding programs have already been discussed. But at an even greater scale, policy makers should encourage local farmers to develop a thriving domestic agricultural economy that is not entirely based on commodities for export. Reducing food import dependency will strengthen the economic bonds between cities and rural areas and secure an affordable, healthy stream of culturally appropriate foods for the urban consumer.

Food was the largest expenditure for Cristina, and when I interviewed her she felt it would become an ever larger proportion of her budget over the coming months. Thousands of women like her exist in Accra, faced with food shortages at home when the city itself is ripe with supply. Urban food security is a function of *access* to food, with food prices, stagnant incomes, market locations, and other budgetary constraints acting as barriers to adequate food consumption. While the second round of the Women's Health Survey in Accra has shown improvements in women's food security situations, the issue merits clearly further in-depth research and analysis.

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